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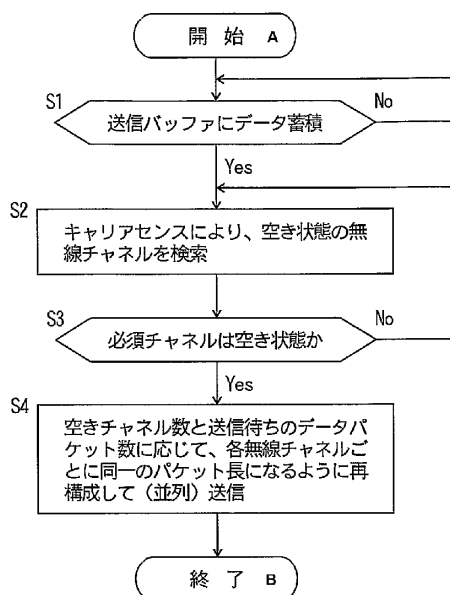
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[続葉有]

(54) Title: RADIO PACKET COMMUNICATION METHOD AND RADIO PACKET COMMUNICATION APPARATUS

(54) 発明の名称: 無線パケット通信方法および無線パケット通信装置



A START
S1 STORE DATA IN TRANSMISSION BUFFER
S2 SEARCH FOR OPEN RADIO CHANNEL BY USE OF CARRIER SENSE
S3 INDISPENSABLE CHANNEL IS OPEN?
S4 RECONSTARCT DATA PACKETS SUCH THAT THEIR PACKET LENGTHS ARE EQUAL TO EACH OTHER FOR EACH RADIO CHANNEL IN ACCORDANCE WITH NUMBER OF OPEN CHANNELS AND NUMBER OF DATA PACKETS WAITING FOR TRANSMISSION, AND (PARALLEL) TRANSMIT THE DATA PACKETS
B END

(57) Abstract: In a radio packet communication method for parallel transmitting a plurality of radio packets by use of a plurality of radio channels that are judged as being open by carrier sense, or for parallel transmitting a plurality of radio packets by use of space division multiplexing using a single radio channel that is judged as being open, or for parallel transmitting a plurality of radio packets by use of combination of them, an indispensable channel to be necessarily used for transmission is set, and only when the indispensable channel is open, radio channels including this indispensable channel are used to transmit the radio packets. That is, in a case of parallel transmitting a plurality of radio packets, radio channels including the indispensable channel are used for transmission, and if the indispensable channel is not open, the transmission is inhibited.

(57) 要約: キャリアセンスによって空き状態と判定された複数の無線チャンネルを用いて複数の無線パケットを並列送信するか、または空き状態と判定された 1 つの無線チャンネルを用いて空間分割多重方式により複数の無線パケットを並列送信するか、または両者を併用して複数の無線パケットを並列送信する無線パケット通信方法において、送信に必ず使用する必須チャンネルを設定し、この必須チャンネルが空き状態のときに限り必須チャンネルを含む無線チャンネルを用いて無線パケットの送信を行う。すなわ

ち、複数の無線パケットを並列送信する場合に、必須チャンネルを含む無線チャンネルを用いて送信を行うようにし、必須チャンネルが空き状態でなければ送信を禁止する。

MediaTek Exhibit 1059
MediaTek v. Nippon
IPR2020-01404



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明細書

無線パケット通信方法および無線パケット通信装置

5 技術分野

本発明は、複数の無線チャネルまたは空間分割多重方式を利用して複数の無線パケットを並列に送受信する無線パケット通信方法および無線パケット通信装置に関する。

10 背景技術

従来の無線パケット通信装置では、使用する無線チャネルを事前に1つだけ決めておき、データパケットの送信に先立って当該無線チャネルが空き状態か否かを検出（キャリアセンス）し、当該無線チャネルが空き状態の場合にのみ1つのデータパケットを送信していた。このような制御により、1つの無線チャネルを複数の無線局で互いに時間をずらして共用することができた（(1) IEEE802.11“MAC and PHY Specification for Metropolitan Area Networks”, IEEE 802.11, 1998、(2) 小電力データ通信システム／広帯域移動アクセスシステム（CSMA）標準規格、ARIB SDT-T71 1.0版、（社）電波産業会、平成12年策定）。

これに対して、キャリアセンスの際に複数の無線チャネルが空き状態であれば、その複数の無線チャネルを用いて複数の無線パケットを並列送信する無線パケット通信方法がある。以下、この手法の概要について、図13、図14を参照して説明する。

図13(1)は、3個の無線パケットに対して、空き状態の無線チャネルが2個ある場合であり、2個の無線チャネルを用いて3個のうちの2個の無線パケットを並列送信する。図13(2)は、2個の無線パケットに対して、空き状態の無線チャネルが3個ある場合であり、2個の無線チャネルを用いて全て（2個）の無線パケットを並列送信する。

図14は、公知の空間分割多重技術（黒崎 外、MIMOチャネルにより100Mb/sを実現する広帯域移動通信用SDM-COFDM方式の提案、電子情報通信

学会技術研究報告、A・P 2001-96, RCS2001-135(2001-10)) を併用する場合である。空間分割多重は、複数のアンテナから同じ無線チャネルで同時に異なる無線
5 パケットを送信し、対向する無線局の複数のアンテナに受信された各無線パケットの伝搬係数の違いに対応するデジタル信号処理により、同じ無線チャネルで同時に送信された複数の無線パケットを分離する方式である。なお、伝搬係数等
10 に応じて空間分割多重数が決定される。

図 1 4 (1) は、各無線チャネルの空間分割多重数を 2 としたときに、7 個の無線
15 パケットに対して、空き状態の無線チャネルが 3 個ある場合である。各無線チャネルごとに空間分割多重を併用することにより最大 6 個の無線パケットの並列
伝送が可能であるので、3 個の無線チャネルを用いて 7 個のうちの 6 個の無線パ
ケットを並列送信する。

図 1 4 (2), (3) は、各無線チャネルの空間分割多重数を 2 としたときに、4 個
15 の無線パケットに対して、空き状態の無線チャネルが 3 個ある場合である。各無線チャネルごとに空間分割多重を併用することにより最大 6 個の無線パケットの
並列伝送が可能であるが、送信待ちの無線パケットは 4 個であるので、一部の無線
20 チャネルについて空間分割多重を併用する。例えば、図 1 4 (2) に示すように、
1 個の無線チャネルは空間分割多重で 2 個の無線パケットを送信し、残りの 2 個
の無線チャネルは空間分割多重を用いずにそれぞれ 1 個の無線パケットを送信し、
全体で 3 個の無線チャネルを用いて 4 個の無線パケットを並列送信する。また、
20 図 1 4 (3) に示すように、2 個の無線チャネルでそれぞれ空間分割多重を併用し、
全体で 4 個の無線パケットを並列送信する。

ところで、同時に使用する複数の無線チャネルの中心周波数が互いに近接して
いる場合には、一方の無線チャネルから他方の無線チャネルが使用している周波
数領域へ漏れ出す漏洩電力の影響が大きくなる。一般に、無線パケットを伝送す
25 る場合には、送信側の無線局が無線パケットを送信した後に、受信側の無線局が
受信した無線パケットに対して送達確認パケット (Ack) を送信側の無線局へ
返送する。送信側の無線局がこの送達確認パケットを受信しようとするときに、
並列送信に使用している他の無線チャネルからの漏洩電力の影響が問題となる。

例えば、図 1 5 に示すように、無線チャネル # 1 と無線チャネル # 2 の中心周

波数が互いに近接し、各無線チャネルから並列送信する無線パケットの送信所要時間が異なる場合を想定する。ここでは、無線チャネル#1から送信された無線パケットが短いので、それに対する送達確認パケット (Ack 1) が受信される
5 ときに無線チャネル#2は送信中である。そのため、無線チャネル#1では、無線チャネル#2からの漏洩電力により送達確認パケット (Ack 1) を受信できない可能性がある。このような状況では、同時に複数の無線チャネルを利用して並列送信を行ったとしてもスループットの改善は見込めない。

例えば無線LANシステムなどでは、ネットワークから入力するデータフレームのデータサイズは一定ではない。したがって、入力するデータフレームを順次
10 に無線パケットに変換して送信する場合には、各無線パケットのパケット長も変化する。そのため、図15に示すように複数の無線パケットを同時に並列送信したとしても、各無線パケットの送信所要時間に違いが生じ、送達確認パケットの受信に失敗する可能性が高くなる。

このような問題に対して、並列送信する複数の無線パケットのパケット長（無線
15 パケットの送信に必要な時間）を同一または同等とすることにより、複数の無線パケットの送信を同時またはほぼ同時に終了させる方法がある。これにより、複数の無線パケットのそれぞれに対する送達確認パケットが到着するタイミングでは、送信局は送信を行っていないので、無線チャネル間の漏洩電力などの影響を受けることなく、すべての送達確認パケットを受信することができ、スループ
20 ットの改善に寄与することができる。

しかし、並列送信する複数の無線パケットのパケット長を同一にしても、漏洩電力の影響が問題になる場合がある。以下、図16を参照して説明する。

タイミング t_1 では、送信局の無線チャネル#1、#2が空き状態であり、無線チャネル#3がビジー状態にあるものとする。そのため、空き状態の無線チャネ
25 ル#1、#2を用いて同一のパケット長の無線パケットを並列送信する。これにより、無線チャネル#1、#2間では互いの漏洩電力の影響は回避できる。しかし、この無線パケットの送信中 (t_2) に無線チャネル#3が空き状態になると、他の無線局では無線チャネル#3を空き状態と判断し、この無線チャネル#3を用いて当該送信局宛てに無線パケットを送信することがある。しかし、送信局で

は無線チャネル# 1, # 2を用いて無線パケットの送信中であり、その漏洩電力のために無線チャネル# 3の無線パケットを受信することができない。すなわち、送信中の無線局は、送信チャネルの近隣の無線チャネルで送られた無線パケットを受信することができない。なお、この問題は複数の無線チャネルを用いた並列
5 送信の場合に限らず、従来の1つの無線チャネルを用いて送信し、漏洩電力の影響を受ける近隣の無線チャネルで受信する場合でも発生する。

本発明の目的は、近隣チャネルへの漏れこみの影響を回避し、並列送信によるスループットの向上を図るところにある。

10 発明の開示

請求の範囲1の発明は、キャリアセンスによって空き状態と判定された複数の無線チャネルを用いて複数の無線パケットを並列送信するか、または空き状態と判定された1つの無線チャネルを用いて空間分割多重方式により複数の無線パケットを並列送信するか、または両者を併用して複数の無線パケットを並列送信す
15 る無線パケット通信方法において、送信に必ず使用する必須チャネルを設定し、この必須チャネルが空き状態のときに限り必須チャネルを含む無線チャネルを用いて無線パケットの送信を行う。

すなわち、複数の無線パケットを並列送信する場合に、必須チャネルを含む無線チャネルを用いて送信を行うようにし、必須チャネルが空き状態でなければ送信を禁止する。なお、送信する際には必須チャネルを含み、必須チャネルがビ
20 ー状態であれば他の無線チャネルが空き状態であっても送信を禁止する必須チャネルについては、複数の優先順位が設定された無線チャネルにおいて最高の優先順位が設定された無線チャネルとみることできる。

請求の範囲2の発明は、キャリアセンスによって空き状態と判定された複数の無線チャネルを用いて複数の無線パケットを並列送信するか、または空き状態と判定された1つの無線チャネルを用いて空間分割多重方式により複数の無線パケットを並列送信するか、または両者を併用して複数の無線パケットを並列送信する無線パケット通信方法において、送信に必ず使用する必須チャネルが設定され
25 る無線局Aと必須チャネルが設定されない無線局Bに区別し、無線局Aを宛先と

する無線パケットの場合には、必須チャネルが空き状態のときに限り必須チャネルを含む無線チャネルを用いて無線パケットの送信を行い、無線局Bを宛先とする無線パケットの場合には、空き状態の無線チャネルを用いて無線パケットの送信を行う。

- 5 無線局Aについては、請求の範囲1の発明と同様の機能を有し、必須チャネルの設定がなされていない無線局Bについては、必須チャネルがビジー状態であってもその無線局間の送信を可能にする。

請求の範囲3の発明は、請求の範囲1または請求の範囲2において、並列送信される複数の無線パケットは、パケットサイズまたは伝送所要時間に相当するパ

- 10 ケット長が互いに同一または同等に設定される。

請求の範囲4の発明は、請求の範囲1または請求の範囲2において、データ数や伝搬環境に応じた空間分割多重数に応じて、複数の無線チャネルを用いる並列送信か空間分割多重方式を用いる並列送信かを選択する。

- 請求の範囲5の発明は、キャリアセンスによって空き状態と判定された複数の無線チャネルを用いて複数の無線パケットを並列送信するか、または空き状態と判定された1つの無線チャネルを用いて空間分割多重方式により複数の無線パケットを並列送信するか、または両者を併用して複数の無線パケットを並列送信する無線パケット通信装置において、送信に必ず使用する必須チャネルを設定し、この必須チャネルが空き状態のときに限り必須チャネルを含む無線チャネルを用いて無線パケットの送信を行う手段を備える。
- 15 20

- 請求の範囲6の発明は、キャリアセンスによって空き状態と判定された複数の無線チャネルを用いて複数の無線パケットを並列送信するか、または空き状態と判定された1つの無線チャネルを用いて空間分割多重方式により複数の無線パケットを並列送信するか、または両者を併用して複数の無線パケットを並列送信する無線パケット通信装置において、送信に必ず使用する必須チャネルが設定される無線局Aと必須チャネルが設定されない無線局Bに区別し、無線パケットの宛先を検出し、無線局Aを宛先とする無線パケットの場合には、必須チャネルが空き状態のときに限り必須チャネルを含む無線チャネルを用いて無線パケットの送信を行い、無線局Bを宛先とする無線パケットの場合には、空き状態の無線チャ
- 25

ネルを用いて無線パケットの送信を行う手段を備える。

請求の範囲 7 の発明は、請求の範囲 5 または請求の範囲 6 において、並列送信される複数の無線パケットは、パケットサイズまたは伝送所要時間に相当するパケット長が互いに同一または同等に設定される。

- 5 請求の範囲 8 の発明は、請求の範囲 5 または請求の範囲 6 において、データ数や伝搬環境に応じた空間分割多重数に応じて、複数の無線チャネルを用いる並列送信か空間分割多重方式を用いる並列送信かを選択する。

図面の簡単な説明

- 10 図 1 は、本発明の第 1 の実施形態を示すフローチャートである。
 図 2 は、本発明の第 1 の実施形態の動作例を示すタイムチャートである。
 図 3 は、データパケットの再構成の方法を説明する図である。
 図 4 は、本発明の第 2 の実施形態を示すフローチャートである。
 図 5 は、本発明の第 2 の実施形態の動作例を示すタイムチャートである。
15 図 6 は、本発明の第 3 の実施形態を示すフローチャートである。
 図 7 は、本発明の第 4 の実施形態を示すフローチャートである。
 図 8 は、本発明の第 5 の実施形態を示すフローチャートである。
 図 9 は、本発明の第 6 の実施形態を示すフローチャートである。
 図 10 は、本発明の第 7 の実施形態を示すフローチャートである。
20 図 11 は、本発明の第 8 の実施形態を示すフローチャートである。
 図 12 は、本発明の無線パケット通信装置の実施形態を示すブロック図である。
 図 13 は、複数の無線チャネルを用いて複数の無線パケットを並列送信する方法を説明する図である。
 図 14 は、複数の無線チャネルを用いて複数の無線パケットを並列送信する方法（空間分割多重を併用）を説明する図である。
25 図 15 は、無線チャネルの漏洩電力の影響を説明する図である。
 図 16 は、並列送信する無線パケットのパケット長を同一にしても漏洩電力の影響が問題になる場合を説明する図である。
 図 17 は、本発明の無線パケット通信装置で用いる無線パケットの構成を示す

図である。

発明を実施するための最良の形態

〔第 1 の実施形態〕

- 5 図 1 は、本発明の無線パケット通信方法の第 1 の実施形態のフローチャートを示す。図 2 は、本発明の無線パケット通信方法の第 1 の実施形態のタイムチャートを示す。ここでは、無線チャネル # 1, # 2, # 3 が用意され、各無線局に一律に必須チャネルとして無線チャネル # 1 が設定されているものとする。必須チャネルは、各無線局に対して定期的に報知され、各無線局は必須チャネルがビジー状態の場合には、仮に他の無線チャネルが空き状態であっても送信は行わないものとし、すべての送信が禁止される。また、無線チャネル # 1, # 2, # 3 は、互いに漏れこみを生じさせる関係にあり、1 つの無線チャネルが送信中であれば他の無線チャネルで受信できないものとする。

- 15 まず、送信バッファにデータが蓄積されると、キャリアセンスによって空き状態の無線チャネルを検索する (S 1, S 2)。ここでは、送信データ生起 (1) のタイミングにおいて無線チャネル # 3 がビジー状態であり、無線チャネル # 1 および無線チャネル # 2 が空き状態として検索される。次に、必須チャネルが空き状態か否かを判断し (S 3)、必須チャネルがビジー状態であれば空き状態の無線チャネルの検索に戻る。一方、必須チャネルが空き状態であれば、空きチャネル数と送信待ちのデータパケット数に応じて、各無線チャネルごとに同一のパケット長になるように再構成して (並列) 送信する (S 4)。ここでは、必須チャネルである無線チャネル # 1 が空き状態であるので、無線チャネル # 2 を含む 2
- 20 チャネルによって無線パケットの並列送信が行われる。

- 25 データパケットの再構成の方法としては、次の 3 つの方法がある。例えばデータパケットが 1 つで空きチャネル数が 2 つの場合には、図 3 (1) に示すようにデータパケットを分割することにより、同一パケット長の 2 つのデータパケットを生成する。またデータパケットが 3 つで空きチャネル数が 2 つの場合には、図 3 (2) に示すように、例えばデータパケット 2 を分割してそれぞれデータパケット 1 およびデータパケット 3 と結合することにより、同一パケット長の 2 つのデー

タパケットを生成する。あるいは、3つのデータパケットを連結してから2分割しても同様である。また、図3(3)に示すように、データパケット1とデータパケット2を連結し、データパケット3にダミービットを付加し、同一パケット長の2つのデータパケットを生成する。また、複数の無線チャネルを使用する際に

5 各無線チャネルの伝送速度が異なる場合には、各データパケットのサイズ比を伝送速度比に対応させてパケット長が同じになるように調整する。

なお、他の無線局では無線チャネル#3が空き状態になっても、必須チャネルである無線チャネル#1がビジー状態であるので、送信は禁止される。一方、送信データ生起(2)のタイミングでは、必須チャネルである無線チャネル#1を含む

10 むすべての無線チャネルが空き状態となるので、各無線局は送信可能状態となる。例えば、送信データ生起(1)のタイミングで無線パケットを送信した送信局に対して他の無線局が無線パケットを送信したい場合には、送信データ生起(2)のタイミングで行われる。

[第2の実施形態]

15 図4は、本発明の無線パケット通信方法の第2の実施形態のフローチャートを示す。図5は、本発明の無線パケット通信方法の第2の実施形態のタイムチャートを示す。ここでは、必須チャネルが設定される無線局Aと、必須チャネルが設定されない無線局Bが存在し、無線局Bを宛先とする送信の場合には特に制限はなく、無線局Aを宛先とする送信の場合には必須チャネルが空き状態のときに限り送信可能とし、必須チャネルがビジー状態であれば他の無線チャネルが空き状態であっても送信は禁止されるものとする。なお、第1の実施形態の場合には、

20 すべての無線局に一律に必須チャネルが設定されているので、無線パケットの宛先を考慮することなく、送信する際には必ず必須チャネルを含む制御になっている。

25 まず、送信バッファにデータが蓄積されると、キャリアセンスによって空き状態の無線チャネルを検索する(S1, S2)。ここでは、送信データ生起(1)のタイミングにおいて無線チャネル#3がビジー状態であり、無線チャネル#1および無線チャネル#2が空き状態として検索される。次に、送信バッファに到着した1つのデータパケットの宛先を解読し(S11)、その宛先となる無線局に必

須チャネルが設定されているか否かを判断する（S12）。宛先の無線局に必須チャネルが設定されていれば、その必須チャネルが空き状態か否かを判断し（S13）、必須チャネルが空き状態であれば、空きチャネル数と送信待ちのデータパケット数に応じて、各無線チャネルごとに同一のパケット長になるように再構成して（並列）送信する（S4）。ここでは、無線局A宛ての無線パケットについて、
5 必須チャネルである無線チャネル#1が空き状態であるので、無線チャネル#2を含む2チャネルによって無線パケットの並列送信が行われる。

一方、S12において、宛先の無線局に必須チャネルが設定されていなければ、必須チャネルの空き状態を考慮することなく、空きチャネル数と送信待ちのデータパケット数に応じて各無線チャネルごとに同一のパケット長になるように再構成して（並列）送信する（S4）。また、S13において、必須チャネルが空き状態でなければ、必須チャネルが設定されている無線局A宛ての無線パケットの送信はできないので、送信バッファに他のデータパケットがあるか否かを判断し
10 （S14）、他のデータパケットがあればS11の宛先解読に戻り、他のデータパケットがなければS2の空き状態の無線チャネルの検索を行う。
15

ここでは、無線チャネル#3が空き状態となったときに、無線チャネル#3を用いて必須チャネルが設定されていない無線局B宛ての無線パケットの送信が可能となる。一方、無線チャネル#3による無線局A宛ての無線パケットの送信は、無線チャネル#1がビジー状態であるので禁止され、無線チャネル#1が空き状態になるまで待たされる。
20

なお、送信データ生起(2)のタイミングでは無線チャネル#1、#2が空き状態となるので、必須チャネルが設定されている無線局A宛ての無線パケット、あるいは必須チャネルが設定されていない無線局B宛ての無線パケットのいずれでも、それらの無線チャネルを用いて送信が可能となる。

25 [第3の実施形態]

図6は、本発明の無線パケット通信方法の第3の実施形態のフローチャートを示す。本実施形態の特徴は、第1の実施形態において無線パケットの並列送信に空間分割多重方式を併用するところにある。第1の実施形態におけるS4で無線パケットを再構成する際に、空きチャネルの各空間分割多重数の総和に相当する

並列送信数に対して、それぞれ同一の packets 長になるように再構成する (S 5)。その他は第 1 の実施形態と同様である。

[第 4 の実施形態]

図 7 は、本発明の無線 packets 通信方法の第 4 の実施形態のフローチャートを示す。本実施形態の特徴は、無線 packets の並列送信に空間分割多重方式を併用する場合に、第 3 の実施形態における S 5 で空きチャネルの各空間分割多重数の総和に相当する並列送信数に対してそれぞれ同一の packets 長になるように再構成する前に、伝搬係数よりアンテナ相関を求め、予め定めた閾値により 1 チャネルに重複可能な空間分割多重数を求めるところにある (S 6)。その他は第 3 の実施形態と同様である。

[第 5 の実施形態]

図 8 は、本発明の無線 packets 通信方法の第 5 の実施形態のフローチャートを示す。本実施形態の特徴は、第 1 の実施形態に示すように複数の無線チャネルを用いて並列送信を行うか、第 3 の実施形態に示す空間分割多重方式を用いて並列送信を行うか、送信バッファに蓄積されたデータ数や第 4 の実施形態で示した伝搬環境に応じた空間分割多重数に応じて選択するところにある (S 7)。この選択に応じて、空きチャネル数または空間分割多重数に対してそれぞれ同一の packets 長になるように再構成して並列送信する (S 4, S 8)。その他は第 1 の実施形態と同様である。

[第 6 の実施形態]

図 9 は、本発明の無線 packets 通信方法の第 6 の実施形態のフローチャートを示す。本実施形態の特徴は、第 2 の実施形態において無線 packets の並列送信に空間分割多重方式を併用するところにある。第 2 の実施形態における S 4 で無線 packets を再構成する際に、空きチャネルの各空間分割多重数の総和に相当する並列送信数に対してそれぞれ同一の packets 長になるように再構成する (S 5)。その他は第 2 の実施形態と同様である。

[第 7 の実施形態]

図 10 は、本発明の無線 packets 通信方法の第 7 の実施形態のフローチャートを示す。本実施形態の特徴は、無線 packets の並列送信に空間分割多重方式を併

用する場合に、第 6 の実施形態における S 5 で空きチャネルの各空間分割多重数の総和に相当する並列送信数に対してそれぞれ同一の packets 長になるように再構成する前に、伝搬係数よりアンテナ相関を求め、予め定めた閾値により 1 チャネルに重複可能な空間分割多重数を求めるところにある (S 6)。その後は第 6 の実施形態と同様である。

[第 8 の実施形態]

図 1 1 は、本発明の無線 packets 通信方法の第 8 の実施形態のフローチャートを示す。本実施形態の特徴は、第 2 の実施形態に示すように複数の無線チャネルを用いて並列送信を行うか、第 6 の実施形態に示す空間分割多重方式を用いて並列送信を行うか、送信バッファに到着したデータ数や第 7 の実施形態で示した伝搬環境に応じた空間分割多重数に応じて選択するところにある (S 7)。この選択に応じて、空きチャネル数または空間分割多重数に対してそれぞれ同一の packets 長になるように再構成して並列送信する (S 4, S 8)。その後は第 2 の実施形態と同様である。

[無線 packets 通信装置の構成例]

図 1 2 は、本発明の無線 packets 通信装置の構成例を示す。ここでは、3 個の無線チャネル # 1, # 2, # 3 を用いて 3 個の無線 packets を並列に送受信可能な無線 packets 通信装置の構成について示すが、その並列数は任意に設定可能である。なお、各無線チャネルごとに空間分割多重を利用する場合には、複数の無線チャネルの各空間分割多重数の総和に相当する並列送信数の無線 packets を並列に送受信可能であるが、ここでは空間分割多重については省略する。また、複数の無線チャネルを個々に独立に使用する場合についても同様である。

図において、無線 packets 通信装置は、送受信処理部 1 0-1, 1 0-2, 1 0-3 と、送信バッファ 2 1, データ packets 生成部 2 2, データフレーム管理部 2 3, チャネル状態管理部 2 4, packets 振り分け送信制御部 2 5, packets 順序管理部 2 6 およびヘッダ除去部 2 7 とを備える。

送受信処理部 1 0-1, 1 0-2, 1 0-3 は、互いに異なる無線チャネル # 1, # 2, # 3 で無線通信を行う。これらの無線チャネルは、互いに無線周波数などが異なるので互いに独立であり、同時に複数の無線チャネルを利用して無線

通信できる構成になっている。各送受信処理部 10 は、変調器 11、無線送信部 12、アンテナ 13、無線受信部 14、復調器 15、パケット選択部 16 およびキャリア検出部 17 を備える。

5 他の無線パケット通信装置が互いに異なる無線チャネル # 1、# 2、# 3 を介して送信した無線信号は、それぞれ対応する送受信処理部 10-1、10-2、10-3 のアンテナ 13 を介して無線受信部 14 に入力される。各無線チャネル対応の無線受信部 14 は、入力された無線信号に対して周波数変換、フィルタリング、直交検波および A/D 変換を含む受信処理を施す。なお、各無線受信部 14 には、それぞれ接続されたアンテナ 13 が送信のために使用されていない時に、
10 各無線チャネルにおける無線伝搬路上の無線信号が常時入力されており、各無線チャネルの受信電界強度を表す RSSI 信号がキャリア検出部 17 へ出力される。また、無線受信部 14 に対応する無線チャネルで無線信号が受信された場合には、受信処理されたベースバンド信号が復調器 15 へ出力される。

 復調器 15 は、無線受信部 14 から入力されたベースバンド信号に対してそれぞれ復調処理を行い、得られたデータパケットはパケット選択部 16 へ出力される。パケット選択部 16 は、入力されたデータパケットに対して CRC チェックを行い、データパケットが誤りなく受信された場合には、そのデータパケットが自局に対して送信されたものか否かを識別する。すなわち、各データパケットの宛先 ID が自局と一致するか否かを調べ、自局宛てのデータパケットをパケット
20 順序管理部 26 へ出力するとともに、図示しない送達確認パケット生成部で送達確認パケットを生成して変調器 11 に送出し、応答処理を行う。このとき、送達確認パケットの送信にあたって、伝送速度の設定や空間分割多重を適用しないなどの送信モードの設定を行うようにしてもよい。一方、自局宛でないデータパケットの場合には、パケット選択部 16 で当該パケットが破棄される。

25 パケット順序管理部 26 は、入力された各データパケットに付加されているシーケンス番号を調べ、受信した複数のデータパケットの並びを適切な順番、すなわちシーケンス番号順に並べ替える。その結果を受信データパケット系列としてヘッダ除去部 27 へ出力する。ヘッダ除去部 27 は、入力された受信データパケット系列に含まれている各々のデータパケットからヘッダ部分を除去し、受信デ

ータフレーム系列として出力する。

キャリア検出部 17 は、RSSI 信号が入力されると、その信号によって表される受信電界強度の値と予め設定した閾値とを比較する。そして、所定の期間中の受信電界強度が連続的に閾値よりも小さい状態が継続すると、割り当てられた無線チャンネルが空き状態であると判定し、それ以外の場合には割り当てられた無線チャンネルがビジーであると判定する。各無線チャンネルに対応するキャリア検出部 17 は、この判定結果をキャリア検出結果 CS 1 ～CS 3 として出力する。なお、各送受信処理部 10 において、アンテナ 13 が送信状態である場合にはキャリア検出部 17 に RSSI 信号が入力されない。また、アンテナ 13 が既に送信状態にある場合には、同じアンテナ 13 を用いて他のデータパケットを無線信号として同時に送信することはできない。したがって、各キャリア検出部 17 は RSSI 信号が入力されなかった場合には、割り当てられた無線チャンネルがビジーであることを示すキャリア検出結果を出力する。

各無線チャンネルに対応するキャリア検出部 17 から出力されるキャリア検出結果 CS 1 ～CS 3 は、チャンネル状態管理部 24 に入力される。チャンネル状態管理部 24 は、各無線チャンネルに対応するキャリア検出結果に基づいて各無線チャンネルの空き状態を管理し、空き状態の無線チャンネルおよび空きチャンネル数などの情報をデータフレーム管理部 23 に通知する（図 12, a）。

一方、送信バッファ 21 には、送信すべき送信データフレーム系列が入力され、バッファリングされる。この送信データフレーム系列は、1 つあるいは複数のデータフレームで構成される。送信バッファ 21 は、現在保持しているデータフレームの数、宛先となる無線パケット通信装置の ID 情報、データサイズ、バッファ上の位置を表すアドレス情報などをデータフレーム管理部 23 に逐次通知する（b）。

データフレーム管理部 23 は、送信バッファ 21 から通知された各宛先無線局 ID ごとのデータフレームに関する情報と、チャンネル状態管理部 24 から通知された無線チャンネルに関する情報に基づき、どのデータフレームからどのようにデータパケットを生成し、どの無線チャンネルで送信するかを決定し、それぞれ送信バッファ 21, データパケット生成部 22 およびデータパケット振り分け送信制

御部 25 に通知する (c, d, e)。例えば、必須チャネルを含む空き状態の無線チャネル数 N が送信バッファ 21 にある送信待ちのデータフレーム数 K より少ない場合に、必須チャネルを含む空き状態の無線チャネル数 N を並列送信するデータパケット数として決定し、送信バッファ 21 に対して K 個のデータフレーム

5 から N 個のデータフレームを指定するアドレス情報を通知する (c)。また、データパケット生成部 22 に対しては、送信バッファ 21 から入力したデータフレームから N 個のデータパケットを生成するための情報を通知する (d)。また、パケット振り分け送信制御部 25 に対しては、データパケット生成部 22 で生成された N 個のデータパケットと空き状態の無線チャネルとの対応を指示する

10 (e)。

送信バッファ 21 は、出力指定されたデータフレームをデータパケット生成部 22 に出力する (f)。データパケット生成部 22 は、各データフレームからデータ領域を抽出して複数のデータブロックを生成し、このデータブロックに当該データパケットの宛先となる宛先無線局の ID 情報やデータフレームの順番を表

15 すシーケンス番号などの制御情報を含むヘッダ部と、誤り検出符号である CRC 符号 (FCS 部) を付加し、図 17 に示すようなデータパケットを生成する。なお、制御情報には、受信側の無線局がデータパケットを受信した際に、元のデータフレームに変換するために必要な情報も含まれる。パケット振り分け送信制御部 25 は、データパケット生成部 22 から入力された各データパケットと各無線

20 チャネルとの対応付けを行う。

このような対応付けの結果、無線チャネル #1 に対応付けられたデータパケットは送受信処理部 10-1 内の変調器 11 に入力され、無線チャネル #2 に対応付けられたデータパケットは送受信処理部 10-2 内の変調器 11 に入力され、無線チャネル #3 に対応付けられたデータパケットは送受信処理部 10-3 内の

25 変調器 11 に入力される。各変調器 11 は、パケット振り分け送信制御部 25 からデータパケットが入力されると、そのデータパケットに対して所定の変調処理を施して無線送信部 12 に出力する。各無線送信部 12 は、変調器 11 から入力された変調処理後のデータパケットに対して、DA 変換、周波数変換、フィルタリング及び電力増幅を含む送信処理を施し、それぞれ対応する無線チャネルを介

してアンテナ 1 3 から無線パケットとして送信する。

第 1 の実施形態～第 8 の実施形態で示した必須チャネルを考慮した処理は、データフレーム管理部 2 3 の制御に基づいて行われる。これにより、複数の無線チャネルを使用する場合に、隣接チャネルへの漏れこみなどに起因して無線パケッ

5 トが受信できない事態を回避する。

産業上の利用可能性

本発明は、必須チャネルを含む無線チャネルを用いて送信している送信局に対しては、他の無線局から送信が行われないので、送信局で自局宛ての無線パケットの受信ができない事態を回避することができる。一方、他の無線局では、必須

10 チャネルが空き状態になるのを待って送信局に対して無線パケットを送信することにより、確実に無線パケットを伝送することができ、スループットの改善を図ることができる。

また、必須チャネルの設定がなされていない無線局がある場合には、必須チャネルがビジー状態であってもその無線局間の送信を可能にすることにより、スループットの低下を抑制することができる。

15

請求の範囲

(1) キャリアセンスによって空き状態と判定された複数の無線チャネルを用いて複数の無線パケットを並列送信するか、または空き状態と判定された1つの無線チャネルを用いて空間分割多重方式により複数の無線パケットを並列送信するか、または両者を併用して複数の無線パケットを並列送信する無線パケット通信方法において、

送信に必ず使用する必須チャネルを設定し、この必須チャネルが空き状態のときに限り必須チャネルを含む無線チャネルを用いて無線パケットの送信を行うことを特徴とする無線パケット通信方法。

(2) キャリアセンスによって空き状態と判定された複数の無線チャネルを用いて複数の無線パケットを並列送信するか、または空き状態と判定された1つの無線チャネルを用いて空間分割多重方式により複数の無線パケットを並列送信するか、または両者を併用して複数の無線パケットを並列送信する無線パケット通信方法において、

送信に必ず使用する必須チャネルが設定される無線局Aと必須チャネルが設定されない無線局Bに区別し、

前記無線局Aを宛先とする無線パケットの場合には、前記必須チャネルが空き状態のときに限り必須チャネルを含む無線チャネルを用いて無線パケットの送信を行い、前記無線局Bを宛先とする無線パケットの場合には、空き状態の無線チャネルを用いて無線パケットの送信を行うことを特徴とする無線パケット通信方法。

(3) 請求の範囲1または請求の範囲2に記載の無線パケット通信方法において、並列送信される複数の無線パケットは、パケットサイズまたは伝送所要時間に相当するパケット長が互いに同一または同等に設定されることを特徴とする無線パケット通信方法。

(4) 請求の範囲1または請求の範囲2に記載の無線パケット通信方法において、データ数や伝搬環境に応じた空間分割多重数に応じて、複数の無線チャネルを用いる並列送信か空間分割多重方式を用いる並列送信かを選択することを特徴と

する無線パケット通信方法。

- (5) キャリアセンスによって空き状態と判定された複数の無線チャネルを用いて複数の無線パケットを並列送信するか、または空き状態と判定された1つの無線チャネルを用いて空間分割多重方式により複数の無線パケットを並列送信するか、または両者を併用して複数の無線パケットを並列送信する無線パケット通信装置において、

送信に必ず使用する必須チャネルを設定し、この必須チャネルが空き状態のときに限り必須チャネルを含む無線チャネルを用いて無線パケットの送信を行う手段を備えたことを特徴とする無線パケット通信装置。

- (6) キャリアセンスによって空き状態と判定された複数の無線チャネルを用いて複数の無線パケットを並列送信するか、または空き状態と判定された1つの無線チャネルを用いて空間分割多重方式により複数の無線パケットを並列送信するか、または両者を併用して複数の無線パケットを並列送信する無線パケット通信装置において、

- 15 送信に必ず使用する必須チャネルが設定される無線局Aと必須チャネルが設定されない無線局Bに区別し、

- 前記無線パケットの宛先を検出し、前記無線局Aを宛先とする無線パケットの場合には、前記必須チャネルが空き状態のときに限り必須チャネルを含む無線チャネルを用いて無線パケットの送信を行い、前記無線局Bを宛先とする無線パケットの場合には、空き状態の無線チャネルを用いて無線パケットの送信を行う手段を備えたことを特徴とする無線パケット通信装置。

- (7) 請求の範囲5または請求の範囲6に記載の無線パケット通信装置において、
並列送信される複数の無線パケットは、パケットサイズまたは伝送所要時間に相当するパケット長が互いに同一または同等に設定される構成であることを特徴とする無線パケット通信装置。

- (8) 請求の範囲5または請求の範囲6に記載の無線パケット通信装置において、
データ数や伝搬環境に応じた空間分割多重数に応じて、複数の無線チャネルを用いる並列送信か空間分割多重方式を用いる並列送信かを選択する手段を備えたことを特徴とする無線パケット通信装置。

1 / 1 2

FIG. 1

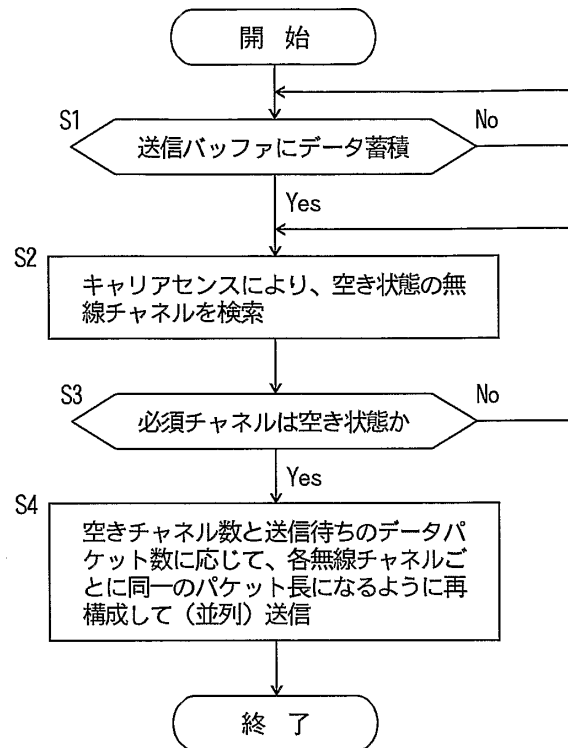
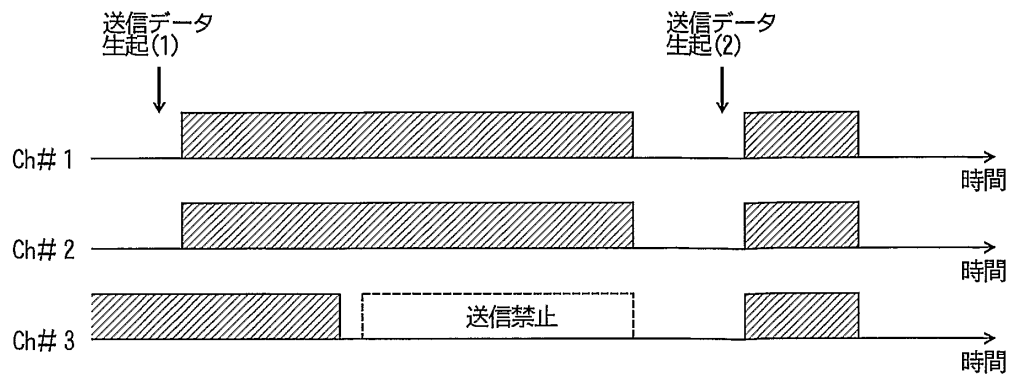


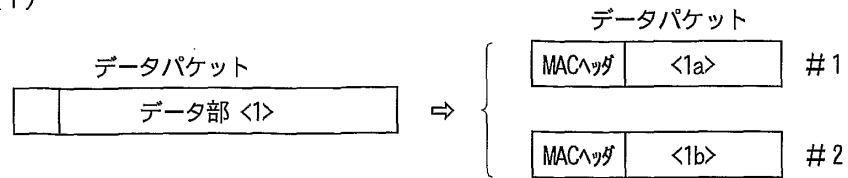
FIG. 2



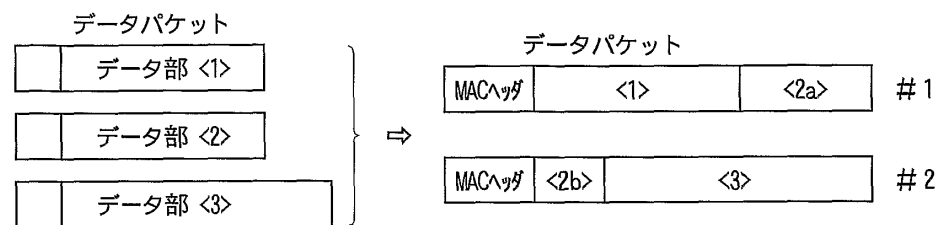
2 / 1 2

FIG. 3

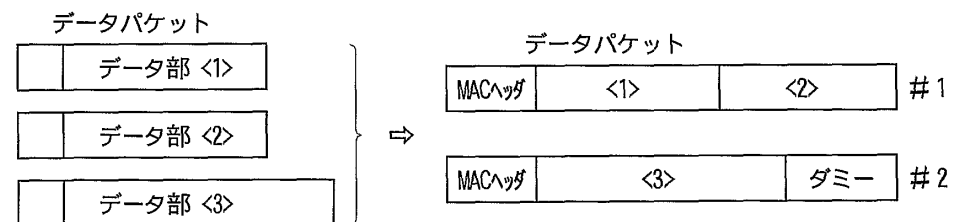
(1)



(2)



(3)



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FIG. 4

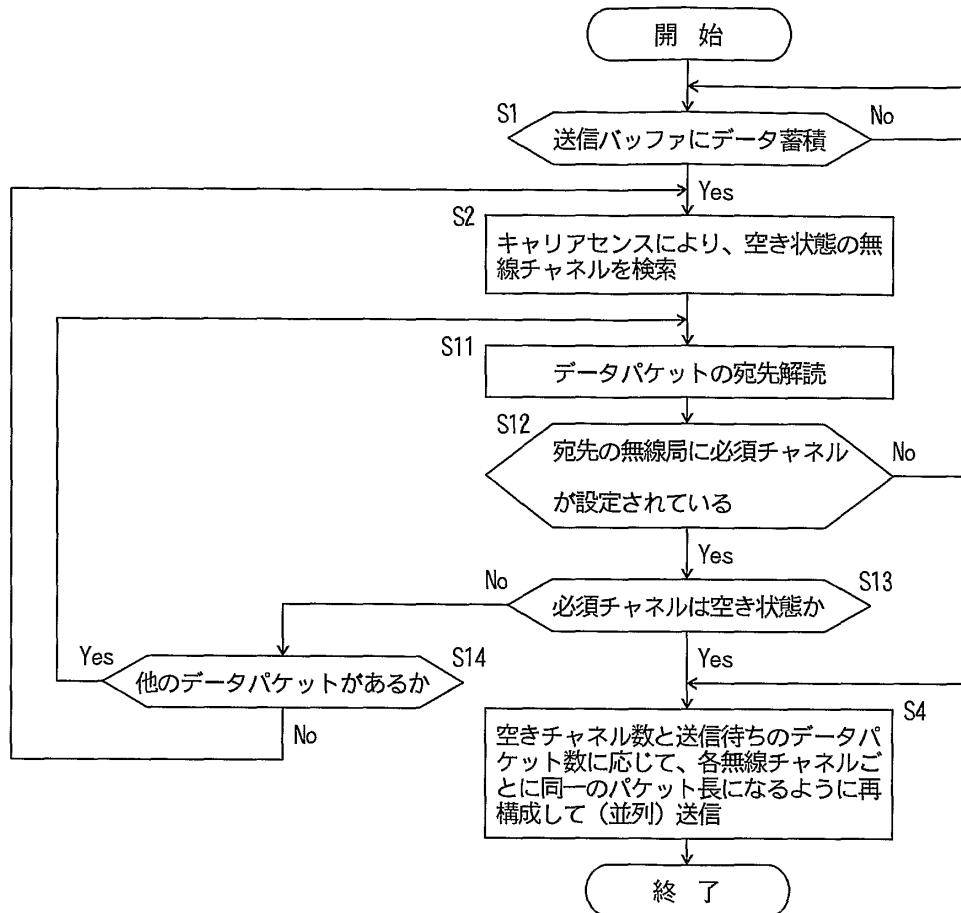
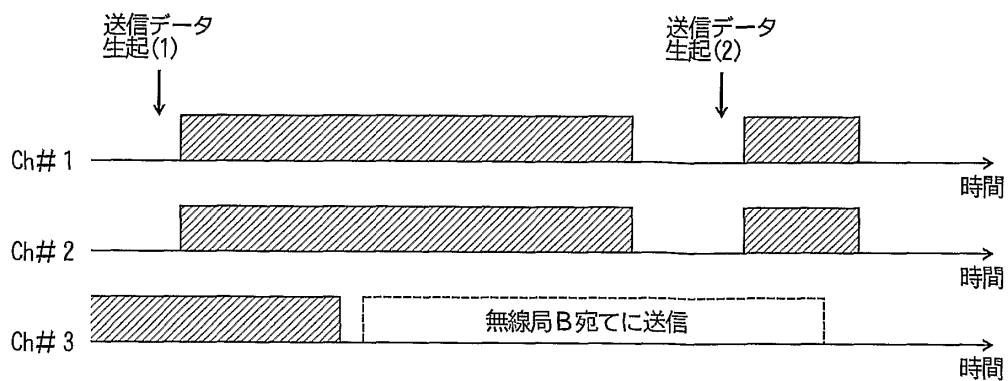
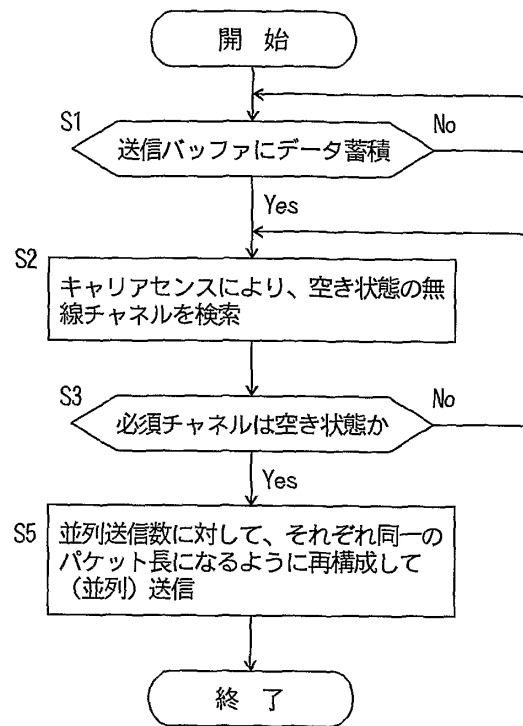


FIG. 5



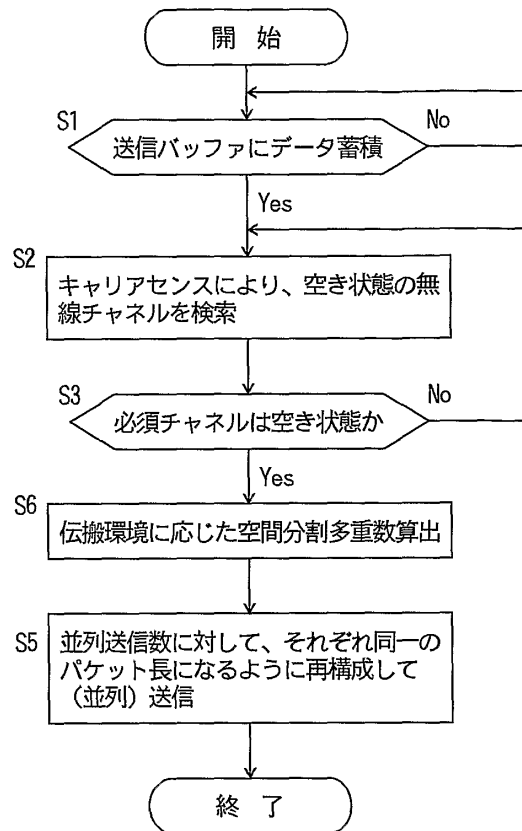
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FIG. 6



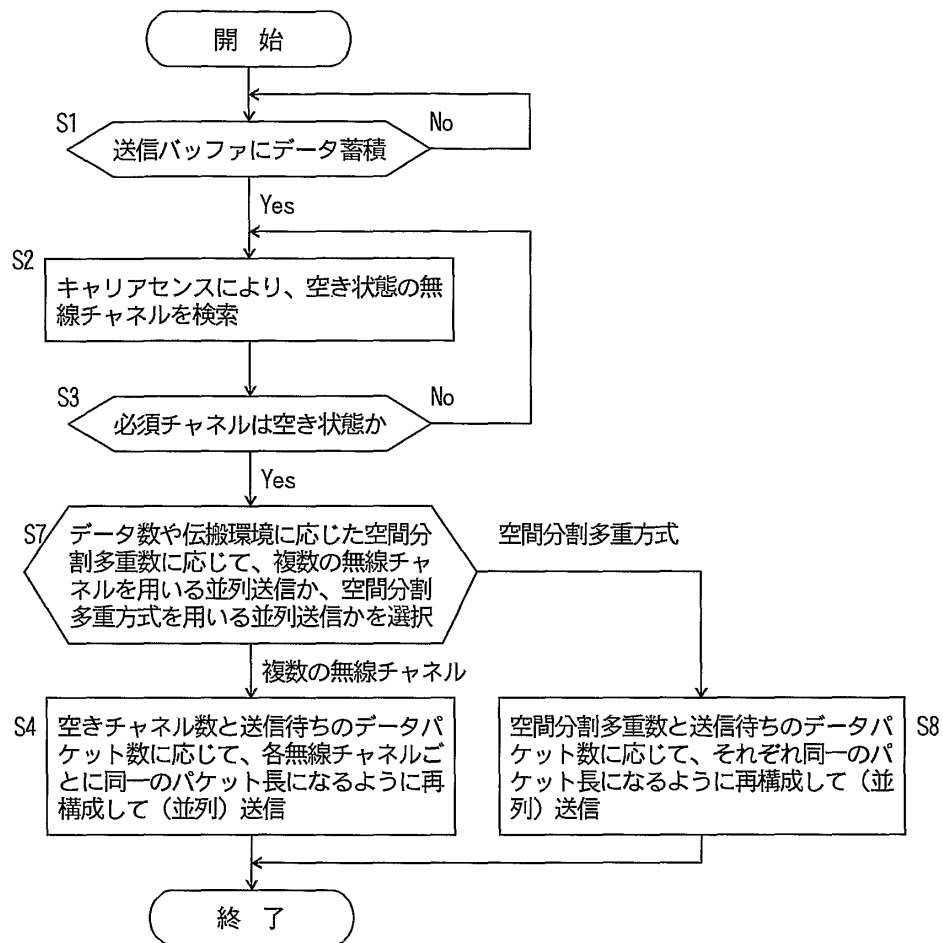
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FIG. 7



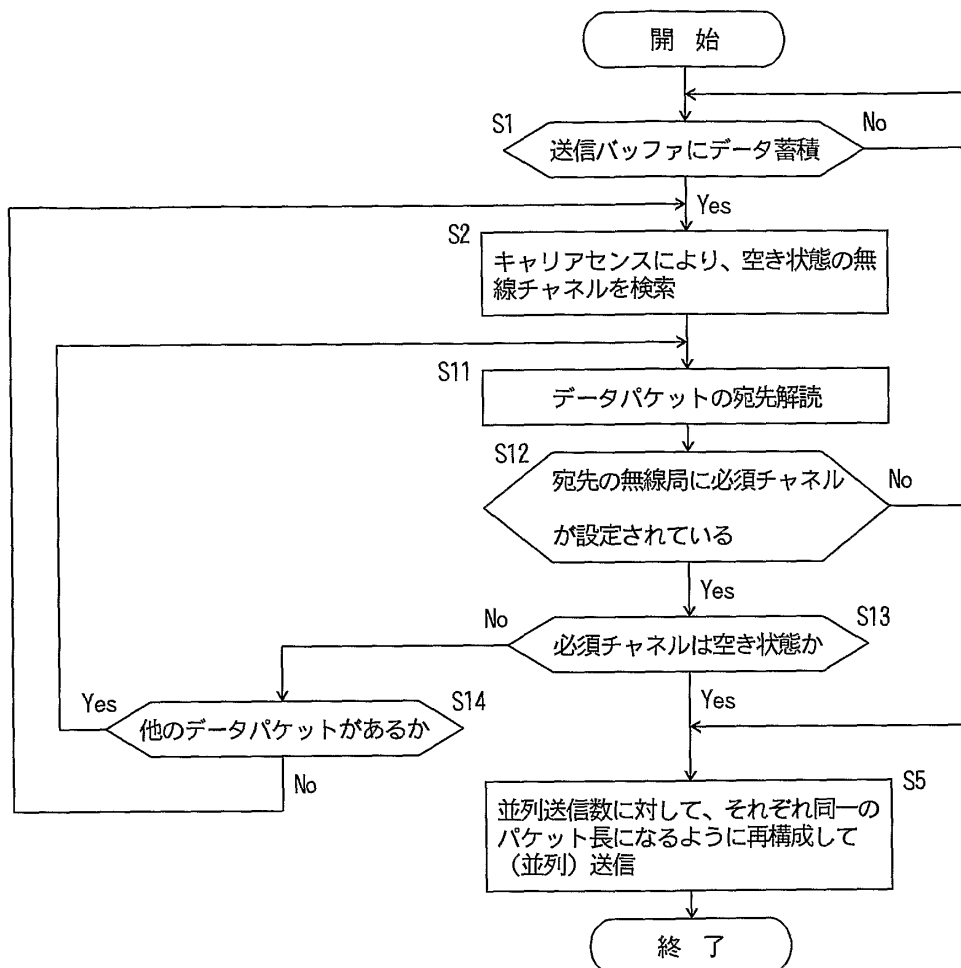
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FIG. 8



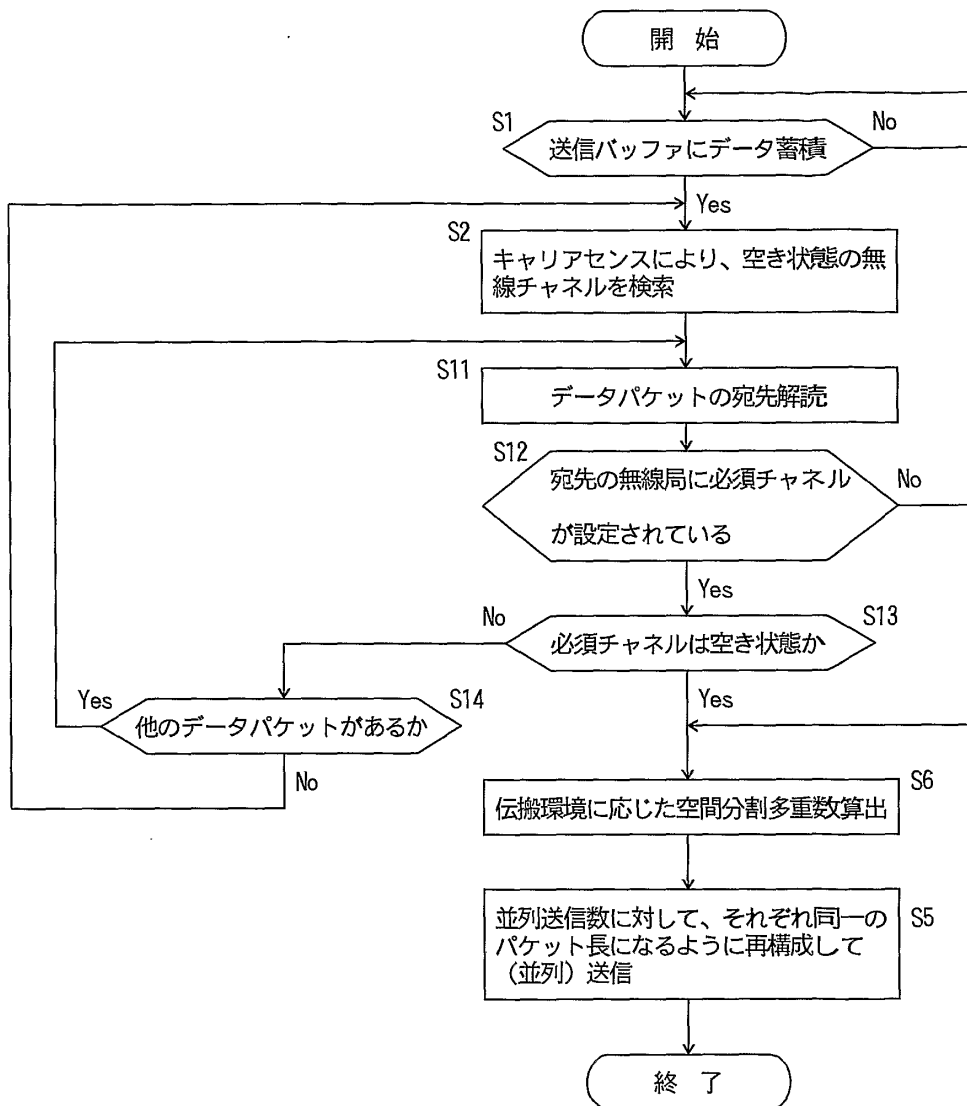
7/12

FIG. 9



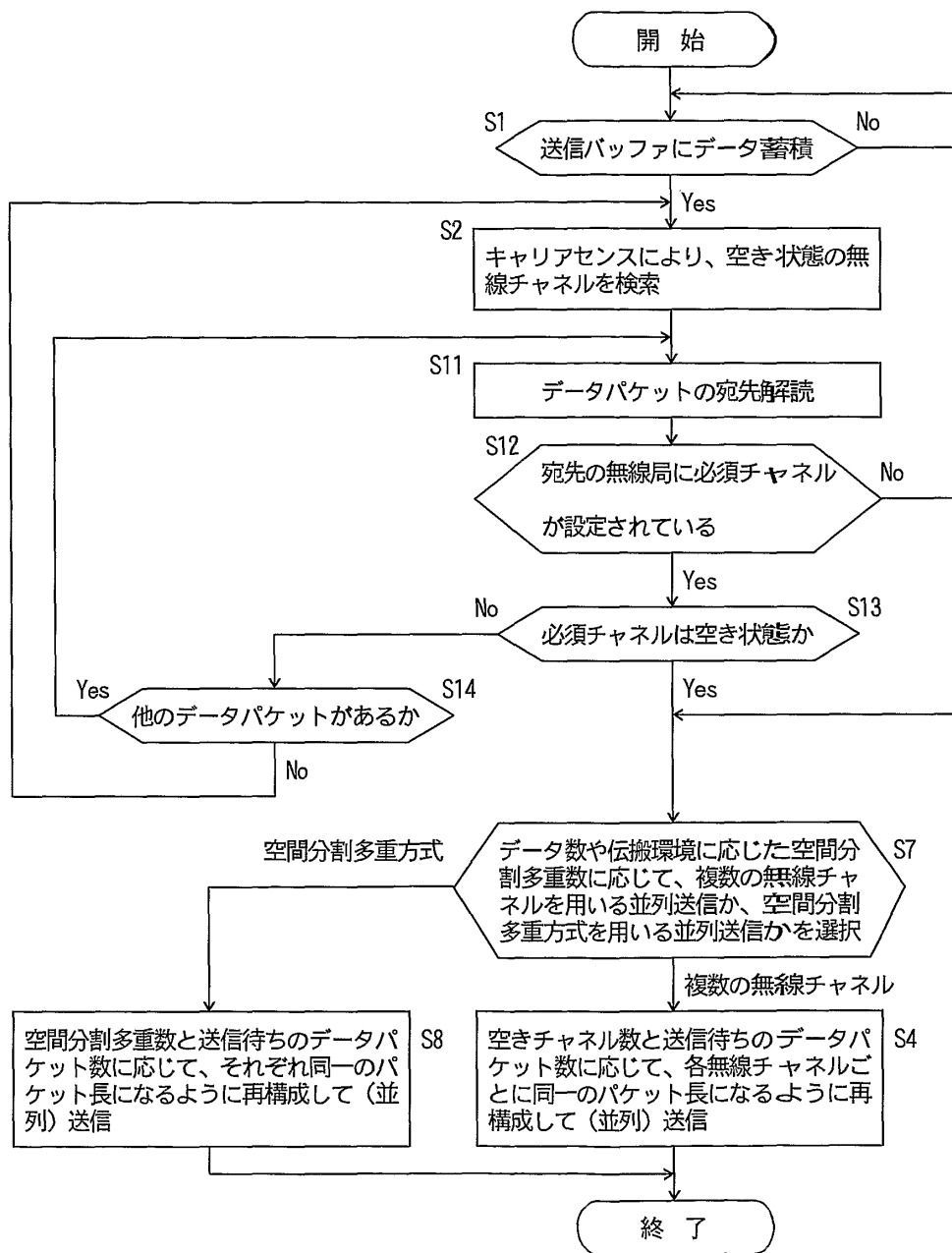
8/12

FIG. 10



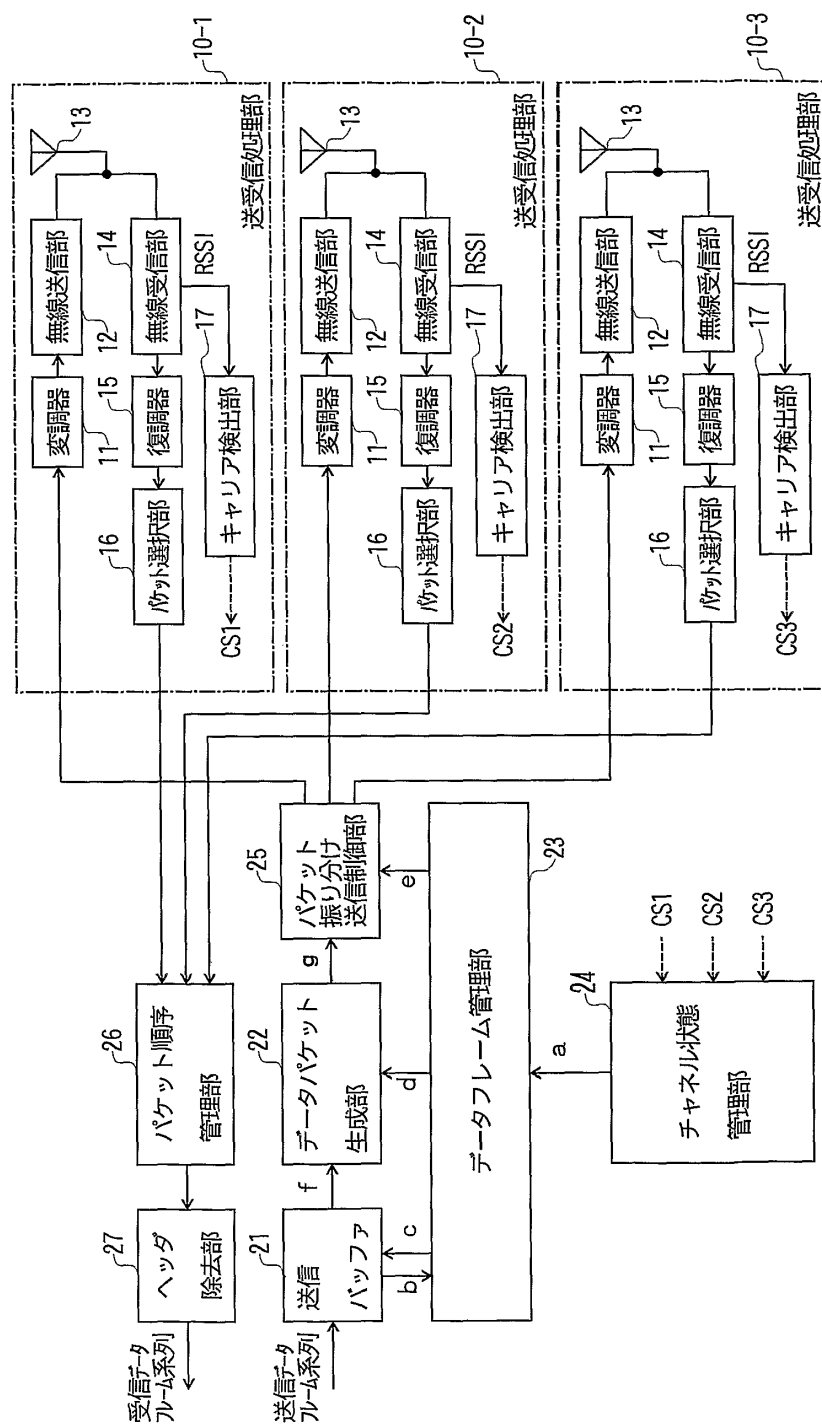
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FIG. 11



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FIG. 12



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FIG. 13

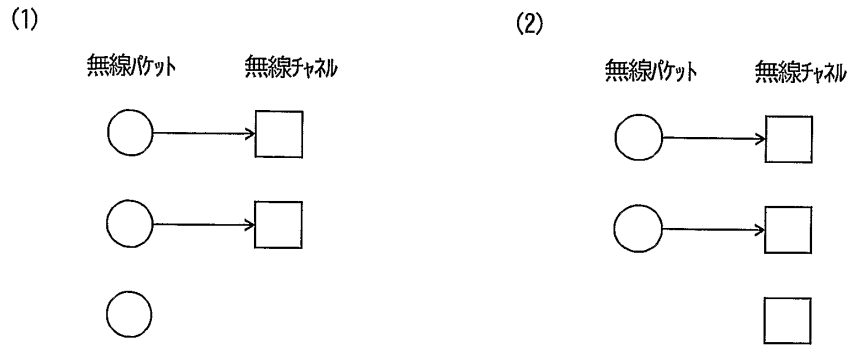
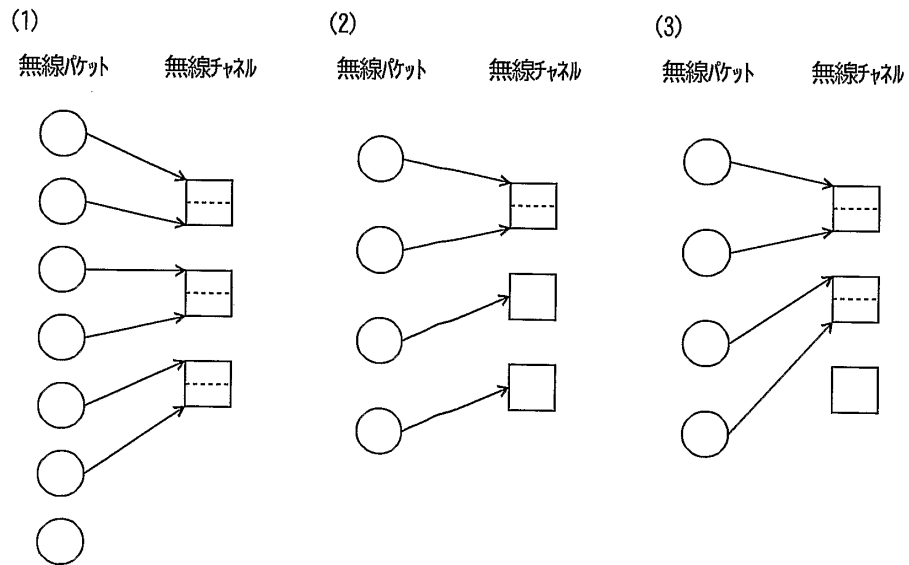


FIG. 14



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FIG. 15

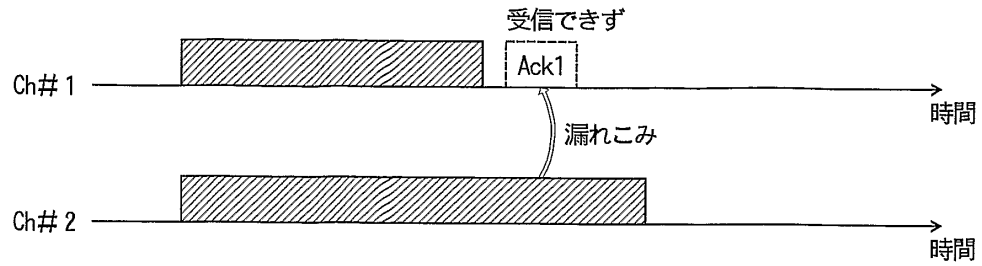


FIG. 16

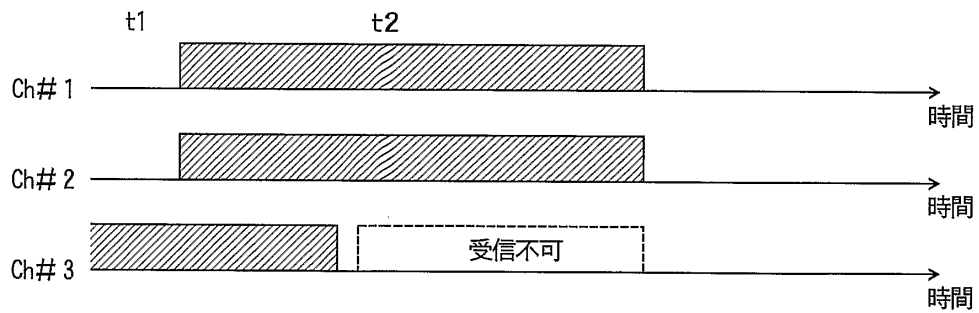
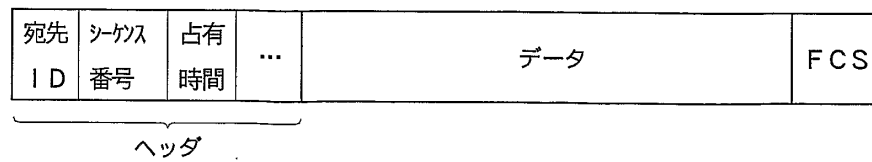


FIG. 17



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2004/013483

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl⁷ H04Q7/36, H04J15/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl⁷ H04J3/00-3/26, H04J15/00, H04B7/24-7/26, H04Q7/00-7/38,
H04L13/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P, A	JP 2003-259430 A (Sanyo Electric Co., Ltd.), 12 September, 2003 (12.09.03), Par. No. [0026] (Family: none)	1-2, 4-6, 8
A	JP 2002-198933 A (Sanyo Electric Co., Ltd.), 12 July, 2002 (12.07.02), Par. Nos. [0018] to [0019] (Family: none)	1-2, 5-6
A	JP 07-303090 A (AT & T Corp.), 14 November, 1995 (14.11.95), Par. No. [0020]; Figs. 5, 10 (Family: none)	3, 7

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

* Special categories of cited documents:

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

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"P" document published prior to the international filing date but later than the priority date claimed

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
06 December, 2004 (06.12.04)

Date of mailing of the international search report
21 December, 2004 (21.12.04)

Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

A. 発明の属する分野の分類 (国際特許分類 (IPC)) IPC第7版 H04Q 7/36 H04J 15/00		
B. 調査を行った分野 調査を行った最小限資料 (国際特許分類 (IPC)) IPC第7版 H04J 3/00 - 3/26, H04J 15/00 H04B 7/24 - 7/26, H04Q 7/00 - 7/38 H04L 13/00		
最小限資料以外の資料で調査を行った分野に含まれるもの		
国際調査で使用した電子データベース (データベースの名称、調査に使用した用語)		
C. 関連すると認められる文献		
引用文献の カテゴリー*	引用文献名 及び一部の箇所が関連するときは、その関連する箇所の表示	関連する 請求の範囲の番号
PA	JP 2003-259430 A (三洋電機株式会社) 2003.09.12, 第26段落 (ファミリーなし)	1-2, 4-6, 8
A	JP 2002-198933 A (三洋電機株式会社) 2002.07.12, 第18-19段落 (ファミリーなし)	1-2, 5-6
A	JP 07-303090 A (エイ・ティ・アンド・ティ・コーポレーション) 1995.11.14, 第20段落, 第5, 10図 (ファミリーなし)	3, 7
☐ C欄の続きにも文献が列挙されている。 ☐ パテントファミリーに関する別紙を参照。		
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国際調査を完了した日 06.12.2004	国際調査報告の発送日 21.12.2004	
国際調査機関の名称及びあて先 日本国特許庁 (ISA/JP) 郵便番号100-8915 東京都千代田区霞が関三丁目4番3号	特許庁審査官 (権限のある職員) 佐藤 聡史	5 J 3571
電話番号 03-3581-1101 内線 3535		

PCT/JP2004/013483

日 本 国 特 許 庁
JAPAN PATENT OFFICE

09.09.2004

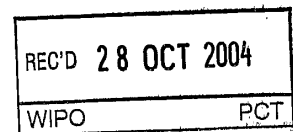
別紙添付の書類に記載されている事項は下記の出願書類に記載されている事項と同一であることを証明する。

This is to certify that the annexed is a true copy of the following application as filed with this Office.

出 願 年 月 日 2 0 0 3 年 9 月 9 日
Date of Application:

出 願 番 号 特 願 2 0 0 3 - 3 1 7 1 0 0
Application Number:
[ST. 10/C]: [J P 2 0 0 3 - 3 1 7 1 0 0]

出 願 人 日 本 電 信 電 話 株 式 会 社
Applicant(s):

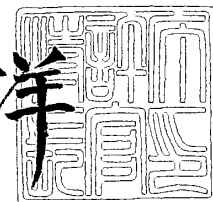


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2 0 0 4 年 1 0 月 1 4 日

特許庁長官
Commissioner,
Japan Patent Office

小 川 洋



出 証 番 号 出 証 特 2 0 0 4 - 3 0 9 2 3 1 3

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【整理番号】 NTTH156172
【提出日】 平成15年 9月 9日
【あて先】 特許庁長官 殿
【国際特許分類】 H04L 12/28
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【代理人】
 【識別番号】 100072718
 【弁理士】
 【氏名又は名称】 古谷 史旺
 【電話番号】 3343-2901
【手数料の表示】
 【予納台帳番号】 013354
 【納付金額】 21,000円
【提出物件の目録】
 【物件名】 特許請求の範囲 1
 【物件名】 明細書 1
 【物件名】 図面 1
 【物件名】 要約書 1
 【包括委任状番号】 9701422

【書類名】 特許請求の範囲**【請求項 1】**

キャリアセンスによって空き状態と判定された複数の無線チャネルを用いて複数の無線パケットを並列送信するか、または空き状態と判定された1つの無線チャネルを用いて空間分割多重方式により複数の無線パケットを並列送信するか、または両者を併用して複数の無線パケットを並列送信する無線パケット通信方法において、

送信に必ず使用する必須チャネルを設定し、この必須チャネルが空き状態のときに限り必須チャネルを含む無線チャネルを用いて無線パケットの送信を行うことを特徴とする無線パケット通信方法。

【請求項 2】

キャリアセンスによって空き状態と判定された複数の無線チャネルを用いて複数の無線パケットを並列送信するか、または空き状態と判定された1つの無線チャネルを用いて空間分割多重方式により複数の無線パケットを並列送信するか、または両者を併用して複数の無線パケットを並列送信する無線パケット通信方法において、

送信に必ず使用する必須チャネルが設定される無線局 A と必須チャネルが設定されない無線局 B に区別し、

前記無線局 A を宛先とする無線パケットの場合には、前記必須チャネルが空き状態のときに限り必須チャネルを含む無線チャネルを用いて無線パケットの送信を行い、前記無線局 B を宛先とする無線パケットの場合には、空き状態の無線チャネルを用いて無線パケットの送信を行うことを特徴とする無線パケット通信方法。

【請求項 3】

請求項 1 または請求項 2 に記載の無線パケット通信方法において、

並列送信される複数の無線パケットは、パケットサイズまたは伝送所要時間に相当するパケット長が互いに同一または同等に設定されることを特徴とする無線パケット通信方法。

【請求項 4】

請求項 1 または請求項 2 に記載の無線パケット通信方法において、

データ数や伝搬環境に応じた空間分割多重数に応じて、複数の無線チャネルを用いる並列送信か空間分割多重方式を用いる並列送信かを選択することを特徴とする無線パケット通信方法。

【請求項 5】

キャリアセンスによって空き状態と判定された複数の無線チャネルを用いて複数の無線パケットを並列送信するか、または空き状態と判定された1つの無線チャネルを用いて空間分割多重方式により複数の無線パケットを並列送信するか、または両者を併用して複数の無線パケットを並列送信する無線パケット通信装置において、

送信に必ず使用する必須チャネルを設定し、この必須チャネルが空き状態のときに限り必須チャネルを含む無線チャネルを用いて無線パケットの送信を行う手段を備えたことを特徴とする無線パケット通信装置。

【請求項 6】

キャリアセンスによって空き状態と判定された複数の無線チャネルを用いて複数の無線パケットを並列送信するか、または空き状態と判定された1つの無線チャネルを用いて空間分割多重方式により複数の無線パケットを並列送信するか、または両者を併用して複数の無線パケットを並列送信する無線パケット通信装置において、

送信に必ず使用する必須チャネルが設定される無線局 A と必須チャネルが設定されない無線局 B に区別し、

前記無線パケットの宛先を検出し、前記無線局 A を宛先とする無線パケットの場合には、前記必須チャネルが空き状態のときに限り必須チャネルを含む無線チャネルを用いて無線パケットの送信を行い、前記無線局 B を宛先とする無線パケットの場合には、空き状態の無線チャネルを用いて無線パケットの送信を行う手段を備えたことを特徴とする無線パケット通信装置。

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【請求項 7】

請求項 5 または請求項 6 に記載の無線パケット通信装置において、

並列送信される複数の無線パケットは、パケットサイズまたは伝送所要時間に相当するパケット長が互いに同一または同等に設定される構成であることを特徴とする無線パケット通信装置。

【請求項 8】

請求項 1 または請求項 2 に記載の無線パケット通信装置において、

データ数や伝搬環境に応じた空間分割多重数に応じて、複数の無線チャネルを用いる並列送信か空間分割多重方式を用いる並列送信かを選択する手段を備えたことを特徴とする無線パケット通信装置。

【書類名】 明細書**【発明の名称】 無線パケット通信方法および無線パケット通信装置****【技術分野】****【0001】**

本発明は、複数の無線チャネルを利用して複数の無線パケットを並列に送受信する無線パケット通信方法および無線パケット通信装置に関する。

【背景技術】**【0002】**

従来は、使用する無線チャネルを事前に1つだけ決めておき、無線パケットの送信に先立って当該無線チャネルが空き状態か否かを検出（キャリアセンス）し、空き状態の場合にのみ1つの無線パケットを送信していた。このような制御により、1つの無線チャネルを複数の無線局で互いに時間をずらして共用することができた（非特許文献1）。

【0003】

これに対して、キャリアセンスの際に複数の無線チャネルが空き状態であれば、その複数の無線チャネルを用いて複数の無線パケットを並列送信する無線パケット通信方法を提案している（特願2003-173914）。以下、この手法の概要について、図13、図14を参照して説明する。

【0004】

図13(1)は、3個の無線パケットに対して、空き状態の無線チャネルが2個ある場合であり、2個の無線チャネルを用いて3個のうちの2個の無線パケットを並列送信する。図13(2)は、2個の無線パケットに対して、空き状態の無線チャネルが3個ある場合であり、2個の無線チャネルを用いて全て（2個）の無線パケットを並列送信する。

【0005】

図14は、公知の空間分割多重技術（非特許文献2）を併用する場合である。なお、空間分割多重は、複数のアンテナから同じ無線チャネルで同時に異なる無線パケットを送信し、対向する無線局の複数のアンテナに受信された各無線パケットの伝搬係数の違いに対応するデジタル信号処理により、同じ無線チャネルで同時に送信された複数の無線パケットを分離する方式である。なお、伝搬係数等に応じて空間分割多重数が決定される。

【0006】

図14(1)は、各無線チャネルの空間分割多重数を2としたときに、7個の無線パケットに対して、空き状態の無線チャネルが3個ある場合である。各無線チャネルごとに空間分割多重を併用することにより最大6個の無線パケットの並列伝送が可能であるので、3個の無線チャネルを用いて7個のうちの6個の無線パケットを並列送信する。

【0007】

図14(2)、(3)は、各無線チャネルの空間分割多重数を2としたときに、4個の無線パケットに対して、空き状態の無線チャネルが3個ある場合である。各無線チャネルごとに空間分割多重を併用することにより最大6個の無線パケットの並列伝送が可能であるが、送信待ちの無線パケットは4個であるので、一部の無線チャネルについて空間分割多重を併用する。例えば、図14(2)に示すように、1個の無線チャネルは空間分割多重で2個の無線パケットを送信し、残りの2個の無線チャネルは空間分割多重を用いずにそれぞれ1個の無線パケットを送信し、全体で3個の無線チャネルを用いて4個の無線パケットを並列送信する。また、図14(3)に示すように、2個の無線チャネルでそれぞれ空間分割多重を併用し、全体で4個の無線パケットを並列送信する。

【0008】

ところで、同時に使用する複数の無線チャネルの中心周波数が互いに近接している場合には、一方の無線チャネルから他方の無線チャネルが使用している周波数領域へ漏れ出す漏洩電力の影響が大きくなる。一般に、無線パケットを伝送する場合には、送信側の無線局が無線パケットを送信した後に、受信側の無線局が受信した無線パケットに対して送達確認パケット（Ack）を送信側の無線局へ返送する。送信側の無線局がこの送達確認パケットを受信しようとするときに、並列送信に使用している他の無線チャネルからの漏洩

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電力の影響が問題となる。

【0009】

例えば、図15に示すように、無線チャネル#1と無線チャネル#2の中心周波数が互いに近接し、各無線チャネルから並列送信する無線パケットの送信所要時間が異なる場合を想定する。ここでは、無線チャネル#1から送信された無線パケットが短いので、それに対する送達確認パケット(Ack1)が受信されるときに無線チャネル#2は送信中である。そのため、無線チャネル#1では、無線チャネル#2からの漏洩電力により送達確認パケット(Ack1)を受信できない可能性がある。このような状況では、同時に複数の無線チャネルを利用して並列送信を行ったとしてもスループットの改善は見込めない。

【0010】

例えば無線LANシステムなどでは、ネットワークから入力するデータフレームのデータサイズは一定ではない。したがって、入力するデータフレームを順次に無線パケットに変換して送信する場合には、各無線パケットのパケット長も変化する。そのため、図15に示すように複数の無線パケットを同時に並列送信したとしても、各無線パケットの送信所要時間に違いが生じ、送達確認パケットの受信に失敗する可能性が高くなる。

【0011】

このような問題に対して、並列送信する複数の無線パケットのパケット長(無線パケットの送信に必要な時間)を同一または同等とすることにより、複数の無線パケットの送信を同時またはほぼ同時に終了させる方法を提案している(特願2003-173922、特願2003-177097、以下「先願」という)。これにより、複数の無線パケットのそれぞれに対する送達確認パケットが到着するタイミングでは、送信局は送信を行っていないので、無線チャネル間の漏洩電力などの影響を受けることなく、すべての送達確認パケットを受信することができ、スループットの改善に寄与することができる。

【非特許文献1】小電力データ通信システム/広帯域移動アクセスシステム(CSMA)標準規格、ARIB SDT-T71 1.0版、(社)電波産業会、平成12年策定

【非特許文献2】黒崎 外、MIMOチャネルにより100Mbit/sを実現する広帯域移動通信用SDM-COFDM方式の提案、電子情報通信学会技術研究報告、A・P2001-96, RCS2001-135(2001-10)

【発明の開示】

【発明が解決しようとする課題】

【0012】

ところで、並列送信する複数の無線パケットのパケット長を同一にしても、漏洩電力の影響が問題になる場合がある。以下、図16を参照して説明する。

【0013】

タイミングt1では、送信局の無線チャネル#1、#2が空き状態であり、無線チャネル#3がビジー状態にあるものとする。そのため、空き状態の無線チャネル#1、#2を用いて同一のパケット長の無線パケットを並列送信する。これにより、無線チャネル#1、#2間では互いの漏洩電力の影響は回避できる。しかし、この無線パケットの送信中(t2)に無線チャネル#3が空き状態になると、他の無線局では無線チャネル#3を空き状態と判断し、この無線チャネル#3を用いて当該送信局宛てに無線パケットを送信することがある。しかし、送信局では無線チャネル#1、#2を用いて無線パケットの送信中であり、その漏洩電力のために無線チャネル#3の無線パケットを受信することができない。すなわち、送信中の無線局は、送信チャネルの近隣の無線チャネルで送られた無線パケットを受信することができない。なお、この問題は複数の無線チャネルを用いた並列送信の場合に限らず、従来の1つの無線チャネルを用いて送信し、漏洩電力の影響を受ける近隣の無線チャネルで受信する場合でも発生する。

【0014】

本発明は、並列送信によるスループットの向上を目指す上で、近隣チャネルへの漏れこ

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みの影響を回避することができる無線パケット通信方法および無線パケット通信装置を提供することを目的とする。

【課題を解決するための手段】

【0015】

請求項1に記載の発明は、キャリアセンスによって空き状態と判定された複数の無線チャネルを用いて複数の無線パケットを並列送信するか、または空き状態と判定された1つの無線チャネルを用いて空間分割多重方式により複数の無線パケットを並列送信するか、または両者を併用して複数の無線パケットを並列送信する無線パケット通信方法において、送信に必ず使用する必須チャネルを設定し、この必須チャネルが空き状態のときに限り必須チャネルを含む無線チャネルを用いて無線パケットの送信を行う。

【0016】

請求項2に記載の発明は、キャリアセンスによって空き状態と判定された複数の無線チャネルを用いて複数の無線パケットを並列送信するか、または空き状態と判定された1つの無線チャネルを用いて空間分割多重方式により複数の無線パケットを並列送信するか、または両者を併用して複数の無線パケットを並列送信する無線パケット通信方法において、送信に必ず使用する必須チャネルが設定される無線局Aと必須チャネルが設定されない無線局Bに区別し、無線局Aを宛先とする無線パケットの場合には、必須チャネルが空き状態のときに限り必須チャネルを含む無線チャネルを用いて無線パケットの送信を行い、無線局Bを宛先とする無線パケットの場合には、空き状態の無線チャネルを用いて無線パケットの送信を行う。

【0017】

ここで、並列送信される複数の無線パケットは、パケットサイズまたは伝送所要時間に相当するパケット長が互いに同一または同等に設定される（請求項3）。また、データ数や伝搬環境に応じた空間分割多重数に応じて、複数の無線チャネルを用いる並列送信か空間分割多重方式を用いる並列送信かを選択するようにしてもよい（請求項4）。

【0018】

請求項5に記載の発明は、キャリアセンスによって空き状態と判定された複数の無線チャネルを用いて複数の無線パケットを並列送信するか、または空き状態と判定された1つの無線チャネルを用いて空間分割多重方式により複数の無線パケットを並列送信するか、または両者を併用して複数の無線パケットを並列送信する無線パケット通信装置において、送信に必ず使用する必須チャネルを設定し、この必須チャネルが空き状態のときに限り必須チャネルを含む無線チャネルを用いて無線パケットの送信を行う手段を備える。

【0019】

請求項6に記載の発明は、キャリアセンスによって空き状態と判定された複数の無線チャネルを用いて複数の無線パケットを並列送信するか、または空き状態と判定された1つの無線チャネルを用いて空間分割多重方式により複数の無線パケットを並列送信するか、または両者を併用して複数の無線パケットを並列送信する無線パケット通信装置において、送信に必ず使用する必須チャネルが設定される無線局Aと必須チャネルが設定されない無線局Bに区別し、無線パケットの宛先を検出し、無線局Aを宛先とする無線パケットの場合には、必須チャネルが空き状態のときに限り必須チャネルを含む無線チャネルを用いて無線パケットの送信を行い、無線局Bを宛先とする無線パケットの場合には、空き状態の無線チャネルを用いて無線パケットの送信を行う手段を備える。

【0020】

ここで、並列送信される複数の無線パケットは、パケットサイズまたは伝送所要時間に相当するパケット長が互いに同一または同等に設定される構成とする（請求項7）。また、データ数や伝搬環境に応じた空間分割多重数に応じて、複数の無線チャネルを用いる並列送信か空間分割多重方式を用いる並列送信かを選択する手段を備えるようにしてもよい（請求項8）。

【発明の効果】

【0021】

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本発明は、複数の無線チャネルを用いるか空間分割多重方式を用いることにより複数の無線パケットを並列送信する場合に、必須チャネルを含む無線チャネルを用いて送信を行うようにし、必須チャネルが空き状態でなければ送信を禁止する。これにより、必須チャネルを含む無線チャネルを用いて送信している送信局に対しては、他の無線局から送信が行われないので、送信局で自局宛ての無線パケットの受信ができない事態を回避することができる。一方、他の無線局では、必須チャネルが空き状態になるのを待って送信局に対して無線パケットを送信することにより、確実に無線パケットを伝送することができ、スループットの改善を図ることができる。

【0022】

なお、送信する際には必須チャネルを含み、必須チャネルがビジー状態であれば他の無線チャネルが空き状態であっても送信を禁止する必須チャネルについては、複数の優先順位が設定された無線チャネルにおいて最高の優先順位が設定された無線チャネルとみることとできる。

【0023】

また、必須チャネルの設定がなされていない無線局がある場合には、必須チャネルがビジー状態であってもその無線局間の送信を可能にすることにより、スループットの低下を抑制することができる。

【発明を実施するための最良の形態】

【0024】

(無線パケット通信方法の第1の実施形態)

図1は、本発明の無線パケット通信方法の第1の実施形態のフローチャートを示す。図2は、本発明の無線パケット通信方法の第1の実施形態のタイムチャートを示す。ここでは、無線チャネル#1、#2、#3が用意され、各無線局に一律に必須チャネルとして無線チャネル#1が設定されているものとする。必須チャネルは、各無線局に対して定期的に報知され、各無線局は必須チャネルがビジー状態の場合には、仮に他の無線チャネルが空き状態であっても送信は行わないものとし、すべての送信が禁止される。また、無線チャネル#1、#2、#3は、互いに漏れこみを生じさせる関係にあり、1つの無線チャネルが送信中であれば他の無線チャネルで受信できないものとする。

【0025】

まず、送信バッファにデータが到着すると、キャリアセンスによって空き状態の無線チャネルを検索する(S1、S2)。ここでは、送信データ生起(1)のタイミングにおいて無線チャネル#3がビジー状態であり、無線チャネル#1および無線チャネル#2が空き状態として検索される。次に、必須チャネルが空き状態か否かを判断し(S3)、必須チャネルがビジー状態であれば空き状態の無線チャネルの検索に戻る。一方、必須チャネルが空き状態であれば、空きチャネル数と送信待ちのデータパケット数に応じて、例えば先願に示す方法により各無線チャネルごとに同一のパケット長になるように再構成して(並列)送信する(S4)。ここでは、必須チャネルである無線チャネル#1が空き状態であるので、無線チャネル#2を含む2チャネルによって無線パケットの並列送信が行われる。

【0026】

データパケットの再構成の方法としては、例えばデータパケットが1つで空きチャネル数が2つの場合には、図3(1)に示すようにデータパケットを均等に2つに分割する。またデータパケットが2つで空きチャネル数が2つの場合には、図3(2)に示すように同一のパケット長になるようにデータパケットを適当に切り貼りする。また、複数の無線チャネルを使用する際に各無線チャネルの伝送速度が異なる場合には、各無線パケットのサイズ比を伝送速度比と同一になるように調整する。

【0027】

なお、他の無線局では無線チャネル#3が空き状態になっても、必須チャネルである無線チャネル#1がビジー状態であるので、送信は禁止される。一方、送信データ生起(2)のタイミングでは、必須チャネルである無線チャネル#1を含むすべての無線チャネルが

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空き状態となるので、各無線局は送信可能状態となる。例えば、送信データ生起(1)のタイミングで無線パケットを送信した送信局に対して他の無線局が無線パケットを送信した場合には、送信データ生起(2)のタイミングで行われる。

【0028】

(無線パケット通信方法の第2の実施形態)

図4は、本発明の無線パケット通信方法の第2の実施形態のフローチャートを示す。図5は、本発明の無線パケット通信方法の第2の実施形態のタイムチャートを示す。ここでは、必須チャンネルが設定される無線局Aと、必須チャンネルが設定されない無線局Bが存在し、無線局Bを宛先とする送信の場合には特に制限はなく、無線局Aを宛先とする送信の場合には必須チャンネルが空き状態のときに限り送信可能とし、必須チャンネルがビジー状態であれば他の無線チャンネルが空き状態であっても送信は禁止されるものとする。なお、第1の実施形態の場合には、すべての無線局に一律に必須チャンネルが設定されているので、無線パケットの宛先を考慮することなく、送信する際には必ず必須チャンネルを含む制御になっている。

【0029】

まず、送信バッファにデータが到着すると、キャリアセンスによって空き状態の無線チャンネルを検索する(S1, S2)。ここでは、送信データ生起(1)のタイミングにおいて無線チャンネル#3がビジー状態であり、無線チャンネル#1および無線チャンネル#2が空き状態として検索される。次に、送信バッファに到着した1つのデータパケットの宛先を解読し(S11)、その宛先となる無線局に必須チャンネルが設定されているか否かを判断する(S12)。宛先の無線局に必須チャンネルが設定されていれば、その必須チャンネルが空き状態か否かを判断し(S13)、必須チャンネルが空き状態であれば、空きチャンネル数と送信待ちのデータパケット数に応じて、例えば先願に示す方法により各無線チャンネルごとに同一のパケット長になるように再構成して(並列)送信する(S4)。ここでは、無線局A宛ての無線パケットについて、必須チャンネルである無線チャンネル#1が空き状態であるので、無線チャンネル#2を含む2チャンネルによって無線パケットの並列送信が行われる。

【0030】

一方、S12において、宛先の無線局に必須チャンネルが設定されていなければ、必須チャンネルの空き状態を考慮することなく、空きチャンネル数と送信待ちのデータパケット数に応じて各無線チャンネルごとに同一のパケット長になるように再構成して(並列)送信する(S4)。また、S13において、必須チャンネルが空き状態でなければ、必須チャンネルが設定されている無線局A宛ての無線パケットの送信はできないので、送信バッファに他のデータパケットがあるか否かを判断し(S14)、他のデータパケットがあればS11の宛先解読に戻り、他のデータパケットがなければS2の空き状態の無線チャンネルの検索を行う。

【0031】

ここでは、無線チャンネル#3が空き状態となったときに、無線チャンネル#3を用いて必須チャンネルが設定されていない無線局B宛ての無線パケットの送信が可能となる。一方、無線チャンネル#3による無線局A宛ての無線パケットの送信は、無線チャンネル#1がビジー状態であるので禁止され、無線チャンネル#1が空き状態になるまで待たされる。

【0032】

なお、送信データ生起(2)のタイミングでは無線チャンネル#1、#2が空き状態となるので、必須チャンネルが設定されている無線局A宛ての無線パケット、あるいは必須チャンネルが設定されていない無線局B宛ての無線パケットのいずれでも、それらの無線チャンネルを用いて送信が可能となる。

【0033】

(無線パケット通信方法の第3の実施形態)

図6は、本発明の無線パケット通信方法の第3の実施形態のフローチャートを示す。本実施形態の特徴は、第1の実施形態において無線パケットの並列送信に空間分割多重方式を併用するところにある。第1の実施形態におけるS4で無線パケットを再構成する際に、空間分割多重数×空きチャンネル数に対してそれぞれ同一のパケット長になるように再構

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成する (S5)。その他は第1の実施形態と同様である。

【0034】

(無線パケット通信方法の第4の実施形態)

図7は、本発明の無線パケット通信方法の第4の実施形態のフローチャートを示す。本実施形態の特徴は、無線パケットの並列送信に空間分割多重方式を併用する場合に、第3の実施形態におけるS5で空間分割多重数×空きチャネル数に対してそれぞれ同一のパケット長になるように再構成する前に、伝搬係数よりアンテナ相関を求め、予め定めた閾値により1チャネルに重複可能な空間分割多重数を求めるところにある (S6)。その他は第3の実施形態と同様である。

【0035】

(無線パケット通信方法の第5の実施形態)

図8は、本発明の無線パケット通信方法の第5の実施形態のフローチャートを示す。本実施形態の特徴は、第1の実施形態に示すように複数の無線チャネルを用いて並列送信を行うか、第3の実施形態に示す空間分割多重方式を用いて並列送信を行うか、送信バッファに到着したデータ数や第4の実施形態で示した伝搬環境に応じた空間分割多重数に応じて選択するところにある (S7)。この選択に応じて、空きチャネル数または空間分割多重数に対してそれぞれ同一のパケット長になるように再構成して並列送信する (S4, S8)。その他は第1の実施形態と同様である。

【0036】

(無線パケット通信方法の第6の実施形態)

図9は、本発明の無線パケット通信方法の第6の実施形態のフローチャートを示す。本実施形態の特徴は、第2の実施形態において無線パケットの並列送信に空間分割多重方式を併用するところにある。第2の実施形態におけるS4で無線パケットを再構成する際に、空間分割多重数×空きチャネル数に対してそれぞれ同一のパケット長になるように再構成する (S5)。その他は第2の実施形態と同様である。

【0037】

(無線パケット通信方法の第7の実施形態)

図10は、本発明の無線パケット通信方法の第7の実施形態のフローチャートを示す。本実施形態の特徴は、無線パケットの並列送信に空間分割多重方式を併用する場合に、第6の実施形態におけるS5で空間分割多重数×空きチャネル数に対してそれぞれ同一のパケット長になるように再構成する前に、伝搬係数よりアンテナ相関を求め、予め定めた閾値により1チャネルに重複可能な空間分割多重数を求めるところにある (S6)。その他は第6の実施形態と同様である。

【0038】

(無線パケット通信方法の第8の実施形態)

図11は、本発明の無線パケット通信方法の第8の実施形態のフローチャートを示す。本実施形態の特徴は、第2の実施形態に示すように複数の無線チャネルを用いて並列送信を行うか、第6の実施形態に示す空間分割多重方式を用いて並列送信を行うか、送信バッファに到着したデータ数や第7の実施形態で示した伝搬環境に応じた空間分割多重数に応じて選択するところにある (S7)。この選択に応じて、空きチャネル数または空間分割多重数に対してそれぞれ同一のパケット長になるように再構成して並列送信する (S4, S8)。その他は第2の実施形態と同様である。

【0039】

(無線パケット通信装置の実施形態)

図12は、本発明の無線パケット通信装置の実施形態を示す。ここでは、3個の無線チャネル#1, #2, #3を用いて3個の無線パケットを並列に送受信可能な無線パケット通信装置の構成について示すが、その並列数は任意に設定可能である。なお、各無線チャネルごとに空間分割多重を利用する場合には、(無線チャネル数×空間分割多重数)の無線パケットを並列に送受信可能であるが、ここでは空間分割多重については省略する。

【0040】

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図において、無線パケット通信装置は、送受信処理部10-1, 10-2, 10-3と、送信バッファ21, パケット生成/再構成処理部22, 送信チャネル選択制御部23, パケット振り分け送信制御部24, パケット順序管理部25およびヘッダ除去部26とを備える。

【0041】

送受信処理部10-1, 10-2, 10-3は、互いに異なる無線チャネル#1, #2, #3で無線通信を行う。これらの無線チャネルは、互いに無線周波数などが異なるので互いに独立であり、同時に複数の無線チャネルを利用して無線通信できる構成になっている。各送受信処理部10は、変調器11, 無線送信部12, アンテナ13, 無線受信部14, 復調器15, パケット選択部16およびキャリア検出部17を備える。

【0042】

送信バッファ21の入力には、送信すべき送信データフレーム系列が入力され、バッファリングされる。この送信データフレーム系列は、1つあるいは複数のデータフレームで構成される。実際に扱うデータフレームとしては、例えばイーサネット（登録商標）フレームなどが想定される。送信バッファ21は、現在保持しているデータフレームの数、宛先となる無線パケット通信装置のID情報、データサイズ、バッファ上の位置を表すアドレス情報などをパケット生成/再構成処理部22に逐次与え、さらにそれらの情報が送信チャネル選択制御部23に通知される。

【0043】

パケット生成/再構成処理部22は、図17に示すデータパケットを生成する。すなわち、送信バッファ21にバッファリングされた送信データフレーム系列中の各々のデータフレームに対して、当該データフレームの宛先となる無線パケット通信装置のID情報や、宛先ごとに独立したデータフレームの順番を表すシーケンス番号や、無線チャネル上での占有時間を表すフィールドを含むヘッダと、無線パケットの誤りを検出するためのCRC符号部が付加される。また、複数の無線チャネルや空間分割多重方式を用いて複数の無線パケットを並列送信する場合には、図3に示すように各無線パケットが同等のパケット長になるように再構成する。

【0044】

一方、他の無線パケット通信装置が互いに異なる無線チャネル#1, #2, #3を介して送信した無線信号は、それぞれ対応する送受信処理部10-1, 10-2, 10-3のアンテナ13を介して無線受信部14に入力される。各無線チャネル対応の無線受信部14は、入力された無線信号に対して周波数変換、フィルタリング、直交検波およびAD変換を含む受信処理を施す。なお、各無線受信部14には、それぞれ接続されたアンテナ13が送信のために使用されていない時に、各無線チャネルにおける無線伝搬路上の無線信号が常時入力されており、各無線チャネルの受信電界強度を表すRSSI信号がキャリア検出部17へ出力される。また、無線受信部14に対応する無線チャネルで無線信号が受信された場合には、受信処理されたベースバンド信号が復調部15へ出力される。

【0045】

復調器15は、無線受信部14から入力されたベースバンド信号に対してそれぞれ復調処理を行い、得られたデータパケットはパケット選択部16へ出力される。パケット選択部16は、入力されたデータパケットに対してCRCチェックを行い、誤りが検出されなかったデータパケットをキャリア検出部17へ出力する（後述するNAV設定用）。また、データパケットが誤りなく受信された場合には、その事実を送信チャネル選択制御部23に通知する（C1-1, C2-1, C3-1）とともに、そのデータパケットが自局に対して送信されたものか否かを識別する。すなわち、各データパケットの宛先IDが自局と一致するかどうかを調べ、自局宛てのデータパケットをパケット順序管理部25へ出力する。また、自局宛でないデータパケットの場合には、パケット選択部16で当該パケットが破棄される。パケット順序管理部25は、入力された各データパケットに付加されているシーケンス番号を調べ、受信した複数のデータパケットの並びを適切な順番、すなわちシーケンス番号順に並べ替える。その結果を受信データパケット系列としてヘッダ除去部26へ出力す

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る。ヘッダ除去部 26 は、入力された受信データパケット系列に含まれている各々のデータパケットからヘッダ部分を除去し、受信データフレーム系列として出力する。

【0046】

キャリア検出部 17 は、RSSI 信号が入力されると、その信号によって表される受信電界強度の値と予め設定した閾値とを比較する。そして、所定の期間中の受信電界強度が連続的に閾値よりも小さい状態が継続すると、割り当てられた無線チャネルが空き状態であると判定し、それ以外の場合には割り当てられた無線チャネルがビジーであると判定する。各無線チャネルに対応するキャリア検出部 17 は、この判定結果をキャリア検出結果として出力する。なお、各送受信処理部 10 において、アンテナ 13 が送信状態である場合にはキャリア検出部 17 に RSSI 信号が入力されない。また、アンテナ 13 が既に送信状態にある場合には、同じアンテナ 13 を用いて他のデータパケットを無線信号として同時に送信することはできない。したがって、各キャリア検出部 17 は RSSI 信号が入力されなかった場合には、割り当てられた無線チャネルがビジーであることを示すキャリア検出結果を出力する。

【0047】

また、キャリア検出部 17 は、パケット選択部 16 から入力されたデータパケット内に記述された占有時間を NAV に設定する。そして、この NAV の値および無線受信部 14 から入力された RSSI 信号に応じて、対応する無線チャネルが空き状態かビジーかを判定し、そのキャリア検出結果を送信チャネル選択制御部 23 へ出力する (C1-2, C2-2, C3-2)。送信チャネル選択制御部 23 は、各無線チャネルに対応するキャリア検出結果と、送信バッファ 22 に蓄積されたデータパケット数とに基づいて、並列送信するデータパケット数を決定する。また、送信チャネル選択制御部 23 はデータパケットの送信に用いる無線チャネルを選択し、選択結果の情報をパケット振り分け送信制御部 24 に与える。

【0048】

送信チャネル選択制御部 23 は、たとえば空き状態の無線チャネル数 N が送信バッファ 22 に蓄積されたデータパケット数 K 以上の場合には、このデータパケット数 K を並列送信するデータパケット数として決定し、決定したデータパケット数 K と同数の無線チャネルを空き状態の無線チャネルの中から選択し、その結果をパケット振り分け送信制御部 24 に通知する (例えば図 13 (2) の場合)。また、空き状態の無線チャネル数 N が送信バッファ 22 に蓄積されたデータパケット数 K よりも少ない場合には、空き状態の無線チャネル数 N と同数のデータパケットを並列送信するデータパケット数として決定し、全ての空き状態の無線チャネルを選択し、その結果をパケット振り分け送信制御部 24 に通知する (例えば図 13 (1) の場合)。

【0049】

パケット振り分け送信制御部 24 は、送信チャネル選択制御部 23 から通知された並列送信するデータパケット数に基づいて、これと同数のデータパケットの出力を要求する要求信号をパケット生成/再構成処理部 22 に出力する。パケット生成/再構成処理部 22 は、パケット振り分け送信制御部 24 から入力された要求信号の内容を参照し、送信バッファ 21 が保持しているデータパケットのうち、送信バッファ 21 に入力された時刻が早いデータパケットから順に要求された数のデータパケットを取り出し、複数の無線パケットを並列送信する場合には各無線パケットが同等のパケット長になるように再構成してパケット振り分け送信制御部 24 に出力する。

【0050】

さらに、パケット振り分け送信制御部 24 は、パケット生成/再構成処理部 22 から入力された各データパケットと送信チャネル選択制御部 23 が選択した無線チャネルとの対応付けを行う。たとえば、送受信処理部 10-1, 10-2, 10-3 に対応する 3 つの無線チャネル #1, #2, #3 が全て空き状態であり、送信チャネル選択制御部 23 が 3 つの無線チャネル #1, #2, #3 を全て選択し、送信バッファ 22 から 3 つのデータパケットが同時に入力され、かつこれらが同等のパケット長である場合には、これらの 3 つのデータパケットをそれぞれ無線チャネル #1, #2, #3 に順番に対応付けられたい。

出証特 2004-3092313

【0051】

このような対応付けの結果、無線チャネル#1に対応付けられたデータパケットは送受信処理部10-1内の変調器11に入力され、無線チャネル#2に対応付けられたデータパケットは送受信処理部10-2内の変調器11に入力され、無線チャネル#3に対応付けられたデータパケットは送受信処理部10-3内の変調器11に入力される。各変調器11は、パケット振り分け送信制御部24からデータパケットが入力されると、そのデータパケットに対して所定の変調処理を施して無線送信部12に出力する。各無線送信部12は、変調器11から入力された変調処理後のデータパケットに対して、DA変換、周波数変換、フィルタリング及び電力増幅を含む送信処理を施し、それぞれ対応する無線チャネルを介してアンテナ13から無線パケットとして送信される。

【図面の簡単な説明】

【0052】

【図1】本発明の無線パケット通信方法の第1の実施形態を示すフローチャート。

【図2】本発明の無線パケット通信方法の第1の実施形態を示すタイムチャート。

【図3】データパケットの再構成の方法を示す図。

【図4】本発明の無線パケット通信方法の第2の実施形態を示すフローチャート。

【図5】本発明の無線パケット通信方法の第2の実施形態を示すタイムチャート。

【図6】本発明の無線パケット通信方法の第3の実施形態を示すフローチャート。

【図7】本発明の無線パケット通信方法の第4の実施形態を示すフローチャート。

【図8】本発明の無線パケット通信方法の第5の実施形態を示すフローチャート。

【図9】本発明の無線パケット通信方法の第6の実施形態を示すフローチャート。

【図10】本発明の無線パケット通信方法の第7の実施形態を示すフローチャート。

【図11】本発明の無線パケット通信方法の第8の実施形態を示すフローチャート。

【図12】本発明の無線パケット通信装置の実施形態を示すブロック図。

【図13】複数の無線チャネルを用いて複数の無線パケットを並列送信する方法を説明する図。

【図14】複数の無線チャネルを用いて複数の無線パケットを並列送信する方法（空間分割多重を併用）を説明する図。

【図15】無線チャネルの漏洩電力の影響を説明する図。

【図16】並列送信する無線パケットのパケット長を同一にしても漏洩電力の影響が問題になる場合を説明する図。

【図17】本発明の無線パケット通信装置で用いる無線パケットの構成を示す図。

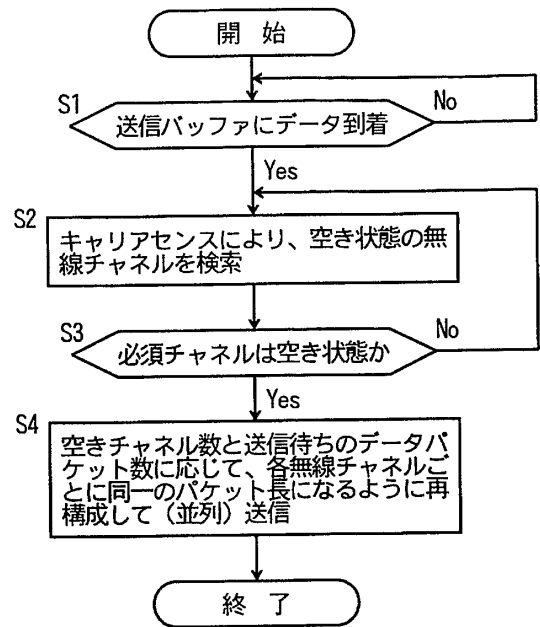
【符号の説明】

【0053】

- 10 送受信処理部
- 11 変調器
- 12 無線送信部
- 13 アンテナ
- 14 無線受信部
- 15 復調器
- 16 パケット選択部
- 17 キャリア検出部
- 21 送信バッファ
- 22 パケット生成／再構成処理部
- 23 送信チャネル選択制御部
- 24 パケット振り分け送信制御部
- 25 パケット順序管理部
- 26 ヘッダ除去部

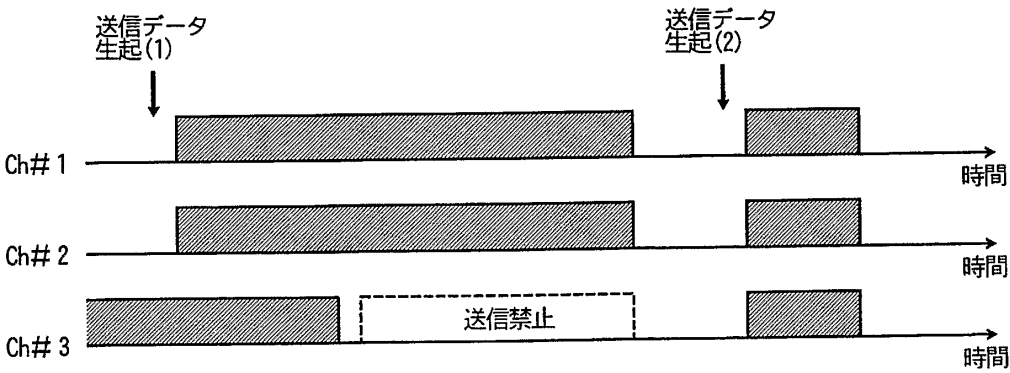
【書類名】 図面
【図 1】

本発明の無線パケット通信方法の第 1 の実施形態



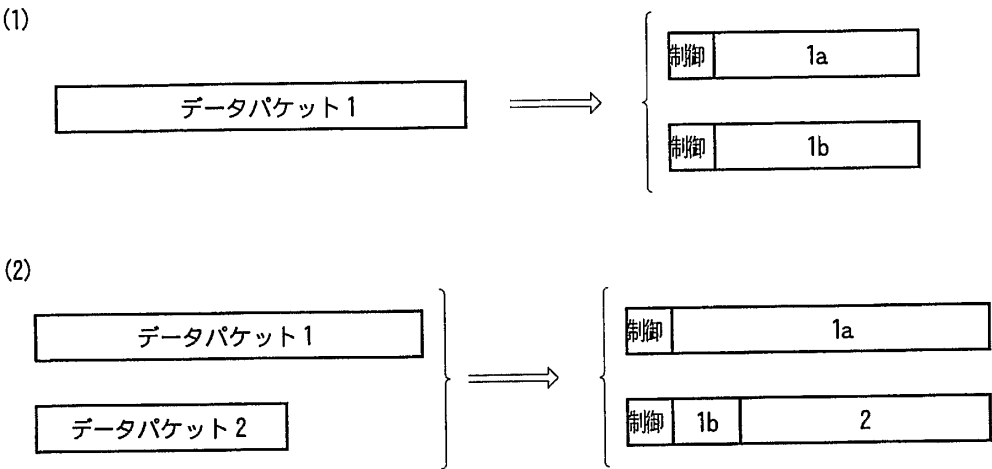
【図 2】

本発明の無線パケット通信方法の第 1 の実施形態



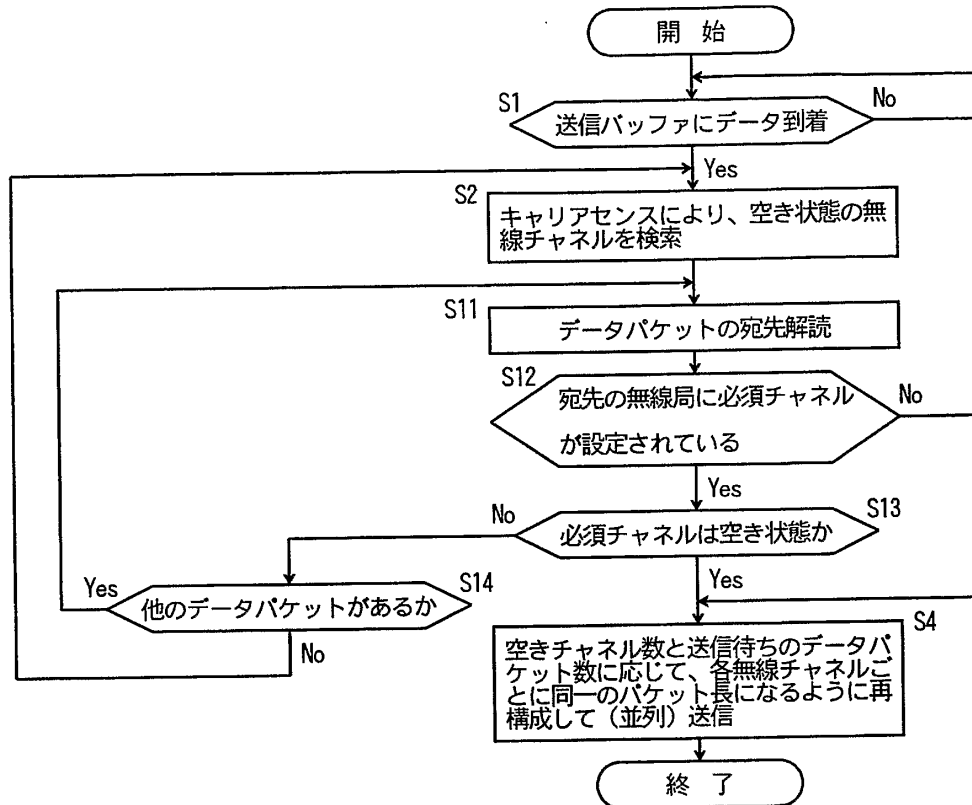
【図 3】

データパケットの再構成の方法



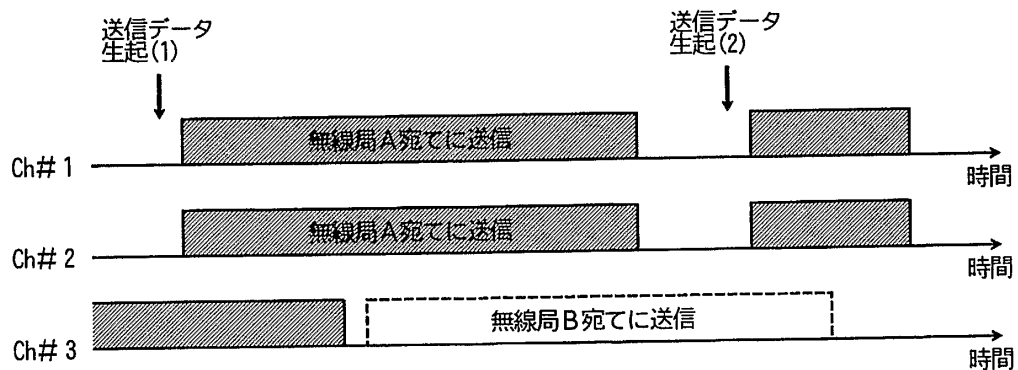
【図 4】

本発明の無線パケット通信方法の第 2 の実施形態



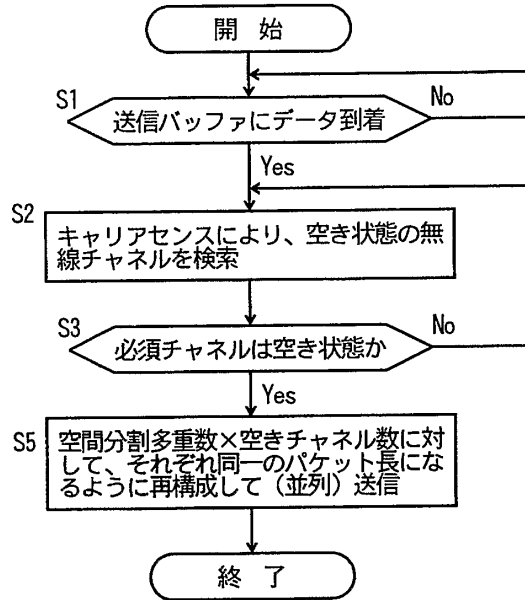
【図 5】

本発明の無線パケット通信方法の第 2 の実施形態



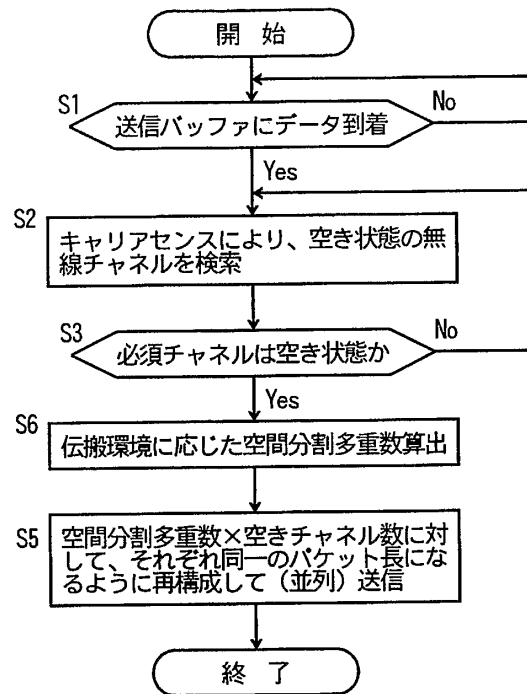
【図 6】

本発明の無線パケット通信方法の第 3 の実施形態



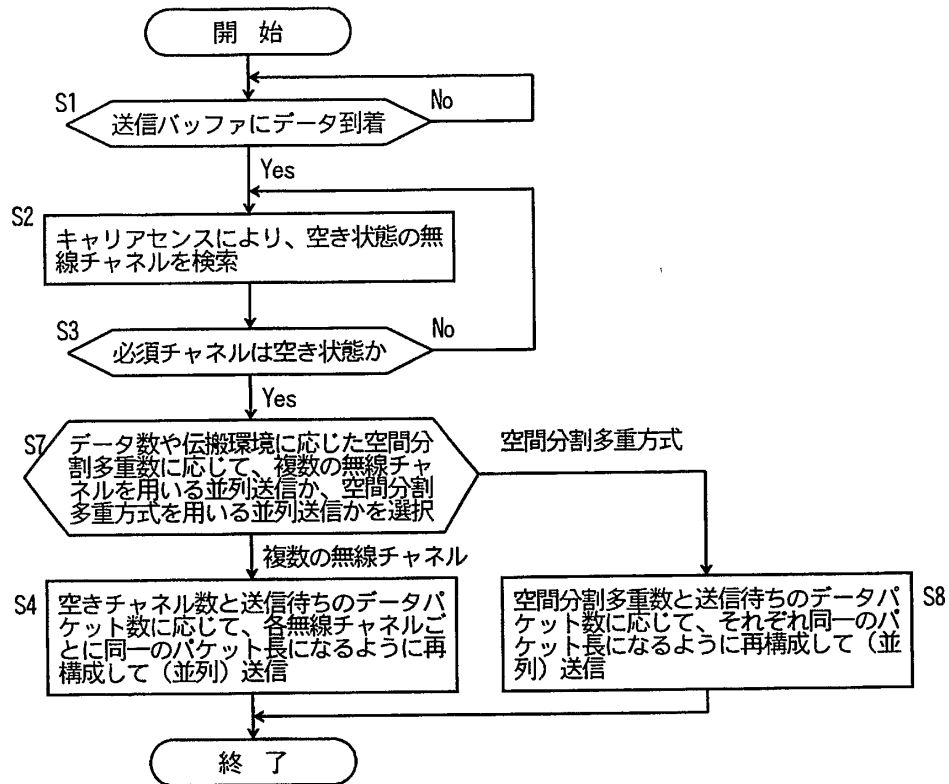
【図 7】

本発明の無線パケット通信方法の第 4 の実施形態



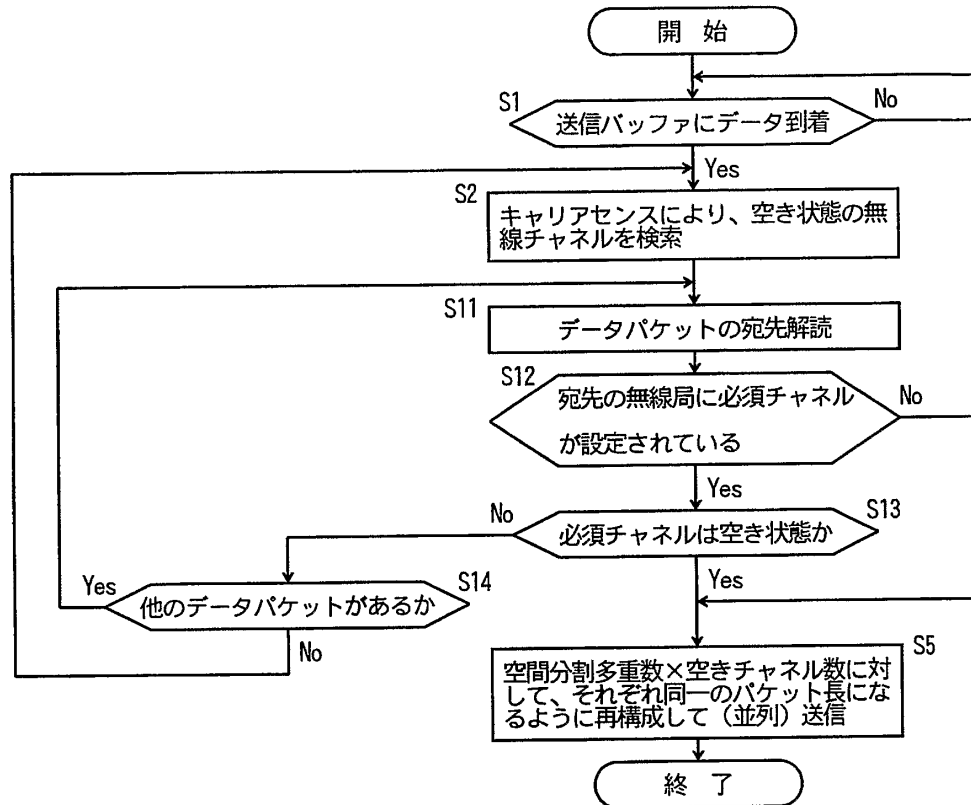
【図 8】

本発明の無線パケット通信方法の第 5 の実施形態



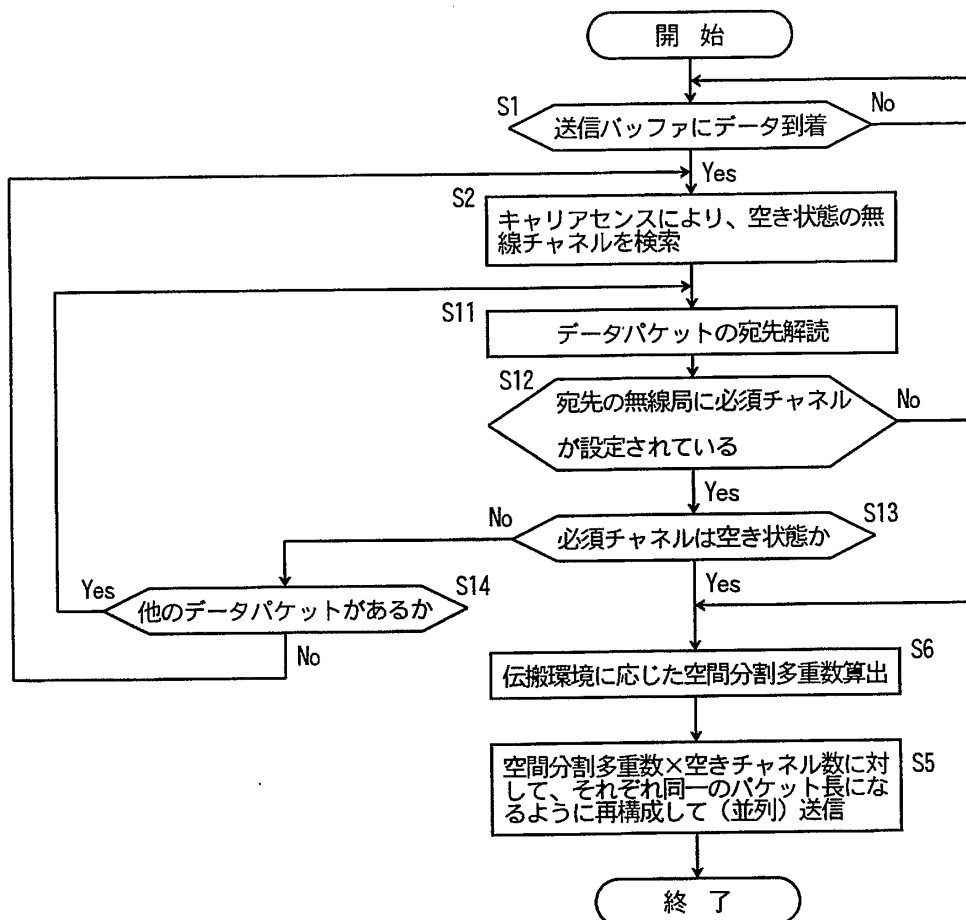
【図 9】

本発明の無線パケット通信方法の第 6 の実施形態



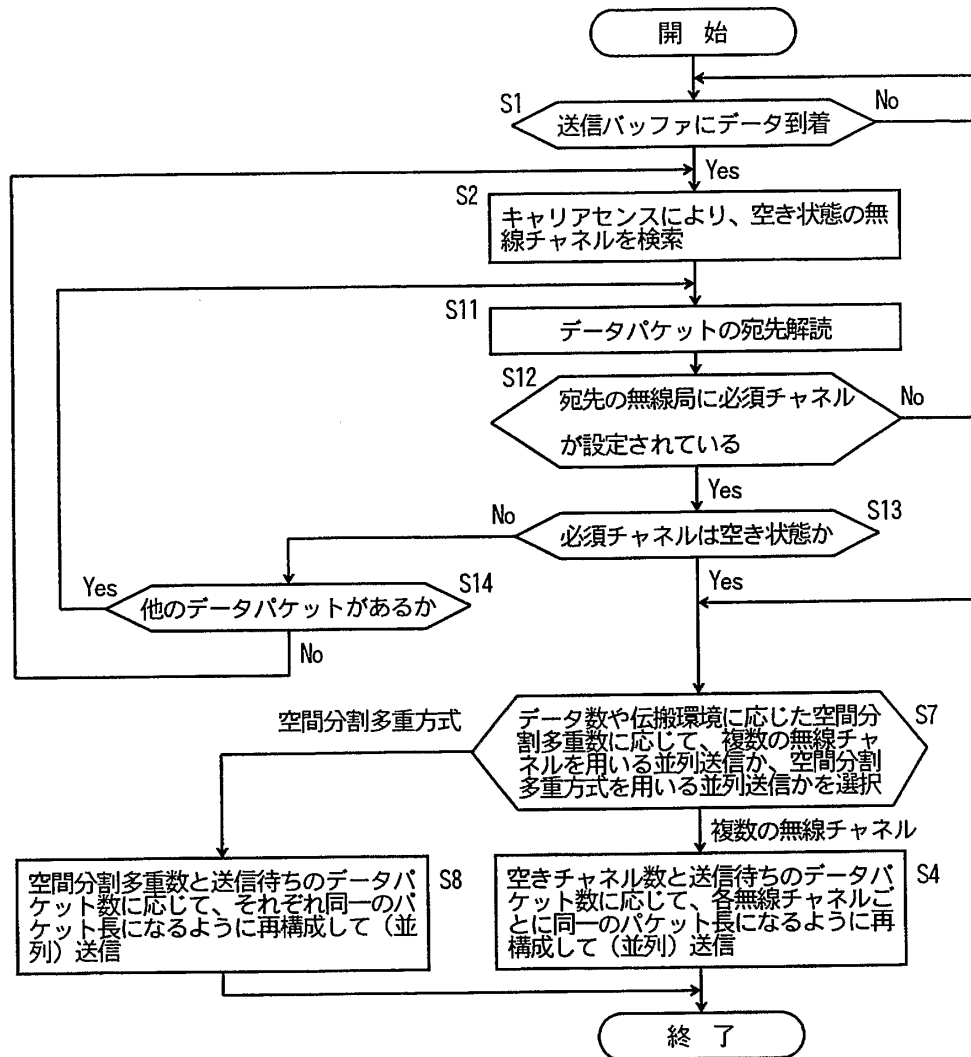
【図 10】

本発明の無線パケット通信方法の第 7 の実施形態

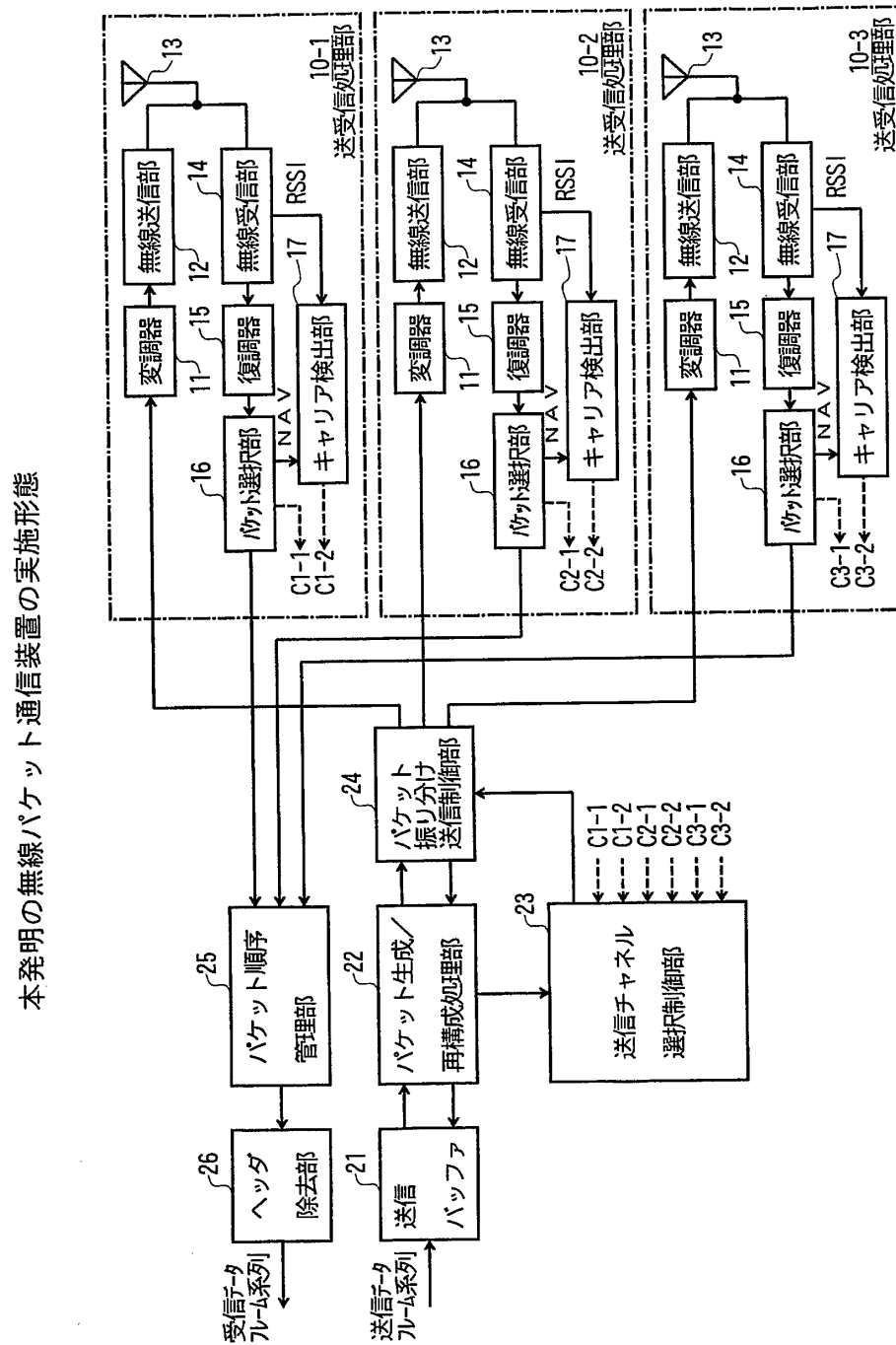


【図 11】

本発明の無線パケット通信方法の第 8 の実施形態



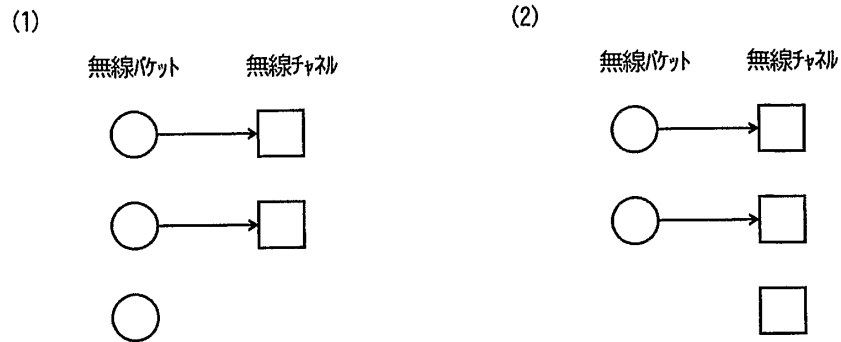
【图 1 2】



本発明の無線パケット通信装置の実施形態

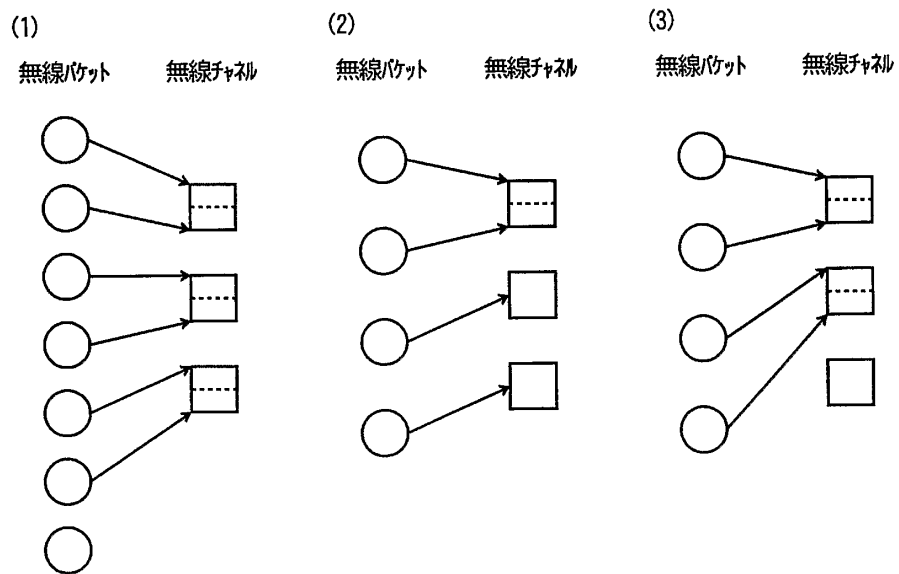
【図 13】

複数の無線チャネルを用いた複数の無線パケットを並列送信する方法



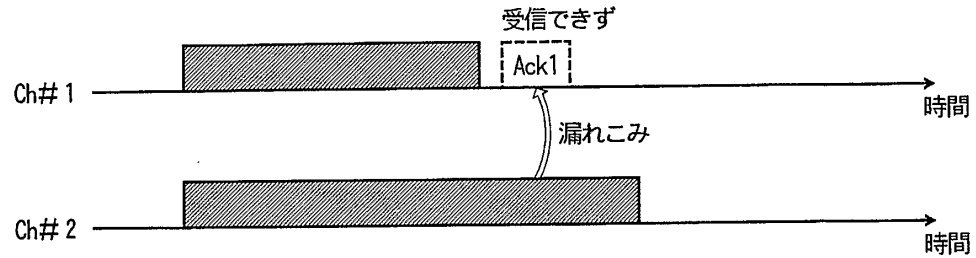
【図 14】

複数の無線チャネルを用いて複数の無線パケットを並列送信する方法



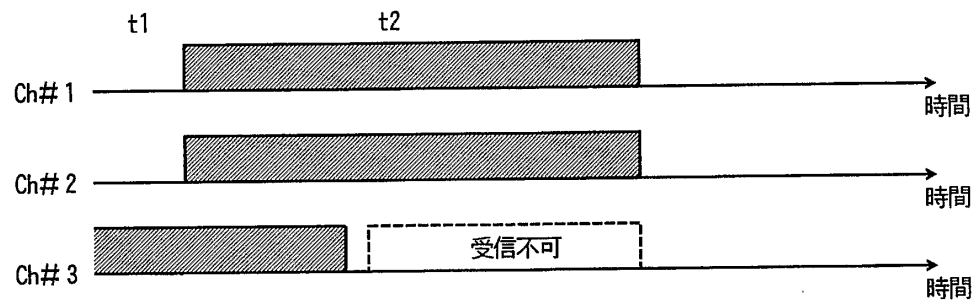
【図 15】

無線チャネルの漏洩電力の影響



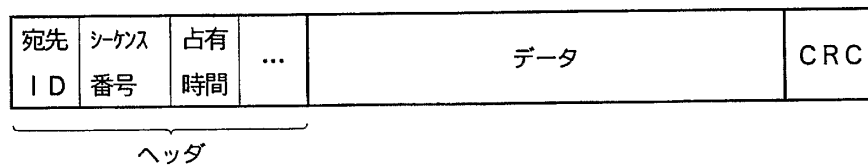
【図 16】

並列送信する無線パケットの packets 長を同一にしても漏洩電力の影響が問題になる場合



【図 17】

本発明の無線パケット通信装置で用いる無線パケットの構成



【書類名】 要約書**【要約】**

【課題】 送信中の無線局が送信チャネルの近隣の無線チャネルで送られた無線パケットを受信できない問題を解決し、並列送信によるスループットの向上を目指す。

【解決手段】 キャリアセンスによって空き状態と判定された複数の無線チャネルを用いて複数の無線パケットを並列送信するか、または空き状態と判定された1つの無線チャネルを用いて空間分割多重方式により複数の無線パケットを並列送信するか、または両者を併用して複数の無線パケットを並列送信する無線パケット通信方法において、送信に必ず使用する必須チャネルを設定し、この必須チャネルが空き状態のときに限り必須チャネルを含む無線チャネルを用いて無線パケットの送信を行う。

【選択図】 図 1

特願 2003-317100

出願人履歴情報

識別番号 [000004226]

1. 変更年月日	1999年 7月15日
[変更理由]	住所変更
住 所	東京都千代田区大手町二丁目3番1号
氏 名	日本電信電話株式会社



An das Europäische Patentamt

To the European Patent Office

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1

EPO - Munich
88**Eintritt in die
europäische Phase
(EPA als Bestimmungsamt
oder ausgewähltes Amt)****Entry into the
European phase
(EPO as designated or
elected Office)****Entrée dans la
phase européenne
(l'OEB agissant en qualité
d'office désigné ou élu)**

Europäische Anmeldenummer oder, falls nicht bekannt, PCT-Aktenzeichen oder PCT-Veröffentlichungsnummer	European application number, or, if not known, PCT application or publication number	Numéro de dépôt de la demande de brevet européen ou, à défaut, numéro de dépôt PCT ou de publication PCT
PCT/JP2004/013483		
Zeichen des Anmelders oder Vertreters (max. 15 Positionen)	Applicant's or representative's reference (max. 15 spaces)	Référence du demandeur ou du mandataire (15 caractères ou espaces au maximum)
110 895 a/jme		
☒ 1. Anmelder Die Angaben über den (die) Anmelder sind in der internationalen Veröffentlichung enthalten oder vom Internationalen Büro nach der internationalen Veröffentlichung vermerkt worden.	1. Applicant Indications concerning the applicant(s) are contained in the international publication or recorded by the International Bureau after the international publication.	1. Demandeur Les indications concernant le(s) demandeur(s) figurent dans la publication internationale ou ont été enregistrées par le Bureau international après la publication internationale.
☐ Änderungen, die das Internationale Büro noch nicht vermerkt hat, sind auf einem Zusatzblatt angegeben. Zustellanschrift (siehe Merkblatt II, 1)	Changes which have not yet been recorded by the International Bureau are set out on an additional sheet. Address for correspondence (see Notes II, 1)	Les changements qui n'ont pas encore été enregistrés par le Bureau international sont indiqués sur une feuille additionnelle. Adresse pour la correspondance (voir notice II, 1)
2. Vertreter Name (Nur einen Vertreter angeben, der in das europäische Patentregister eingetragen und an den zugestellt wird) Geschäftsanschrift Telefon Telefax ☐ Weitere(r) Vertreter auf Zusatzblatt	2. Representative Name (Name only one representative who will be listed in the Register of European Patents and to whom notification will be made) Address of place of business HOFFMANN · EITLE Patent- und Rechtsanwälte Arabellastrasse 4 D-81925 Munich - Association No. 151 Telephone 089 / 92409-0 Fax 089 / 918356 Additional representative(s) on additional sheet	2. Mandataire Nom (N'indiquer qu'un seul mandataire, qui sera inscrit au Registre européen des brevets et auquel signification sera faite) Adresse professionnelle Téléphone Téléfax Autre(s) mandataire(s) sur une feuille additionnelle
3. Vollmacht ☐ Einzelvollmacht ist beigefügt. ☐ Allgemeine Vollmacht ist registriert unter Nummer: ☐ Allgemeine Vollmacht ist eingereicht, aber noch nicht registriert. ☐ Die beim EPA als PCT-Anmeldeamt eingereichte Vollmacht schließt ausdrücklich die europäische Phase ein.	3. Authorisation Individual authorisation is attached. General authorisation has been registered under No: A general authorisation has been filed, but not yet registered. The authorisation filed with the EPO as PCT receiving Office expressly includes the European phase.	3. Pouvoir Un pouvoir spécial est joint. Un pouvoir général a été enregistré sous le n°: Un pouvoir général a été déposé, mais n'est pas encore enregistré. Le pouvoir général déposé à l'OEB agissant en qualité d'office récepteur au titre du PCT s'applique expressément à la phase européenne.

☒ 4. Prüfungsantrag Hiermit wird die Prüfung der Anmeldung gemäß Art. 94 EPU beantragt. Die Prüfungsgebühr wird (wurde) entrichtet. Prüfungsantrag in einer zugelassenen Nichtamtssprache (siehe Merkblatt III, 5.2) : 	4. Request for examination Examination of the application under Art. 94 EPC is hereby requested. The examination fee is being (has been, will be) paid. Request for examination in an admissible non-EPO language (see Notes III, 5.2) : 	4. Requête en examen Il est demandé que soit examinée la demande de brevet conformément à l'art. 94 CBE. Il est (a été, sera) procédé au paiement de la taxe d'examen. Requête en examen dans une langue non officielle autorisée (voir notice III, 5.2) :
☒ 5. Abschriften Zusätzliche Abschrift(en) der im ergänzenden europäischen Recherchenbericht angeführten Schriftstücke wird (werden) beantragt. Anzahl der zusätzlichen Sätze von Abschriften 	5. Copies Additional copy (copies) of the documents cited in the supplementary European search report is (are) requested. Number of additional sets of copies 1	5. Copies Prière de fournir une ou plusieurs copies supplémentaires des documents cités dans le rapport complémentaire de recherche européenne. Nombre de jeux supplémentaires de copies
6. Für das Verfahren vor dem EPA bestimmte Unterlagen 6.1 Dem Verfahren vor dem EPA als Bestimmungsamt (PCT I) sind folgende Unterlagen zugrunde zu legen: ☒ die vom Internationalen Büro veröffentlichten Anmeldungsunterlagen (mit allen Ansprüchen, Beschreibung und Zeichnungen), gegebenenfalls mit den geänderten Ansprüchen nach Art. 19 PCT ☐ soweit sie nicht ersetzt werden durch die beigefügten Änderungen . <i>Falls nötig, sind Klarstellungen auf einem Zusatzblatt einzureichen!</i> 6.2 Dem Verfahren vor dem EPA als ausgewähltem Amt (PCT II) sind folgende Unterlagen zugrunde zu legen: ☒ die dem Internationalen vorläufigen Prüfungsbericht zugrunde gelegten Unterlagen , einschließlich seiner eventuellen Anlagen (Solche Anlagen müssen immer beigefügt werden) ☐ soweit sie nicht ersetzt werden durch die beigefügten Änderungen . <i>Falls nötig, sind Klarstellungen auf einem Zusatzblatt einzureichen!</i> ☒ Sind dem EPA als mit der internationalen vorläufigen Prüfung beauftragten Behörde Versuchsberichte zugegangen, dürfen diese dem Verfahren vor dem EPA zugrunde gelegt werden.	6. Documents intended for proceedings before the EPO 6.1 Proceedings before the EPO as designated Office (PCT I) are to be based on the following documents: the application documents published by the International Bureau (with all claims, description and drawings), where applicable with amended claims under Art. 19 PCT unless replaced by the amendments enclosed. <i>Where necessary, clarifications must be submitted on a separate sheet!</i> 6.2 Proceedings before the EPO as elected Office (PCT II) are to be based on the following documents: the documents on which the international preliminary examination report is based , including its possible annexes (Such annexes must always be filed) unless replaced by the amendments enclosed. <i>Where necessary, clarifications must be submitted on a separate sheet!</i> If the EPO as International Preliminary Examining Authority has received test reports , these may be used as the basis of proceedings before the EPO.	6. Pièces destinées à la procédure devant l'OEB 6.1 La procédure devant l'OEB agissant en qualité d' office désigné (PCT I) doit se fonder sur les pièces suivantes : les pièces de la demande publiée par le Bureau international (avec toutes les revendications, la description et les dessins), éventuellement avec les revendications modifiées conformément à l'article 19 du PCT dans la mesure où elles ne sont pas remplacées par les modifications jointes. <i>Le cas échéant, des explications doivent être jointes sur une feuille additionnelle!</i> 6.2 La procédure devant l'OEB agissant en qualité d'office élu (PCT II) doit se fonder sur les pièces suivantes : les pièces sur lesquelles se fonde le rapport d'examen préliminaire international , y compris ses annexes éventuelles (De telles annexes sont toujours à joindre) dans la mesure où elles ne sont pas remplacées par les modifications jointes. <i>Le cas échéant, des explications doivent être jointes sur une feuille additionnelle!</i> Si l'OEB, agissant en qualité d'administration chargée de l'examen préliminaire international, a reçu des rapports d'essais , ceux-ci peuvent constituer la base de la procédure devant l'OEB.

7. Übersetzungen Beigefügt sind die nachfolgend angekreuzten Übersetzungen in einer der Amtssprachen des EPA (Deutsch, Englisch, Französisch): ☒ Im Verfahren vor dem EPA als Bestimmungsamt oder ausgewähltem Amt (PCT I + II): Übersetzung der ursprünglich eingereichten internationalen Anmeldung (Beschreibung, Ansprüche, etwaige Textbestandteile in den Zeichnungen), der veröffentlichten Zusammenfassung, und etwaiger Angaben über biologisches Material nach Regel 13^{ter}.3 und 13^{ter}.4 PCT ☐ Übersetzung der prioritätsbegründenden Anmeldung(en) ☐ Es wird hiermit erklärt, daß die internationale Anmeldung in ihrer ursprünglich eingereichten Fassung eine vollständige Übersetzung der früheren Anmeldung ist (Regel 38(5) EPC) ☐ Zusätzlich im Verfahren vor dem EPA als Bestimmungsamt (PCT II): Übersetzung der nach Art. 19 PCT geänderten Ansprüche nebst Erklärung, falls diese dem Verfahren vor dem EPA zugrunde gelegt werden sollen (siehe Feld 6) ☐ Zusätzlich im Verfahren vor dem EPA als ausgewähltem Amt (PCT II): Übersetzung der Anlagen zum internationalen vorläufigen Prüfungsbericht	7. Translations Translations in one of the official languages of the EPO (English, French, German) are enclosed as crossed below: ☒ In proceedings before the EPO as designated or elected Office (PCT I + II): Translation of the international application (description, claims, any text in the drawings) as originally filed, of the abstract as published and of any indication under Rule 13^{ter}.3 and 13^{ter}.4 PCT regarding biological material ☐ Translation of the priority application(s) It is hereby declared that the international application as originally filed is a complete translation of the previous application (Rule 38(5) EPC) ☐ In addition, in proceedings before the EPO as designated Office (PCT II): Amendments pursuant to Rule 86 EPC Translation of amended claims and any statement under Art. 19 PCT, if the claims as amended are to form the basis for the proceedings before the EPO (see Section 6) ☐ In addition, in proceedings before the EPO as elected Office (PCT II): Translation of any annexes to the international preliminary examination report	7. Traductions Vous trouverez, ci-joint, les traductions cochées ci-après dans l'une des langues officielles de l'OEB (allemand, anglais, français) : ☒ Dans la procédure devant l'OEB agissant en qualité d'office désigné ou élu (PCT I + II): Traduction de la demande internationale telle que déposée initialement (description, revendications, textes figurant éventuellement dans les dessins), de l'abrégé publié, et de toutes indications visées aux règles 13^{ter}.3 et 13^{ter}.4 du PCT concernant le matériel biologique ☐ Traduction de la (des) demande(s) ouvrant le droit de priorité Il est déclaré par la présente que la demande internationale telle que déposée initialement est une traduction intégrale de la demande antérieure (règle 38(5) CBE) ☐ De plus, dans la procédure devant l'OEB agissant en qualité d'office désigné (PCT II) : Traduction des revendications modifiées et de la déclaration faite conformément à l'article 19 du PCT, si la procédure devant l'OEB doit être fondée sur les revendications modifiées (voir la rubrique 6) ☐ De plus, dans la procédure devant l'OEB agissant en qualité d'office élu (PCT II) : Traduction des annexes du rapport d'examen préliminaire international
☐ 8. Biologisches Material Die Erfindung bezieht sich auf bzw. verwendet biologisches Material, das nach Regel 28 EPC hinterlegt worden ist. ☐ Die Angaben nach Regel 28(1)c) EPÜ (falls noch nicht bekannt, die Hinterlegungsstelle und das (die) Bezugszeichen [Nummer, Symbole usw.] des Hinterlegers) sind in der internationalen Veröffentlichung oder in der gemäß Feld 7 eingereichten Übersetzung enthalten auf: Seite(n) / Zeile(n) Die Empfangsbescheinigung(en) der Hinterlegungsstelle ☐ ist (sind) beigefügt ☐ wird (werden) nachgereicht ☐ Verzicht auf die Verpflichtung des Antragstellers nach Regel 28(3) EPÜ auf gesondertem Schriftstück	☐ 8. Biological material The invention relates to and/or uses biological material deposited under Rule 28 EPC. The particulars referred to in Rule 28(1)(c) EPC (if not yet known, the depository institution and the identification reference(s) [number, symbols etc.] of the depositor) are given in the international publication or in the translation submitted under Section 7 on: page(s) / line(s) The receipt(s) of deposit issued by the depository institution ☐ is (are) enclosed ☐ will be filed at a later date ☐ Waiver of the right to an undertaking from the requester pursuant to Rule 28(3) EPC attached.	☐ 8. Matière biologique L'invention concerne et/ou utilise de la matière biologique, déposée conformément à la règle 28 CBE. Les indications visées à la règle 28(1)c) CBE (si non encore connues, l'autorité de dépôt et la (les) référence(s) d'identification [numéro ou symboles etc.] du déposant) figurent dans la publication internationale ou dans une traduction produite conformément à la rubrique 7 à la / aux: page(s) / ligne(s) Le(s) récépissé(s) de dépôt délivré(s) par l'autorité de dépôt ☐ est (sont) joint(s) ☐ sera (seront) produit(s) ultérieurement ☐ Renonciation, sur document distinct, à l'engagement du requérant au titre de la règle 28(3) CBE.

9. Nucleotid- und Aminosäuresequenzen ☐ Die nach Regeln 5.2 und 13^{ter} PCT sowie Regel 111(3) EPÜ erforderlichen Unterlagen liegen dem EPA bereits vor. ☐ Das schriftliche Sequenzprotokoll wird anlegend nachgereicht. ☐ Das Sequenzprotokoll geht nicht über den Inhalt der Anmeldung in der ursprünglich eingereichten Fassung hinaus. ☐ Der vorgeschriebene Datenträger ist beigelegt. ☐ Die auf dem Datenträger gespeicherte Information stimmt mit dem schriftlichen Sequenzprotokoll überein.	9. Nucleotide and amino acid sequences The items necessary in accordance with Rules 5.2 and 13^{ter} PCT and Rule 111(3) EPC have already been furnished to the EPO. The written sequence listing is furnished herewith. The sequence listing does not include matter which goes beyond the content of the application as filed. The prescribed data carrier is enclosed. The information recorded on the data carrier is identical to the written sequence listing.	9. Séquences de nucléotides et d'acides aminés Les pièces requises selon les règles 5.2 et 13^{ter} PCT et la règle 111(3) CBE ont déjà été déposées auprès de l'OEI. La liste de séquences écrite est produite ci-joint. La liste de séquences ne contient pas d'éléments s'étendant au-delà du contenu de la demande telle qu'elle a été déposée. Le support de données prescrit est joint. L'information figurant sur le support de données est identique à celle que contient la liste de séquences écrite.
10. Benennungsgebühren ☒ 10.1 Es ist derzeit beabsichtigt, den siebenfachen Betrag einer Benennungsgebühr zu entrichten. Damit gelten die Benennungsgebühren für alle Vertragsstaaten des EPÜ¹ als entrichtet (Art. 2 Nr. 3 GebO), soweit sie in der internationalen Anmeldung bestimmt sind². ☐ 10.2 Abweichend von der Erklärung in Nr. 10.1 ist derzeit beabsichtigt, weniger als sieben Benennungsgebühren für folgende in der internationalen Anmeldung bestimmte Vertragsstaaten des EPÜ² zu entrichten: (1) ☐ DE <u>Germany</u> (2) ☐ FR <u>France</u> (3) ☐ GB <u>United Kingdom</u> Soweit unter Nr. 10.2 Vertragsstaaten aufgeführt sind, wird beantrag, für die dort nicht aufgeführten Vertragsstaaten von der Zustellung einer Mitteilung nach Regel 108(3) EPÜ abzusehen. ☒ 10.3 Wird ein automatischer Abbuchungsauftrag erteilt (Feld 12), so wird das EPA beauftrag, bei Ablauf der Grundfrist nach Regel 107 (1)d) EPÜ den siebenfachen Betrag einer Benennungsgebühr abzubuchen. Ist eine Erklärung nach Nr. 10.2 abgegeben worden, so sollen die Benennungsgebühren nur für die dort angegebenen Vertragsstaaten abgebucht werden, sofern dem EPA nicht bis zum Ablauf der Grundfrist ein anderslautender Auftrag zugeht.	10. Designation fees 10.1 It is currently intended to pay seven times the amount of the designation fee. The designation fees for all the EPC contracting states¹ designated in the international application² are thereby deemed to have been paid (Art. 2 No. 3 RFees). 10.2 The declaration in No. 10.1 does not apply. Instead, it is currently intended to pay fewer than seven designation fees for the following EPC contracting states² designated in the international application: (4) ☐ (5) ☐ (6) ☐ If contracting states are indicated under No. 10.2, it is requested that no communication under Rule 108(3) EPC be issued for contracting states not thus indicated. 10.3 If an automatic debit order has been issued (Section 12), the EPO is authorised, on expiry of the basic period under Rule 107(1)(d) EPC, to debit seven times the amount of the designation fee. If states are indicated under No. 10.2, the EPO will debit designation fees only for those states, unless instructed otherwise before the basic period expires.	10. Taxes de désignation 10.1 Il est actuellement envisagé de payer un montant correspondant à sept fois la taxe de désignation. Les taxes de désignation sont ainsi réputées payées pour tous les Etats contractants de la CBE¹ désignés dans la demande internationale² (art. 2, point 3 du RRT). 10.2 Contrairement à ce qui est indiqué au n° 10.1, il est actuellement envisagé de payer moins de sept taxes de désignation pour les Etats contractants de la CBE² suivants désignés dans la demande internationale : (4) ☐ (5) ☐ (6) ☐ Si des Etats contractants sont mentionnés au n° 10.2, prière de ne pas procéder à la signification d'une notification prévue par la règle 108(3) CBE pour les Etats contractants n'y étant pas mentionnés. 10.3 Si un ordre de prélèvement automatique est donné (rubrique 12), il est demandé à l'OEI de prélever, à l'expiration du délai normal visé à la règle 107(1)d) CBE, un montant correspondant à sept fois la taxe de désignation. Si une déclaration a été faite au n° 10.2, les taxes de désignation ne sont à prélever que pour les Etats contractants qui y sont indiqués, sauf instruction contraire reçue par l'OEI avant l'expiration du délai normal.

¹ Stand bei Drucklegung: 27 Vertragsstaaten, und zwar: / Status when this form was printed: 27 contracting states, namely / Situation à la date d'impression: 27 Etats contractants, à savoir: **AT** Österreich / Austria / Autriche, **BE** Belgien / Belgium / Belgique, **BG** Bulgarien / Bulgaria / Bulgarie, **CH** / LI Schweiz und Liechtenstein / Switzerland and Liechtenstein / Suisse et Liechtenstein, **CY** Zypern / Cyprus / Chypre, **CZ** Tschechische Republik / Czech Republic / République tchèque, **DE** Deutschland / Germany / Allemagne, **DK** Dänemark / Denmark / Danemark, **EE** Estland / Estonia / Estonie, **ES** Spanien / Spain / Espagne, **FI** Finnland / Finland / Finlande, **FR** Frankreich / France / France, **GB** Vereinigtes Königreich / United Kingdom / Royaume-Uni, **GR** Griechenland / Greece / Grèce, **HU** Ungarn / Hungary / Hongrie, **IE** Irland / Ireland / Irlande, **IT** Italien / Italy / Italie, **LU** Luxemburg / Luxembourg / Luxembourg, **MC** Monaco / Monaco / Monaco, **NL** Niederlande / Netherlands / Pays-Bas, **PT** Portugal / Portugal / Portugal, **RO** Rumänien / Romania / Roumanie, **SE** Schweden / Sweden / Suède, **SI** Slowenien / Slovenia / Slovénie, **SK** Slowakische Republik / Slovak Republic / République slovaque, **TR** Türkei / Turkey / Turquie

² Für folgende Staaten nur möglich, falls in der internationalen Anmeldung am oder nach folgendem Tag bestimmt: Slowakische Republik, Bulgarien, Tschechische Republik und Estland: 1. Juli 2002, Slowenien: 1. Dezember 2002, Ungarn: 1. Januar 2003 und Rumänien: 1. März 2003. / For the following states this is possible only if they are designated in the international application on or after the stated date: Slovak Republic, Bulgaria, Czech Republic and Estonia: 1 July 2002, Slovenia: 1 December 2002, Hungary: 1 January 2003 and Romania: 1 March 2003. / En ce qui concerne les Etats suivants seulement si la désignation a été effectuée dans la demande internationale à la date suivante ou à une date ultérieure: République slovaque, Bulgarie, République tchèque et Estonie: 1^{er} juillet 2002, Slovénie: 1^{er} décembre 2002, Hongrie: 1^{er} janvier 2003 et Roumanie: 1^{er} mars 2003.

☒ 11. Erstreckung des europäischen Patents Bei Zahlung der Erstreckungsgebühr(en) gilt diese Anmeldung auch als wirksamer Erstreckungsantrag für die in der internationalen Anmeldung bestimmten »Erstreckungsstaaten«. Es ist beabsichtigt, diese Gebühr(en) für folgende Staaten zu entrichten: <table border="0"> <tr><td>☐</td><td>SI</td><td>Slowenien ¹⁾</td></tr> <tr><td>☐</td><td>LT</td><td>Litauen</td></tr> <tr><td>☐</td><td>LV</td><td>Lettland</td></tr> <tr><td>☐</td><td>AL</td><td>Albanien</td></tr> <tr><td>☐</td><td>RO</td><td>Rumänien ¹⁾</td></tr> <tr><td>☐</td><td>MK</td><td>Ehemalige jugoslawische Republik Mazedonien</td></tr> <tr><td>☐</td><td colspan="2">_____ ²⁾</td></tr> </table>	☐	SI	Slowenien ¹⁾	☐	LT	Litauen	☐	LV	Lettland	☐	AL	Albanien	☐	RO	Rumänien ¹⁾	☐	MK	Ehemalige jugoslawische Republik Mazedonien	☐	_____ ²⁾		11. Extension of the European patent On payment of the extension fee(s) this application is also deemed to be a request for extension to all the "extension states" designated in the international application. It is intended to pay the fee(s) for the following states: <table border="0"> <tr><td>_____</td><td>Slovenia ¹⁾</td></tr> <tr><td>_____</td><td>Lithuania</td></tr> <tr><td>_____</td><td>Latvia</td></tr> <tr><td>_____</td><td>Albania</td></tr> <tr><td>_____</td><td>Romania ¹⁾</td></tr> <tr><td>_____</td><td>Former Yugoslav Republic of Macedonia</td></tr> <tr><td>_____</td><td>_____ ²⁾</td></tr> </table>	_____	Slovenia ¹⁾	_____	Lithuania	_____	Latvia	_____	Albania	_____	Romania ¹⁾	_____	Former Yugoslav Republic of Macedonia	_____	_____ ²⁾	11. Extension des effets du brevet européen La taxe (Les taxes) d'extension payée(s), la présente demande est également réputée être une demande d'extension à tous les »Etats autorisant l'extension« désignés dans la demande internationale. Il est envisagé de payer la taxe (les taxes) d'extension pour les Etats suivants: <table border="0"> <tr><td>_____</td><td>Slovénie ¹⁾</td></tr> <tr><td>_____</td><td>Lituanie</td></tr> <tr><td>_____</td><td>Lettonie</td></tr> <tr><td>_____</td><td>Albanie</td></tr> <tr><td>_____</td><td>Roumanie ¹⁾</td></tr> <tr><td>_____</td><td>Ex-République yougoslave de Macédoine</td></tr> <tr><td>_____</td><td>_____ ²⁾</td></tr> </table>	_____	Slovénie ¹⁾	_____	Lituanie	_____	Lettonie	_____	Albanie	_____	Roumanie ¹⁾	_____	Ex-République yougoslave de Macédoine	_____	_____ ²⁾
☐	SI	Slowenien ¹⁾																																																	
☐	LT	Litauen																																																	
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_____	Ex-République yougoslave de Macédoine																																																		
_____	_____ ²⁾																																																		
1) Für Slowenien und Rumänien nur möglich, falls in der internationalen Anmeldung bis 30. November 2002 (Slowenien) oder bis 28. Februar 2003 (Rumänien) bestimmt. / For Slovenia and Romania this is possible only if they are designated in the international application up to 30 November 2002 (Slovenia) or 28 February 2003 (Romania). / En ce qui concerne la Slovénie et la Roumanie, seulement si la désignation a été effectuée dans la demande internationale jusqu'au 30 novembre 2002 (Slovénie) ou jusqu'au 28 février 2003 (Roumanie). 2) Platz für Staaten, mit denen »Erstreckungsabkommen« nach Drucklegung dieses Formblatts in Kraft treten und die in der internationalen Anmeldung bestimmt waren. / Space for States with which "extension agreements" enter into force after this form has been printed and which were designated in the international application. / Prévu pour des Etats à l'égard desquels des »accords d'extension« entreront en vigueur après l'impression du présent formulaire et qui ont été désignés dans la demande internationale.																																																			
12. Automatischer Abbuchungsauftrag (Nur möglich für Inhaber von beim EPA geführten laufenden Konten) ☐ Das EPA wird beauftrag, nach Maßgabe der Vorschriften über das automatische Abbuchungsverfahren fällige Gebühren und Auslagen vom untenstehenden laufenden Konto abzubuchen. In Bezug auf die Benennungsgebühren wird auf Feld 10.3 verwiesen. Das EPA wird ferner beauftrag, die Erstreckungsgebühren für jeden in Feld 11 angekreuzten »Erstreckungsstaat« bei Ablauf der Grundfrist zu ihrer Zahlung abzubuchen, sofern ihm nicht bis dahin ein anderslautender Auftrag zugeht. Nummer und Kontoinhaber _____	12. Automatic debit order (for EPO deposit account holders only) The EPO is hereby authorised, under the Arrangements for the automatic debiting procedure, to debit from the deposit account below any fees and costs falling due. For designation fees , see Section 10.3. The EPO is also authorised, on expiry of the basic period for paying the extension fees , to debit those fees for each of the "extension states" marked with a cross in Section 11, unless instructed otherwise before the said period expires. Number and account holder _____	12. Ordre de prélèvement automatique (uniquement possible pour les titulaires de comptes courants ouverts auprès de l'OEB) Par la présente, il est demandé à l'OEB de prélever du compte courant ci-dessous les taxes et frais venant à échéance, conformément à la réglementation relative au prélèvement automatique. Pour les taxes de désignation , se reporter à la rubrique 10.3. Il est en outre demandé à l'OEB de prélever, à l'expiration du délai normal prévu pour leur paiement, les taxes d'extension pour chaque »Etat autorisant l'extension« coché à la rubrique 11, sauf instruction contraire reçue avant l'expiration de ce délai. Numéro et titulaire du compte _____																																																	
☒ 13. Eventuelle Rückzahlungen auf das beim EPA geführte laufende Konto Nummer und Kontoinhaber _____	13. Any reimbursement to EPO deposit account Number and account holder 2800.0039 Hoffmann · Eitle	13. Remboursements éventuels à effectuer sur le compte courant ouvert auprès de l'OEB Numéro et titulaire du compte _____																																																	
14. Unterschrift(en) des (der) Anmelders oder Vertreters Or / Datum Für Angestellte (Art. 133(3) EPÜ) mit allgemeiner Vollmacht: Nr. _____ Name(n) des (der) Unterzeichneten bitte in Druckschrift wiederholen. Bei juristischen Personen bitte auch die Stellung des (der) Unterzeichneten innerhalb der Gesellschaft in Druckschrift angeben.	14. Signature(s) of applicant(s) or representative  P. Wiedemann Association No. 151 Place / Date Munich, Oct. 07, 2005 For employees (Art. 133(3) EPC) having a general authorisation: No. _____ Please print name(s) under signature(s). In the case of legal persons, the position of the signatory within the company should also be printed.	14. Signature(s) du (des) demandeur(s) ou du mandataire Lieu / Date Pour les employés (art. 133(3) CBE) disposant d'un pouvoir général: N° _____ Le ou les noms des signataires doivent être indiqués en caractères d'imprimerie. S'il s'agit d'une personne morale, la position occupée au sein de celle-ci par le ou les signataires doit également être indiquée en caractères d'imprimerie.																																																	

FIG. 1

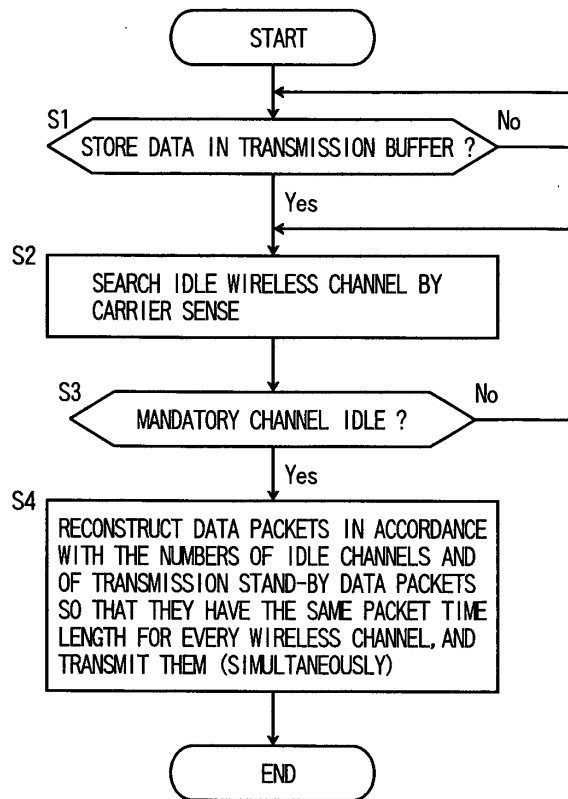


FIG. 2

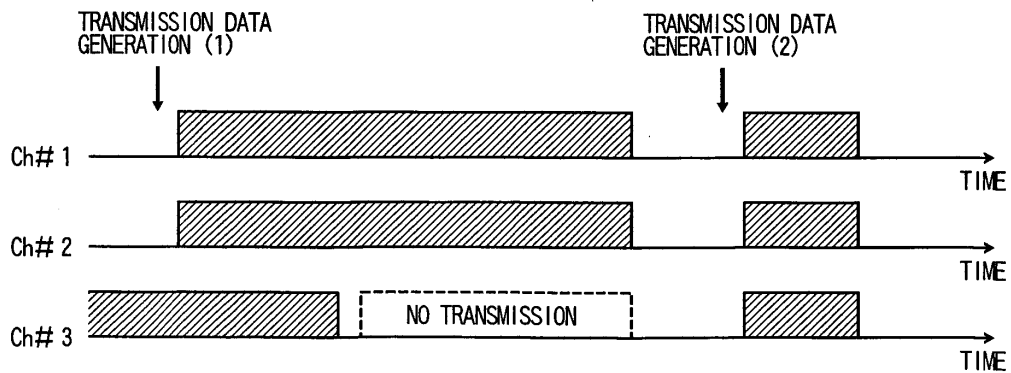
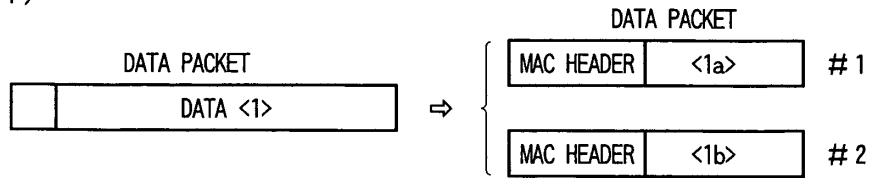
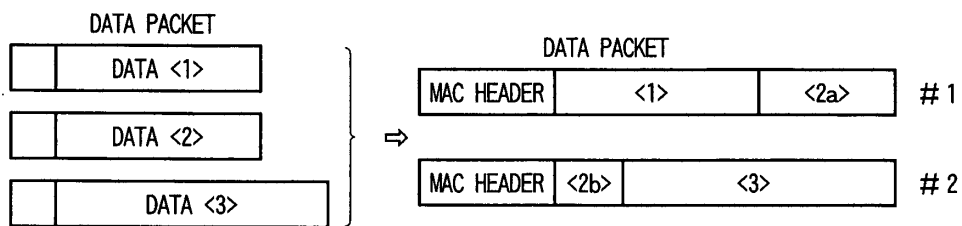


FIG. 3

(1)



(2)



(3)

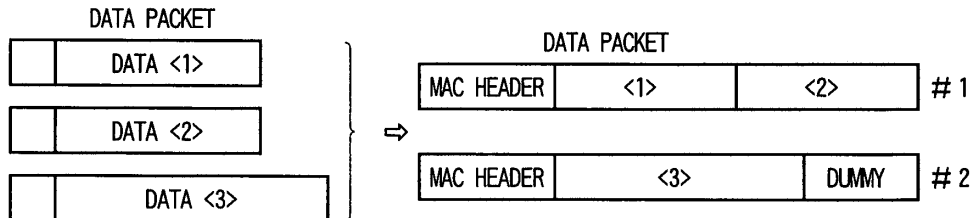


FIG. 4

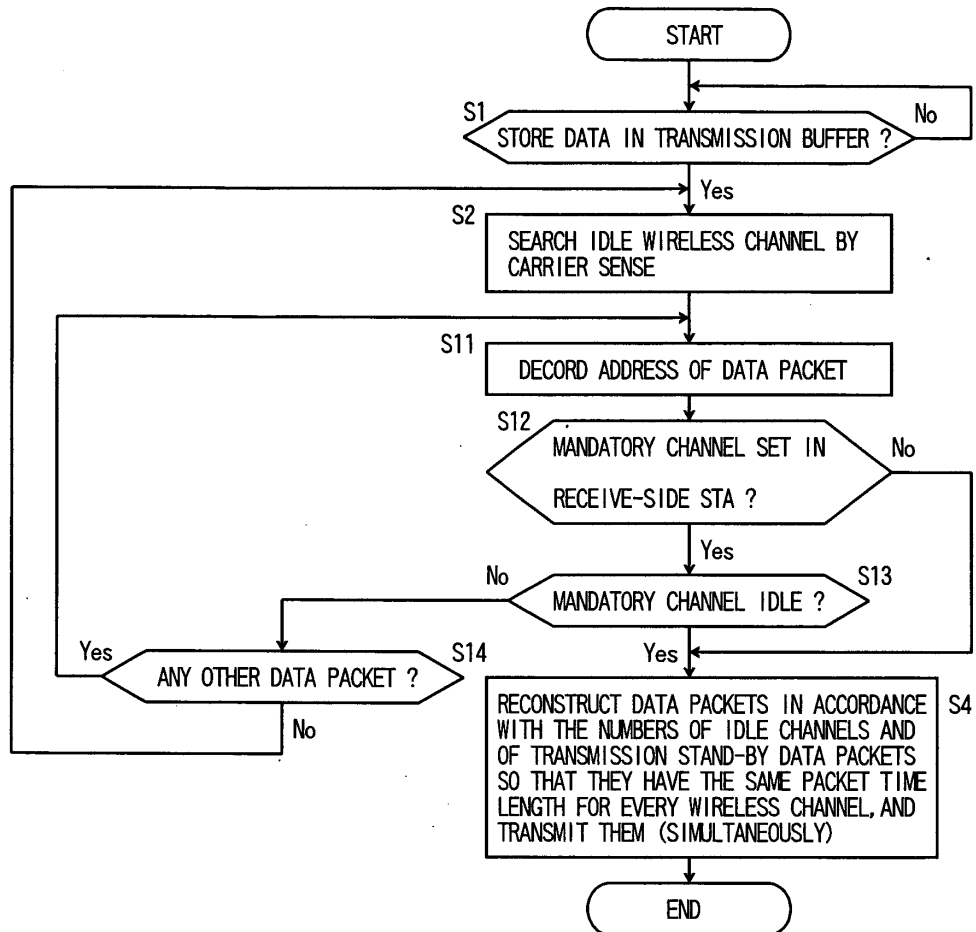


FIG. 5

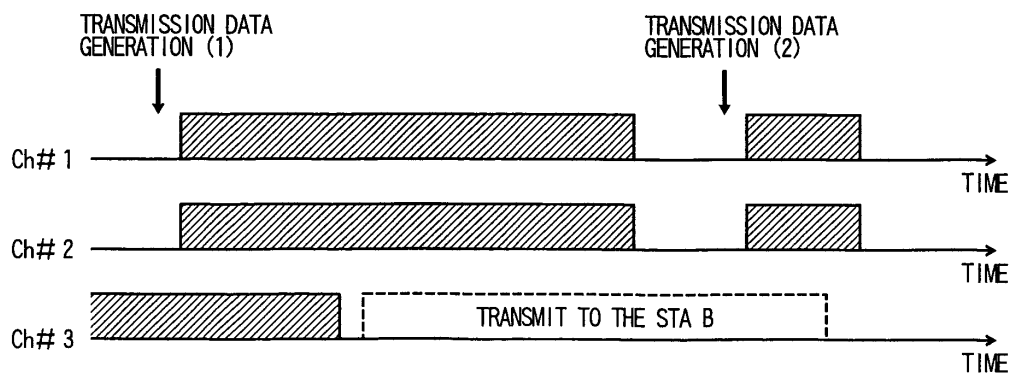


FIG. 6

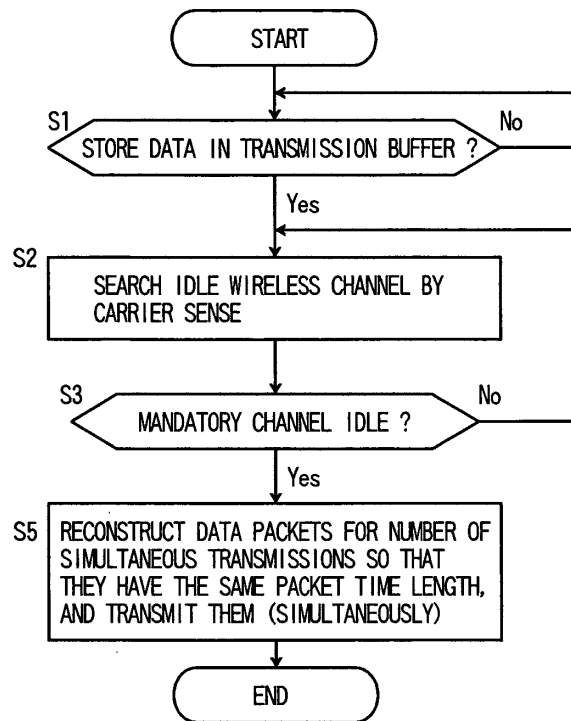


FIG. 7

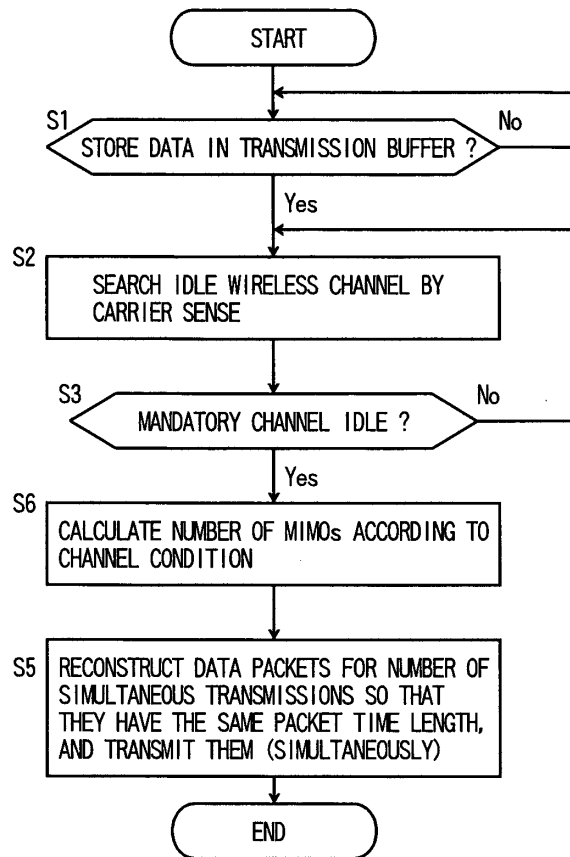


FIG. 8

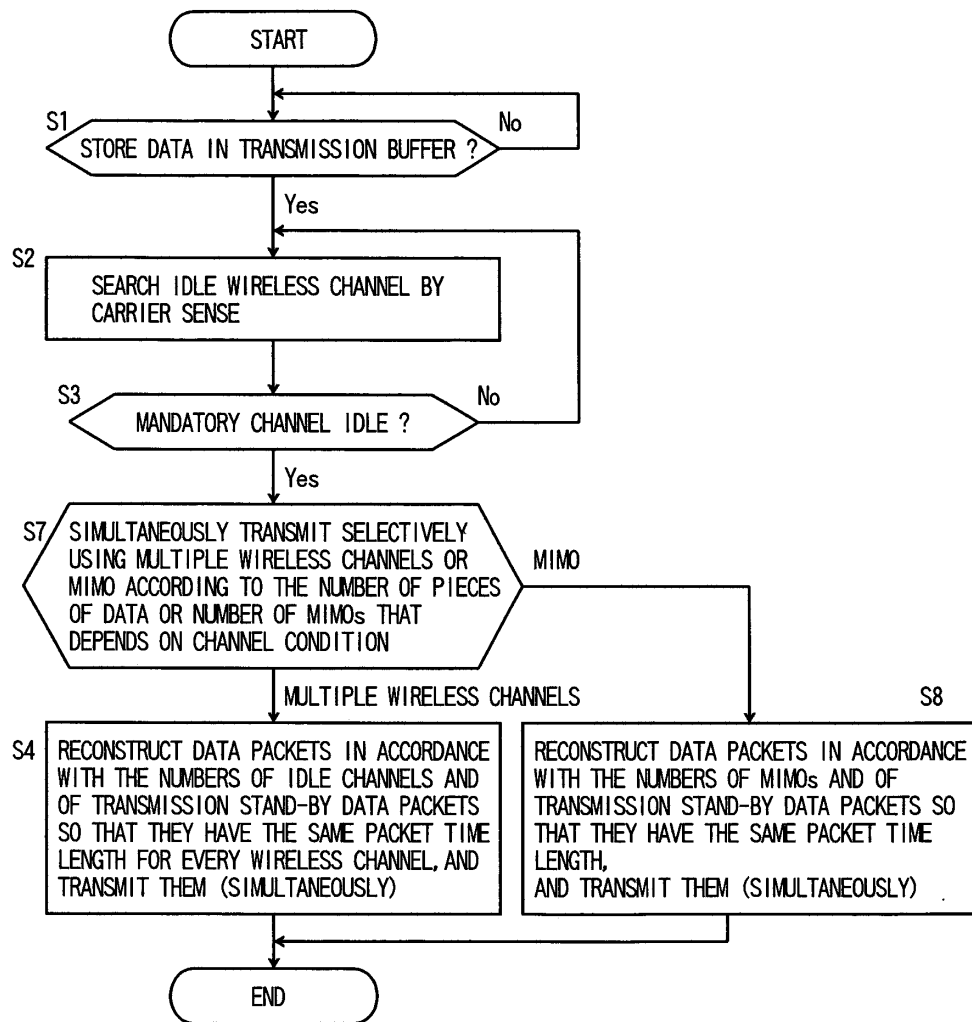


FIG. 9

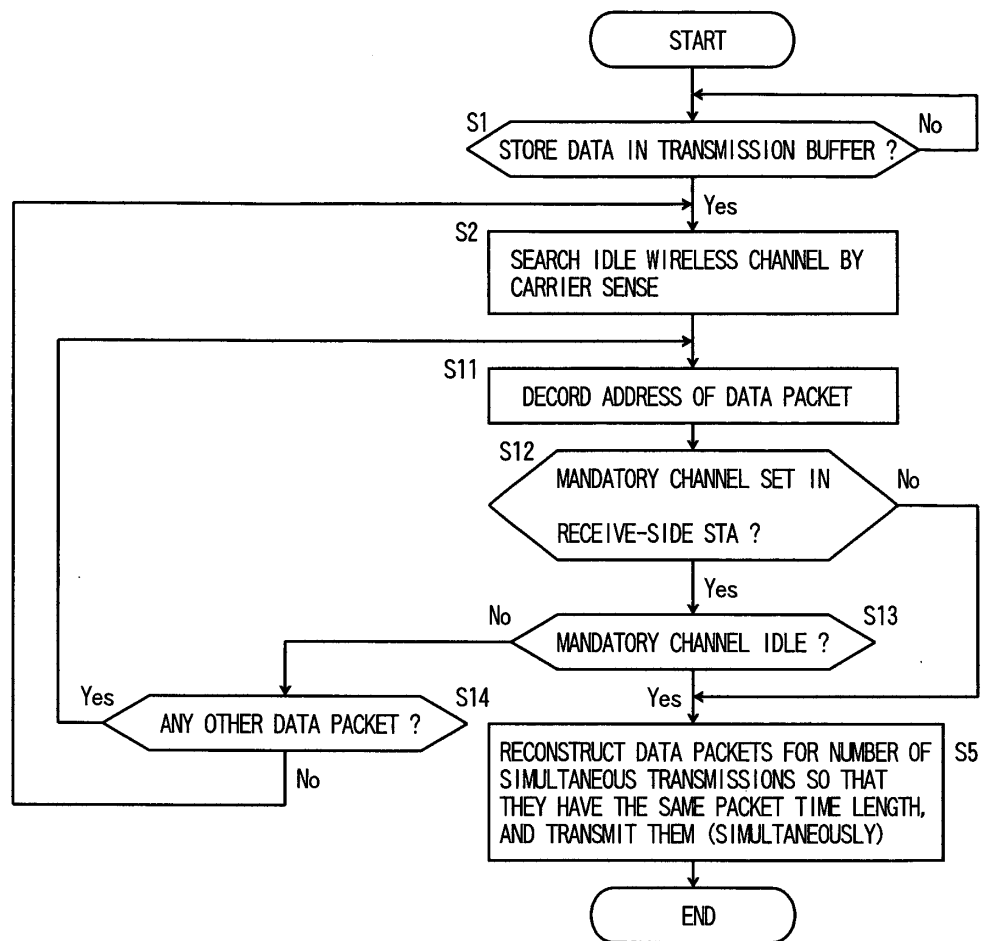


FIG. 10

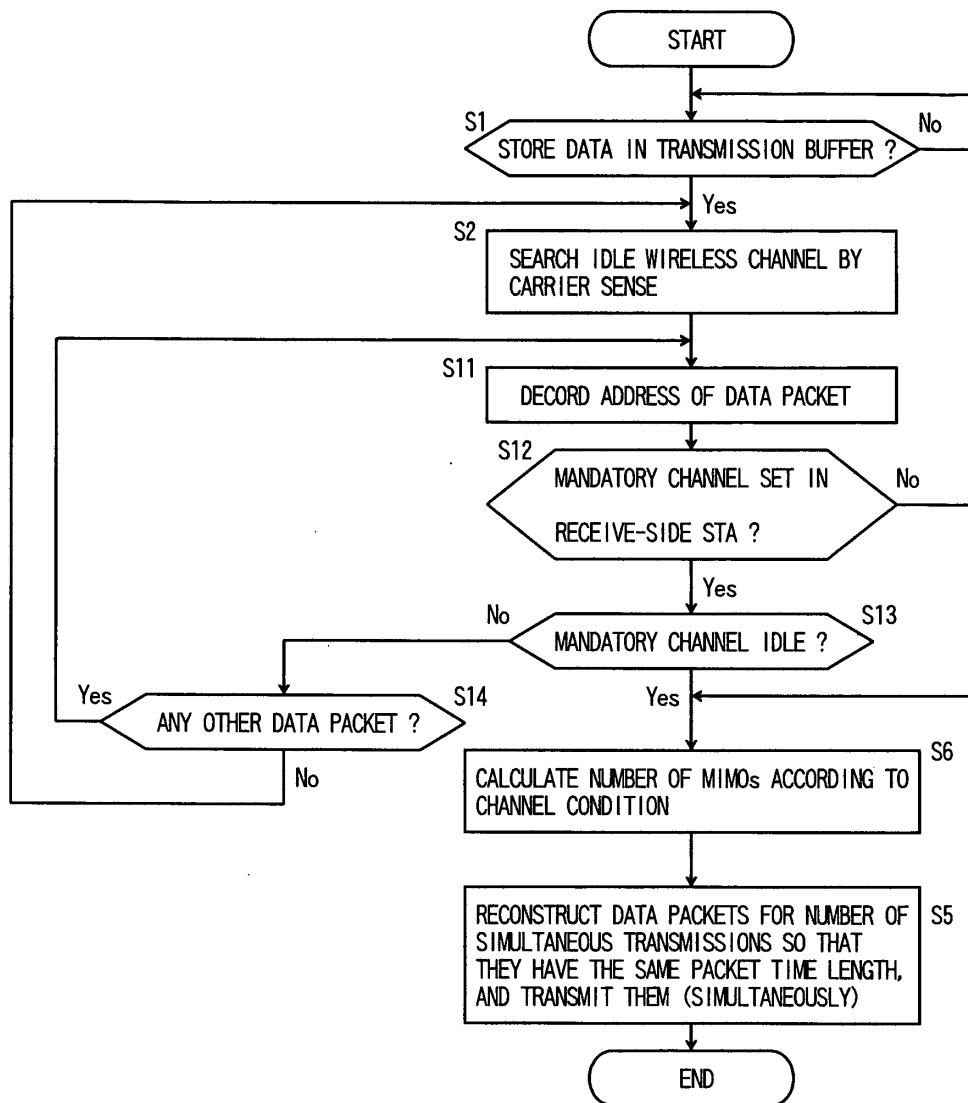


FIG. 11

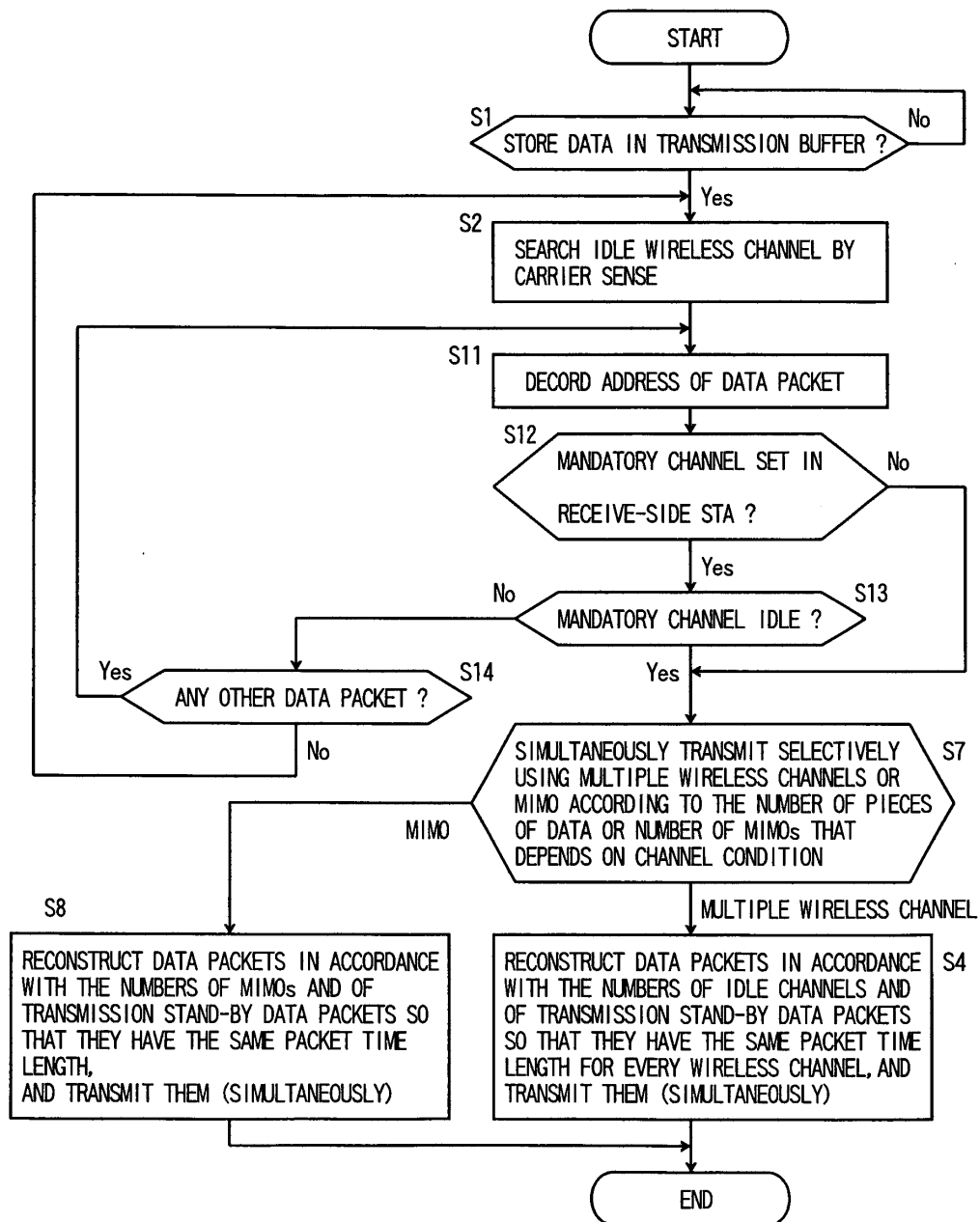


FIG. 12

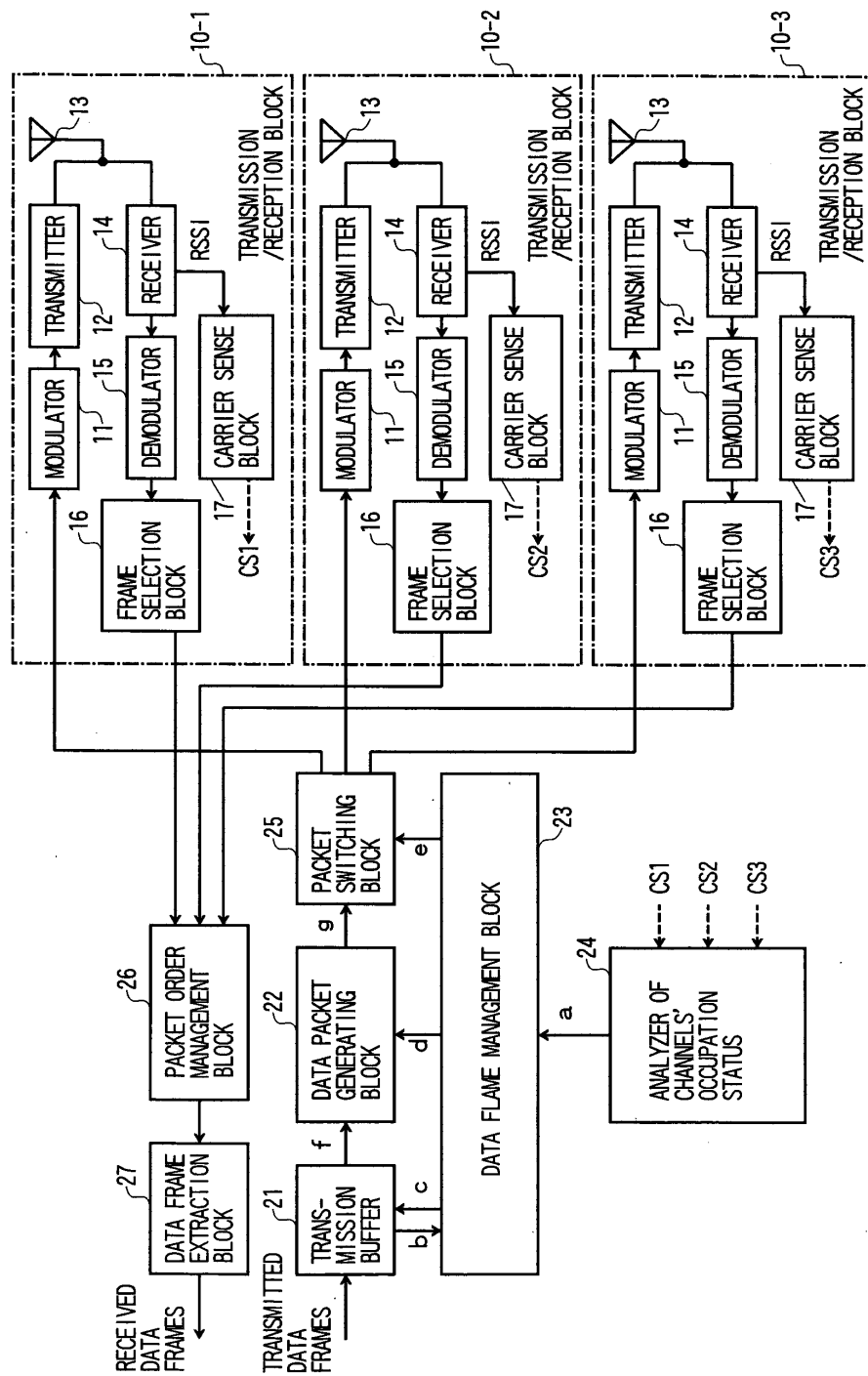


FIG. 13

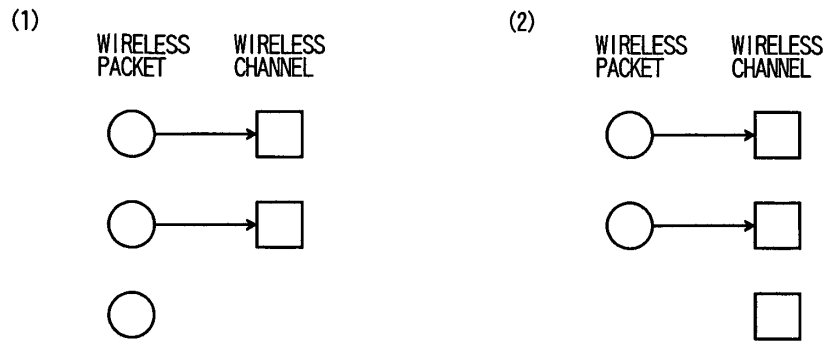
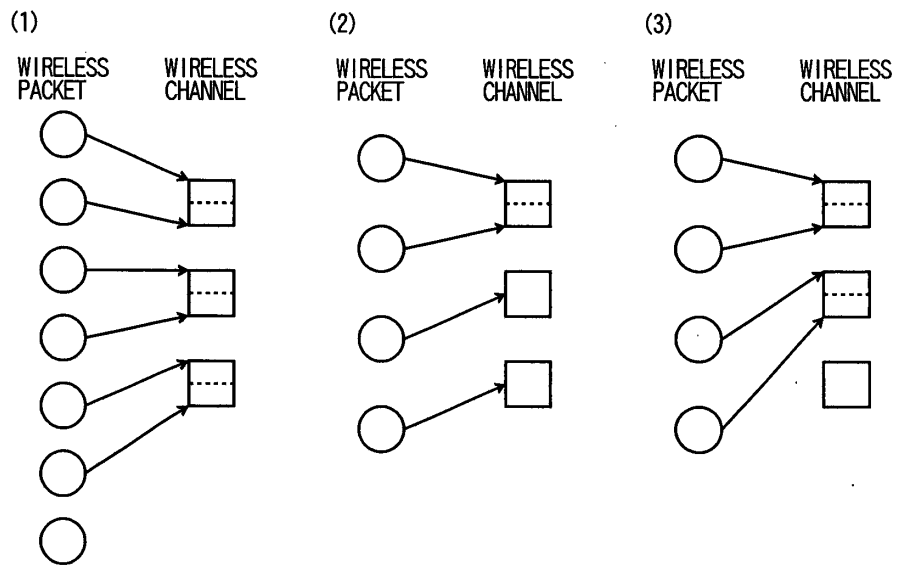


FIG. 14



12/12

FIG. 15

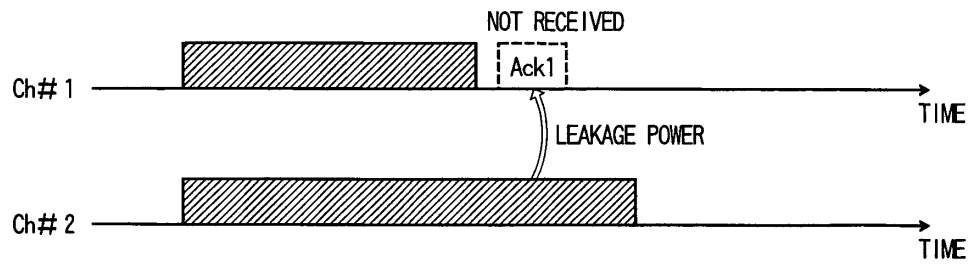


FIG. 16

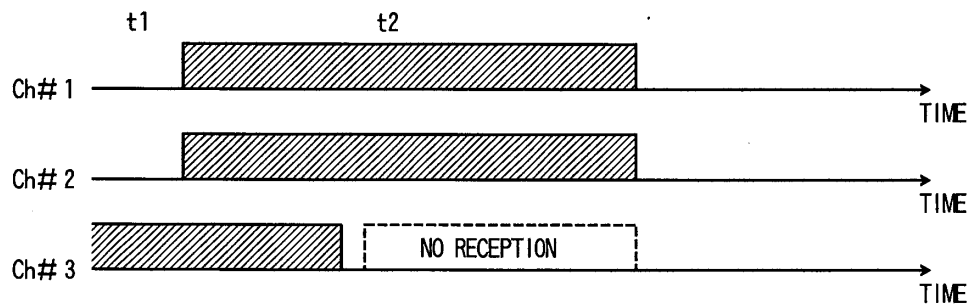
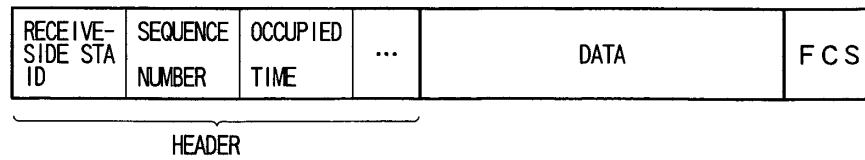


FIG. 17



WIRELESS PACKET COMMUNICATION METHOD AND WIRELESS PACKET COMMUNICATION APPARATUS

TECHNICAL FIELD

5 The present invention relates to a wireless packet communication method and a wireless packet communication apparatus for simultaneously transmitting a plurality of wireless packets by using multiple wireless channels or Multiple Input Multiple Output (hereinafter, MIMO).

BACKGROUND ART

10 In a conventional wireless packet communication apparatus, a wireless channel to be used is determined in advance. Prior to transmission of a data packet, the wireless packet communication apparatus performs carrier sense to detect whether or not that wireless channel is idle. Only when that wireless channel is idle, the wireless packet
15 communication apparatus transmits one data packet. This management allows a plurality of stations (hereinafter, STA) to share one wireless channel in a staggered manner ((1) IEEE 802.11 "MAC and PHY Specification for Metropolitan Area Networks", IEEE 802.11, 1998, (2) "Low-powered Data Communication System/Broadband Mobile Access Communication System (CSMA) Standard", ARIB SDT-T71 version 1.0, Association of Radio Industries and
20 Businesses, settled in 2000).

 On the other hand, a wireless packet communication method is known in which, when multiple wireless channels are found idle by carrier sense, a plurality of wireless packets are transmitted simultaneously by using the wireless channels. This method is generally described with reference to Figs. 13 and 14.

25 Fig. 13(1) shows a case where two wireless channels are idle for three wireless

packets. Two of the three wireless packets are transmitted simultaneously by using the two wireless channels. Fig. 13(2) shows a case where three wireless channels are idle for two wireless packets. All (two) wireless packets are transmitted simultaneously by using the two wireless channels.

5 Fig. 14 shows a case where a known MIMO technique (Kurosaki et al., "100Mbit/s SDM-COFDM over MIMO Channel for Broadband Mobile Communications", Technical Reports of the Institute of Electronics, Information and Communication Engineers, A · P 2001-96, RCS2001-135(2001-10)) is used together. In MIMO, different wireless packets are transmitted from a plurality of antennas at the same time on the same wireless channel.

10 Those wireless packets transmitted at the same time on the same wireless channel are separated from each other by digital signal processing that can deal with a difference between propagation coefficients of the wireless packets received by a plurality of antennas in an opposed STA. The number of MIMOs is determined in accordance with the propagation coefficients and the like.

15 Fig. 14(1) shows a case where three wireless channels are idle for seven wireless packets when the number of MIMOs of each wireless channel is two. When MIMO is applied to each of the three wireless channels, up to six wireless packets can be transmitted simultaneously. Therefore, six of the above seven wireless packets are transmitted simultaneously by using the three wireless channels.

20 Figs. 14(2) and (3) show cases where three wireless channels are idle for four wireless packets when the Number of MIMOs of each wireless channel is two. When MIMO is applied to each of the three wireless channels, up to six wireless packets can be transmitted simultaneously. However, the number of transmission-standby wireless packets is four. Therefore, MIMO is applied to a part of the three wireless channels. For

25 example, one of the wireless channels transmits two wireless packets by using MIMO, while

each of the remaining two wireless channels transmits one wireless packet without using MIMO, as shown in Fig. 14(2). Thus, four wireless packets are transmitted simultaneously by using the three wireless channels in total. Alternatively, four wireless packets are transmitted simultaneously on two wireless channels each using MIMO, as show in Fig.

5 14(3).

In the case where center frequencies of multiple wireless channels used at the same time are close to each other, an effect of leakage power from one wireless channel to a frequency region used by another wireless channel becomes large. In general, in case of transferring a wireless packet, a transmit-side STA transmits the wireless packet and
10 thereafter a receive-side STA transmits an acknowledgment packet (Ack) for the received wireless packet to the transmit-side STA. When the transmit-side STA tries to receive this acknowledgment packet (hereinafter, ACK packet), the effect of leakage power from another wireless channel used for simultaneous transmission becomes a problem.

For example, a case is considered where center frequencies of wireless channels #1
15 and #2 are close to each other and transmission times of wireless packets transmitted simultaneously from the respective wireless channels are different from each other, as shown in Fig. 15. In this case, the wireless packet transmitted on the wireless channel #1 is shorter. Thus, when an ACK packet (Ack1) for that wireless packet is received, the wireless channel #2 is performing transmission. Therefore, the wireless channel #1 may not receive
20 that ACK packet (Ack1) because of leakage power from the wireless channel #2. In this situation, throughput cannot be improved even if simultaneous transmission is performed using multiple wireless channels at the same time.

In a wireless LAN system, for example, data sizes of data frames input from a network are not constant. Thus, in case of sequentially converting the input data frames
25 into wireless packets for transmission, packet time lengths of the wireless packets are also

different. Therefore, even when a plurality of wireless packets are transmitted simultaneously at the same time, as shown in Fig. 15, the transmission time of each wireless packet is different. This increases a possibility of unsuccessful receiving of the ACK packet.

5 In order to overcome the above problem, there is a known method in which transmission of a plurality of wireless packets is terminated at the same time or substantially at the same time by making equal or equivalent packet time lengths (time required to transmit the wireless packets) of the wireless packets transmitted simultaneously. In this case, a transmit-side STA is not performing transmission at a
10 timing at which ACK packets for the respective wireless packets reach the transmit-side STA. Thus, the transmit-side STA can receive all the ACK packets without being affected by leakage power between wireless channels or the like. Therefore, the throughput can be improved.

However, even if the packet time lengths of the wireless packets transmitted
15 simultaneously are made the same, the effect of leakage power may become a problem. This case is now described with reference to Fig. 16.

At timing t1, wireless channels #1 and #2 of a transmit-side STA are idle, while a wireless channel #3 is busy. Thus, the transmit-side STA transmits wireless packets having the same packet time length by using the idle wireless channels #1 and #2. Therefore, the
20 effect of leakage power can be avoided between the wireless channels #1 and #2. When the wireless channel #3 becomes idle during transmission of those wireless packets (at timing t2), another STA may determine that the wireless channel #3 is idle and may transmit a wireless packet to the above transmit-side STA by using the wireless channel #3. However, the transmit-side STA is transmitting the wireless packets by using the wireless
25 channels #1 and #2 and therefore cannot receive the wireless packet on the wireless

channel #3 because of leakage power from the wireless channels #1 and #2. In other words, the STA in transmission cannot receive a wireless packet transmitted on a wireless channel that is adjacent to the wireless channel being in transmission. This problem occurs not only in case of simultaneous transmission using multiple wireless channels but also in a conventional case where wireless packets are transmitted by using one wireless channel and an adjacent wireless channel that is affected by leakage power receives the wireless packets.

It is an object of the present invention to avoid leakage power from affecting an adjacent channel so as to improve throughput by simultaneous transmission.

10

DISCLOSURE OF THE INVENTION

The invention of claim 1 provides a wireless packet communication method for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, or the multiple wireless channels and the MIMO. The wireless packet communication method includes setting a mandatory channel that is always used for transmission and transmitting the wireless packets by using a wireless channel or wireless channels that includes/include the mandatory channel, only when the mandatory channel is idle.

20 In other words, for transmitting a plurality of wireless packets simultaneously, transmission is performed by using the wireless channel(s) including the mandatory channel. Transmission is not performed when the mandatory channel is not idle. Moreover, wireless packets are always transmitted via wireless channels including the mandatory channel, and when the mandatory channel is busy, transmission is not performed even if there is another wireless channel. In other words, the mandatory channel can be regarded as a wireless

25

channel having the highest priority among wireless channels that have a plurality of priorities.

The invention of claim 2 provides a wireless packet communication method for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, or the multiple wireless channels and the MIMO. The wireless packet communication method includes distinguishing an STA A, for which a mandatory channel always used for transmission is set, from an STA B for which no mandatory channel is set. Wireless packets addressed to the STA A are transmitted by using the wireless channel(s) including the mandatory channel, only when the mandatory channel is idle. Wireless packets addressed to the STA B are transmitted by using the idle wireless channel(s).

The STA A has a similar function as that of the invention of claim 1. The STA B for which no mandatory channel is set, is made transmittable even when the mandatory channel is busy.

The invention of claim 3 is such that the plurality of wireless packets transmitted simultaneously are set to have the same or equivalent packet time length that corresponds to a packet size or a transmission time in the invention of claim 1 or 2.

The invention of claim 4 is such that in the invention recited in claim 1 or 2, wireless packets are simultaneously transmitted selectively using the multiple wireless channels or MIMO in accordance with the number of pieces of data or the number of MIMOs that depends on a channel condition.

The invention of claim 5 provides a wireless packet communication apparatus for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels determined to be idle by carrier sense, a wireless channel determined to be idle and MIMO, or the multiple wireless channels and the MIMO. The wireless packet

communication apparatus includes a unit setting a mandatory channel that is always used for transmission and transmitting the wireless packets by using the multiple wireless channels or the wireless channel that include/includes the mandatory channel, only when the mandatory channel is idle.

5 The invention of claim 6 provides a wireless packet communication apparatus for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, or the multiple wireless channels and the MIMO. The wireless packet communication apparatus includes a unit distinguishing an STA A, for which a mandatory
10 channel that is always used for transmission is set, from an STA B for which no mandatory channel is set, and determining destinations of the wireless packets. In case of wireless packets addressed to the STA A, the unit transmits the wireless packets by using the multiple wireless channels or the wireless channel that include/includes the mandatory channel, only when the mandatory channel is idle. In case of wireless packets addressed to
15 the STA B, the unit transmits the wireless packets by using idle wireless channel or channels.

 The invention of claim 7 is such that in the invention recited in claim 5 or 6, the plurality of wireless packets transmitted simultaneously are set to have the same or equivalent packet time length that corresponds to a packet size or a transmission time.

 The invention of claim 8 is such that in the invention recited in claim 5 or 6,
20 wireless packets are simultaneously transmitted selectively using the multiple wireless channels or MIMO in accordance with the number of pieces of data or the number of MIMOs that depends on a channel condition.

BRIEF DESCRIPTION OF THE DRAWINGS

25 Fig. 1 is a flowchart according to a first embodiment of the present invention.

Fig. 2 is a time chart of an exemplary operation in the first embodiment of the present invention.

Fig. 3 explains methods for reconstructing a data packet.

Fig. 4 is a flowchart according to a second embodiment of the present invention.

5 Fig. 5 is a time chart of an exemplary operation in the second embodiment of the present invention.

Fig. 6 is a flowchart according to a third embodiment of the present invention.

Fig. 7 is a flowchart according to a fourth embodiment of the present invention.

Fig. 8 is a flowchart according to a fifth embodiment of the present invention.

10 Fig. 9 is a flowchart according to a sixth embodiment of the present invention.

Fig. 10 is a flowchart according to a seventh embodiment of the present invention.

Fig. 11 is a flowchart according to an eighth embodiment of the present invention.

Fig. 12 is a block diagram of an exemplary wireless packet communication apparatus according to the present invention.

15 Fig. 13 explains exemplary methods for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels.

Fig. 14 explains exemplary methods for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels (and MIMO).

Fig. 15 explains an effect of leakage power of a wireless channel.

20 Fig. 16 explains a case where the effect of leakage power becomes a problem even if packet time lengths of wireless packets transmitted simultaneously are made the same.

Fig. 17 shows a structure of a wireless packet used in the wireless packet communication apparatus of the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

[First Embodiment]

Fig. 1 is a flowchart of a wireless packet communication method according to the first embodiment of the present invention. Fig. 2 is a time chart of the wireless communication method according to the first embodiment of the present invention. In this embodiment, wireless channels #1, #2, and #3 are provided, and the wireless channel #1 is set as a mandatory channel for every STA. Each STA is regularly notified of the mandatory channel. When the mandatory channel is busy, each STA does not perform transmission even if there is other idle wireless channel. That is, no transmission is performed. It is assumed that the wireless channels #1, #2, and #3 affect each other due to a leakage and that when one of the wireless channels is in transmission, the other channels cannot receive data.

When data is stored in a transmission buffer, an idle wireless channel is searched by carrier sense (S1 and S2). In this example, it is found that the wireless channel #3 is busy at a timing data is generated (1), and the wireless channels #1 and #2 are idle. Then, it is determined whether or not the mandatory channel is idle (S3). When the mandatory channel is busy, a procedure goes back to the search of an idle wireless channel. On the other hand, when the mandatory channel is idle, data packets are reconstructed to data packets having the same packet time length for every wireless channel in accordance with the number of idle channels and the number of transmission stand-by data packets. The reconstructed data packets are transmitted (simultaneously) (S4). In this example, since the wireless channel #1 as the mandatory channel is idle, the wireless packets is simultaneously transmitted by using two wireless channels as the wireless channels #1 and #2.

The following three methods are known data packet reconstruction methods. In

the case where there is one data packet and two idle channels, for example, two data packets having the same packet time length are generated by fragmenting the data packet, as shown in Fig. 3(1). In the case where there are three data packets and two idle channels, a data packet 2 is divided into two portions and the two portions are connected to data packets 1 and 3, respectively, for example, as shown in Fig. 3(2). In this manner, two data packets having the same packet time length are generated. Alternatively, the two data packets having the same packet time length can be generated by connecting the three data packets into one block and then dividing the block into two. Alternatively, the data packets 1 and 2 may be aggregated to each other and dummy data is added to the data packet 3, as shown in Fig. 3(3), thereby obtaining two data packets having the same packet time length. Moreover, in the case where multiple wireless channels having different transmission rates are used, the packet time lengths of data packets are adjusted to be the same by associating a size ratio of each data packet with a ratio of the transmission rates.

Even when the wireless channel #3 becomes idle, another STA does not perform transmission because the wireless channel #1 set as the mandatory channel is busy. On the other hand, at a timing data is generated (2), all the wireless channels including the wireless channel #1 set as the mandatory channel are idle. Therefore, each STA becomes transmittable. For example, in the case where an STA transmits the wireless packets at the timing data is generated (1), another STA transmits a wireless packet to the STA having transmitted at the timing data is generated (2).

[Second Embodiment]

Fig. 4 is a flowchart of a wireless packet communication method according to the second embodiment of the present invention. Fig. 5 is a time chart of that wireless packet communication method. In this embodiment, there are an STA A for which a mandatory channel is set and an STA B for which no mandatory channel is set. There is no specific

limitation to transmission to the STA B, while transmission to the STA A is allowed only when the mandatory channel is idle, and is not performed when the mandatory channel is busy even if another wireless channel is idle. Please note that in the first embodiment a mandatory channel is set for every STA so that packet transmission is always performed via
5 wireless channels including the mandatory channel without an address of a wireless packet being considered.

First, when data is stored in a transmission buffer, an idle wireless channel is searched by carrier sense (S1 and S2). In this example, it is found that at a timing data is generated (1), a wireless channel #3 is busy and wireless channels #1 and #2 are idle.
10 Then, an address of one data packet stored in the transmission buffer is decoded (S11), and it is determined whether or not any mandatory channel is set for an STA that is the decoded address (S12). When a mandatory channel is set for the receive-side STA, it is determined whether or not that mandatory channel is idle (S13). When that mandatory channel is idle, transmission stand-by data packets are reconstructed to have the same packet time length
15 for every wireless channel in accordance with the number of idle channels and the number of the transmission stand-by data packets. The reconstructed data packets are transmitted (simultaneously) (S4). In this example, for wireless packets addressed to the STA A, simultaneous transmission is performed using two wireless channels as the wireless channels #1 and #2 because the wireless channel #1 set as the mandatory channel is idle.

20 On the other hand, when no mandatory channel is set for the receive-side STA in S12, the state of the mandatory channel need not be considered so that the transmission stand-by data packets are reconstructed to have the same packet time length for every wireless channel in accordance with the number of idle channels and the number of the transmission stand-by data packets. The reconstructed data packets are transmitted
25 (simultaneously) (S4). Moreover, when the mandatory channel is not idle in S13, the

wireless packet cannot be transmitted to the STA A for which the mandatory channel is set. Therefore, it is then determined whether or not there is another data packet in the transmission buffer (S14). With a presence of a data packet therein, a procedure returns to decoding of an address of the data packet in S11. With no data packet, an idle channel is
5 searched in S2.

In this example, when the wireless channel #3 becomes idle, transmission of a wireless packet to the STA B in which no mandatory channel is set using the wireless channel #3 becomes possible. On the other hand, transmission of a wireless packet to the STA A using the wireless channel #3 is not performed because the wireless channel #1 is
10 busy, and has to wait until the wireless channel #1 becomes idle.

At a timing data is generated (2), the wireless channels #1 and #2 are idle. Therefore, wireless packets addressed to the STA A for which the mandatory channel is set and to the STA B for which no mandatory channel is set can be transmitted by using the wireless channels #1 and #2.

15 [Third Embodiment]

Fig. 6 is a flowchart of a wireless packet communication method according to the third embodiment of the present invention. This embodiment has a feature in using MIMO additionally for simultaneous transmission of wireless packets in the first embodiment as well as in reconstructing wireless packets in S4 in the first embodiment such that
20 reconstructed wireless packets have the same packet time length for the number of simultaneous transmissions that corresponds to a total number of MIMOs of idle channels (S5). Except for the above, this embodiment is the same as the first embodiment.

[Fourth Embodiment]

Fig. 7 is a flowchart of a wireless packet communication method according to the
25 fourth embodiment of the present invention. This embodiment has the following feature.

In case of applying MIMO to simultaneous transmission of wireless packets, antenna correlation is obtained from propagation coefficients prior to reconstruction of wireless packets to wireless packets having the same packet time length for the number of simultaneous transmissions that corresponds to a total number of MIMOs of idle channels in S5 in the third embodiment. Then, the number of MIMOs that that can be multiplexed in one channel is obtained by using a predetermined threshold value (S6). Except for the above, this embodiment is the same as the third embodiment.

[Fifth Embodiment]

Fig. 8 is a flowchart of a wireless packet communication method according to the fifth embodiment of the present invention. This embodiment has a feature that simultaneous transmission using multiple wireless channels as described in the first embodiment or simultaneous transmission using MIMO as described in the third embodiment is selected in accordance with the number of pieces of data stored in the transmission buffer or the number of MIMOs as described in the fourth embodiment that depends on a channel condition (S7). In accordance with this selection, wireless packets are reconstructed to have the same packet time length for the number of idle channels or the Number of MIMOs. The reconstructed packets are transmitted simultaneously (S4 and S8). Except for the above, this embodiment is the same as the first embodiment.

[Sixth Embodiment]

Fig. 9 is a flowchart of a wireless packet communication method according to the sixth embodiment of the present invention. This embodiment has a feature that MIMO is applied to simultaneous transmission of wireless packets in the second embodiment. More specifically, wireless packets in S4 in the second embodiment is reconstructed in such a manner that reconstructed wireless packets have the same packet time length for the number of simultaneous transmissions that corresponds to a total number of MIMOs of idle

channels (S5). Except for the above, this embodiment is the same as the second embodiment.

[Seventh Embodiment]

Fig. 10 is a flowchart of a wireless packet communication method according to the seventh embodiment of the present invention. This embodiment has the following feature. In case of applying MIMO to simultaneous transmission of wireless packets, antenna correlation is obtained from propagation coefficients prior to reconstruction of wireless packets to wireless packets having the same packet time length for the number of simultaneous transmissions that corresponds to a total number of MIMOs of idle channels in S5 in the sixth embodiment. Then, the number of MIMOs that can be multiplexed in one channel is obtained by using a predetermined threshold value (S6). Except for the above, this embodiment is the same as the sixth embodiment.

[Eighth Embodiment]

Fig. 11 is a flowchart of a wireless packet communication method according to the eighth embodiment of the present invention. This embodiment has a feature that simultaneous transmission using multiple wireless channels as described in the second embodiment or simultaneous transmission using MIMO as described in the sixth embodiment is selected in accordance with the number of pieces of data stored in the transmission buffer or the number of MIMOs described in the seventh embodiment that depends on a channel condition (S7). In accordance with this selection, reconstruction of wireless packets is performed in such a manner that reconstructed wireless packets have the same packet time length for the number of idle channels or the Number of MIMOs. The reconstructed wireless packets are transmitted simultaneously (S4 and S8). Except for the above, this embodiment is the same as the second embodiment.

[Exemplary structure of a wireless packet communication apparatus]

Fig. 12 shows an exemplary structure of a wireless packet communication apparatus of the present invention. Although the following description will be directed to the structure of the wireless packet communication apparatus capable of transmitting and receiving three wireless packets simultaneously by using three wireless channels #1, #2, and #3, the number of simultaneously transmittable/receivable wireless packets may be set arbitrarily. Where MIMO is used for each wireless channel, wireless packets can be transmitted and received simultaneously in the number of simultaneous transmissions that is equal to the sum of MIMO numbers of multiple wireless channels. However, the MIMO will not be taken into consideration in the following description as well as a case where multiple wireless channels are independently used.

In Fig. 12, the wireless packet communication apparatus includes a transmission/reception block 10-1, 10-2, and 10-3, a transmission buffer 21, a data packet generating block 22, a data frame management block 23, an analyzer of channels' occupation status 24, a packet switching block 25, a packet order management block 26, and a data frame extraction block 27.

The transmission/reception blocks 10-1, 10-2, and 10-3 perform wireless communication via different wireless channels #1, #2, and #3, respectively. These wireless channels are independent of each other because they have different wireless frequencies from each other, therefore, the blocks can perform wireless communication using multiple wireless channels at the same time. Each transmission/reception block 10 includes a modulator 11, a transmitter 12, an antenna 13, a receiver 14, a demodulator 15, a frame selection block 16, and a carrier sense block 17.

Radio frequency signals transmitted from another wireless packet communication apparatus via different wireless channels #1, #2, and #3 are input to the receivers 14 through the antennas 13 of the transmission/reception block 10-1, 10-2, and 10-3,

respectively. Each receiver 14 corresponding to each wireless channel performs a reception processing on the input radio frequency signal. The reception processing contains frequency conversion, filtering, quadrature detection, and AD conversion. A radio frequency signal on a wireless propagation path of each wireless channel is always input to the corresponding receiver 14 except during periods the antenna 13 connected to the receiver 14 is used for transmission. The receiver 14 outputs, to the carrier sense block 17, an RSSI signal indicating a received electric field strength of each wireless channel. When receiving a radio frequency signal on the corresponding wireless channel, the receiver 14 outputs to the demodulator 15 a baseband signal for which the reception processing is performed.

The demodulator 15 performs a demodulation processing on the baseband signal input from the receiver 14, and outputs a resulting data packet to the frame selection block 16. The frame selection block 16 performs CRC check on the input data packet. In the case where the data packet has been received correctly, the frame selection block 16 determines whether or not the data packet is directed to an own STA. More specifically, the frame selection block 16 determines whether or not a receive-side STA ID of the data packet is coincident with ID of the own STA. Then, the frame selection block 16 outputs the data packet addressed to the own STA to the packet order management block 26 while transmitting to the modulator 11 an ACK packet generated in an ACK packet generating block (not shown) and performs a reply processing. In transmission of the ACK packet, a transmission mode may be set in such a manner that a transmission rate is set or MIMO is not applied. On the other hand, when the data packet is not directed to the own STA, the frame selection block 16 discards the data packet.

The packet order management block 26 checks sequence numbers added to received data packets and rearranges the received data packets in an appropriate order, i.e.,

in order of sequence numbers. The rearranged data packets are output to the data frame extraction block 27 as received data packets. The data frame extraction block 27 removes a packet header from each of the data packets contained in the received data packets, and outputs the resulting data packets as received data frames.

5 When receiving an RSSI signal, the carrier sense block 17 compares a value of a received electric field strength represented by the RSSI signal with a preset threshold value. When a state where the received electric field strength is smaller than the threshold value continues for a predetermined period, the carrier sense block 17 determines that the assigned wireless channel is idle. Otherwise, the carrier sense block 17 determines that the
10 assigned wireless channel is busy. The carrier sense blocks 17 corresponding to the respective wireless channels output the determination results as carrier sense results CS1 to CS3. Please note that in each transmission/reception block 10, no RSSI signal is input to the carrier sense block 17 while the antenna 13 is in transmission. Moreover, in the case where the antenna 13 has already been in a transmission state, it is not possible to
15 simultaneously transmit another data packet as a radio frequency signal by means of the same antenna 13. Therefore, when receiving the RSSI signal, each carrier sense block 17 outputs the carrier sense result indicating that the wireless channel assigned thereto is busy.

The carrier sense results CS1 to CS3 that are output from the carrier sense blocks 17 corresponding to the respective wireless channels are input to the analyzer of channels' occupation status 24. The analyzer of channels' occupation status 24 manages an idle
20 status of each wireless channel based on the corresponding carrier sense result and notifies the data frame management block 23 of information on an idle wireless channel, the number of idle channels, and the like (Fig. 12, a).

On the other hand, sent data frames to be transmitted are input to and buffered in
25 the transmission buffer 21. The sent data frames consists one or more data frames. The

transmission buffer 21 successively notifies the data frame management block 23 of the number of data frames the transmission buffer 21 currently stores, ID information of a receive-side wireless packet communication apparatus, a data size, address information indicating a position in the buffer, and other information (b).

5 The data frame management block 23 determines how to generate data packets from which data frame and on which wireless channel to transmit, according to information about data frames for each receive-side STA ID from the transmission buffer 21 and information about the wireless channels from the analyzer of channels' occupation status 24. The data frame management block 23 then notifies the transmission buffer 21, the
10 data packet generating block 22, and the data packet switching block 25 of the determined data frame, generation manner, and wireless channel, respectively (c, d, and e). For example, in the case where the number N of idle wireless channels including the mandatory channel is smaller than the number K of transmission stand-by data frames in the transmission buffer 21, the number N of idle wireless channels including the mandatory
15 channel is determined as the number of data packets transmitted simultaneously. The transmission buffer 21 is notified of address information to designate N data frames from the K data frames (c). The data packet generating block 22 is notified of information necessary for generating N data packets from data frames input from the transmission buffer 21 (d). The packet switching block 25 is instructed to associate the N data packets
20 generated by the data packet generating block 22 with the idle wireless channels (e).

 According to an output instruction, the transmission buffer 21 outputs the data frames to the data packet generating block 22 (f). The data packet generating block 22 extracts data fields from the respective data frames to generate a plurality of data blocks having the same packet time length, and adds a packet header and a CRC code (FCS region)
25 to each of the data blocks to generate data packets shown in Fig. 17. The packet header

contains ID information on a receive-side STA as a destination of the corresponding data packet, control information such as a sequence number indicating an order of the data frame, and other information. The control information also contains information required for a receive-side STA to convert a data packet into the original data frame when it receives the data packet. The packet switching block 25 associates the data packets input from the data packet generating block 22 with the respective wireless channels.

As a result, the data packet associated with the wireless channel #1 is input to the modulator 11 in the transmission/reception block 10-1; the data packet associated with the wireless channel #2 is input to the modulator 11 in the transmission/reception block 10-2; and the data packet associated with the wireless channel #3 is input to the modulator 11 in the transmission/reception block 10-3. When receiving a data packet from the packet switching block 25, each modulator 11 performs a predetermined modulation processing on the data packet and outputs the processed data packet to the transmitter 12. Each transmitter 12 performs a transmission processing on the modulated data packet input from the modulator 11. The transmission processing contains DA conversion, frequency conversion, filtering, and power amplification. After the transmission processing, each transmitter 12 transmits the processed data packet as a wireless packet on the corresponding wireless channel via the corresponding antenna 13.

The processings described in the first to eight embodiments are performed under a control of the data frame management block 23 with the mandatory channel taken into consideration. This can prevent a situation that a wireless packet cannot be received by use of multiple wireless channels because of leakage of power from one channel to an adjacent channel.

25

INDUSTRIAL AVAILABILITY

According to the present invention, while a transmit-side STA is in transmission using one or more wireless channels including a mandatory channel, the other STAs do not perform transmission to the transmit-side STA. Thus, it is possible to avoid a situation
5 that the transmit-side STA cannot receive a wireless packet addressed to an own STA. On the other hand, the other STAs can surely transfer a wireless packet to the transmit-side STA by transmitting the wireless packet after the mandatory channel becomes idle. Thus, throughput can be improved.

Moreover, in the case where there is an STA for which no mandatory channel is set,
10 transmission is enabled between STAs including the STA even when the mandatory channel is busy. Thus, reduction of the throughput can be suppressed.

CLAIMS

1. A wireless packet communication method for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, or the multiple wireless channels and the MIMO, the method characterized by comprising:
 - setting a mandatory channel that is always used for transmission; and
 - transmitting the wireless packets by using a wireless channel/wireless channels that includes/include the mandatory channel, only when the mandatory channel is idle.
2. A wireless packet communication method for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, or the multiple wireless channels and the MIMO, the method characterized by comprising:
 - distinguishing an STA A from an STA B, the STA A for which a mandatory channel is set, the STA B for which no mandatory channel is set, the mandatory channel being always used for transmission; and
 - when wireless packets are addressed to said STA A, transmitting the wireless packets to said STA A by using a wireless channel/wireless channels that includes/include the mandatory channel, only when the mandatory channel is idle; and
 - when wireless packets are addressed to said STA B, transmitting the wireless packets to said STA B by using idle wireless channel(s).
3. The wireless packet communication method according to Claim 1 or 2, characterized in that
 - the plurality of wireless packets transmitted simultaneously are set to have a same or equivalent packet time length that corresponds to a packet size or a transmission time.
4. The wireless packet communication method according to Claim 1 or 2,

characterized by further comprising

simultaneously transmitting wireless packets selectively using the multiple wireless channels or the MIMO in accordance with a number of pieces of data or a number of MIMOs that depends on a channel condition.

- 5 5. A wireless packet communication apparatus for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, or the multiple wireless channels and the MIMO, the apparatus characterized by comprising

10 a unit setting a mandatory channel that is always used for transmission, and transmitting the wireless packets only when the mandatory channel is idle by using a wireless channel or wireless channels that includes/include the mandatory channel.

6. A wireless packet communication apparatus for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, or the multiple wireless
15 channels and the MIMO, the apparatus characterized by comprising

a unit distinguishing an STA A from an STA B and determining destinations of the wireless packets so as to transmit wireless packets addressed to said STA A only when said mandatory channel is idle by using a wireless channel or wireless channels that includes/include a mandatory channel, and to transmit wireless packets addressed to said
20 STA B by using idle wireless channel or channels, the mandatory channel being always used for transmission, the STA A for which the mandatory channel is set, the STA B for which no mandatory channel is set.

7. The wireless packet communication apparatus according to Claim 5 or 6, characterized in that

25 the plurality of wireless packets transmitted simultaneously are set to have a same

or equivalent packet time length that corresponds to a packet size or a transmission time.

8. The wireless packet communication apparatus according to Claim 5 or 6, characterized by further comprising:

5 a unit simultaneously transmitting wireless packets selectively using the multiple wireless channels or the MIMO in accordance with a number of pieces of data or a number of MIMOs that depends on a channel condition.

(12)特許協力条約に基づいて公開された国際出願

(19) 世界知的所有権機関
国際事務局



(43) 国際公開日
2005 年 3 月 24 日 (24.03.2005)

PCT

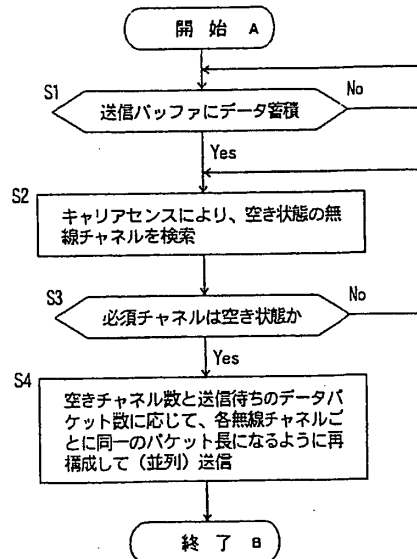
(10) 国際公開番号
WO 2005/027555 A1

- (51) 国際特許分類: H04Q 7/36, H04J 15/00 (72) 発明者; および
(21) 国際出願番号: PCT/JP2004/013483 (75) 発明者/出願人 (米国についてのみ): 永田 健悟 (NAGATA, Kengo) [JP/JP]; 〒1808585 東京都武蔵野市緑町 3 丁目 9-1 1 N T T 知的財産センタ内 Tokyo (JP). 熊谷 智明 (KUMAGAI, Tomoaki) [JP/JP]; 〒1808585 東京都武蔵野市緑町 3 丁目 9-1 1 N T T 知的財産センタ内 Tokyo (JP). 大槻 信也 (OTSUKI, Shinya) [JP/JP]; 〒1808585 東京都武蔵野市緑町 3 丁目 9-1 1 N T T 知的財産センタ内 Tokyo (JP). 斎藤 一寛 (SAITO, Kazuyoshi) [JP/JP]; 〒1808585 東京都武蔵野市緑町 3 丁目 9-1 1 N T T 知的財産センタ内 Tokyo (JP). 相河 聡 (AIKAWA, Satoru) [JP/JP]; 〒1808585 東京都武蔵野市緑町 3 丁目 9-1 1 N T T 知的財産センタ内 Tokyo (JP).
- (22) 国際出願日: 2004 年 9 月 9 日 (09.09.2004)
- (25) 国際出願の言語: 日本語
- (26) 国際公開の言語: 日本語
- (30) 優先権データ:
特願2003-317100 2003 年 9 月 9 日 (09.09.2003) JP
- (71) 出願人 (米国を除く全ての指定国について): 日本電信電話株式会社 (NIPPON TELEGRAPH AND TELEPHONE CORPORATION) [JP/JP]; 〒1008116 東京都千代田区大手町二丁目 3 番 1 号 Tokyo (JP).

[続有]

(54) Title: RADIO PACKET COMMUNICATION METHOD AND RADIO PACKET COMMUNICATION APPARATUS

(54) 発明の名称: 無線パケット通信方法および無線パケット通信装置



A START
S1 STORE DATA IN TRANSMISSION BUFFER
S2 SEARCH FOR OPEN RADIO CHANNEL BY USE OF CARRIER SENSE
S3 INDISPENSABLE CHANNEL IS OPEN?
S4 RECONSTRUCT DATA PACKETS SUCH THAT THEIR PACKET LENGTHS ARE EQUAL TO EACH OTHER FOR EACH RADIO CHANNEL IN ACCORDANCE WITH NUMBER OF OPEN CHANNELS AND NUMBER OF DATA PACKETS WAITING FOR TRANSMISSION, AND (PARALLEL) TRANSMIT THE DATA PACKETS
B END

(57) Abstract: In a radio packet communication method for parallel transmitting a plurality of radio packets by use of a plurality of radio channels that are judged as being open by carrier sense, or for parallel transmitting a plurality of radio packets by use of space division multiplexing using a single radio channel that is judged as being open, or for parallel transmitting a plurality of radio packets by use of combination of them, an indispensable channel to be necessarily used for transmission is set, and only when the indispensable channel is open, radio channels including this indispensable channel are used to transmit the radio packets. That is, in a case of parallel transmitting a plurality of radio packets, radio channels including the indispensable channel are used for transmission, and if the indispensable channel is not open, the transmission is inhibited.

(57) 要約: キャリアセンスによって空き状態と判定された複数の無線チャンネルを用いて複数の無線パケットを並列送信するか、または空き状態と判定された 1 つの無線チャンネルを用いて空間分割多重方式により複数の無線パケットを並列送信するか、または両者を併用して複数の無線パケットを並列送信する無線パケット通信方法において、送信に必ず使用する必須チャンネルを設定し、この必須チャンネルが空き状態のときに限り必須チャンネルを含む無線チャンネルを用いて無線パケットの送信を行う。すなわ

ち、複数の無線パケットを並列送信する場合に、必須チャンネルを含む無線チャンネルを用いて送信を行うようにし、必須チャンネルが空き状態でなければ送信を禁止する。



(74) 代理人: 古谷 史旺, 外(FURUYA, Fumio et al.); 〒1600023 東京都新宿区西新宿 1 丁目 1 9 番 5 号 第 2 明宝ビル 9 階 Tokyo (JP).

(81) 指定国(表示のない限り、全ての種類の国内保護が可能): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) 指定国(表示のない限り、全ての種類の広域保護が可能): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD,

SL, SZ, TZ, UG, ZM, ZW), ユーラシア (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), ヨーロッパ (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

添付公開書類:

- 国際調査報告書
- 請求の範囲の補正の期限前の公開であり、補正書受領の際には再公開される。

2文字コード及び他の略語については、定期発行される各PCTガゼットの巻頭に掲載されている「コードと略語のガイダンスノート」を参照。

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2004/013483

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl⁷ H04Q7/36, H04J15/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl⁷ H04J3/00-3/26, H04J15/00, H04B7/24-7/26, H04Q7/00-7/38,
H04L13/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,A	JP 2003-259430 A (Sanyo Electric Co., Ltd.), 12 September, 2003 (12.09.03), Par. No. [0026] (Family: none)	1-2, 4-6, 8
A	JP 2002-198933 A (Sanyo Electric Co., Ltd.), 12 July, 2002 (12.07.02), Par. Nos. [0018] to [0019] (Family: none)	1-2, 5-6
A	JP 07-303090 A (AT & T Corp.), 14 November, 1995 (14.11.95), Par. No. [0020]; Figs. 5, 10 (Family: none)	3, 7

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
06 December, 2004 (06.12.04)

Date of mailing of the international search report
21 December, 2004 (21.12.04)

Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

Form PCT/ISA/210 (second sheet) (January 2004)

ABSTRACT

In a wireless packet communication method for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels determined to be idle by carrier sense, a wireless channel determined to be idle and MIMO, or the multiple wireless channel
5 and the MIMO, a mandatory channel that is always used for transmission is set. The wireless packets are transmitted by using the wireless channel(s) including the mandatory channel only when the mandatory channel is idle. That is, in case of transmitting a plurality of wireless packets simultaneously, transmission is performed by using the wireless channel(s) including the mandatory channel, and transmission is not performed when the
10 mandatory channel is not idle.

**WIRELESS PACKET COMMUNICATION METHOD AND
WIRELESS PACKET COMMUNICATION APPARATUS**

TECHNICAL FIELD

The present invention relates to a wireless packet communication method and a wireless packet communication apparatus for simultaneously transmitting a plurality of wireless packets by using multiple wireless channels or Multiple Input Multiple Output (hereinafter, MIMO).

BACKGROUND ART

In a conventional wireless packet communication apparatus, a wireless channel to be used is determined in advance. Prior to transmission of a data packet, the wireless packet communication apparatus performs carrier sense to detect whether or not that wireless channel is idle. Only when that wireless channel is idle, the wireless packet communication apparatus transmits one data packet. This management allows a plurality of stations (hereinafter, STA) to share one wireless channel in a staggered manner ((1) "International Standard ISO/IEC 8802-11 ANSI/IEEE Std 802.11, 1999 edition, Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications", (2) "Low-powered Data Communication System/Broadband Mobile Access Communication System (CSMA) Standard", ARIB STD-T71 version 1.0, Association of Radio Industries and Businesses, settled in 2000).

On the other hand, a wireless packet communication method is known in which, when multiple wireless channels are found idle by carrier sense, a plurality of wireless packets are transmitted simultaneously by using the wireless channels. This method is generally described with reference to Figs. 13 and 14.

Fig. 13(1) shows a case where two wireless channels are idle for three wireless

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter I of the Patent Cooperation Treaty)

(PCT Rule 44bis)

Applicant's or agent's file reference 3219	FOR FURTHER ACTION	See item 4 below
International application No. PCT/JP2004/013483	International filing date (<i>day/month/year</i>) 09 September 2004 (09.09.2004)	Priority date (<i>day/month/year</i>) 09 September 2003 (09.09.2003)
International Patent Classification (8th edition unless older edition indicated) See relevant information in Form PCT/ISA/237		
Applicant NIPPON TELEGRAPH AND TELEPHONE CORPORATION		

1.	This international preliminary report on patentability (Chapter I) is issued by the International Bureau on behalf of the International Searching Authority under Rule 44 <i>bis</i> .1(a).																								
2.	This REPORT consists of a total of 4 sheets, including this cover sheet. In the attached sheets, any reference to the written opinion of the International Searching Authority should be read as a reference to the international preliminary report on patentability (Chapter I) instead.																								
3.	This report contains indications relating to the following items: <table style="width: 100%; border: none;"> <tr> <td style="width: 15%; text-align: center;">☒</td> <td style="width: 35%;">Box No. I</td> <td style="width: 50%;">Basis of the report</td> </tr> <tr> <td style="text-align: center;">☐</td> <td>Box No. II</td> <td>Priority</td> </tr> <tr> <td style="text-align: center;">☐</td> <td>Box No. III</td> <td>Non-establishment of opinion with regard to novelty, inventive step and industrial applicability</td> </tr> <tr> <td style="text-align: center;">☐</td> <td>Box No. IV</td> <td>Lack of unity of invention</td> </tr> <tr> <td style="text-align: center;">☒</td> <td>Box No. V</td> <td>Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement</td> </tr> <tr> <td style="text-align: center;">☐</td> <td>Box No. VI</td> <td>Certain documents cited</td> </tr> <tr> <td style="text-align: center;">☐</td> <td>Box No. VII</td> <td>Certain defects in the international application</td> </tr> <tr> <td style="text-align: center;">☐</td> <td>Box No. VIII</td> <td>Certain observations on the international application</td> </tr> </table>	☒	Box No. I	Basis of the report	☐	Box No. II	Priority	☐	Box No. III	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability	☐	Box No. IV	Lack of unity of invention	☒	Box No. V	Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement	☐	Box No. VI	Certain documents cited	☐	Box No. VII	Certain defects in the international application	☐	Box No. VIII	Certain observations on the international application
☒	Box No. I	Basis of the report																							
☐	Box No. II	Priority																							
☐	Box No. III	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability																							
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☐	Box No. VI	Certain documents cited																							
☐	Box No. VII	Certain defects in the international application																							
☐	Box No. VIII	Certain observations on the international application																							
4.	The International Bureau will communicate this report to designated Offices in accordance with Rules 44bis.3(c) and 93bis.1 but not, except where the applicant makes an express request under Article 23(2), before the expiration of 30 months from the priority date (Rule 44bis .2).																								

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland Facsimile No. +41 22 740 14 35	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="padding: 5px;">Date of issuance of this report 13 March 2006 (13.03.2006)</td> </tr> <tr> <td style="padding: 5px;">Authorized officer Masashi Honda </td> </tr> <tr> <td style="padding: 5px;">Telephone No. +41 22 338 70 10</td> </tr> </table>	Date of issuance of this report 13 March 2006 (13.03.2006)	Authorized officer Masashi Honda	Telephone No. +41 22 338 70 10
Date of issuance of this report 13 March 2006 (13.03.2006)				
Authorized officer Masashi Honda				
Telephone No. +41 22 338 70 10				

Form PCT/IB/373 (January 2004)

特許協力条約

発信人 日本国特許庁（国際調査機関）

出願人代理人

古谷 史旺

様

あて名

〒 160-0023

東京都新宿区西新宿1丁目19番5号
第2明宝ビル9階

REC'D 22 DEC 200

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国際調査機関の見解書
(法施行規則第40条の2)
[PCT規則43の2.1]

発送日
(日.月.年)

21.12.2004

出願人又は代理人
の書類記号

3219

今後の手続きについては、下記2を参照すること。

国際出願番号

PCT/JP2004/013483

国際出願日

(日.月.年) 09.09.2004

優先日

(日.月.年) 09.09.2003

国際特許分類 (IPC) IPC第7版 H04Q 7/36
H04J 15/00

出願人 (氏名又は名称)

日本電信電話株式会社

1. この見解書は次の内容を含む。

☒ 第I欄 見解の基礎

☐ 第II欄 優先権

☐ 第III欄 新規性、進歩性又は産業上の利用可能性についての見解の不作成

☐ 第IV欄 発明の単一性の欠如

☒ 第V欄 PCT規則43の2.1(a)(i)に規定する新規性、進歩性又は産業上の利用可能性についての見解、それを裏付けるための文献及び説明

☐ 第VI欄 ある種の引用文献

☐ 第VII欄 国際出願の不備

☐ 第VIII欄 国際出願に対する意見

2. 今後の手続き

国際予備審査の請求がされた場合は、出願人がこの国際調査機関とは異なる国際予備審査機関を選択し、かつ、その国際予備審査機関がPCT規則66.1の2(b)の規定に基づいて国際調査機関の見解書を国際予備審査機関の見解書とみなさない旨を国際事務局に通知していた場合を除いて、この見解書は国際予備審査機関の最初の見解書とみなされる。

この見解書が上記のように国際予備審査機関の見解書とみなされる場合、様式PCT/ISA/220を送付した日から3月又は優先日から22月のうちいずれか遅く満了する期限が経過するまでに、出願人は国際予備審査機関に、適当な場合は補正書とともに、答弁書を提出することができる。

さらなる選択肢は、様式PCT/ISA/220を参照すること。

3. さらなる詳細は、様式PCT/ISA/220の備考を参照すること。

見解書を作成した日

08.12.2004

名称及びあて先

日本国特許庁 (ISA/JP)

郵便番号100-8915

東京都千代田区霞が関三丁目4番3号

特許庁審査官 (権限のある職員)

佐藤 聡史

5J

357.1

電話番号 03-3581-1101 内線 3535

様式PCT/ISA/237 (表紙) (2004年1月)

第 I 欄 見解の基礎

1. この見解書は、下記に示す場合を除くほか、国際出願の言語を基礎として作成された。

- ☐ この見解書は、_____語による翻訳文を基礎として作成した。
それは国際調査のために提出された PCT 規則 12.3 及び 23.1(b) にいう翻訳文の言語である。

2. この国際出願で開示されかつ請求の範囲に係る発明に不可欠なヌクレオチド又はアミノ酸配列に関して、以下に基づき見解書を作成した。

- a. タイプ ☐ 配列表
☐ 配列表に関連するテーブル
- b. フォーマット ☐ 書面
☐ コンピュータ読み取り可能な形式
- c. 提出時期 ☐ 出願時の国際出願に含まれる
☐ この国際出願と共にコンピュータ読み取り可能な形式により提出された
☐ 出願後に、調査のために、この国際調査機関に提出された

3. ☐ さらに、配列表又は配列表に関連するテーブルを提出した場合に、出願後に提出した配列若しくは追加して提出した配列が出願時に提出した配列と同一である旨、又は、出願時の開示を超える事項を含まない旨の陳述書の提出があった。

4. 補足意見：

第Ⅴ欄 新規性、進歩性又は産業上の利用可能性についてのPCT規則43の2.1(a)(i)に定める見解、それを裏付ける文献及び説明

1. 見解

新規性 (N)	請求の範囲	1-8	有 無
	請求の範囲		
進歩性 (IS)	請求の範囲	1-8	有 無
	請求の範囲		
産業上の利用可能性 (IA)	請求の範囲	1-8	有 無
	請求の範囲		

2. 文献及び説明

- 1) J P 2003-259430 A (三洋電機株式会社) 2003. 09. 12, 第26段落 (ファミリーなし)

該文献に記載された発明には、複数の移動端末装置が空間分割多重接続できる無線基地局におけるスロット割当方法であって、該移動端末装置が空間分割多重に適しているか否かを判定し、その判定結果が空間分割多重に適している場合には空間分割多重可能なスロットを割り当て、該判定結果が空間分割多重に適していない場合には空間分割多重が制限されるスロットを割り当てることが記載されている。

- 2) J P 2002-198933 A (三洋電機株式会社) 2002. 07. 12, 第18-19段落 (ファミリーなし)

該文献に記載された発明には、空間分割多重接続方式におけるチャネル割当方法であって、時間軸方向へのチャネル割当、及び、パス多重方向へのチャネル割当を行うことが記載されている。

- 3) J P 07-303090 A (エイ・ティ・アンド・ティ・コーポレーション) 1995. 11. 14, 第20段落, 第5, 10図 (ファミリーなし)

該文献に記載された発明において、第5図では周波数軸、時間軸で構成される二次元空間におけるユーザのアクセス速度に応じたタイムスロットの割当方法、及び、第10図では周波数軸、時間軸、符号空間軸で構成される三次元空間におけるユーザのアクセス速度に応じたタイムスロットの割当方法について記載されている。

本願の請求の範囲に係る発明は、必須チャネルを設けること、及び、該必須チャネルが空き状態のときに限り、該必須チャネルを含む無線チャネルを用いて無線パケットの送信を行う構成となっているが、上記文献に記載された発明はそのような構成を有していない点で相違する。

しかして、本願の請求の範囲に係る発明は、国際調査報告に引用されたいずれの文献にも上記の構成は記載されておらず、当業者にとって自明なものでもない。



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Date

26-04-2006

Reference 110 895 a/jme	Application No./Patent No. 04773142.7 - 2412 PCT/JP2004013483
Applicant/Proprietor NIPPON TELEGRAPH AND TELEPHONE CORPORATION	

Communication pursuant to Rules 109 and 110 EPC

(1) Amendment of application documents, especially the claims (R. 109 EPC)

The above mentioned international (Euro-PCT) application has entered the European phase, or can do so, once the necessary conditions are fulfilled.

Under Articles 28, 41 PCT, Rules 52, 78 PCT and Rule 86(2) to (4) EPC, the applicant may amend the application documents after receiving the international search report.

Whether or not he has already done so, he now has a further opportunity to file amended claims or other application documents within a non-extendable time limit of one month after notification of the present communication (R. 109 EPC).

The claims applicable on expiry of the above time limit, i.e. those filed on entry into the European phase or in response to the present communication, will form the basis for the calculation of any claims fee to be paid (see page 2) and for any supplementary search to be carried out under Article 157(2) EPC (R. 109 EPC).

--2/

**(2) Claims fees under Rule 110 EPC**

If the application documents on which the European grant procedure is to be based comprise more than ten claims, a claims fee shall be payable for the eleventh and each subsequent claim within the period provided for in Rule 107(1) EPC.

- ☒ Based on the application documents currently on file, all necessary claims fees have already been paid (or the documents do not comprise more than 10 claims).
- ☐ All necessary fees will be/have been debited automatically according to the automatic debit order.
- ☐ The claims fee due for the claims to were not paid within the above-mentioned period.

Any non-paid claims fee, either based on the current set of claims or on any amended claims to be filed pursuant to Rule 109 EPC (see page 1), may still be validly paid within a non-extendable period of grace of **one month** after notification of this communication.

If a payment is made for only some of the claims, it must be indicated for which claims it is intended. If a claims fee is not paid in due time, the claim concerned is deemed to be abandoned (R. 110(4) EPC).

If claims fees have already been paid, but on expiry of the above-mentioned time limit there is a new set of claims containing fewer fee-incurring claims than previously, the claims fees in excess of those due under Rule 110(2), 2nd sentence, EPC will be refunded (R. 110(3) EPC).

You are reminded that any supplementary search under Article 157(2) EPC will relate only to the last set of claims applicable on expiry of the above time limit AND will be confined to those fee-incurring claims for which fees have been paid in due time.

The fee for the eleventh and each subsequent claim is EUR 45,00.

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Date

10.05.06

Reference
110 895 a/jme

Application No./Patent No.
04773142.7 - 2412 PCT/JP2004013483

Applicant/Proprietor
NIPPON TELEGRAPH AND TELEPHONE CORPORATION

Notification of European publication number and information on the application of Article 67(3) EPC

You are hereby informed that the technical preparations for the publication of the translation of the above-mentioned international application as supplied to the EPO pursuant to Article 158(2) EPC have been completed.

The translation will be published on 07.06.06.

The publication number is: 1667480.

The publication in accordance with Article 158(3) EPC will be mentioned in European Patent Bulletin number 2006/23. (http://www.european-patent-office.org/e_pub/bulletin/index.htm).

The title of the invention in the three official languages of the European Patent Office is worded as follows:

FUNKPAKETKOMMUNIKATIONSVERFAHREN UND
FUNKPAKETKOMMUNIKATIONSVORRICHTUNG
RADIO PACKET COMMUNICATION METHOD AND RADIO PACKET COMMUNICATION
APPARATUS
PROCEDE DE COMMUNICATION DE PAQUETS RADIO ET APPAREIL DE COMMUNICATION DE
PAQUETS RADIO

The provisional protection under Article 67(1) and (2) EPC in the individual contracting states becomes effective only when the conditions referred to in Article 67(3) EPC have been fulfilled. For further information, also with respect to extension states, please refer to the EPO brochure "National Law relating to the EPC" (<http://www.european-patent-office/legal/national/index.htm>).

In all future communications to the EPO, please quote the application number as indicated above, i.e. including the final four figures (which identify the Directorate responsible for the subsequent procedure).



Date

Sheet 2

Application No. 04773142.7

REMARK:

For European patent applications with a date of publication after 01.04.05, no paper copies will be forwarded to the applicant any longer. The publication can be downloaded, free of charge, from the EPO publication server <https://publications.european-patent-office.org> or can be ordered from the Vienna sub-office upon payment of a fee (see Decision of the President of the EPO dated 22 December 2004, OJ 2005, 124 and Notice from the EPO dated 22 December 2004 concerning the introduction of electronic publication of European patent applications (A-documents) and European patent specifications (B-documents) as well as changes to Rules 51(4), 54 and 108 EPC, OJ EPO 2005, 126).

Receiving Section



Europäisches Patentamt München
13. Feb. 2011
Dir. 5.2.4

Eingegangen

31. Jan. 2011

epi Secretariat

31. 01. 11

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Europäisches Patentamt München
13. Feb. 2011
Dir. 5.2.4

26.01.2011

Meine Streichung in der Liste des Instituts der beim Europäischen Patentamt zugelassenen Vertreter

Sehr geehrte Damen und Herren,

ich hatte die mir kürzlich zugestellte Erklärung zur Wahl zum Rat des Institutes über meine freiberufliche oder anderweitige Tätigkeit dazu verwendet, meinen Austritt aus dem Institut bzw. die Streichung meines Namens in der Liste der zugelassenen Vertreter zu veranlassen - sicher keine gute Idee. Daher dieses getrennte Schreiben, in dem ich die Bitte wiederhole. Ich darf Sie also bitten, mich aus der Liste zu streichen, nachdem ich 17 Jahre lang brav meinen Beitrag bezahlt habe, um auch als Maler an Ausstellungen der epi-Mitglieder teilnehmen zu können, die dieses Institut, turnusmäßig zunächst im Hauptgebäude, in den letzten Jahren in dem epa-Gebäude in der Bayerstraße, veranstaltet hat. Ich selbst war der Initiator der epi-Ausstellungen und habe mich dadurch auch verpflichtet gefühlt, weiter in den vergangenen Jahren epi-Mitglied zu bleiben, obgleich ich keine berufliche Tätigkeit mehr ausgeübt habe. Ich weiß nicht ob die langjährige Sekretärin vom epi, Frau Moneger, noch bei Ihnen ist oder zwischenzeitlich, wie sie mir mitgeteilt hatte, ausgeschieden ist. Frau Moneger kennt meine Situation. Ich habe übrigens veranlasst, dass vor einigen Tagen der Mitgliedsbeitrag für das Institut für das laufende Jahr i. H. von 160,00 € überwiesen wurde.

Mit freundlichen kollegialen Grüßen

Klaus Hoffmann

Dr. Klaus Hoffmann

ID-Number	5580
Deleted from list	10-02-11
Remove reason	R. 154 (1)/2 nd alt. ■ R. 154 (2)
OJ	/
done on	by

Anlage

Erklärung zur Wahl des Instituts (zweckentfremdet)

IFREP

Hoffmann Erle => Ass

E. 31/1/11

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Date
23.02.11

Reference 110 895 a/jme	Application No./Patent No. 04773142.7 - 2412 / 1667480
Applicant/Proprietor NIPPON TELEGRAPH AND TELEPHONE CORPORATION	

Communication of amended entries concerning the representative (R. 143(1)(h) EPC)

As requested, for the above-mentioned European patent application / European patent the entries concerning the representative have been amended as follows:

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The amendment will be recorded in the Register of European Patents.

Receiving Section



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**SUPPLEMENTARY
EUROPEAN SEARCH REPORT**

Application Number
EP 04 77 3142

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
E	WO 2004/114561 A1 (NIPPON TELEGRAPH & TELEPHONE [JP]; NAGATA KENGO [JP]; KUMAGAI TOMOAKI) 29 December 2004 (2004-12-29) * abstract * & EP 1 635 492 A1 (NIPPON TELEGRAPH & TELEPHONE [JP]) 15 March 2006 (2006-03-15) * column 8, line 32 - column 9, line 37; figures 1,2 * -----	1,2,5,6	INV. H04W74/08 H04Q7/36 H04J15/00
			TECHNICAL FIELDS SEARCHED (IPC)
			H04W
The supplementary search report has been based on the last set of claims valid and available at the start of the search.			
Place of search Munich		Date of completion of the search 14 March 2011	Examiner Lastoria, Gianluca
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

2
EPO FORM 1503 03.82 (P04C04)

EP 04 77 3142

14-03-2011

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2004114561 A1	29-12-2004	CA 2513343 A1	29-12-2004
		EP 1635492 A1	15-03-2006
		JP 4045286 B2	13-02-2008
		KR 20050098933 A	12-10-2005
		US 2006209874 A1	21-09-2006

EPO FORM P0459

Ex. 1059 - Page 117



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Date
24.03.11

Reference 110 895 a/jme	Application No./Patent No. 04773142.7 - 2414 / 1667480 PCT/JP2004013483
Applicant/Proprietor NIPPON TELEGRAPH AND TELEPHONE CORPORATION	

Communication

The European Patent Office herewith transmits as an enclosure the supplementary European search report under Article 153(7) EPC for the above-mentioned European patent application.

If applicable, copies of the documents cited in the European search report are attached.

- ☒ 1 additional set(s) of copies of the documents cited in the European search report is (are) enclosed as well.

Refund of search fee

If applicable under Article 9 Rules relating to fees, a separate communication from the Receiving Section on the refund of the search fee will be sent later.





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12.04.11

Reference 110 895 a/jme	Application No./Patent No. 04773142.7 - 2414 / 1667480 PCT/JP2004013483
Applicant/Proprietor NIPPON TELEGRAPH AND TELEPHONE CORPORATION	

Proceeding further with the European patent application pursuant to Rule 70(2) EPC

A supplementary European search report has been drawn up concerning the above European patent application (publication number 1667480).

Since a request for examination has been filed (R. 70(1) EPC) and the examination fee has been paid (Art. 94(1) EPC) prior to the transmission of the supplementary European search report, you are hereby invited to indicate within

two months

of notification of this invitation whether you desire to proceed further with the European patent application.

If you do not indicate in due time that you desire to proceed further with the European patent application, it will be deemed to be withdrawn (R. 70(3) EPC).

If you wish you may comment on the supplementary European search report and amend, where appropriate, the description, claims and drawings (R. 70(2) EPC).

Receiving Section



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EPO Form 1224 12.07 (non-RTB) DMEX

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European Patent Office

80298 Munich

EPO - Munich
62

19. Mai 2011

Munich, May 19, 2011

Our Ref.: 110 895 a/agn
European Patent Application No. 04 773 142.7
NIPPON TELEGRAPH AND
TELEPHONE CORPORATION

In reply to the official communication dated April 12, 2011 we hereby confirm that the applicants wish to proceed further with this application.



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EUROPEAN PATENT ATTORNEY

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[7] regulated by IPREG

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Michelle Baccelli, Dott. in Ing.
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Substantive Examiner
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Application No. 04 773 142.7 - 2414	Ref. 110 895 a/me	Date 18.07.2011
Applicant NIPPON TELEGRAPH AND TELEPHONE CORPORATION		

Communication pursuant to Article 94(3) EPC

The examination of the above-identified application has revealed that it does not meet the requirements of the European Patent Convention for the reasons enclosed herewith. If the deficiencies indicated are not rectified the application may be refused pursuant to Article 97(2) EPC.

You are invited to file your observations and insofar as the deficiencies are such as to be rectifiable, to correct the indicated deficiencies within a period

of 4 months

from the notification of this communication, this period being computed in accordance with Rules 126(2) and 131(2) and (4) EPC. One set of amendments to the description, claims and drawings is to be filed within the said period on separate sheets (R. 50(1) EPC).

If filing amendments, you must identify them and indicate the basis for them in the application as filed. Failure to meet either requirement may lead to a communication from the Examining Division requesting that you correct this deficiency (R. 137(4) EPC).

Failure to comply with this invitation in due time will result in the application being deemed to be withdrawn (Art. 94(4) EPC).

The notification of this communication starts the 24-month period according to Rule 36(1)(a) EPC for filing a voluntary divisional application divided from this application or from any sequential application. For further information see Guidelines for Examination, A-IV, 1.1.1.2 and 1.1.1.4.



Lastoria, Gianluca
Primary Examiner
For the Examining Division

Enclosure(s): 5 page/s reasons (Form 2906)

Datum
Date 18.07.2011
Date

Blatt
Sheet 1
Feuille

Anmelde-Nr:
Application No: 04 773 142.7
Demande n°:

The examination is being carried out on the **following application documents**

Description, Pages

1-20 filed with entry into the regional phase before the EPO

Claims, Numbers

1-8 filed with entry into the regional phase before the EPO

Drawings, Sheets

1/12-12/12 filed with entry into the regional phase before the EPO

1 Reference is made to the following document; the numbering will be adhered to in the rest of the procedure.

D1 WO 2004/114561 A1 (NIPPON TELEGRAPH & TELEPHONE [JP]; NAGATA KENGO [JP]; KUMAGAI TOMOAKI) 29 December 2004 (2004-12-29); & EP 1 635 492 A1 (NIPPON TELEGRAPH & TELEPHONE [JP]) 15 March 2006 (2006-03-15)

2 The claims do, for the following reasons, **not** meet the requirements of Article 84 EPC in respect of clarity:

2.1 The various definitions of the method given in independent **claims 1 and 2** as well as the various definitions of the apparatus given in independent **claims 5 and 6** are such that the claims as a whole are **not concise**, contrary to Article 84 EPC. Moreover, lack of clarity of the claims as a whole arises, since the plurality of independent claims makes it difficult, if not impossible, to determine the matter for which protection is sought, and places an undue burden on others seeking to establish the extent of the protection.

Under Article 84 in combination with Rule 43(2) EPC an application may contain more than one independent claim in a particular category only if the claimed subject-matter falls within one or more of the exceptional situations set out in paragraphs (a), (b) or (c) of Rule 43(2) EPC.

In the present case, the above cited independent claims do **not** meet this requirement, since **claims 2 and 6** are basically a rewording of, respectively, **claims 1 and 5**.

The applicant is requested to file an amended set of claims which complies with Rule 43(2) EPC. Failure to do so, or to submit convincing arguments as to why the current set of claims does in fact comply with these provisions, will lead to refusal of the application under Article 97(2) EPC.

- 2.2 It is clear from the description that the feature of having packets **of the same lengths** transmitted simultaneously is **essential** for preventing reception problems caused by power leakage (see in particular page 4, lines 5 to 13 of the description).

While **independent claims 1, 2, 5 and 6** contain the feature of simultaneous transmission, they do **not** contain the feature of sending packets of the same length. Therefore, claims 1, 2, 5 and 6 do **not** meet the requirements of Article 84 EPC taken in combination with Rules 43(1) and (3) EPC that any independent claim must contain **all** the technical features essential to the definition of the invention.

To overcome this objection, the wording of **claims 1, 2, 5 and 6** must be revised by including the above essential feature into said claims.

- 2.3 The sentence "*by using multiple wireless channels determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, or the multiple wireless channels and the MIMO*" used in **claims 1, 2, 5 and 6** is not clear, Article 84 EPC. While the first part of the sentence can be understood, it is not clear how the sentence concatenate. It is furthermore not clear how a channel could be determined to be MIMO, being MIMO a technology,

rather than a channel. For the examination of the claims, the sentence will be interpreted as "*by using multiple wireless channels determined to be idle by carrier sense*".

- 2.4 Furthermore, the feature "...*setting a **mandatory** channel...*" used in **claims 1, 2, 5 and 6** is **vague** and unclear and leaves the reader in doubt as to the meaning of the technical feature to which it refers, thereby rendering the definition of the subject-matter of said claim unclear (Article 84 EPC).

The wording of the claims should be revised by explaining the meaning of "**mandatory**" (see in particular page 5, line 25 to page 6, line 2 of the description).

- 2.5 The features "*wireless channel/wireless channels*" used in **claims 1, 2, 5 and 6** are interpreted as an alternative. If only one channel is present, than said only channel is automatically defined as "**mandatory**".

- 3 In so far as the present text can be understood, the present application does not meet the requirements of Articles 52(1) and 54(3) EPC 1973 because the subject-matter of the claims is not new.

- 3.1 The PCT application WO 2004/114561 A1 (document **D1**) published on the 29-12-2004 (WO 2004/114561 A1) claims the priority date of 18-06-2003. It has been supplied to the European Patent Office in one of its official languages and the national fee provided for in Article 22, paragraph 1 or Article 39, paragraph 1 of the Patent Cooperation Treaty has been paid. The requirements of Article 158(2) EPC are thus fulfilled.

Its content as filed is therefore considered as comprised in the state of the art relevant to the question of novelty, pursuant to Article 54(3) and (4) EPC.

- 3.2 Document **D1** (*the passages below refers to the content of document **EP 1 635 492 A1**, which is a family member of WO 2004/114561 A1*) discloses, according to all the features of **claim 1** a wireless packet communication method for transmitting a plurality of wireless packets simultaneously by using multiple

wireless channels determined to be idle by carrier sense (*see in particular column 8, lines 40 to 43 and figure 2 for the simultaneous transmission of the packets*), the method characterized by comprising:

- setting a mandatory channel that is always used for transmission (*see point 2.4 above and column 8, lines 50 to 53*); and
- transmitting the wireless packets by using a wireless channel/wireless channels that includes/include the mandatory channel, only when the mandatory channel is idle (*see again column 8, lines 50 to 53; see also paragraph [0042]*).

The subject-matter of claim 1 is therefore **not** new, Article 54(3) EPC 1973, insofar as the same Contracting States are designated, and, thus, claim 1 is **not** allowable, Article 52(1) EPC.

- 3.3 The same reasoning can be applied also to **independent claims 2, 5 and 6**, since said claims are based on the same essential feature combination as **claim 1** (*see also point 2.1 above*).

The subject-matter of claims 2, 5 and 6 is therefore **not** new, Article 54(3) EPC 1973, insofar as the same Contracting States are designated, and, thus, claims 2, 5 and 6 **not** allowable, Article 52(1) EPC.

- 4 Should the Applicant intend to file a new set of claims, the following requirements should also be taken into consideration:

- 4.1 To meet the requirements of Rule 43(1) EPC any new independent claim should be properly cast in the **two-part form**, when such a form does not turn out to be too artificial and inappropriate, with those features which in combination are part of the closest prior art being placed in the preamble.

- 4.2 **Reference signs** in parentheses should be inserted in the claims to increase their intelligibility, Rule 43(7) EPC. This applies to both the preamble and characterising portion (*see the Guidelines, C-III, 4.19*).

Datum
Date 18.07.2011
Date

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Sheet 5
Feuille

Anmelde-Nr:
Application No: 04 773 142.7
Demande n°:

4.3 The opening part of the description should be modified to bring it into agreement with any new independent claim, Rule 42(1)(c) EPC.

5 Care should be taken during revision not to add subject-matter which extends beyond the content of the application as originally filed, Article 123(2) EPC.

In his letter of reply, the Applicant should indicate the parts of the originally filed application serving as a basis for subject-matter newly introduced into the claims.

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30. Sep. 2011

Munich, September 30, 2011

Our Ref.: 110 895 q4/q21/clu
European Patent Application No. 04 773 142.7-2414
NIPPON TELEGRAPH AND TELEPHONE CORPORATION

In response to the communication pursuant to Article 94(3)
EPC dated July 18, 2011

I.

New Documents

1. We herewith submit new claims 1 to 8 for the further procedure. The new claims are respectively based on the claims which were filed with the entry into the regional phase before the EPO.

Independent claims 1, 2, 5, and 6 have been amended by stating that the plurality of wireless packets have "equal or equivalent packet time lengths" as for example disclosed on page 4, line 7. In view of these amendments, it is respectfully submitted that the new independent claims contain all technical features essential to the definition of the invention.

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2. Furthermore, we submit new description pages 5, 5a, 6, and 7 which acknowledge the prior art and have been adapted to the new claims.

II.

The present invention

The present invention relates to a wireless packet communication method and a wireless packet communication apparatus for simultaneously transmitting a plurality of wireless packets by using multiple wireless channels or Multiple Input Multiple Output (MIMO).

It is an object of the present invention to avoid leakage power from affecting an adjacent channel so as to improve throughput by simultaneous transmission.

This object is accomplished by the communication apparatus of claims 1 and 2 and the communication apparatus of claims 5 and 6.

Especially, in claims 1 and 5 a mandatory channel is set that is always used for a transmission and wireless packages are transmitted by using a wireless channel or wireless channels that includes/include the mandatory channel, only when the mandatory channel is idle.

As an alternative solution, claims 2 and 6 describe that a mandatory channel is only set for certain stations. More specifically, an STA A is distinguished from an STA B, the STA A for which a mandatory channel is set, the STA B for which no mandatory channel is set, the mandatory channel being always used for transmission. When wireless packets are addressed to said STA A, the wireless packets are transmitted to said STA A by using a wireless channel/wireless channels that includes/include the mandatory channel, only when the mandatory channel is idle. When wireless packets are addressed to said STA B, the wireless packets are transmitted to said STA B by using idle wireless channel(s).

III.

Requirements of Article 84 EPC

1. In view of the conciseness objection, it is respectfully submitted that independent claims 1 and 2 each are alternative solutions to the particular problem of avoiding leakage power as detailed above. Furthermore, it is inappropriate to rewrite claim 2

depending on claim 1 as this would considerably impair the intelligibility of the claims. Especially, claim 2 is not a rewording of claim 1 as claim 1 does not distinguish between two stations of which one uses a mandatory channel and the other does not. This applies *mutatis mutandis* to independent claims 5 and 6.

Therefore, it is respectfully submitted that the claims are concise pursuant to Rule 43(2) (c) EPC.

2. It is respectfully submitted that the first paragraph of the independent claims is clear. Especially, three ways of how the wireless packets can be transmitted simultaneously are described. These are:
 - The wireless packets can be transmitted by using multiple wireless channels which are determined to be idle by carrier sense, as for example described in Figure 2 and the description of the first embodiment.
 - The wireless packets can be transmitted by using a single wireless channel, which is determined to be idle, and MIMO, as for example described in the third and fourth embodiment.
 - The wireless packets can be transmitted by using the multiple wireless channels and the MIMO.
3. Moreover, it is respectfully submitted that the feature "setting a mandatory channel" is clear. More specifically, the independent claims already define the mandatory channel by stating that it is a channel "*that is always used for transmission*". Defining a mandatory channel in terms of priorities, as has been suggested in the above-referenced communication, would only add unnecessary features to the independent claims, thereby rendering the claims unclear.
4. The feature "wireless channel/wireless channels" used in the independent claims should not be considered unclear. The fact that, in case of only one channel, this channel is defined as the mandatory channel does not lead to any inconsistencies. Therefore, this feature does not render the independent claims unclear.

5. In summary, it is respectfully submitted that the new claim set meets the requirements of Article 84 EPC.

IV.

Prior Art and Patentability

1. Prior art document D1 relates to a radio packet communication method and radio packet communication apparatus.

In D1 data packets are transmitted between two stations capable of using plural radio channels and MIMO together, by using idle channels and MIMO. When at least one idle channel has been detected, plural data packets are generated in the same number as the sum of MIMO numbers of the respective idle channels, in which the data packets are generated from one or plural data frames, and plural data packets having the same packet time length are transmitted simultaneously between the two stations by using the idle channels and MIMO.

2. In contrast thereto, independent claim 1 discloses usage of a mandatory channel, wherein wireless packets are always transmitted via wireless channels including the mandatory channel and when the mandatory channel is busy, transmission is not performed even if there is another wireless channel. Especially, the mandatory channel is set *before* idle wireless channels are searched (see, for example, page 9, lines 13 to 17).

Prior art document D1 does only teach to first search for idle radio channels (e.g. S001 in Fig. 1) and to distribute the data packets to be transmitted using the idle radio channels (S007, S009, S010 in Fig. 1). Nothing in D1 corresponds to the mandatory channel according to independent claim 1.

3. Therefore, the subject-matter of independent claims 1, 2, 5, and 6 are novel in view of prior art document D1.

V.
Requests

1. It is requested to grant a patent on the basis of the new claims, new description pages and the remaining documents on file.
2. If rejection of the present application is considered, it is requested to schedule

oral proceedings.

3. The Applicant requests to correct the title of the present application to "WIRELESS PACKET COMMUNICATION METHOD AND WIRELESS PACKET COMMUNICATION APPARATUS".



Dr. Lorenz von Kurowski
European Patent Attorney
Association No. 151

Encl.:

- new claims 1 to 8, fair and mark-up copy
- new description pages 5, 5a, 6, and 7, fair and mark-up copy
- PACE request

channel #3 because of leakage power from the wireless channels #1 and #2. In other words, the STA in transmission cannot receive a wireless packet transmitted on a wireless channel that is adjacent to the wireless channel being in transmission. This problem occurs not only in case of simultaneous transmission using multiple wireless channels but also in a conventional case where wireless packets are transmitted by using one wireless channel and an adjacent wireless channel that is affected by leakage power receives the wireless packets.

WO 2004/114561 A1 relates to a radio packet communication method and radio packet communication apparatus. Data packets are transmitted between two stations capable of using plural radio channels and MIMO together, by using idle channels and MIMO. When at least one idle channel has been detected, plural data packets are generated in the same number as the sum of MIMO numbers of the respective idle channels, in which the data packets are generated from one or plural data frames, and plural data packets having the same packet time length are transmitted simultaneously between the two stations by using the idle channels and MIMO.

It is an object of the present invention to avoid leakage power from affecting an adjacent channel so as to improve throughput by simultaneous transmission.

This object is accomplished by the independent claims. Advantageous embodiments are described in the dependent claims.

DISCLOSURE OF THE INVENTION

A first aspect of the invention provides a wireless packet communication method for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, or the multiple wireless channels and the MIMO. The wireless packet communication method includes setting a mandatory channel that is always used for

transmission and transmitting the wireless packets by using a wireless channel or wireless channels that includes/include the mandatory channel, only when the mandatory channel is idle.

In other words, for transmitting a plurality of wireless packets simultaneously, transmission is performed by using the wireless channel(s) including the mandatory channel. Transmission is not performed when the mandatory channel is not idle. Moreover, wireless packets are always transmitted via wireless channels including the mandatory channel, and when the mandatory channel is busy, transmission is not performed even if there is another wireless channel. In other words, the mandatory channel can be regarded as a wireless

channel having the highest priority among wireless channels that have a plurality of priorities.

A second aspect of the invention provides a wireless packet communication method for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, or the multiple wireless channels and the MIMO. The wireless packet communication method includes distinguishing an STA A, for which a mandatory channel always used for transmission is set, from an STA B for which no mandatory channel is set. Wireless packets addressed to the STA A are transmitted by using the wireless channel(s) including the mandatory channel, only when the mandatory channel is idle. Wireless packets addressed to the STA B are transmitted by using the idle wireless channel(s).

The STA A has a similar function as that of the invention of claim 1. The STA B for which no mandatory channel is set, is made transmittable even when the mandatory channel is busy.

Another aspect of the invention is such that the plurality of wireless packets transmitted simultaneously are set to have the same or equivalent packet time length that corresponds to a packet size or a transmission time.

Another aspect of the invention is such that wireless packets are simultaneously transmitted selectively using the multiple wireless channels or MIMO in accordance with the number of pieces of data or the number of MIMOs that depends on a channel condition.

Another aspect of the invention provides a wireless packet communication apparatus for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels determined to be idle by carrier sense, a wireless channel determined to be idle and MIMO, or the multiple wireless channels and the MIMO. The wireless packet

communication apparatus includes a unit setting a mandatory channel that is always used for transmission and transmitting the wireless packets by using the multiple wireless channels or the wireless channel that include/includes the mandatory channel, only when the mandatory channel is idle.

Another aspect of the invention provides a wireless packet communication apparatus for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, or the multiple wireless channels and the MIMO. The wireless packet communication apparatus includes a unit distinguishing an STA A, for which a mandatory channel that is always used for transmission is set, from an STA B for which no mandatory channel is set, and determining destinations of the wireless packets. In case of wireless packets addressed to the STA A, the unit transmits the wireless packets by using the multiple wireless channels or the wireless channel that include/includes the mandatory channel, only when the mandatory channel is idle. In case of wireless packets addressed to the STA B, the unit transmits the wireless packets by using idle wireless channel or channels.

Another aspect of the invention is such that the plurality of wireless packets transmitted simultaneously are set to have the same or equivalent packet time length that corresponds to a packet size or a transmission time.

Another aspect of the invention is such that wireless packets are simultaneously transmitted selectively using the multiple wireless channels or MIMO in accordance with the number of pieces of data or the number of MIMOs that depends on a channel condition.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a flowchart according to a first embodiment of the present invention.

Claims

1. A wireless packet communication method for transmitting a plurality of wireless packets having equal or equivalent packet time lengths simultaneously by using multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, or the multiple wireless (Ch#1, Ch#2) channels and the MIMO, the method characterized by comprising:

setting a mandatory channel that is always used for transmission; and

transmitting the wireless packets by using a wireless channel/wireless channels (Ch#1, Ch#2) that includes/include the mandatory channel, only when the mandatory channel is idle.

2. A wireless packet communication method for transmitting a plurality of wireless packets having equal or equivalent packet time lengths simultaneously by using multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, or the multiple wireless channels (Ch#1, Ch#2) and the MIMO, the method characterized by comprising:

distinguishing an STA A from an STA B, the STA A for which a mandatory channel is set, the STA B for which no mandatory channel is set, the mandatory channel being always used for transmission; and

when wireless packets are addressed to said STA A,
transmitting the wireless packets to said STA A by using
a wireless channel/wireless channels (Ch#1, Ch#2) that
includes/include the mandatory channel, only when the
mandatory channel is idle; and

when wireless packets are addressed to said STA B,
transmitting the wireless packets to said STA B by using
idle wireless channel(s) (Ch#1, Ch#2).

3. The wireless packet communication method according to
claim 1 or 2,

characterized in that

the packet time length corresponds to a packet size or a
transmission time.

4. The wireless packet communication method according to
claim 1 or 2,

characterized by further comprising

simultaneously transmitting wireless packets selectively
using the multiple wireless channels (Ch#1, Ch#2) or the
MIMO in accordance with a number of pieces of data or a
number of MIMOs that depends on a channel condition.

5. A wireless packet communication apparatus for
transmitting a plurality of wireless packets having
equal or equivalent packet time lengths simultaneously
by using multiple wireless channels (Ch#1, Ch#2)
determined to be idle by carrier sense, a single
wireless channel determined to be idle and MIMO, or the
multiple wireless channels (Ch#1, Ch#2) and the MIMO,
the apparatus characterized by comprising

a unit setting a mandatory channel that is always used for transmission, and transmitting the wireless packets only when the mandatory channel is idle by using a wireless channel or wireless channels (Ch#1, Ch#2) that includes/include the mandatory channel.

6. A wireless packet communication apparatus for transmitting a plurality of wireless packets having equal or equivalent packet time lengths simultaneously by using multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, or the multiple wireless channels (Ch#1, Ch#2) and the MIMO, the apparatus characterized by comprising

a unit distinguishing an STA A from an STA B and determining destinations of the wireless packets so as to transmit wireless packets addressed to said STA A only when said mandatory channel is idle by using a wireless channel or wireless channels (Ch#1, Ch#2) that includes/include a mandatory channel, and to transmit wireless packets addressed to said STA B by using idle wireless channel or channels (Ch#1, Ch#2), the mandatory channel being always used for transmission, the STA A for which the mandatory channel is set, the STA B for which no mandatory channel is set.

7. The wireless packet communication apparatus according to claim 5 or 6,

characterized in that

the packet time length corresponds to a packet size or a transmission time.

8. The wireless packet communication apparatus according to claim 5 or 6, characterized by further comprising:

a unit simultaneously transmitting wireless packets selectively using the multiple wireless channels (Ch#1, Ch#2) or the MIMO in accordance with a number of pieces of data or a number of MIMOs that depends on a channel condition.

channel #3 because of leakage power from the wireless channels #1 and #2. In other words, the STA in transmission cannot receive a wireless packet transmitted on a wireless channel that is adjacent to the wireless channel being in transmission. This problem occurs not only in case of simultaneous transmission using multiple wireless channels but also in a conventional case where wireless packets are transmitted by using one wireless channel and an adjacent wireless channel that is affected by leakage power receives the wireless packets.

WO 2004/114561 A1 relates to a radio packet communication method and radio packet communication apparatus. Data packets are transmitted between two stations capable of using plural radio channels and MIMO together, by using idle channels and MIMO. When at least one idle channel has been detected, plural data packets are generated in the same number as the sum of MIMO numbers of the respective idle channels, in which the data packets are generated from one or plural data frames, and plural data packets having the same packet time length are transmitted simultaneously between the two stations by using the idle channels and MIMO

It is an object of the present invention to avoid leakage power from affecting an adjacent channel so as to improve throughput by simultaneous transmission.

This object is accomplished by the independent claims. Advantageous embodiments are described in the dependent claims.

DISCLOSURE OF THE INVENTION

~~The invention of claim 1A~~ first aspect of the invention provides a wireless packet communication method for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, or the multiple wireless channels and the MIMO. The wireless packet communication method includes setting a mandatory channel that is always used for

transmission and transmitting the wireless packets by using a wireless channel or wireless channels that includes/include the mandatory channel, only when the mandatory channel is idle.

In other words, for transmitting a plurality of wireless packets simultaneously, transmission is performed by using the wireless channel(s) including the mandatory channel. Transmission is not performed when the mandatory channel is not idle. Moreover, wireless packets are always transmitted via wireless channels including the mandatory channel, and when the mandatory channel is busy, transmission is not performed even if there is another wireless channel. In other words, the mandatory channel can be regarded as a wireless

channel having the highest priority among wireless channels that have a plurality of priorities.

~~The invention of claim 2A~~ second aspect of the invention provides a wireless packet communication method for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, or the multiple wireless channels and the MIMO. The wireless packet communication method includes distinguishing an STA A, for which a mandatory channel always used for transmission is set, from an STA B for which no mandatory channel is set. Wireless packets addressed to the STA A are transmitted by using the wireless channel(s) including the mandatory channel, only when the mandatory channel is idle. Wireless packets addressed to the STA B are transmitted by using the idle wireless channel(s).

The STA A has a similar function as that of the invention of claim 1. The STA B for which no mandatory channel is set, is made transmittable even when the mandatory channel is busy.

~~Another aspect of the invention of claim 3~~ is such that the plurality of wireless packets transmitted simultaneously are set to have the same or equivalent packet time length that corresponds to a packet size or a transmission time ~~in the invention of claim 1 or 2~~.

~~Another aspect of the invention of claim 4~~ is such that ~~in the invention recited in claim 1 or 2~~, wireless packets are simultaneously transmitted selectively using the multiple wireless channels or MIMO in accordance with the number of pieces of data or the number of MIMOs that depends on a channel condition.

~~Another aspect of the invention of claim 5~~ provides a wireless packet communication apparatus for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels determined to be idle by carrier sense, a wireless channel determined to be idle and MIMO, or the multiple wireless channels and the MIMO. The wireless packet

communication apparatus includes a unit setting a mandatory channel that is always used for transmission and transmitting the wireless packets by using the multiple wireless channels or the wireless channel that include/includes the mandatory channel, only when the mandatory channel is idle.

Another aspect of ~~T~~the invention ~~of claim 6~~ provides a wireless packet communication apparatus for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, or the multiple wireless channels and the MIMO. The wireless packet communication apparatus includes a unit distinguishing an STA A, for which a mandatory channel that is always used for transmission is set, from an STA B for which no mandatory channel is set, and determining destinations of the wireless packets. In case of wireless packets addressed to the STA A, the unit transmits the wireless packets by using the multiple wireless channels or the wireless channel that include/includes the mandatory channel, only when the mandatory channel is idle. In case of wireless packets addressed to the STA B, the unit transmits the wireless packets by using idle wireless channel or channels.

Another aspect of ~~T~~the invention ~~of claim 7~~ is such that ~~in the invention recited in claim 5 or 6,~~ the plurality of wireless packets transmitted simultaneously are set to have the same or equivalent packet time length that corresponds to a packet size or a transmission time.

Another aspect of ~~T~~the invention ~~of claim 8~~ is such that ~~in the invention recited in claim 5 or 6,~~ wireless packets are simultaneously transmitted selectively using the multiple wireless channels or MIMO in accordance with the number of pieces of data or the number of MIMOs that depends on a channel condition.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a flowchart according to a first embodiment of the present invention.

Claims

1. A wireless packet communication method for transmitting a plurality of wireless packets having equal or equivalent packet time lengths simultaneously by using multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, or the multiple wireless (Ch#1, Ch#2) channels and the MIMO, the method characterized by comprising:

setting a mandatory channel that is always used for transmission; and

transmitting the wireless packets by using a wireless channel/wireless channels (Ch#1, Ch#2) that includes/include the mandatory channel, only when the mandatory channel is idle.

2. A wireless packet communication method for transmitting a plurality of wireless packets having equal or equivalent packet time lengths simultaneously by using multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, or the multiple wireless channels (Ch#1, Ch#2) and the MIMO, the method characterized by comprising:

distinguishing an STA A from an STA B, the STA A for which a mandatory channel is set, the STA B for which no mandatory channel is set, the mandatory channel being always used for transmission; and

when wireless packets are addressed to said STA A,
transmitting the wireless packets to said STA A by using
a wireless channel/wireless channels (Ch#1, Ch#2) that
includes/include the mandatory channel, only when the
mandatory channel is idle; and

when wireless packets are addressed to said STA B,
transmitting the wireless packets to said STA B by using
idle wireless channel(s) (Ch#1, Ch#2).

3. The wireless packet communication method according to
claim 1 or 2,

characterized in that

~~the plurality of wireless packets transmitted
simultaneously are set to have a same or equivalent
packet time length that corresponds to a packet size or
a transmission time.~~

4. The wireless packet communication method according to
claim 1 or 2,

characterized by further comprising

simultaneously transmitting wireless packets selectively
using the multiple wireless channels (Ch#1, Ch#2) or the
MIMO in accordance with a number of pieces of data or a
number of MIMOs that depends on a channel condition.

5. A wireless packet communication apparatus for
transmitting a plurality of wireless packets having
equal or equivalent packet time lengths simultaneously
by using multiple wireless channels (Ch#1, Ch#2)
determined to be idle by carrier sense, a single
wireless channel determined to be idle and MIMO, or the

multiple wireless channels (Ch#1, Ch#2) and the MIMO,
the apparatus characterized by comprising

a unit setting a mandatory channel that is always used
for transmission, and transmitting the wireless packets
only when the mandatory channel is idle by using a
wireless channel or wireless channels (Ch#1, Ch#2) that
includes/include the mandatory channel.

6. A wireless packet communication apparatus for
transmitting a plurality of wireless packets having
equal or equivalent packet time lengths simultaneously
by using multiple wireless channels (Ch#1, Ch#2)
determined to be idle by carrier sense, a single
wireless channel determined to be idle and MIMO, or the
multiple wireless channels (Ch#1, Ch#2) and the MIMO,
the apparatus characterized by comprising

a unit distinguishing an STA A from an STA B and
determining destinations of the wireless packets so as
to transmit wireless packets addressed to said STA A
only when said mandatory channel is idle by using a
wireless channel or wireless channels (Ch#1, Ch#2) that
includes/include a mandatory channel, and to transmit
wireless packets addressed to said STA B by using idle
wireless channel or channels (Ch#1, Ch#2), the mandatory
channel being always used for transmission, the STA A
for which the mandatory channel is set, the STA B for
which no mandatory channel is set.

7. The wireless packet communication apparatus according to
claim 5 or 6,

characterized in that

~~the plurality of wireless packets transmitted
simultaneously are set to have a same or equivalent~~

| packet time length ~~that~~ corresponds to a packet size or
a transmission time.

8. The wireless packet communication apparatus according to
claim 5 or 6, characterized by further comprising:

| a unit simultaneously transmitting wireless packets
selectively using the multiple wireless channels (Ch#1,
Ch#2) or the MIMO in accordance with a number of pieces
of data or a number of MIMOs that depends on a channel
condition.



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Application No. 04 773 142.7 - 2414	Ref. 110 895 a/jme	Date 10.04.2012
Applicant NIPPON TELEGRAPH AND TELEPHONE CORPORATION		

Communication pursuant to Article 94(3) EPC

The examination of the above-identified application has revealed that it does not meet the requirements of the European Patent Convention for the reasons enclosed herewith. If the deficiencies indicated are not rectified the application may be refused pursuant to Article 97(2) EPC.

You are invited to file your observations and insofar as the deficiencies are such as to be rectifiable, to correct the indicated deficiencies within a period

of 4 months

from the notification of this communication, this period being computed in accordance with Rules 126(2) and 131(2) and (4) EPC. One set of amendments to the description, claims and drawings is to be filed within the said period on separate sheets (R. 50(1) EPC).

If filing amendments, you must identify them and indicate the basis for them in the application as filed. Failure to meet either requirement may lead to a communication from the Examining Division requesting that you correct this deficiency (R. 137(4) EPC).

Failure to comply with this invitation in due time will result in the application being deemed to be withdrawn (Art. 94(4) EPC).



Lastoria, Gianluca
Primary Examiner
For the Examining Division

Enclosure(s): 3 page/s reasons (Form 2906)

Datum
Date 10.04.2012
Date

Blatt
Sheet 1
Feuille

Anmelde-Nr:
Application No: 04 773 142.7
Demande n°:

The examination is being carried out on the **following application documents**

Description, Pages

1-20 filed with entry into the regional phase before the EPO

Claims, Numbers

1-8 received on 30-09-2011 with letter of 30-09-2011

Drawings, Sheets

1/12-12/12 filed with entry into the regional phase before the EPO

- 1 The arguments of the Applicant brought forward in the letter dated 30.09.2011 have been carefully considered. However, the amended claims do not permit the examining division to change its opinion, as set out in the first communication.
- 2 The claims do, for the following reasons, **not** meet the requirements of Article 84 EPC in respect of clarity:
 - 2.1 While the explanation given by the Applicant on page 3, point 2 of the letter of reply dated 30.09.2011 is clear, the sentence "*by using multiple wireless channels determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, or the multiple wireless channels and the MIMO*" used in **claims 1, 2, 5 and 6** is **still** considered as not clear, Article 84 EPC for the reasoning explained in point 2.3 of the previous communication.
 - 2.2 Furthermore, the feature "*...setting a **mandatory** channel...*" used in **claims 1, 2, 5 and 6** is considered to be **vague** and unclear and leaves the reader in doubt as to the meaning of the technical feature to which it refers, thereby rendering the definition of the subject-matter of said claim unclear (Article 84

EPC). Interpreting the feature in its broader meaning, a channel is considered to be **mandatory** when it is **needed** for sending information between a sender and a receiver (no information could be sent if no channel is present).

2.3 Finally the feature "...having equal or **equivalent** packet time lengths..." used in **claims 1, 2, 5 and 6** is considered to be **vague** and unclear and leaves the reader in doubt as to the meaning of the technical feature to which it refers, thereby rendering the definition of the subject-matter of said claim unclear (Article 84 EPC). Two lengths are either equal or different, when measured with the same SI unit.

3 In so far as the present text can be understood, the present application does not meet the requirements of Articles 52(1) and 54(3) EPC 1973 because the subject-matter of the claims is not new.

3.1 Document **D1** (*the passages below refers to the content of document **EP 1 635 492 A1**, which is a family member of WO 2004/114561 A1*) discloses, according to all the features of **claim 1** a wireless packet communication method for transmitting a plurality of wireless packets having equal packet time length (*see e.g. column 3, lines 24 to 27*) simultaneously by using multiple wireless channels determined to be idle by carrier sense (*see in particular column 8, lines 40 to 43 and figure 2 for the simultaneous transmission of the packets*), the method characterized by comprising:

- setting a mandatory channel that is always used for transmission (*see column 8, lines 50 to 53; at this point it should be noted that at least a channel is **mandatory** for sending packets between two stations, see also point 2.2 above*); and
- transmitting the wireless packets by using a wireless channel/wireless channels that includes/include the mandatory channel, only when the mandatory channel is idle (*see again column 8, lines 50 to 53; see also paragraph [0042]*).

The subject-matter of claim 1 is therefore **not** new, Article 54(3) EPC 1973, insofar as the same Contracting States are designated, and, thus, claim 1 is **not** allowable, Article 52(1) EPC.

- 3.2 The same reasoning can be applied also to **independent claim 5**, since said claim is based on the same essential feature combination as **claim 1**.

The subject-matter of claim 5 is therefore **not** new, Article 54(3) EPC 1973, insofar as the same Contracting States are designated, and, thus, claim 5 is **not** allowable, Article 52(1) EPC.

- 4 The Applicant should ensure that the documents filed in response to this second action meet all the requirements of the Convention otherwise the Applicant will be invited to attend Oral Proceedings as requested by the applicant in his last letter dated 30.09.2011.

04773142.7 - 2414 / 1667480

09.05.12

Client Database System (CDS) - clean up.

Application Nr.: 04773142.7

Following clean up action in CDS the entries concerning the **Representative for the applicant (association)** have been amended and are now as follows:

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Where appropriate, the Register of European Patents will be updated to show the amended details.

For questions please contact the Client Data Registration department of the European Patent Office in Munich, telephone +49 (0)89 2399 2780.

04773142.7 - 2414 / 1667480

09.05.12

Client Database System (CDS) - clean up.

Application Nr.: 04773142.7

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21. Juni 2012

Munich, June 21, 2012

Our Ref.: 110 895 q4/q21/clu
European Patent Application No. 04 773 142.7-2414
NIPPON TELEGRAPH AND TELEPHONE CORPORATION

In response to the communication pursuant to Article 94(3)
EPC dated April 10, 2012

I.

New Documents

We herewith submit new claims 1 to 8 for the further procedure. The new claims are based on the previous claims submitted on September 30, 2011. More specifically, new claims 1 to 8 are based on previous claims 1 to 8, respectively. Furthermore, independent claims 1, 2, 5, and 6 have been amended as follows.

The new independent claims recite three ways of how the wireless packets can be transmitted simultaneously. Namely, they can be transmitted by using "at least one of multiple wireless channels determined to be idle by carrier sense", "a single wireless channel determined to be idle and MIMO", and "the wireless channels and the MIMO". With this amendment, the clarity objection raised in

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section 2.1 of the above-referenced communication should be overcome.

Furthermore, the mandatory channel in the independent claims has been further specified by stating that a mandatory channel is a channel *having the highest priority among the channels that have a plurality of priorities*, as for example disclosed on page 5, line 25 to page 6, line 2. This amendment has also been proposed by the Examining Division in the communication dated July 18, 2011. With this amendment the clarity objection raised in section 2.2 of the above-mentioned communication should be overcome.

Finally, the feature that the wireless packets have equivalent package time length has been erased. This should overcome the clarity objection raised in section 2.3 of the communication.

II.

Prior Art and Patentability

1. Prior art document D1 relates to a radio packet communication method. In D1 packets are transmitted between two stations capable of using plural radio channels and MIMO. When at least one idle channel has been detected, plural data packets are generated in the same number as the sum of MIMO channels of the respective idle channels, in which the data packets are generated from one or plural data frames, and plural data packets having the same packet time length are transmitted simultaneously between the two stations by using the idle channels and MIMO.
2. Further thereto, independent claim 1 discloses setting a mandatory channel that is always used for transmission and has the highest priority among wireless channels that have a plurality of priorities, and transmitting the wireless packets by using a wireless channel/wireless channels that includes/include the mandatory channel, only when the mandatory channel is idle.

It is respectfully submitted that D1 does not describe anything corresponding to a plurality of priorities. D1 does only teach to first search for idle radio channels (e.g. S001 in Figure 1) and to distribute the data packets to be transmitted using the idle radio channels (S007, S009, S010 in Figure 1). However, the channels do not have any priorities associated with them. Since D1 already failed to disclose priorities, D1 does not describe the features of the mandatory channel. Therefore, the subject-matter

of new independent claim 1 is new. The same reasoning applies *mutatis mutandis* to independent claims 2, 5, and 6.

III.
Requests

1. It is requested to grant a patent on the basis of the new claims and the remaining documents on file.
2. If a rejection of the present application is considered, we maintain our request for oral proceedings.



Dr. Lorenz von Kurowski
European Patent Attorney
Association No. 151

Encl.:

- new claims 1 to 8, *fair and mark-up copy*

Claims

1. A wireless packet communication method for transmitting a plurality of wireless packets having equal packet time lengths simultaneously by using at least one of multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, and the multiple wireless channels (Ch#1, Ch#2) and the MIMO, the method characterized by comprising:

setting a mandatory channel that is always used for transmission and has the highest priority among wireless channels that have a plurality of priorities; and

transmitting the wireless packets by using a wireless channel/wireless channels (Ch#1, Ch#2) that includes/include the mandatory channel, only when the mandatory channel is idle.

2. A wireless packet communication method for transmitting a plurality of wireless packets having equal packet time lengths simultaneously by using at least one of multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, and the multiple wireless channels (Ch#1, Ch#2) and the MIMO, the method characterized by comprising:

distinguishing an STA A from an STA B, the STA A for which a mandatory channel is set, the STA B for which no mandatory channel is set, the mandatory channel being always used for transmission and having the highest

priority among wireless channels that have a plurality of priorities; and

when wireless packets are addressed to said STA A, transmitting the wireless packets to said STA A by using a wireless channel/wireless channels (Ch#1, Ch#2) that includes/include the mandatory channel, only when the mandatory channel is idle; and

when wireless packets are addressed to said STA B, transmitting the wireless packets to said STA B by using idle wireless channel(s) (Ch#1, Ch#2).

3. The wireless packet communication method according to claim 1 or 2,

characterized in that

the packet time length corresponds to a packet size or a transmission time.

4. The wireless packet communication method according to claim 1 or 2,

characterized by further comprising

simultaneously transmitting wireless packets selectively using the multiple wireless channels (Ch#1, Ch#2) or the MIMO in accordance with a number of pieces of data or a number of MIMOs that depends on a channel condition.

5. A wireless packet communication apparatus for transmitting a plurality of wireless packets having equal packet time lengths simultaneously by using at least one of multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, and the

multiple wireless channels (Ch#1, Ch#2) and the MIMO, the apparatus characterized by comprising

a unit setting a mandatory channel that is always used for transmission and has the highest priority among wireless channels that have a plurality of priorities, and transmitting the wireless packets only when the mandatory channel is idle by using a wireless channel or wireless channels (Ch#1, Ch#2) that includes/include the mandatory channel.

6. A wireless packet communication apparatus for transmitting a plurality of wireless packets having equal packet time lengths simultaneously by using at least one of multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, and the multiple wireless channels (Ch#1, Ch#2) and the MIMO, the apparatus characterized by comprising

a unit distinguishing an STA A from an STA B and determining destinations of the wireless packets so as to transmit wireless packets addressed to said STA A only when said mandatory channel having the highest priority among wireless channels that have a plurality of priorities is idle by using a wireless channel or wireless channels (Ch#1, Ch#2) that includes/include a mandatory channel, and to transmit wireless packets addressed to said STA B by using idle wireless channel or channels (Ch#1, Ch#2), the mandatory channel being always used for transmission, the STA A for which the mandatory channel is set, the STA B for which no mandatory channel is set.

7. The wireless packet communication apparatus according to claim 5 or 6,

characterized in that

the packet time length corresponds to a packet size or a transmission time.

8. The wireless packet communication apparatus according to claim 5 or 6, characterized by further comprising:
a unit simultaneously transmitting wireless packets selectively using the multiple wireless channels (Ch#1, Ch#2) or the MIMO in accordance with a number of pieces of data or a number of MIMOs that depends on a channel condition.

Claims

1. A wireless packet communication method for transmitting a plurality of wireless packets having equal ~~or~~ ~~equivalent~~ packet time lengths simultaneously by using at least one of multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, ~~or~~ and the multiple wireless channels (Ch#1, Ch#2) and the MIMO, the method characterized by comprising:

setting a mandatory channel that is always used for transmission and has the highest priority among wireless channels that have a plurality of priorities; and

transmitting the wireless packets by using a wireless channel/wireless channels (Ch#1, Ch#2) that includes/include the mandatory channel, only when the mandatory channel is idle.

2. A wireless packet communication method for transmitting a plurality of wireless packets having equal ~~or~~ ~~equivalent~~ packet time lengths simultaneously by using at least one of multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, ~~or~~ and the multiple wireless channels (Ch#1, Ch#2) and the MIMO, the method characterized by comprising:

distinguishing an STA A from an STA B, the STA A for which a mandatory channel is set, the STA B for which no mandatory channel is set, the mandatory channel being always used for transmission and having the highest

priority among wireless channels that have a plurality of priorities; and

when wireless packets are addressed to said STA A, transmitting the wireless packets to said STA A by using a wireless channel/wireless channels (Ch#1, Ch#2) that includes/include the mandatory channel, only when the mandatory channel is idle; and

when wireless packets are addressed to said STA B, transmitting the wireless packets to said STA B by using idle wireless channel(s) (Ch#1, Ch#2).

3. The wireless packet communication method according to claim 1 or 2,

characterized in that

the packet time length corresponds to a packet size or a transmission time.

4. The wireless packet communication method according to claim 1 or 2,

characterized by further comprising

simultaneously transmitting wireless packets selectively using the multiple wireless channels (Ch#1, Ch#2) or the MIMO in accordance with a number of pieces of data or a number of MIMOs that depends on a channel condition.

5. A wireless packet communication apparatus for transmitting a plurality of wireless packets having equal ~~or equivalent~~ packet time lengths simultaneously by using at least one of multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO,

~~or~~ and the multiple wireless channels (Ch#1, Ch#2) and the MIMO, the apparatus characterized by comprising

a unit setting a mandatory channel that is always used for transmission and has the highest priority among wireless channels that have a plurality of priorities, and transmitting the wireless packets only when the mandatory channel is idle by using a wireless channel or wireless channels (Ch#1, Ch#2) that includes/include the mandatory channel.

6. A wireless packet communication apparatus for transmitting a plurality of wireless packets having equal ~~or equivalent~~ packet time lengths simultaneously by using at least one of multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, ~~or~~ and the multiple wireless channels (Ch#1, Ch#2) and the MIMO, the apparatus characterized by comprising

a unit distinguishing an STA A from an STA B and determining destinations of the wireless packets so as to transmit wireless packets addressed to said STA A only when said mandatory channel having the highest priority among wireless channels that have a plurality of priorities is idle by using a wireless channel or wireless channels (Ch#1, Ch#2) that includes/include a mandatory channel, and to transmit wireless packets addressed to said STA B by using idle wireless channel or channels (Ch#1, Ch#2), the mandatory channel being always used for transmission, the STA A for which the mandatory channel is set, the STA B for which no mandatory channel is set.

7. The wireless packet communication apparatus according to claim 5 or 6,

characterized in that

the packet time length corresponds to a packet size or a transmission time.

8. The wireless packet communication apparatus according to claim 5 or 6, characterized by further comprising:
a unit simultaneously transmitting wireless packets selectively using the multiple wireless channels (Ch#1, Ch#2) or the MIMO in accordance with a number of pieces of data or a number of MIMOs that depends on a channel condition.

Application No.: 04 773 142.7

Preparation for oral proceedings - Instructions to Support Service

Oral proceedings are to be held in connection with the above patent application

1. The matters to be discussed are set out in the annex (Form 2906)
2. Dispatch the summons using Form 2008/2310 and Form 2906 for the parties to attend on:

Day 08.10.2013 Time 09:00

ROOMS

CAF
Room 909 booked

ORAL 01, 02, 03 and 05
coded

07.02.13
Date Initials

- 2.1 Parties' submissions in preparation for the oral proceedings,
if any, should be made no later than

1 month(s)

before the date of the oral proceedings
(transfer to Form 2008.1 / 2310.1)

- 2.2 Encode ORAL(04)

coded

07.02.13
Date Initials

- 2.3 Dispatch Form 2008.7 / 2310.7 to division

07.02.13
Date Initials

3. ☐ Arrange for the following special equipment
to be provided in the conference room:

.....
Date Initials



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80298 MUNICH
GERMANY
Tel: +49 89 2399 0
Fax: +49 89 2399 4465

4. Request language service to provide simultaneous interpretation facilities as necessary

.....
Date Initials

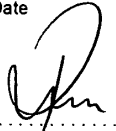
5. Return the dossier to primary examiner with Form 2041 (15 days before the oral proceedings)

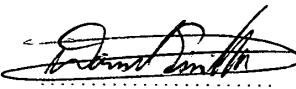
.....
Date Initials

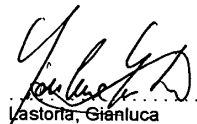
6. Check that summons has been received (Form 2936 / advice of delivery)

7. 15 days before the oral proceedings:
- dispatch the dossier to the primary examiner.

07.07.13
.....
Date


.....
Maciejewski, Robert
Chairman


.....
Pinilla-Ariza, D
2nd examiner


.....
Lastoria, Gianluca
1st examiner

.....
Legal member

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Date

14-02-2013

Reference 110 895 a/jme	Application No./Patent No. 04773142.7 - 1858 / 1667480
Applicant/Proprietor NIPPON TELEGRAPH AND TELEPHONE CORPORATION	

Summons to attend oral proceedings pursuant to Rule 115(1) EPC

You are hereby summoned to attend oral proceedings arranged in connection with the above-mentioned European patent application.

The matters to be discussed are set out in the communication accompanying this summons (EPO Form 2906).

The oral proceedings, which will not be public, will take place before the Examining Division.

on 08.10.13 at 09.00 hrs at the EPO, Capitellum
Landsbergerstr. 30, 80339 München

No changes to the date of the oral proceedings can be made, except on serious grounds (see OJ EPO 1/2009, 68). If you do not appear as summoned, the oral proceedings may continue without you (R. 115(2) EPC, see also OJ EPO 10/2008, 471).

Your attention is drawn to Rule 4 EPC, regarding the language of the oral proceedings, and to the Special edition No. 3 OJ EPO 2007, L.1., concerning the filing of authorisations for company employees and lawyers acting as representatives before the EPO.

The final date for making written submissions and/or amendments (R. 116 EPC) is 09.09.13.

The actual room number as well as the waiting room numbers will be given to you by the porter in the foyer at the above EPO address.

Parking is available in the underground car park, accessible only via the entrance "Grasserstrasse 2/6". On presentation of the summons to oral proceedings at one of the porters' lodges in the PschorrHöfe, the parking ticket will be revoked.

1st Examiner:
Latoria G

2nd Examiner:
Pinilla-Ariza D

Chairman:
Maciejewski R

For the Examining Division



Annexes:
Confirmation of receipt (Form 2936)
Communication (EPO Form 2906)

Registered letter with advice of delivery
EPO Form 2008 12.12 [ORAL03=9999] (07/02/13)

to EPO postal service: 07.02.13

Datum
Date 14.02.2013
Date

Blatt
Sheet 1
Feuille

Anmelde-Nr:
Application No: 04 773 142.7
Demande n°:

The examination is being carried out on the **following application documents**

Description, Pages

1-4, 8-20	filed with entry into the regional phase before the EPO		
5, 5a, 6, 7	received on	30-09-2011 with letter of	30-09-2011

Claims, Numbers

1-8	received on	21-06-2012 with letter of	21-06-2012

Drawings, Sheets

1/12-12/12	filed with entry into the regional phase before the EPO

1 The following documents are cited by the Examiner. A copy of the documents is annexed to the communication and the numbering will be adhered to in the rest of the procedure.

D2 EP 1 263 168 A2 (TOSHIBA KK [JP]) 4 December 2002 (2002-12-04)

D3 US 2002/176386 A1 (SINGH GURPREET [US] SINGH GURPRETT [US]) 28 November 2002 (2002-11-28)

2 The amendments submitted in response to the last official communication have not placed the application in order for grant. Oral Proceedings in accordance with Article 116 EPC are considered necessary to bring the examination to a timely close.

- 3 The oral proceedings will be focusing on the lack of clarity and consequently inventive step of the subject-matter of **claims 1 to 8**. Other issues involving formal points may still be discussed if the need arises.
- 4 The claims do, for the following reasons, **not** meet the requirements of Article 84 EPC in respect of clarity:
- 4.1 The sentence "*...a single wireless channel determined to be idle and MIMO, and the multiple wireless channels (Ch#1, Ch#2) and the MIMO*" used in **claims 1, 2, 5 and 6** is not clear, Article 84 EPC.
- 4.1.1 The sentence seems not be grammatically correct, as it is not possible to understand how the second part of the sentence (i.e. "*and the multiple wireless channels (Ch#1, Ch#2) and the MIMO*") relates to the first part.
- 4.1.2 Secondly, it is not clear what is performed on "*and the multiple wireless channels (Ch#1, Ch#2) and the MIMO*"
- 4.1.3 Finally it is not clear what "*the MIMO*" alone means, set aside that MIMO means Multiple Input Multiple Output.
- 4.2 It is furthermore not clear how a channel could be determined to be MIMO, being MIMO a technology, rather than a channel.
- 4.3 The claims, furthermore, seem to contain contradictory features, as e.g. **claim 1** claims the simultaneous transmission of packets having the same length on a plurality of channels (see the first part of claim 1) and than it claims the possibility of transmitting packet simultaneously using only one channel (see the last sentence of the claim).
- 5 In so far as the present text can be understood, the present application does not meet the requirements of Articles 52(1) and 56 EPC because the subject-matter of the claims does not involve an inventive step.

- 5.1 Document **D2** discloses, according to the main features of **claim 1**, a wireless packet communication method for transmitting a plurality of wireless packets having equal packet time lengths simultaneously by using at least one of multiple wireless channels (*see e.g. column 8, lines 14 to 20*) determined to be idle by carrier sense (*this is implicit in a wireless network using CSMA, see paragraph [0002]*), the method comprising:
- setting a mandatory channel that is always used for transmission (*as said in the previous communication, a channel is mandatory as without a channel a wireless packet cannot be transmitted*); and
 - transmitting the wireless packets by using a wireless channel/wireless channels that includes/include the mandatory channel, only when the mandatory channel is idle (*see e.g. step S14 in figure 3*).

The subject-matter of **claim 1** differs from the disclosure of document **D2** in that the mandatory channel is further characterised by having the highest priority among the channels having priority.

The problem to be solved by the present invention may therefore be regarded as how to rank channels for e.g. reducing the bit error rate.

In consulting the prior art in the general field of mobile communication, the person skilled in the art, wishing to find a solution to overcome the above mentioned shortcoming and bearing in mind the disclosure of document **D2**, would therefore come across document **D3**, which discloses the ranking of channel based on priority assigned to the available channels (*see e.g. figure 6, step 703*).

For the person skilled in the art, therefore, starting from the method described in document **D2** and being aware both of the above problem and of the principle of the solution described in document **D3** (i.e. the assigning priority to the channels), it would be obvious to apply said principle to the method of document **D2**, in order to arrive at a method wherein the above problem has been overcome.

The skilled person would thus arrive, without the exercise of inventive skill, at the method corresponding to the subject-matter of **claim 1**.

The subject-matter of claim 1 therefore does **not** involve an inventive step, as defined in Article 56 EPC, and thus claim 1 is **not** allowable, Article 52(1) EPC.

- 6 The same consideration also apply for newly filed **independent claims 2, 5 and 6**, since **claim 2** comprises the feature combination of claim 1 with the difference of having one station assigned to a priority channel (disclosed in document **D3**) and one station on a channel without priority (as in document **D2**), while **claims 5 and 6** are based based on the same essential feature combination as **claims 1 and 2** respectively in terms of an apparatus adapted to implement the correspondent method.

The subject-matter of claims 2, 5 and 6 therefore does **not** involve an inventive step, Article 56 EPC, and hence said claims are **not** allowable, Article 52 (1) EPC.

- 7 According to Rule 137(3) EPC consent of the examining division is required for amendments filed at any time, Consent will only be given for amendments clearly addressing the above raised objections.

It is remarked that in case the examining division decides during the oral proceedings that the present claims are not admissible, and the applicant maintains the current request, the application will be refused under Article 97(2) EPC.

- 8 Should the applicant decide not to attend the oral proceedings or should he also intend not to file any new amendments and/or comments, attention is further drawn to the possibility of a request for a decision "on the state of the file as it stands" (Guidelines E-IX,4.4).

- 9 The applicant is reminded (see EPO Official Journal, 10/2008, 471) that if an applicant who has been duly summoned to oral proceedings does not appear as summoned, oral proceedings may be conducted without him (Rule 115(2) EPC, Guidelines for Examination in the European Patent Office E-III, 8.3.3.3). The decision may be given orally in the absence of the applicant (Rule 111(1) EPC).

An applicant who files amended claims or other submissions in reply to the summons to oral proceedings has to expect that any objection relating to the amended claims and submissions will be dealt with at the oral proceedings. The fact that oral proceedings are maintained indicates that objections are still outstanding and they will be discussed at the oral proceedings.

The oral proceedings give the applicant the opportunity to present her comments, in accordance with Article 113(1) EPC. If the applicant decides not to attend the oral proceedings he chooses not to make use of the opportunity to comment at the oral proceedings on any of the objections, but relies on the arguments as set out in the written submissions.

The applicant has thus to expect that a decision based on objections which arise against the amended claims during oral proceedings will be taken in his/her absence.



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Date
14-02-2013

Reference 110 895 a/jme	Application No./Patent No. 04773142.7 - 1858 / 1667480
Applicant/Proprietor NIPPON TELEGRAPH AND TELEPHONE CORPORATION	

EPA/EPO/OEB Formblatt/Form/Formulaire : F. 2008

Empfangsbescheinigung über den Zugang des vorstehend bezeichneten Schriftstücks
Acknowledgement of receipt of the document specified above
Récépissé du document spécifié ci-dessus

Unter Bezugnahme auf die Mitteilung im ABI EPA 7/2010, 377 wird gebeten, die Empfangsbescheinigung mit Empfangsdatum und Unterschrift zu versehen und **umgehend** an das EPA zurückzusenden:

With reference to the Notice in OJ EPO 7/2010, 377, you are requested to date and sign the acknowledgement of receipt and return it to the EPO **immediately**:

Conformément au communiqué paru au JO OEB 7/2010, 377, vous êtes prié d'indiquer sur le récépissé la date de réception du document, de signer le récépissé et de le renvoyer **sans délai** à l' OEB:

- **über die Online-Dienste des EPA** (als Anlage zu EPA Form 1038) / **through EPO Online Services** (as annex to EPO Form 1038) / **par les services en ligne de l'OEB** (en tant que pièce jointe au formulaire OEB 1038),
- **per Fax / by fax / par téléfax** (+49 (0) 89 2399-4465 or +31 (0) 70 340-3016)
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18. Feb. 2013



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Reference 110 895 a/jme	Application No./Patent No. 04773142.7 - 1858 / 1667480
Applicant/Proprietor NIPPON TELEGRAPH AND TELEPHONE CORPORATION	

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Empfangsbescheinigung über den Zugang des vorstehend bezeichneten Schriftstücks
Acknowledgement of receipt of the document specified above
Récépissé du document spécifié ci-dessus

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15. Feb. 2013

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12. Juli 2013

Munich, July 12, 2013

Our Ref.: 110 895 q4/q21

European Patent Application No. 04 773 142.7 – 1858

NIPPON TELEGRAPH AND TELEPHONE CORPORATION

In response to the summons to attend oral proceedings dated
February 14, 2013

I. New Documents

1. We herewith submit a new main request in preparation for the oral proceedings. The main request is based on the previous claims submitted on June 21, 2012. More specifically, claims 1-8 are based on previous claims 1-8, respectively.

Furthermore, the formulation “among multiple wireless channels” is supported by p. 6, l. 1 of the original description.

2. We also submit an auxiliary request. The auxiliary request is based on the main request wherein the independent claims include features disclosed in original claims 3 and 7.

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In cooperation with/in Kooperation mit

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II. Clarity

1. In order to overcome the clarity objections in section 4.1 of the summons, the preamble of the independent claims has been rewritten such that it is clear that the wireless packets are transmitted using *multiple* wireless channels and MIMO.

This is illustrated in Fig. 14. Especially, Fig. 14 shows the case in which a plurality of wireless packets is mapped to a single wireless channel by using the multiple input multiple output technology.

2. In response to section 4.2 of the summons, it is respectfully submitted that claim 1 does not state that a channel is determined to be MIMO. Rather, claim 1 recites that that the wireless packets are transmitted using *idle* multiple wireless channels and MIMO.
3. In section 4.3 of the summons, the Examiner is of the opinion that the claims as currently on file cover the case in which only a single wireless channel is used to transmit the wireless packets. This allegedly causes a contradiction in claim 1.

In order to overcome this objection, the subject-matter of the new independent claims relates to a transmission over *more than one* wireless channel. Therefore, this objection should be overcome.

III. Patentability of the Main Request

1. Newly cited prior-art document D2 relates to a wireless communication apparatus in a wireless communication system employing CSMA (carrier sense multiple access). In CSMA an access point senses a carrier for transmitting the packet prior to transmitting the packet to a wireless station. The wireless communication apparatus comprises an adaptive array antenna generating a plurality of radio waves with comparatively narrow directivities to a plurality of stations. The number of antenna beams and the number of stations carrying out simultaneous communication may be arbitrarily two or more. By means of the antenna beams, the access point can communicate with the plurality of stations via the substantially same channel or adjacent channel while reducing interference between stations. The transmission data

is transmitted as data packets each having the same packet length (see especially paragraphs [0018], [0019], [0020], and [0026]).

In contrast thereto, according to the wireless packet communication method according to new claim 1 of the main request, the method comprises setting a mandatory channel among multiple wireless channels that is always used for transmission and has the highest priority among wireless channels that have a plurality of priorities, and transmitting the wireless packets by using wireless channels that include the mandatory channel, only when the mandatory channel is idle.

In other words, claim 1 discloses multiple wireless channels one of which is defined as the mandatory channel. The mandatory channel is characterized in that it is always used for transmission and has the highest priority of the wireless channels. The Examiner has already acknowledged that the different priorities are not disclosed in D2. Furthermore, it is respectfully submitted that D2 does not disclose setting a mandatory channel that is always used for transmission. Especially, a mandatory channel with these features is used in all transmissions after the mandatory channel has been set. D2 does not disclose a channel with these features.

Furthermore, in contrast to D2, the wireless packets according to claim 1 are transmitted by using wireless channels that include the mandatory channel. D2 only discloses to use a single channel for data transmission (see for example paragraph [0019]). Furthermore, in contrast to D2, new claim 1 discloses to transmit the wireless packets only when the mandatory channel is idle.

2. The Examiner comes to the conclusion that it is an objective technical problem to be solved by the present invention to rank channels for reducing the bit-error rate.

It is respectfully submitted that this formulation of the technical problem is not correct. Especially, according to the Guidelines of Examination Part G-VII 5.2, the objective technical problem must be so formulated as not to contain pointers to the technical solution. By referring to “ranking channels” in the problem, the Examiner included a pointer to the solution offered by claim 1 in that ranking already hints at defining priorities for the different wireless channels.

In view thereof, the technical problem to be solved by the present invention is avoiding leakage power from adjacent channels in order to improve throughput by simultaneous transmission (see also page 5, lines 8 and 9 of the description).

3. Document D2 does not provide any incentive in direction of these differences.

Newly cited prior-art document D3 relates to a method for configuring network nodes in a wireless local area network by detecting noise levels on each of the available channels in the network. Each stationary access point listens on available channels on the network. Each of the stationary access points determines a prioritized list of preferred frequencies or channels of operation based on the noise levels from the surrounding channels in use by other stationary access points. The listening stationary access point chooses a frequency and sets itself to the associated channel based on the strength of the other signals on the channel in the network. The formation of the prioritized list is further described in paragraph [0046].

In other words, D3 describes to select a prioritized sequence of preferred frequency bands for operation. However, the highest priority channel is not necessarily used. On the contrary, the present invention according to the new independent claims discloses that a mandatory channel is always used for transmission and no transmission is performed when the mandatory channel is busy even if there are other idle channels.

Furthermore, the skilled person would not consult D3 when faced with the above-mentioned problem. D3 is concerned with implementing an optimum pattern or distribution of channel frequencies and switching between channels to utilize the best communication link. In contrast thereto, the present invention according to the independent claims is concerned with a specific problem occurring when wireless packets are transmitted over multiple channels. Therefore, the skilled person is not provided with any incentive to combine the teachings of D2 and D3.

Furthermore, even if the skilled person would hypothetically combine the teachings of D2 and D3, he would not arrive at the subject-matter of the independent claims. Both D2 and D3 already fail to disclose the simultaneous transmission of wireless packets by using multiple wireless channels. Furthermore, a combination of D2 and D3 fails to result in the definition of a mandatory channel with the highest priority which has to be present in the multiple wireless channels determined to be idle which

are used in transmitting the wireless packets. In other words, in contrast to a hypothetical combination of D2 and D3, the new independent claims describe that wireless packets are always transmitted by wireless channels including the mandatory channel, and when the mandatory channel is busy, the transmission is not performed even if there is another idle channel.

IV. Patentability of the Auxiliary Request

Further to the main request, the auxiliary request discloses that the packet time length corresponds to a packet size or a transmission time. This feature is not disclosed in D2. Furthermore, none of the cited references renders this feature obvious. Therefore, it is respectfully submitted that the subject-matter of the independent claims of the auxiliary request involves an inventive step. This assessment appears to be shared by the Examining Division as no objections against previous claim 3 were raised in the summons.

V. Requests

It is requested to grant a patent on the basis of the new main request and the remaining documents on file.

As an auxiliary measure, it is requested to grant a patent on the basis of the auxiliary request and the remaining documents on file.



Dr. Lorenz von Kurowski
European Patent Attorney
Association No 151

Encl.:

- main request, *fair and mark-up copy*
- auxiliary request, *fair and mark-up copy*

Claims
(Auxiliary Request)

1. A wireless packet communication method for transmitting a plurality of wireless packets having equal packet time lengths simultaneously by using multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense and MIMO, the method characterized by comprising:

setting a mandatory channel among multiple wireless channels that is always used for transmission and has the highest priority among wireless channels that have a plurality of priorities; and

transmitting the wireless packets by using wireless channels (Ch#1, Ch#2) that include the mandatory channel, only when the mandatory channel is idle, wherein

the packet time length corresponds to a packet size or a transmission time.

2. A wireless packet communication method for transmitting a plurality of wireless packets having equal packet time lengths simultaneously by using multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense and MIMO, the method characterized by comprising:

distinguishing an STA A from an STA B, the STA A for which a mandatory channel among multiple wireless channels is set, the STA B for which no mandatory channel among multiple wireless channels is set, the mandatory channel being always used for transmission and having the highest priority among wireless channels that have a plurality of priorities; and

when wireless packets are addressed to said STA A, transmitting the wireless packets to said STA A by using wireless channels (Ch#1, Ch#2) that include the mandatory channel, only when the mandatory channel is idle; and

when wireless packets are addressed to said STA B, transmitting the wireless packets to said STA B by using idle wireless channel(s) (Ch#1, Ch#2), wherein

the packet time length corresponds to a packet size or a transmission time.

3. The wireless packet communication method according to claim 1 or 2, characterized by further comprising

simultaneously transmitting wireless packets selectively using the multiple wireless channels (Ch#1, Ch#2) or the MIMO in accordance with a number of pieces of data or a number of MIMOs that depends on a channel condition..

4. A wireless packet communication apparatus for transmitting a plurality of wireless packets having equal packet time lengths simultaneously by using multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense and MIMO, the apparatus characterized by comprising

a unit (23) setting a mandatory channel among multiple wireless channels that is always used for transmission and has the highest priority among wireless channels that have a plurality of priorities, and transmitting the wireless packets only when the mandatory channel is idle by using wireless channels (Ch#1, Ch#2) that include the mandatory channel, wherein

the packet time length corresponds to a packet size or a transmission time.

5. A wireless packet communication apparatus for transmitting a plurality of wireless packets having equal packet time lengths simultaneously by using multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense and MIMO, the apparatus characterized by comprising

a unit (23) distinguishing an STA A from an STA B and determining destinations of the wireless packets so as to transmit wireless packets addressed to said STA A only when a mandatory channel among multiple wireless channels having the highest priority among wireless channels that have a plurality of priorities is idle by using wireless channels (Ch#1, Ch#2) that include a mandatory channel, and to transmit wireless packets addressed to said STA B by using idle wireless channel or channels (Ch#1, Ch#2), the mandatory channel being always used for transmission, the STA A for which the mandatory channel is set, the STA B for which no mandatory channel is set, wherein

the packet time length corresponds to a packet size or a transmission time.

6. The wireless packet communication apparatus according to claim 4 or 5, characterized by further comprising:

a unit simultaneously transmitting wireless packets selectively using the multiple wireless channels (Ch#1, Ch#2) or the MIMO in accordance with a number of pieces of data or a number of MIMOs that depends on a channel condition.

Claims
(Main Request)

1. A wireless packet communication method for transmitting a plurality of wireless packets having equal packet time lengths simultaneously by using multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense and MIMO, the method characterized by comprising:

setting a mandatory channel among multiple wireless channels that is always used for transmission and has the highest priority among wireless channels that have a plurality of priorities; and

transmitting the wireless packets by using wireless channels (Ch#1, Ch#2) that include the mandatory channel, only when the mandatory channel is idle.

2. A wireless packet communication method for transmitting a plurality of wireless packets having equal packet time lengths simultaneously by using multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense and MIMO, the method characterized by comprising:

distinguishing an STA A from an STA B, the STA A for which a mandatory channel among multiple wireless channels is set, the STA B for which no mandatory channel among multiple wireless channels is set, the mandatory channel being always used for transmission and having the highest priority among wireless channels that have a plurality of priorities; and

when wireless packets are addressed to said STA A, transmitting the wireless packets to said STA A by using wireless channels (Ch#1, Ch#2) that include the

mandatory channel, only when the mandatory channel is idle; and

when wireless packets are addressed to said STA B, transmitting the wireless packets to said STA B by using idle wireless channel(s) (Ch#1, Ch#2).

3. The wireless packet communication method according to claim 1 or 2, characterized in that

the packet time length corresponds to a packet size or a transmission time.

4. The wireless packet communication method according to claim 1 or 2, characterized by further comprising

simultaneously transmitting wireless packets selectively using the multiple wireless channels (Ch#1, Ch#2) or the MIMO in accordance with a number of pieces of data or a number of MIMOs that depends on a channel condition.

5. A wireless packet communication apparatus for transmitting a plurality of wireless packets having equal packet time lengths simultaneously by using multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense and MIMO, the apparatus characterized by comprising

a unit (23) setting a mandatory channel among multiple wireless channels that is always used for transmission and has the highest priority among wireless channels that have a plurality of priorities, and transmitting the wireless packets only when the mandatory channel is idle by using wireless channels (Ch#1, Ch#2) that include the mandatory channel.

6. A wireless packet communication apparatus for transmitting a plurality of wireless packets having equal packet time lengths simultaneously by using multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense and MIMO, the apparatus characterized by comprising

a unit (23) distinguishing an STA A from an STA B and determining destinations of the wireless packets so as to transmit wireless packets addressed to said STA A only when a mandatory channel among multiple wireless channels having the highest priority among wireless channels that have a plurality of priorities is idle by using wireless channels (Ch#1, Ch#2) that include a mandatory channel, and to transmit wireless packets addressed to said STA B by using idle wireless channel or channels (Ch#1, Ch#2), the mandatory channel being always used for transmission, the STA A for which the mandatory channel is set, the STA B for which no mandatory channel is set.

7. The wireless packet communication apparatus according to claim 5 or 6, characterized in that

the packet time length corresponds to a packet size or a transmission time.

8. The wireless packet communication apparatus according to claim 5 or 6, characterized by further comprising:

a unit simultaneously transmitting wireless packets selectively using the multiple wireless channels (Ch#1, Ch#2) or the MIMO in accordance with a number of pieces of data or a number of MIMOs that depends on a channel condition.

Claims
(Main Request)

1. A wireless packet communication method for transmitting a plurality of wireless packets having equal packet time lengths simultaneously by using ~~at least one of multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, and the multiple wireless channels (Ch#1, Ch#2) and the MIMO~~, the method characterized by comprising:

setting a mandatory channel among multiple wireless channels that is always used for transmission and has the highest priority among wireless channels that have a plurality of priorities; and

transmitting the wireless packets by using ~~a wireless channel/wireless channels (Ch#1, Ch#2) that includes/include~~ the mandatory channel, only when the mandatory channel is idle.

2. A wireless packet communication method for transmitting a plurality of wireless packets having equal packet time lengths simultaneously by using ~~at least one of multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, and the multiple wireless channels (Ch#1, Ch#2) and the MIMO~~, the method characterized by comprising:

distinguishing an STA A from an STA B, the STA A for which a mandatory channel among multiple wireless channels is set, the STA B for which no mandatory channel among multiple wireless channels is set, the

mandatory channel being always used for transmission and having the highest priority among wireless channels that have a plurality of priorities; and

when wireless packets are addressed to said STA A, transmitting the wireless packets to said STA A by using ~~a wireless channel/wireless channels~~ (Ch#1, Ch#2) that ~~includes/include~~ the mandatory channel, only when the mandatory channel is idle; and

when wireless packets are addressed to said STA B, transmitting the wireless packets to said STA B by using idle wireless channel(s) (Ch#1, Ch#2).

3. The wireless packet communication method according to claim 1 or 2, characterized in that

the packet time length corresponds to a packet size or a transmission time.

4. The wireless packet communication method according to claim 1 or 2, characterized by further comprising

simultaneously transmitting wireless packets selectively using the multiple wireless channels (Ch#1, Ch#2) or the MIMO in accordance with a number of pieces of data or a number of MIMOs that depends on a channel condition.

5. A wireless packet communication apparatus for transmitting a plurality of wireless packets having equal packet time lengths simultaneously by using ~~at least one of~~ multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense, ~~a single wireless channel determined to be idle and MIMO, and the multiple wireless channels (Ch#1, Ch#2) and the MIMO,~~ the apparatus characterized by comprising

a unit (23) setting a mandatory channel among multiple wireless channels that is always used for transmission and has the highest priority among wireless channels that have a plurality of priorities, and transmitting the wireless packets only when the mandatory channel is idle by using ~~a wireless channel or~~ wireless channels (Ch#1, Ch#2) that ~~includes/~~include the mandatory channel.

6. A wireless packet communication apparatus for transmitting a plurality of wireless packets having equal packet time lengths simultaneously by using ~~at least one of multiple~~ wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense, ~~a single wireless channel determined to be idle and MIMO, and the multiple wireless channels (Ch#1, Ch#2) and the MIMO,~~ the apparatus characterized by comprising

a unit (23) distinguishing an STA A from an STA B and determining destinations of the wireless packets so as to transmit wireless packets addressed to said STA A only when ~~said a~~ mandatory channel among multiple wireless channels having the highest priority among wireless channels that have a plurality of priorities is idle by using ~~a wireless channel or~~ wireless channels (Ch#1, Ch#2) that ~~includes/~~include a mandatory channel, and to transmit wireless packets addressed to said STA B by using idle wireless channel or channels (Ch#1, Ch#2), the mandatory channel being always used for transmission, the STA A for which the mandatory channel is set, the STA B for which no mandatory channel is set.

7. The wireless packet communication apparatus according to claim 5 or 6, characterized in that

the packet time length corresponds to a packet size or a transmission time.

8. The wireless packet communication apparatus according to claim 5 or 6, characterized by further comprising:

a unit simultaneously transmitting wireless packets selectively using the multiple wireless channels (Ch#1, Ch#2) or the MIMO in accordance with a number of pieces of data or a number of MIMOs that depends on a channel condition.

Claims
(Auxiliary Request)

1. A wireless packet communication method for transmitting a plurality of wireless packets having equal packet time lengths simultaneously by using ~~at least one of multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, and the multiple wireless channels (Ch#1, Ch#2) and the MIMO,~~ the method characterized by comprising:

setting a mandatory channel among multiple wireless channels that is always used for transmission and has the highest priority among wireless channels that have a plurality of priorities; and

transmitting the wireless packets by using a wireless channel/wireless channels (Ch#1, Ch#2) that includes/include the mandatory channel, only when the mandatory channel is idle-, wherein

- ~~3. The wireless packet communication method according to claim 1 or 2, characterized in that~~

the packet time length corresponds to a packet size or a transmission time.

2. A wireless packet communication method for transmitting a plurality of wireless packets having equal packet time lengths simultaneously by using ~~at least one of multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, and the multiple wireless channels~~

~~(Ch#1, Ch#2)~~ and the MIMO, the method characterized by comprising:

distinguishing an STA A from an STA B, the STA A for which a mandatory channel among multiple wireless channels is set, the STA B for which no mandatory channel among multiple wireless channels is set, the mandatory channel being always used for transmission and having the highest priority among wireless channels that have a plurality of priorities; and

when wireless packets are addressed to said STA A, transmitting the wireless packets to said STA A by using ~~a wireless channel/~~wireless channels (Ch#1, Ch#2) that ~~includes/~~include the mandatory channel, only when the mandatory channel is idle; and

when wireless packets are addressed to said STA B, transmitting the wireless packets to said STA B by using idle wireless channel(s) ~~(Ch#1, Ch#2+-)~~, wherein

the packet time length corresponds to a packet size or a transmission time.

43. The wireless packet communication method according to claim 1 or 2, characterized by further comprising

simultaneously transmitting wireless packets selectively using the multiple wireless channels (Ch#1, Ch#2) or the MIMO in accordance with a number of pieces of data or a number of MIMOs that depends on a channel condition.

54. A wireless packet communication apparatus for transmitting a plurality of wireless packets having equal packet time lengths simultaneously by using ~~at least one of~~ multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense, ~~a single~~

~~wireless channel determined to be idle and MIMO, and the multiple wireless channels (Ch#1, Ch#2) and the MIMO, the apparatus characterized by comprising~~

a unit (23) setting a mandatory channel among multiple wireless channels that is always used for transmission and has the highest priority among wireless channels that have a plurality of priorities, and transmitting the wireless packets only when the mandatory channel is idle by using ~~a wireless channel or~~ wireless channels (Ch#1, Ch#2) that ~~includes/include~~ the mandatory channel, wherein

~~7. The wireless packet communication apparatus according to claim 5 or 6, characterized in that~~

the packet time length corresponds to a packet size or a transmission time.

65. A wireless packet communication apparatus for transmitting a plurality of wireless packets having equal packet time lengths simultaneously by using ~~at least one of multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, and/or the multiple wireless channels (Ch#1, Ch#2) and the MIMO, the apparatus characterized by comprising~~

a unit (23) distinguishing an STA A from an STA B and determining destinations of the wireless packets so as to transmit wireless packets addressed to said STA A only when said a mandatory channel among multiple wireless channels having the highest priority among wireless channels that have a plurality of priorities is idle by using ~~a wireless channel or~~ wireless channels (Ch#1, Ch#2) that ~~includes/include~~ a mandatory channel, and to transmit wireless packets addressed to said STA B

by using idle wireless channel or channels (Ch#1, Ch#2), the mandatory channel being always used for transmission, the STA A for which the mandatory channel is set, the STA B for which no mandatory channel is set, wherein

the packet time length corresponds to a packet size or a transmission time.

86. The wireless packet communication apparatus according to claim 54 or 65, characterized by further comprising:

a unit simultaneously transmitting wireless packets selectively using the multiple wireless channels (Ch#1, Ch#2) or the MIMO in accordance with a number of pieces of data or a number of MIMOs that depends on a channel condition.

European patent application No. 04773142.7

URGENT !
To be completed (under II.) and returned to the formalities officer immediately

**Maintenance / Change of date / Cancellation of oral proceedings
arranged for:
day 08.10.13 at 09.00 hrs**

I. To the Examining / Opposition division

1. ☐ The proprietor has requested the revocation (or the like) of his patent
(date:).

2. ☐ The party / witness FREP has indicated (date: 12.07.13)
that he / she
 - ☐ requests the date / time of oral proceedings to be changed.
 - ☐ withdraws the request for oral proceedings.
 - ☐ will not be attending.
 - ☐ wishes to be heard by a national court.
 - ☒ has filed amendments (in examination proceedings).
 - ☐ has requested that the oral proceedings be held as a videoconference
(in examination proceedings).

3. ☐ Two months before the oral proceedings the application is deemed to be withdrawn (in
examination proceedings). The oral proceedings have to be cancelled.

16-07-2013
Date

Reichert, Jacques
Formalities Officer

II. To the Formalities Officer

1. ☐ The date / time fixed for oral proceedings is maintained.
☐ (if necessary) The reasons are indicated on enclosed EPO Form 2906/2906O, which is to be dispatched to the party with EPO Form 2008A/2310A.
2. ☐ At the instigation of the division the oral proceedings cannot take place on the arranged date for the reasons indicated on enclosed EPO Form 2906, which is to be dispatched to the party with EPO Form 2008A/2310A.

Date

Director (see Internal Instructions IE-III, 1.2)

3. ☐ The summons to attend oral proceedings on 08.10.13 should be cancelled.
- 3.1 ☐ The proceedings will be continued in writing.
- 3.2 ☐ A new date will be set later.
- 3.3 ☐ A new date/time is set as follows:
date at hrs.
Parties' written submissions and amendments in preparation for the oral proceedings, if any, should be made not later than
..... month(s) before the date of the oral proceedings.
4. ☐ The request for the oral proceedings to be held as a videoconference
- 4.1 ☐ is allowed.
- 4.2 ☐ is rejected for the reasons indicated on enclosed EPO Form 2906, which is to be dispatched to the party with EPO Form 2008A.

5. ☐ The application is deemed to be withdrawn. The oral proceedings are cancelled.

Date

Chairman

Second member

Primary Examiner

Legal member

III. Action taken by the formalities officer

- ☐ EPO Form 2008A/2310A has been dispatched, if applicable (see point II above) together with EPO Form 2906/2906O.
- ☐ A new summons has been dispatched.
- ☐

Date

Formalities Officer

European patent application No. 04773142.7

URGENT !
To be completed (under II.) and returned to the formalities officer immediately

**Maintenance / Change of date / Cancellation of oral proceedings
 arranged for:
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I. To the Examining / Opposition division

1. ☐ The proprietor has requested the revocation (or the like) of his patent
 (date:).

2. ☐ The party / witness FREP has indicated (date: 12.07.13)
 that he / she
 - ☐ requests the date / time of oral proceedings to be changed.
 - ☐ withdraws the request for oral proceedings.
 - ☐ will not be attending.
 - ☐ wishes to be heard by a national court.
 - ☒ has filed amendments (in examination proceedings).
 - ☐ has requested that the oral proceedings be held as a videoconference
 (in examination proceedings).

3. ☐ Two months before the oral proceedings the application is deemed to be withdrawn (in
 examination proceedings). The oral proceedings have to be cancelled.

16-07-2013

Date

Reichert, Jacques

Formalities Officer

European patent application No. 04773142.7

II. To the Formalities Officer

1. ☒ The date / time fixed for oral proceedings is maintained.
☐ (if necessary) The reasons are indicated on enclosed EPO Form 2906/2906O, which is to be dispatched to the party with EPO Form 2008A/2310A.
2. ☐ At the instigation of the division the oral proceedings cannot take place on the arranged date for the reasons indicated on enclosed EPO Form 2906, which is to be dispatched to the party with EPO Form 2008A/2310A.

Date

Director (see Internal Instructions IE-III, 1.2)

3. ☐ The summons to attend oral proceedings on 08.10.13 should be cancelled.
- 3.1 ☐ The proceedings will be continued in writing.
- 3.2 ☐ A new date will be set later.
- 3.3 ☐ A new date/time is set as follows:
- date at hrs.
Parties' written submissions and amendments in preparation for the oral proceedings, if any, should be made not later than
..... month(s) before the date of the oral proceedings.
4. ☐ The request for the oral proceedings to be held as a videoconference
- 4.1 ☐ is allowed.
- 4.2 ☐ is rejected for the reasons indicated on enclosed EPO Form 2906, which is to be dispatched to the party with EPO Form 2008A.

5. ☐ The application is deemed to be withdrawn. The oral proceedings are cancelled.

17.07.2013

Date

R. Manigandhi
Chairman

Second member

Y. J. J. J.
Primary Examiner

Legal member

III. Action taken by the formalities officer

- ☒ EPO Form 2008A/2310A has been dispatched, if applicable (see point II above) together with EPO Form 2906/2906O.
- ☐ A new summons has been dispatched.
- ☐

27.07.13
Date

[Signature]
Formalities Officer



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Date
29-07-2013

Reference 110 895 a/jme	Application No./Patent No. 04773142.7 - 1858 / 1667480
Applicant/Proprietor NIPPON TELEGRAPH AND TELEPHONE CORPORATION	

BRIEF COMMUNICATION

Oral Proceedings on 08.10.13

Subject: ☒ Your letter of 12.07.13

- Communication: ☐ The summons to attend oral proceedings on 08.10.13 has been cancelled.
- ☐ The procedure will be continued in writing.
- ☒ The date fixed for oral proceedings is maintained.
- ☐ A new date will be set later.
- ☐

Please take note.

For the Examining Division



Registered letter
EPO Form 2008A 12.07 (22/07/13)

JR51264



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Application No. :

04 773 142.7

Personal consultation with the applicant / representative

Despatch for information

Participants

Applicant: NIPPON TELEGRAPH AND TELEPHONE CORPORATION

Representative: HOFFMANN EITLE

Member(s) of the
Examining Division: Lastoria, Gianluca

Result of consultation

See Separate Sheet



12.09.2013

.....
Date

Lastoria, Gianluca

.....
Examiner

Enclosure(s):
Form 2906, WO03/069800, XP011044465, XP010636043, XP010593704



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Tel: +49 89 2399 - 7339

Application No. 04 773 142.7 - 1858	Ref. 110 895 a/me	Date 18.09.2013
Applicant NIPPON TELEGRAPH AND TELEPHONE CORPORATION		

Result of consultation

A copy of the result of consultation of 12.09.2013 is enclosed for your information.



Lastoria, Gianluca
For the Examining Division

Enclosure(s): Copy of result of consultation (Form 2036)
Form 2906, WO03/069800, XP011044465, XP010636043, XP010593704

During the telephone conversation held on the 12.09.2013 the examiner informed the Applicant that new documents were going to be introduced in the procedure.

In particular, the following documents will be used during the oral proceedings scheduled for the 08.10.2013.

- D2 EP 1 263 168 A2 (TOSHIBA KK [JP]) 4 December 2002 (2002-12-04)
- D4 WO 03/069800 A1 (NOKIA CORP [FI]; TIRKKONEN OLAV [FI]; SOININEN PEKKA [US]) 21 August 2003 (2003-08-21)
- D5 REINHARD BECHER ET AL: "Broad-Band Wireless Access and Future Communication Networks", PROCEEDINGS OF THE IEEE, IEEE. NEW YORK, US, vol. 89, no. 1, 1 January 2001 (2001-01-01), XP011044465, ISSN: 0018-9219
- D6 YA-HAN PAN ET AL: "Dynamic sub-channel allocation with adaptive beamforming for broadband ofdm wireless systems", GLOBECOM'02. 2002 - IEEE GLOBAL TELECOMMUNICATIONS CONFERENCE. CONFERENCE PROCEEDINGS. TAIPEI, TAIWAN, NOV. 17 - 21, 2002; [IEEE GLOBAL TELECOMMUNICATIONS CONFERENCE], NEW YORK, NY : IEEE, US, vol. 1, 17 November 2002 (2002-11-17), pages 711-715, XP010636043, DOI: 10.1109/GLOCOM.2002.1188171 ISBN: 978-0-7803-7632-8
- D7 KOUTSOPOULOS I ET AL: "Adaptive resource allocation in SDMA-based wireless broadband networks with OFDM signaling", PROCEEDINGS IEEE INFOCOM 2002. THE CONFERENCE ON COMPUTER COMMUNICATIONS. 21ST. ANNUAL JOINT CONFERENCE OF THE IEEE COMPUTER AND COMMUNICATIONS SOCIETIES. NEW YORK, NY, JUNE 23 - 27, 2002; [PROCEEDINGS IEEE INFOCOM. THE CONFERENCE ON COMPUTER COMMUNI, vol. 3, 23 June 2002 (2002-06-23), pages 1376-1385, XP010593704, DOI: 10.1109/INFCOM.2002.1019388 ISBN: 978-0-7803-7476-8

Datum
Date 18.09.2013
Date

Blatt
Sheet 2
Feuille

Anmelde-Nr:
Application No: 04 773 142.7
Demande n°:

In particular, document D2 and D4 will be used for assessing the inventive step of the subject-matter of the claims of both main and auxiliary request (*please see the attached form 2906*) while D5 to D7 will be used as support for common general knowledge on MIMO technology.

Dynamic Sub-channel Allocation with Adaptive Beamforming for Broadband OFDM Wireless Systems[†]

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Abstract—Orthogonal frequency division multiplexing (OFDM) has been widely regarded as an effective modulation technique for mitigating the effects of ISI in a frequency selective fading channel and for providing reliable high data rate transmission over wireless links. Adaptive antenna arrays at the base and mobile stations can achieve further increases in system's capacity and bandwidth efficiency, as well as in QoS improvement in conventional OFDM systems. The conventional adaptive antenna arrays based OFDM systems always use the sub-carriers characterized by the first largest eigenvalues to transmit the OFDM block symbols. In this paper and in contrast to previous work, we proposed dynamic sub-channel allocation with adaptive beamforming for broadband OFDM wireless transmission systems. The proposed system adaptively selects the eigenvectors associated with the relatively large sub-channel eigenvalues to generate the beamforming weights at the mobile and base stations and then dynamically assigns the corresponding best sub-channels to transmit the OFDM block symbols. It is shown by simulation that, without adding much complexity, the proposed system can achieve a better performance than an adaptive antenna arrays based OFDM system without dynamic sub-channel allocation over multipath fading channels. Simulation results also reveal that the proposed system is not too sensitive to channel estimation errors.

I. INTRODUCTION

The next-generation mobile wireless communication systems are expected to place stringent demands for high quality, high data rates, and high capacity over mobile radio channels [1]. To achieve these objectives, various technical challenges must be overcome. One challenge is how to provide high data rate with high quality of services (QoS) over hostile mobile environments with limited spectrum and intersymbol interference (ISI) caused by multipath fading. Orthogonal frequency division multiplexing (OFDM) has been widely regarded as an effective modulation technique for mitigating the effects of ISI in a frequency selective fading channel and for providing reliable high-data transmission over wireless links [2]. As a result, this technique has been receiving tremendous interest and has been recently selected as the air-interface technology for many standards including digital audio broadcasting

(DAB), digital terrestrial video broadcasting (DVB-T), and wireless local-area networks (WLAN) standards such as IEEE 802.11a and ETSI BRAN Hiperlan II and ARIB MMAC [3].

Recent studies have also shown that multiple antennas based spatio-temporal parallel processing at both the transmitter and receiver promises to provide significant increases in a system's capacity and bandwidth efficiency as well as in QoS improvement in wireless communications [4], [5]. Although multiple-input multiple-output (MIMO) systems may not be practical in current mobile systems, reductions in antenna sizes and the emerging use of portable computers in wireless systems will make this feasible in the near future. Therefore, it is worthwhile investigating the use of smart antennas at both the base and mobile stations which operate jointly and, in particular, the use of MIMO systems with OFDM. In fact, adaptive antenna arrays at both the base and mobile stations have been recently suggested to achieve further increases in capacity as well as improvements in the performance of OFDM systems [6]. In this previous work, the eigenvalue decomposition method (EVD), based on the joint optimal transmit and receive antenna weights, was proposed for multipath fading channels. The objective was to maximize the signal-to-noise ratio (SNR). Given the eigenvectors associated with the first largest eigenvalues on each sub-carrier, the optimal weights for the transmit and receive antennas in each sub-carrier were obtained. It was shown that the system in [6] could effectively resolve the problem of ISI and cochannel interference (CCI). By doing so, great reductions in average bit error probability, compared to those of conventional OFDM systems with a single antenna at the transmitter and receiver, can be obtained. However, this previous work only deals with the sub-channels related to the first largest eigenvalues and does not take into consideration the other sub-channels. In general, the entire channels are divided into N narrow parallel sub-carriers in OFDM, and each sub-carrier mainly experiences flat fading. Each sub-carrier can be further decomposed into several parallel spatial sub-channels characterized by their eigenvalues using the EVD method on each sub-carrier channel matrix. It is then possible that the first largest eigenvalues of some sub-carriers are smaller than, say, the second largest eigenvalues of others sub-carriers. Therefore, adaptive antenna arrays based OFDM which always uses the first largest eigenvalues is not the best way to transmit the fixed-throughput N parallel symbols. Instead, these N parallel symbols should be transmitted over N sub-channels associated with the largest eigenvalues selected from all the spatial sub-channels, instead of only using the first largest eigenvalues. It

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will be shown through analysis and simulation that indeed significant performance improvement can be achieved by only selecting the sub-channels that correspond to only the first and second largest eigenvalues.

In this paper, we propose dynamic spatial sub-channel allocation with adaptive beamforming for broadband OFDM wireless transmission systems. By applying an EVD on each sub-carrier channel matrix, the two parallel spatial sub-channels corresponding to the first largest eigenvalue and second largest eigenvalue in each sub-carrier can be obtained. Then, the eigenvectors associated with the N largest eigenvalues (out of the $2N$ already identified first and second largest eigenvalues) are adaptively selected to generate the beamforming weights at the mobile and base stations. By doing so, the corresponding best sub-channels are always dynamically assigned for data transmission. As a result, a better performance than that of the conventional adaptive antenna arrays based OFDM system over multipath fading channels can be achieved.

The rest of this paper is organized as follows. Section 2 describes the proposed system model, while Section 3 describes the proposed dynamic spatial sub-channel allocation strategy. In Section 4, we present sample simulation results to demonstrate the potential of the proposed method. We also investigate the effects of channel estimation errors on the proposed system in this section. Finally, we present our conclusion in Section 5.

II. SYSTEM MODEL

The system under consideration is given in Fig. 1. The serial-to-parallel unit converts a fixed-throughput binary source $\mathbf{d} = [d_0, d_1, \dots, d_{N-1}]$ into N parallel output symbols which represent N parallel sub-carriers in the frequency domain. The N best parallel sub-channels are allocated to transmit N parallel symbols $\mathbf{d} = [d_0, d_1, \dots, d_{N-1}]$ as will be discussed in the next section. Then, beamforming for each allocated sub-channel is performed with M antenna weights. The inverse fast Fourier transform (IFFT) transforms the beamformed symbols into time-domain samples. These samples are transmitted through M antennas over fading channels after the parallel-to-serial conversion is completed and the cyclic extension with length G is inserted.

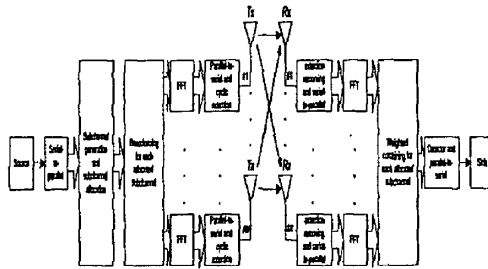


Fig. 1: Proposed OFDM system with dynamic sub-channel allocation and adaptive beamforming

At the receive side, the cyclic extension of each received signal is removed and the signal is transformed back into the frequency domain with an FFT. The output symbols on the allocated sub-

channels from K receiving antennas are then weighted and combined to form the array of output signals $\hat{\mathbf{d}} = [\hat{d}_0, \hat{d}_1, \dots, \hat{d}_{N-1}]$. Finally, the transmitted data are estimated and converted back into a serial form.

The wireless communication channel can be characterized by a multipath fading channel and can be represented by its impulse response using a L -ray model described by

$$h_{m,k}(t) = \sum_{j=0}^{L-1} \gamma_{m,k}^j \delta(t - \tau_{m,k}^j), \quad (1)$$

where $\tau_{m,k}^j$ is the time delay for the j th path of the diversity channel between the m th and k th antenna at the transmitter and receiver, respectively and $\gamma_{m,k}^j$ is the corresponding complex gain. Likewise, L is the total number of paths. Throughout this paper, $\gamma_{m,k}^j$'s are modeled as zero mean, stationary complex Gaussian processes, which are independent for different paths.

Let $\tilde{\mathbf{h}}(\tilde{n})$ denote the discrete-time channel matrix, then

$$\tilde{\mathbf{h}}(\tilde{n}) = \begin{bmatrix} \tilde{h}_{1,1}(\tilde{n}) & \tilde{h}_{1,2}(\tilde{n}) & \dots & \tilde{h}_{1,K}(\tilde{n}) \\ \tilde{h}_{2,1}(\tilde{n}) & \tilde{h}_{2,2}(\tilde{n}) & \dots & \tilde{h}_{2,K}(\tilde{n}) \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{h}_{M,1}(\tilde{n}) & \tilde{h}_{M,2}(\tilde{n}) & \dots & \tilde{h}_{M,K}(\tilde{n}) \end{bmatrix}, \quad (2)$$

where $\tilde{h}_{m,k}(\tilde{n})$ is equal to $(g \otimes h_{m,k})|_{t=\tilde{n}T}$ in which $g(t)$ is the pulse shaping function at the transmitter, and $\otimes$ denotes the convolution operator between two continuous time signals.

If the cyclic extension length G is larger than the delay spread $\tau_{\max}$, where $\tau_{\max}$ is the largest delay spread of the fading channel, then the channel convolutions become cyclic. Hence, in the frequency domain all sub-channels remain orthogonal and the convolutions become equivalent to multiplication with the Fourier transform of the channel $\tilde{\mathbf{h}}(\tilde{n})$, $\mathbf{H}^T$. Denote the transmitting beamforming coefficient and the receiving weighting coefficient for the i th sub-carrier of the m th transmit antenna and the k th receive antenna as $w_{i,m}^T$ and $w_{i,k}^R$, respectively. Also let

$$\mathbf{W}_i^T = [w_{i,1}^T, w_{i,2}^T, \dots, w_{i,M}^T]^T \text{ and } \mathbf{W}_i^R = [w_{i,1}^R, w_{i,2}^R, \dots, w_{i,K}^R]^T. \text{ Then,}$$

the received signal, $\hat{d}_i$, for sub-carrier i can be written as

$$\hat{d}_i = (\mathbf{W}_i^R)^H (\mathbf{H}^T)^T \mathbf{W}_i^T d_i + (\mathbf{W}_i^R)^H \mathbf{n}^T, \quad (3)$$

where the superscript H denotes the Hermitian operation, the superscript T denotes the transpose operation, and $\mathbf{n}^T$ is a $K \times 1$ column vector with elements modeled as complex additive white Gaussian noise (AWGN) with variance σ_n^2 .

III. DYNAMIC SUB-CHANNEL ALLOCATION

In this section, dynamic spatial sub-channel allocation with adaptive beamforming for MIMO/OFDM systems is presented. We assume that the channel state information is available at the receiver and is then fed back to the transmitter via an ideal feedback channel. Consider a single-user downlink system with M transmitting antennas and K receiving antennas ($M \geq K \geq 2$) as shown in

Fig. 1. Let $\hat{d}_i$ be described as in (3), and assume that the transmitting beamforming vector, $\mathbf{W}_i^t$, is computed at the receiver and then transmitted to the transmitter via an uplink feedback channel. The receiving weights vector is set to be $\mathbf{W}_i^r = (\mathbf{H}^i)^H \mathbf{W}_i^t$.

Then, $\hat{d}_i$ can be written as

$$\hat{d}_i = (\mathbf{W}_i^r)^H (\mathbf{H}^i)^H (\mathbf{H}^i)^T \mathbf{W}_i^t d_i + (\mathbf{W}_i^r)^H (\mathbf{H}^i)^H \mathbf{n}^i, \quad (4)$$

where the superscript $*$ denotes the complex conjugate operation. By applying EVD on the i th sub-carrier channel matrix $[(\mathbf{H}^i)^H (\mathbf{H}^i)^T]$ [7], n_i ($\leq \min(M, K)$) parallel spatial sub-channels can be generated at this frequency sub-carrier. We assume that the transmitted data and received data on the l th sub-channel of the i th sub-carrier are denoted by $d_{i,l}$ and $\hat{d}_{i,l}$, respectively. Since the probability that the third largest eigenvalue of a sub-carrier is larger than those of the N relatively larger eigenvalues selected from the first and second largest eigenvalues of all sub-carriers is very low (will be further discussed at the end of this section), it follows that we only need to consider the two sub-channels corresponding to the first largest eigenvalue and the second largest eigenvalue on each sub-carrier. By doing so, the received data on the l th sub-channel of the i th sub-carrier can be written as

$$\hat{d}_{i,l} = (\mathbf{W}_{i,l}^r)^H (\mathbf{H}^i)^H (\mathbf{H}^i)^T \mathbf{W}_{i,l}^t d_{i,l} + (\mathbf{W}_{i,l}^r)^H (\mathbf{H}^i)^H \mathbf{n}^i \quad (l=1,2). \quad (5)$$

Assuming that the beamforming vector, $\mathbf{W}_i^t$, is chosen to maximize the instantaneous SNR at the receiver output on sub-channel l . Then, the optimum $\mathbf{W}_{i,l}^t$ and the resulting equivalent, $\hat{d}_{i,l}$ on the l th ($l=1,2$) sub-channel of the i th sub-carrier can be rewritten as follows [6] [8]

$$(\mathbf{W}_{i,l}^t)_{\text{opt}} = \arg \max_{\|\mathbf{W}_{i,l}^t\|=1} \{ (\mathbf{W}_{i,l}^t)^H (\mathbf{H}^i)^H (\mathbf{H}^i)^T \mathbf{W}_{i,l}^t = \text{eigvec}_{\text{max}} [(\mathbf{H}^i)^H (\mathbf{H}^i)^T] \} \quad (6)$$

$$(\mathbf{W}_{i,l}^r)_{\text{opt}} = \arg \max_{\|\mathbf{W}_{i,l}^r\|=1} \{ (\mathbf{W}_{i,l}^r)^H (\mathbf{H}^i)^H (\mathbf{H}^i)^T \mathbf{W}_{i,l}^t = \text{eigvec}_{\text{max}} [(\mathbf{H}^i)^H (\mathbf{H}^i)^T] \}, \quad (7)$$

and

$$\hat{\mathbf{d}}_i = \Gamma_i \mathbf{d}_i + \mathbf{n}^i, \quad (8)$$

$$\Gamma_i = \text{diag} \left(\sqrt{\lambda_{\text{max}} [(\mathbf{H}^i)^H (\mathbf{H}^i)^T]}, \sqrt{\lambda_{\text{sec}} [(\mathbf{H}^i)^H (\mathbf{H}^i)^T]} \right), \quad (9)$$

where $\hat{\mathbf{d}}_i = [\hat{d}_{i,1}, \hat{d}_{i,2}]^T$, $\mathbf{d}_i = [d_{i,1}, d_{i,2}]^T$, $\lambda_{\text{max}} [\mathbf{A}]$ and $\text{eigvec}_{\text{max}} [\mathbf{A}]$ are the first largest eigenvalue and eigenvector of the matrix $\mathbf{A}$, respectively. Likewise, $\lambda_{\text{sec}} [\mathbf{A}]$ and $\text{eigvec}_{\text{sec}} [\mathbf{A}]$ are the second largest eigenvalue and eigenvector of the matrix $\mathbf{A}$, respectively. Finally, $\mathbf{n}^i$ is a $n_i \times 1$ column vector with elements modeled as AWGN with zero mean and variance σ_n^2 . Hence, each sub-carrier can be approximately divided into two major spatial sub-channels, and each received sub-channel signal is effectively the transmitted symbol weighted by an equivalent channel gain and corrupted by white noise. Assuming QPSK modulation, we can

write the instantaneous BER, $P_{\text{eb}}^{i,l}$, for sub-channel l of sub-carrier i given $\mathbf{H}^i$ and $\mathbf{W}_i^{t,l}$ ($l=1,2$) as follows

$$P_{\text{eb}}^{i,1} = Q \left(\sqrt{\frac{2E_b}{N_0} \cdot \lambda_{\text{max}} [(\mathbf{H}^i)^H (\mathbf{H}^i)^T]} \right), \quad (10)$$

$$P_{\text{eb}}^{i,2} = Q \left(\sqrt{\frac{2E_b}{N_0} \cdot \lambda_{\text{sec}} [(\mathbf{H}^i)^H (\mathbf{H}^i)^T]} \right), \quad (11)$$

where E_b is the energy per bit, N_0 is the single-sided white noise spectral density ratio, which is equal to σ_n^2 , and

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^\infty e^{-\frac{u^2}{2}} du. \quad \text{Since } Q(x) \text{ is a strictly decreasing}$$

function of $x \geq 0$, it follows that if $\lambda_{\text{sec}} [(\mathbf{H}^i)^H (\mathbf{H}^i)^T]$ is larger than $\lambda_{\text{max}} [(\mathbf{H}^j)^H (\mathbf{H}^j)^T]$ ($j \neq i$), then $P_{\text{eb}}^{j,2}$ is lower than $P_{\text{eb}}^{i,1}$. Thus, the instantaneous quality of the second sub-channel of sub-carrier j is better than that of the first sub-channel of sub-carrier i .

Since some $\lambda_{\text{sec}} [(\mathbf{H}^j)^H (\mathbf{H}^j)^T]$'s are larger than some $\lambda_{\text{max}} [(\mathbf{H}^i)^H (\mathbf{H}^i)^T]$'s ($j \neq i$), an adaptive antenna arrays based OFDM, which always uses the first largest eigenvalues, is not the best way to transmit $\hat{\mathbf{d}} = [\hat{d}_0, \hat{d}_1, \dots, \hat{d}_{N-1}]$. In other words, for a fixed-throughput binary source $\mathbf{d} = [d_0, d_1, \dots, d_{N-1}]$, assigning the transmitted data $\mathbf{d}_i$ to the first sub-channel with the first largest eigenvalue $\lambda_{\text{max}} [(\mathbf{H}^i)^H (\mathbf{H}^i)^T]$ of sub-carrier i doesn't always turn out to be a good allocation strategy. Instead, we should assign some transmitted data $\mathbf{d}_i$ to the second sub-channels with the second largest eigenvalues $\lambda_{\text{sec}} [(\mathbf{H}^j)^H (\mathbf{H}^j)^T]$ of sub-carrier j . The best way to transmit N symbols $\hat{\mathbf{d}} = [\hat{d}_0, \hat{d}_1, \dots, \hat{d}_{N-1}]$ is, therefore, to assign these symbols to the N spatial sub-channels selected from both the N spatial sub-channels corresponding the first largest eigenvalues and the N sub-channels corresponding the second largest eigenvalues. By doing so, an adaptive sub-channel allocation strategy would result. Such dynamic allocation will select the N best parallel sub-channels from the $N \times 2$ spatial sub-channels, corresponding to the first and second largest eigenvalues to transmit N parallel symbols. Since the eigenvectors associated with relatively larger eigenvalues are adaptively selected to generate the beamforming weights at the mobile and base stations and the associated best spatial sub-channels are always dynamically assigned to transmit data, a significant performance improvement can be achieved compared to that of conventional adaptive antenna arrays based OFDM systems.

IV. SIMULATION RESULTS

In this section, we present some simulation results and comparisons that demonstrate the potential of our proposed system. The proposed approach is investigated for broadband wireless transmission by computer simulation over a 4th-order multiray (MR) frequency-selective Rayleigh fading channel. A L th-order multiray

channel consists of $L+1$ equal-power channel taps with each tap modeled as a complex Gaussian random variable with zero mean and variance $1/(L+1)$ [9]. The RMS delay spread of the 4th-order MR channel we use is $1.4142 \mu\text{s}$. We consider an OFDM system employing QPSK with 128 sub-carriers and different antenna configurations. In this case, the number of bits per OFDM symbol is 256. We use one OFDM symbol of $148 \mu\text{s}$ comprised of one OFDM data symbol duration of $128 \mu\text{s}$ and a cyclic prefix duration of $20 \mu\text{s}$. We also assume that ideal channel state information (CSI) is known at both the base and mobile stations.

Fig. 2 shows the average bit error probability of the proposed system with various numbers of adaptive antennas at both the base and mobile stations versus the average bit energy-to-noise spectral density ratio (E_b/N_0). Throughout this section, we use the notation B_iM_j where i denotes the number of antennas at the base station and j denotes the number of antennas at the mobile station. For example, B3M2 means that three transmitting antennas and two receiving antennas are used at the base station and at the mobile station, respectively. For comparison, the performance of the conventional adaptive antenna arrays based OFDM system without dynamic spatial sub-channel allocation is also plotted. A close observation of this figure indicates that performance improvement is achieved when the proposed approach is used. For example, a gain of about 2.5dB is achieved by using dynamic sub-channel allocation for a BER of 10^{-5} with the B2M2 configuration. Likewise, a gain of about 1.5dB for a BER of 10^{-5} is achieved with the B3M2 configuration. Finally, a gain of about 1dB for a BER of 10^{-5} is obtained with the B3M3 configuration. This is mainly because the proposed dynamic sub-channel allocation avoids transmitting over the sub-channels that are in deep fade. These deep faded sub-carriers are replaced in the proposed system by other better sub-channels which correspond to the second largest eigenvalues. It should be pointed out that as we increase the number of transmitting or/and receiving antennas, the performance gain of the proposed system,

compared to that of a conventional adaptive arrays based OFDM system, decreases. This is expected as the variation of the eigenvalues become more moderate as the number of antennas increases.

Channel state information is obviously very critical in the proposed system. The channel must be estimated at the receiver and is then fed back to the transmitter via a feedback channel. The results listed in Fig. 2 assume perfect channel estimation and, hence, indicate the potential performance gain of the proposed system over that of conventional adaptive antenna arrays based OFDM systems. It is important, however, to investigate the robustness of the proposed scheme to channel estimation errors. Usually, this can be measured in terms of the Mean Square Error (MSE) which is defined by [10]

$$MSE = E \left\{ \frac{1}{NMK} \left\| \hat{\mathbf{H}}^T - \mathbf{H}^T \right\|^2 \right\}. \quad (12)$$

In Fig. 3, we present the effects of channel estimation errors on the BER performance of the proposed system under the configuration of B2M2 over the MR channel. Furthermore, the BER curves for various MSE values for the conventional adaptive antenna arrays based OFDM system with the same configuration are also shown. In the simulation, estimation errors are introduced by adding a zero-mean complex Gaussian noise to the channel frequency response [11] [12]. It can be observed that the proposed system for a MSE of 1% (-20dB) in channel estimation errors has a performance that is almost as good as the one with ideal channel information at a BER of 10^{-4} , for instance. It is noted, however, that as the MSE increases, the performance of the proposed system degrades and the conventional adaptive antenna arrays based OFDM system outperforms the proposed system for a MSE of -10dB at high SNR value. Fortunately, an MSE lower than 1% can be achieved by using any reasonable channel estimation method such as the estimator described in [13] for the adaptive antenna based multiple-antenna OFDM systems. This is achievable even if the channel SNR is very low. Fig. 4 further lists the performance of the

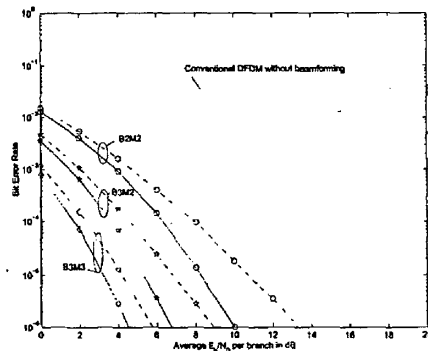


Fig. 2: The BER performance of the conventional OFDM system with beamforming and the proposed system for different antenna configurations under ideal CSI. The conventional OFDM with beamforming and the proposed approach results are listed in dashed and solid lines, respectively.

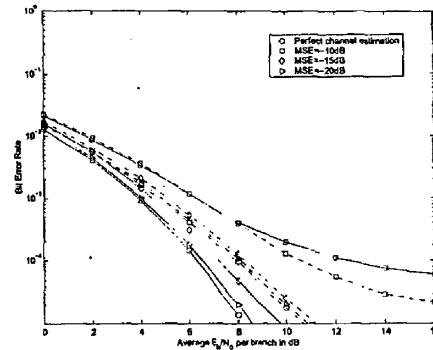


Fig. 3: The BER performance of the conventional OFDM system and the proposed system with B2M2 in the presence of channel estimation errors. The conventional OFDM with beamforming and the proposed approach results are listed in dashed and solid lines, respectively.

proposed adaptive arrays based OFDM system with other antenna arrays configurations under a -20 dB channel estimation error. A close observation of this figure again indicates the performance gain compared to the conventional system. More importantly, it indicates that the proposed system achieves small performance degradation compared to the case where perfect channel estimation is assumed. Therefore, we conclude that the proposed system is not too sensitive to channel estimation errors.

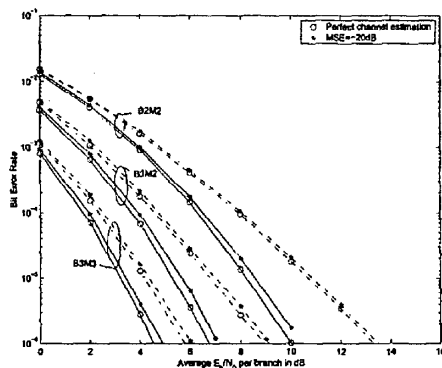


Fig. 4: The effects of channel estimation errors on the BER performance of the proposed OFDM system for different antenna configurations. The conventional OFDM with beamforming and the proposed approach results are listed in dashed and solid lines, respectively.

V. CONCLUSION

The next-generation mobile wireless communication systems are expected to place stringent demands for high quality, high data rates, and higher capacity over mobile radio channels. To meet some of the stated requirements of future wireless communications, this paper proposed dynamic spatial sub-channel allocation with adaptive beamforming for broadband OFDM wireless transmission systems. The proposed MIMO/OFDM system adaptively selects the eigenvectors associated with the largest spatial sub-channel eigenvalues to generate the beamforming weights at the mobile and base stations and then dynamically assigns the corresponding sub-channels to transmit the OFDM block symbols. It was shown that significant performance improvement could be achieved compared to that of conventional adaptive antenna arrays based OFDM systems. It was also shown that the proposed approach was not too sensitive to channel estimation errors. Therefore, the proposed system could prove to be an effective scheme for providing significant increases in system's capacity and bandwidth efficiency as well as bring an improvement in the QoS over wireless communication links.

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Broad-Band Wireless Access and Future Communication Networks

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Invited Paper

This paper presents a vision for wireless communication systems beyond the third generation, which comprises a combination of several optimized access systems on a common IP-based medium-access and core network platform. These different access systems will interwork via horizontal and vertical handover, service negotiation, and global roaming. The different access systems are allocated to different cell layers in the sense of hierarchical cells with respect to cell size, coverage, and mobility to provide globally optimized seamless services to all users. This vision requires extensive international research and standardization activities to solve many technical challenges. Key issues are the global interworking of different access systems on a common platform, the implementation of multimode and multiband terminals and base stations by software-defined radio concepts as well as advanced antenna concepts.

Keywords—Adaptive antennas, IMT-2000, interworking, MIMO channels, mobile communications, software radio, systems beyond the third generation, technical challenges, UMTS, wireless CORBA.

I. FUTURE WIRELESS COMMUNICATION SYSTEMS BEYOND THE THIRD GENERATION

According to forecasts, data traffic in wireline networks routed via IP infrastructure surmounts the traditional voice traffic these days. In addition to this, IP-based data traffic doubles every four months. This process is significantly driven by the deregulation and cost reduction for data transmission (see Fig. 1). This change of paradigm (from voice to data as fastest growing market) has significant impact to the further development of the telecommunication market [1].

In mobile communications, today's main traffic type in terms of users is still voice. However, the usage of the short message service (SMS) in second-generation systems like GSM has increased significantly during the past years. In

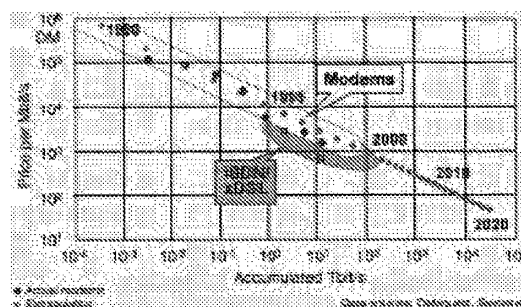


Fig. 1. Digital access technologies—network termination experience curve [2].

Market trend towards multimedia as driving factor in Europe

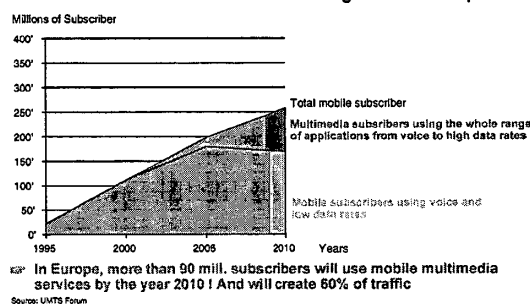


Fig. 2. Use of mobile multimedia services in Europe by the year 2010 [4].

countries with a high mobile penetration, the SMS generates already over 10% of the operators' revenues. The UMTS Forum expects that mobile multimedia services will create around 60% of the whole traffic in Europe (in terms of transmitted bits) by 2010 (see Fig. 2). With the deployment of wireless application protocol (WAP) [3] supporting terminals, a first step toward "Internet on Air," the availability

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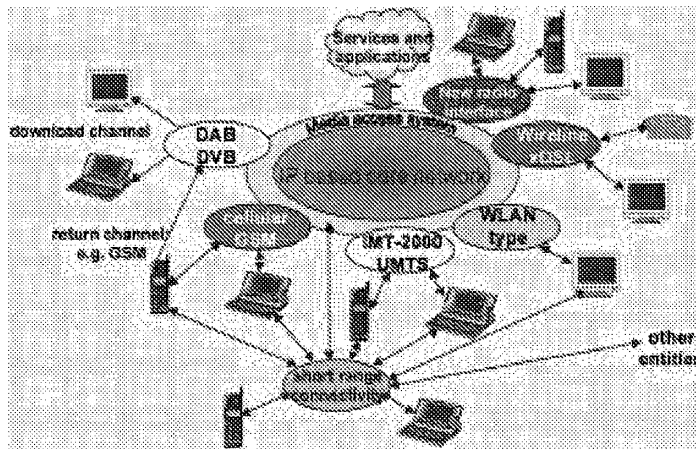


Fig. 3. Seamless future network including a variety of access technologies.

and usage of Internet like mobile data applications will increase significantly. Whereas the first WAP supporting terminals uses circuit switched data bearer, the next generation will use packet data networks, e.g., GPRS for second-generation systems and IMT-2000/UMTS for third-generation systems. Currently these systems are in the deployment or planning phase.

Future communication systems beyond the third generation will be characterized by a horizontal communication model between different access technologies such as cellular, cordless, wireless local area network (WLAN)-type systems, short-range connectivity, broadcast systems, and wired systems as, for instance, explained in [5]. They will be integrated on a common platform to complement each other in an optimum way and to satisfy different service requirements in a variety of radio environments. These access systems will be connected to a common, flexible, and seamless IP core network.

Users will have a single number for all access technologies. A new media access system (generalized access network) that contains the mobility management connects the core network to the appropriate access technology. Global roaming is required for all access technologies. Key requirements include the interworking between these different access systems in terms of horizontal (intrasystem) and vertical (intersystem) handover as well as seamless services with service negotiations including mobility, security, and quality of service (QoS). They will be handled in the (newly developed) media access system and in the core network. Fig. 3 shows this vision of a seamless network that includes a variety of interworking access systems, which are connected to a common IP-based core network. The media access system connects each access system to the common core network.

The different access systems are organized in a layered structure, which can be compared to hierarchical cell structures in cellular mobile radio systems. This concept facilitates an optimum system design for different application areas, cell ranges, and radio environments, since a variety

of access technologies complement each other on a common platform. This layered structure is illustrated in Fig. 4.

- *Distribution layer:* The distribution layer contains emerging digital broadcasting (or distribution) systems such as digital audio broadcasting (DAB), digital video broadcasting (DVB) [6], and satellite systems that have a global coverage and support large cells, full mobility, as well as global access. Individual links are not necessarily needed for broadcasting services. But this technology can also be used as a broad-band downlink channel to provide, for instance, fast Internet content. Basically, all other access systems may be used as return channels for data requests and acknowledgment signaling in highly asymmetric services.
- *Cellular layer:* The cellular layer provides a high-system capacity in terms of users and data rates per unit area. It will consist of second-generation (e.g., GSM and its evolution) and third-generation mobile radio systems (IMT-2000/UMTS: UTRA FDD and TDD) for data rates up to 2 Mb/s [7]. This layer is characterized by full coverage, full mobility, and global roaming and is well suited for multimedia applications. The cellular layer is designed to support individual links.
- *Hot spot layer:* The hot spot layer also supports individual links and is intended for very high data rate applications. It should be employed in hot spots such as in company campus areas, conference centers, and airports. The hot spot layer contains WLAN-type systems as HiperLAN Type 2, IEEE 802.11, or mobile multimedia advanced communications (MMACs). These systems are flexible with respect to asymmetric data services with respect to uplink and downlink, supported data rates, and adaptive modulation. In contrast to cellular systems, this layer contains systems that are characterized by a shorter range and mainly local coverage with local mobility to facilitate an economic system deployment. Global roaming is possible and will be required. Full coverage, however, is not expected.

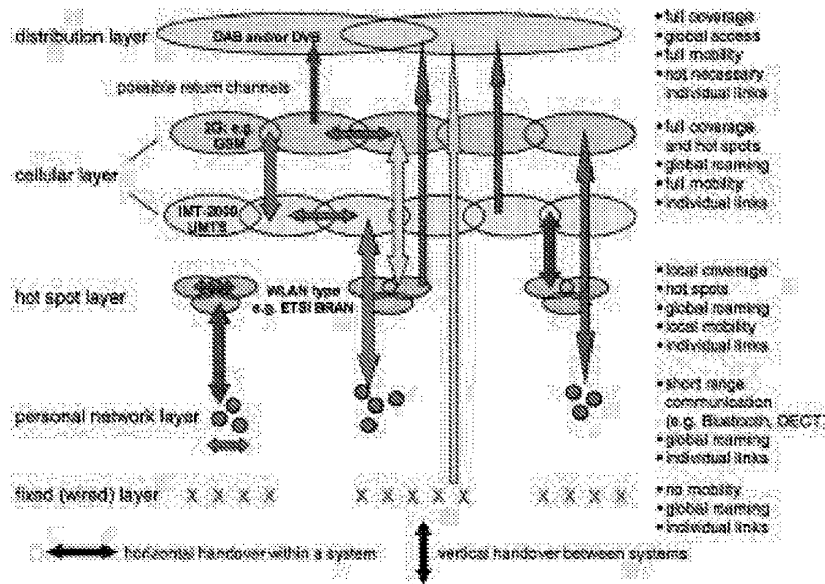


Fig. 4. Layered structure of a seamless future network.

- **Personal network layer:** The personal network layer will mainly be used in office and home (household) environments. Different equipment (laptops, printers, personal digital assistants, etc.) and appliances (refrigerators, toasters, washing machines, smart sensors, etc.) can be connected to each other to provide short-range connectivity via systems such as Bluetooth and DECT. These systems can also be used to connect the equipment directly to the medium-access system or to multimode terminals that can transmit on one of the other network layers and are, of course, also equipped with a short-range connectivity system. This facilitates an efficient interconnection between the devices as well as a connection from these devices to the public network. The systems of the personal network layer in general do not support mobility. Global roaming, however, should be ensured.
- **Fixed (wired) layer:** The fixed layer contains fixed access systems such as optical fiber (e.g., FTTx), twisted pair systems (e.g., xDSL), and coaxial systems (e.g., CATV). Furthermore, fixed wireless access or wireless local loops can be included in this category. Fixed access systems should support mobility (portability) in the sense of terminal portability such that global roaming is feasible. These systems of the fixed layer have a high capacity and in general do support individual links.

The network ensures the interworking between these systems on the common platform by horizontal handover within an access system and, in particular, by vertical handover between different access systems. In general, vertical handover takes place between different layers of the common platform. Vertical handover is combined with service negotiations to

ensure seamless service, because in general different access systems support different user data rates and other bearer and service parameters. The interworking, mobility management, and roaming will be handled via the medium-access system and the IP-based core network (Fig. 3).

Multimode terminals and new appliances are key components of such a seamless network. Among other features, these terminals might comprise a camera, a screen for video and high-resolution Internet applications as well as transceivers that provide short-range connectivity for *ad hoc* networking with other devices. Such terminals may be adaptive with respect to different standards and channel conditions due to sophisticated signal processing algorithms.

Future wireless systems beyond the third generation require the integration of various network technologies stretching from current computer networks to the wireless world. Different enabling technologies starting from low-level signal processing up to the management of distributed network entities must be considered when heterogeneous networks merge together.

In this technology survey, the requirements and possible solutions for both are derived. This vision will be established by allowing an optimized usage of the spectrum resources, a provision of increased flexibility on the terminal side and in the network, the support of global roaming, the personalization of services as well as self-planning and self-configuration of networks.

A variety of networks has created an important need to enhance current middleware concepts for the wireless world. In particular, the reconfiguration of terminals and other network components demands a network management vision with a seamless connection between heterogeneous networks and a new transparency throughout. The forthcoming standard-

ization of wireless CORBA [8] may be a key driver in the integration of existing and future networks by introducing reliable reconfiguration among the network entities and terminals. A framework for reconfiguration is presented with a proposed terminal architecture, and it is shown how the current well-known mobile execution concepts based on the virtual machine (VM) approach can be combined with the CORBA methodology for a reliable reconfiguration. The reconfiguration process can be seen as a special user application and the individual phases in the reconfiguration process are outlined, which need to be taken into account in the forthcoming standardization of wireless CORBA.

The remainder of this paper is organized as follows. The technical challenges for future wireless communication systems beyond the third generation are outlined in Section II. They include the medium-access system illustrated in Fig. 3 and new radio technologies. Then, capacity enhancing features are described in Section III. These features include smart antenna concepts (Section III-A), uplink processing with smart antennas (Section III-B), downlink processing with smart antennas (Section III-C), and multiple antennas at the base station and at the terminal (Section III-D). Finally, Section IV deals with software radio aspects.

II. TECHNICAL CHALLENGES

Many technical challenges have to be solved by extensive research efforts to realize the vision for wireless communication systems beyond the third generation described in the previous section. Key concepts include the interworking between different access systems on a common platform as well as the required adaptive multimode and multiband terminals for different access systems and a wide range of services [5]. There are challenges in several areas such as the radio interface, the radio access network and the core network, implementation issues, and services-related issues. New technologies for tackling increased flexibility and improved transmission performance have to be developed. Furthermore, there are demands on the increase of the transmission capability and versatility of networks and terminals through the support of reconfiguration, the provision of self-planning and self-configuration of networks as well as the support of personal services and service mobility. Future system concepts have to address the terminal architecture in addition to concepts that enable the reliable reconfiguration across network entities. Enabling technologies include analog RF and analog and/or digital IF. New designs evolve to realize linear power amplifiers with a high dynamic range, enhanced digital signal processing, and software techniques that facilitate the programming of distributed components [9].

From the user's point of view, the man-machine interface has to be easy to use and self-explanatory to enable people—even handicapped and elderly people—to use easily advanced services. The content has to be adapted automatically to the actual bearer capability of the used access system.

To this end, extensive international research activities are necessary to solve technical issues and to prepare the consensus building for the international standardization of

new ideas and concepts. Major challenges include the interworking of systems via vertical handover, global roaming, and the optimization of evolving and emerging access systems as well as the radio access and core network.

A. Medium-Access System

Higher layer protocols in the access network (medium-access system) are an important area to improve the system performance even further. These are, for example:

- self-optimizing networks and automatic planning;
- resource allocation algorithms with respect to varying traffic load, services, bearer capabilities, radio environment, and channel conditions;
- dynamic frequency allocation;
- interworking of different access systems on higher layers via horizontal and vertical handover and service negotiation;
- network management.

The interworking of different access systems on an IP-based common platform via the medium-access system with horizontal and vertical handover results in several challenges on the core and the medium-access system. Major topics are related to the improvement and extension of IP for mobile applications and the optimization for radio transmission, such as:

- support of real-time and nonreal-time services with respect to service requirements as QoS and especially delay requirements for real-time services;
- service negotiation for seamless services versus the available access systems and bearer capabilities;
- mobility management including handover and roaming;
- security mechanism such as authentication, authorization, and accounting.

B. New Radio Technologies

In spite of the fact that only existing and emerging communication systems have been mentioned in Section I, systems that use new radio technologies will also be integrated into such a seamless future network. Such new radio technologies include, for instance, generalized multicarrier (GMC) CDMA systems that are capable of multiuser interference (MUI) elimination and intersymbol interference (ISI) suppression, irrespective of the encountered wireless frequency selective channel. This channel-independent feature can be obtained via special block-precoding schemes that are described in [10].

There will also be layered *self-organizing networks*, where a whole service area is divided into multiple subservice areas. Only one base station serves one subservice area, as depicted in Fig. 5. Mobile stations that are on the outside of the coverage area of a base station are connected to one of the adjacent base stations through several repeating mobile stations in a self-organizing fashion (multihop architecture). Thereby, a layered self-organizing wireless network can cover a wide area with fewer conventional (fixed) base stations than a conventional cellular network if a sufficient

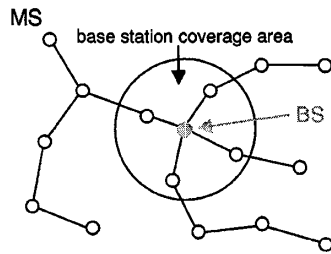


Fig. 5. Subservice area of a layered self-organizing network [11].

penetration of mobiles is available [11]. Hence, less infrastructure is required. Note that the cell size of a cellular system decreases with an increasing demand for capacity. In this case, network planning is not really feasible anymore. Therefore, sophisticated network planning is not necessary and shadowing can be overcome efficiently. Compared to a conventional cellular system, such a self-organizing wireless network requires smaller transmission powers that lead to a reduced overall interference situation in the network.

Mobile terminals can, however, only be used as relays in a particular area if a sufficient subscriber density is available. Moreover, the capacity of such terminals must be large enough.

III. SUMMARY OF CAPACITY ENHANCING FEATURES

Future systems have to use the frequency resources as efficient as possible. Therefore, several physical layer related techniques have to be investigated. These include:

- optimization of evolving and emerging access systems by improved modulation and channel-coding schemes for a further enhancement of the spectrum efficiency and system performance;
- advanced detection schemes such as multiuser detection and interference cancellation to gain from the *a priori* knowledge about intra- and intercell interference signals;
- compression techniques for source coding to reduce the needed user data rate.

All the signal processing algorithms that are implemented in practice realize a tradeoff between the achieved performance gain and the involved computing complexity. Improved algorithms to support these mainly physical layer issues are as follows.

- *Link Adaptation* according to the channel conditions and services for a better usage of the frequency resources and an improved system performance. Such link adaptation techniques include adaptive modulation, adaptive equalization, adaptive power control, and adaptive channel coding. Note that a feedback channel from the terminal to the base station might be required to insure a robust performance. If the channel is fading, adaptive modulation techniques can achieve a significant fraction of the channel capacity [12]. For multiple-input-multiple-output (MIMO) systems this implies varying the modulation format and bit rate across

antennas and across time. Alternative modulation independent signal processing schemes for MIMO channels are discussed in Section III-D.

- *Adaptive Radio Resource Management* to take into account the present traffic load. This includes dynamic radio channel allocation, power control techniques, admission- and load control strategies, congestion control, handover strategies, and resource scheduling. The cell size, their layout, and hierarchical cell structures must also be considered.
- *Adaptive Spectrum Management* techniques between different access systems and the investigation of *coexistence conditions* between different radio access systems.
- *Advanced Antenna Concepts* to improve the link quality and channel capacity (Fig. 6).

These concepts are used to increase the channel capacity of the radio link. Diversity concepts like frequency diversity, time diversity, polarization diversity, or space diversity reduce the impact of fading due to multipath propagation. As an example for capacity enhancing features, an overview of adaptive antenna concepts is given in the sequel. These are key concepts to use the scarce frequency spectrum as efficiently as possible without major impacts on evolving access systems. Third-generation mobile radio systems (IMT-2000/UMTS) have already taken into account necessary prerequisites for adaptive antenna concepts. However, an economic implementation of the different RF front ends and the baseband signal processing are technical challenges.

A. Smart Antenna Concepts

Smart antennas can be realized by an antenna array and intelligent (baseband) signal processing. The antenna array may be located at the base station and/or the mobile terminal depending on the array size. First, we assume that only the base station is equipped with an antenna array. The antenna array is used for adaptive directional reception (on the uplink) and adaptive directional transmission (on the downlink). Thereby, an increased antenna gain and an increased diversity gain are realized toward the desired user, as illustrated in Fig. 7. At the same time, less interference is received from the other directions on the uplink or transmitted in the other directions on the downlink. Therefore, more users can be accommodated by the system and a corresponding capacity increase is achieved.

In contrast to user-dedicated traffic channels, the broadcast channels should be transmitted in an omnidirectional or sectorized fashion. Hence, there is neither an additional antenna array gain nor a diversity gain for these broadcast channels. If no countermeasures are taken, the broadcast channels have a smaller maximum range than the user-specific channels that can be transmitted in a space-selective fashion if the transmit power is the same for both types of channels. To compensate this effect, space-time coding [13] and/or a higher spreading gain may be used for the omnidirectional or sectorized broadcast channels.

1) *Smart Antennas in TDMA-Based Cellular Systems:* In TDMA-based cellular systems, smart antenna concepts can

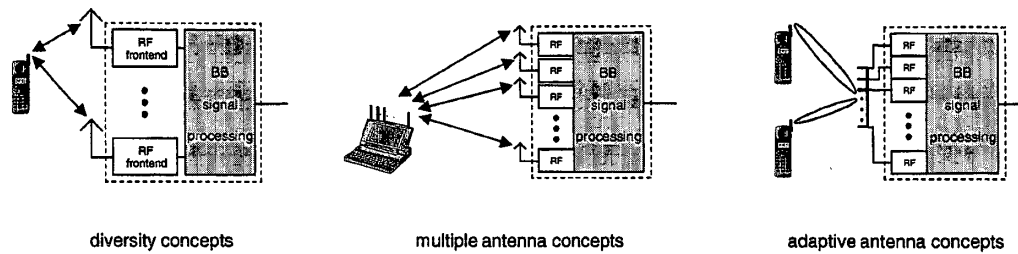


Fig. 6. Advanced antenna concepts.

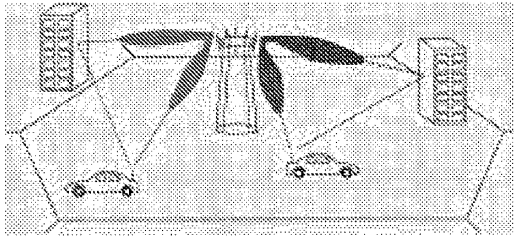


Fig. 7. Smart antennas at the base station of a mobile radio system illustrated for two cochannel users.

be classified according to their area of application [14] as described in the following.

a) High-sensitivity reception (HSR): In the first case, smart antennas are only used on the uplink to increase the uplink antenna gain and suppress cochannel interference. Thereby, the system capacity is increased on the uplink, and the transmit power of mobile stations in a cell served by smart antennas can be reduced. On the more critical downlink, the system capacity is not increased. A range extension and a reduction of base station sites is only possible by balancing the downlink with an increased transmit power.

b) Spatial filtering for interference reduction (SFIR): In the SFIR concept, smart antennas are employed on the uplink as well as the downlink (balanced operation). Thereby, an increased antenna gain and a significant interference reduction can be achieved on both links. Therefore, the frequency reuse distance can be reduced, which leads to an increase of capacity due to a tighter frequency reuse and an increased load in the network. Note that only one cochannel user is served per time and frequency slot.

c) Space-division multiple access (SDMA): In this most advanced mode of operation, which includes uplink and downlink processing, several cochannel users can be served on a single time and frequency slot. Spatial multiplexing through a directional reuse of the spectrum resources leads to a direct capacity increase.

2) Smart Antennas in CDMA-Based Cellular Systems: In CDMA-based systems, there are several cochannel users that are inherently separated by different spreading codes. More and more cochannel users can enter the system until a certain multiple-access interference level has been reached. Here, directional transmission and reception at the base station via smart antennas causes a significant reduction of the multiple-access interference. Therefore, more users can be ac-

commodated by the system and a corresponding capacity increase is achieved. Similar concepts as for TDMA-based systems are applicable.

B. Uplink Processing with Smart Antennas

1) Space-Only Processing: In case of several antennas at the base station, space-only processing (spatial beamforming) is sufficient if the wireless channel has a small delay spread with respect to the chip or symbol duration. Otherwise, a subsequent temporal equalizer is necessary, yielding a hybrid structure that consists of two stages and performs decoupled spatial and temporal processing. Spatial beamforming techniques can be classified into nonadaptive and adaptive techniques.

a) Switched beams: In the switched beam approach, the direction of the beams is not adaptive. There is a beamformer in the RF stage that forms multiple nonadaptive beams. These fixed beams may be generated by independent fixed antennas or by an RF beamforming network that performs a DFT (Butler matrix). In practice, there might be 4–8 beams per sector (assuming that a base station has three sectors of 120°). A switch is used to select the best or the best two beams for the receiver and the transmitter. Existing diversity antennas can easily be replaced by a switched beam antenna system.

The performance gains are due to the array gain, the diversity gain, and a reduced interference if the desired signal and the interference are well separated in angle such that they fall into different beams.

b) Adaptive beamforming: Adaptive spatial beamforming techniques (space-only processing) can be based on the estimated spatial signature, which might be a superposition of several array steering vectors, and/or the transmitted training symbols as, for instance, in the spatial LMS algorithm. They are more flexible than the fixed beam approach, since they provide an improved suppression of interferers by spatial notching and an increased gain for the desired signal. Digital beamforming is achieved via baseband signal processing. In general, M transceivers are required for M antennas.

2) Space-Time Processing: Joint space-time processing schemes achieve a better performance than purely spatial beamforming algorithms. An efficient implementation of joint space-time processing for joint (multiuser) detection in UTRA TDD is described in [15]. Here, the intracell interference is eliminated via joint detection in the space-time

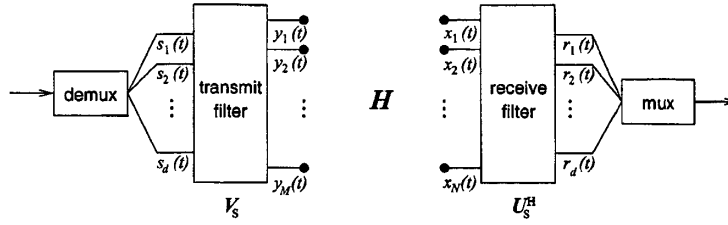


Fig. 8. Illustration of a MIMO wireless communication system with M transmit and N receive antennas, where d parallel data streams are transmitted via d virtual subchannels ($d \leq \min\{M, N\}$).

domain. Moreover, the fact that the base stations of UTRA TDD are frame-synchronized facilitates an efficient suppression of dominant cochannel interferers from adjacent cells (intercell interference) via smart antennas [16]. Several space-time Rake receiver structures for UTRA FDD are presented and compared in [17].

C. Downlink Processing with Smart Antennas

Due to the fact that the uplink and the downlink operate on the same frequency in TDD systems, parameters (e.g., spatial covariance matrices) estimated on the uplink can also be used to calculate the weights for *downlink* beamforming techniques. An efficient spatial downlink beamforming scheme for UTRA TDD is presented in [18]. In FDD systems, the average uplink directions of arrival at the base station are also equal to the average downlink directions of departure from the antenna array at the base station. Therefore, the spatial weights for space-selective downlink transmission could be obtained by transforming the spatial weights estimated on the uplink according to the frequency gap between the uplink and the downlink direction [19].

D. Multiple Antennas at the Base Station and at the Terminal

The throughput can be increased even further if an antenna array is used not only at the base station, but also at the terminal. Multiple antenna concepts are a further extension of diversity concepts. They exploit independent multipath transmissions between the different antenna elements on the base station and the terminal side. As an example, Fig. 8 depicts a MIMO wireless communication system with M antennas at the transmitter and N antennas at the receiver. Such MIMO wireless channels have a significantly higher capacity than single-input–single-output (SISO) wireless channels. They are particularly interesting for laptop type terminals that require high data rates and operate at higher carrier frequencies, e.g., in the 5-GHz range. Multiple antennas can easily be installed on such a terminal due to the fact that the antenna array requires a smaller physical size (aperture) for higher frequencies.

The basic idea is to reuse the same frequency band several times by creating several virtual and uncorrelated subchannels such that several different data streams can be transmitted in parallel. These subchannels experience independent short-term fading. To illustrate this concept, assume that the wireless channel is frequency nonselective

and that h_{ij} is the propagation coefficient from the j th transmit antenna ($j = 1, 2, \dots, M$) to the i th receive antenna ($i = 1, 2, \dots, N$). The channel encountered by a subcarrier of an OFDM systems can, for instance, be modeled as frequency nonselective if the subcarrier is sufficiently narrowband. In practice, the receiver estimates the propagation coefficients by exploiting the knowledge of pilot tones and/or pilot symbols inserted in the transmitted data vectors. A blind technique to estimate the propagation coefficients has been derived in [20]. In a TDD system, the propagation coefficients in both directions (uplink and downlink) can be considered as equal if the time between uplink and downlink transmission is smaller than the coherence time of the channel.

In the sequel, we give a simple illustrative example of how several virtual and uncorrelated subchannels can be created in a MIMO wireless communication system. Let $\mathbf{H}$ be the propagation matrix of size $N \times M$ that contains all propagation coefficients h_{ij} . Moreover, the vector

$$\mathbf{x}(t) = \mathbf{H}\mathbf{y}(t) + \mathbf{n}(t) \in \mathbb{C}^N \quad (1)$$

comprises the array measurements at the receiving antenna array as depicted in Fig. 8, where the vector $\mathbf{n}(t) \in \mathbb{C}^N$ contains the additive noise. Here, it is assumed that the components of the noise vector are uncorrelated zero mean random variables with variance σ^2 such that

$$E\{\mathbf{n}(t)\mathbf{n}^H(t)\} = \sigma^2 \mathbf{I}$$

where the superscript H denotes complex conjugate transpose. Moreover assume that $E\{\mathbf{s}(t)\mathbf{s}^H(t)\} = \mathbf{I}$ and $E\{\mathbf{s}(t)\mathbf{n}^H(t)\} = \mathbf{0}$. If there is only a line of sight (and no reflections) between the transmitter and the receiver, the propagation matrix $\mathbf{H}$ has rank one, since it can be decomposed as

$$\mathbf{H} = \alpha \mathbf{a}_N(\phi) \mathbf{a}_M^T(\theta) \in \mathbb{C}^{N \times M} \quad (2)$$

where $\mathbf{a}_M(\theta) \in \mathbb{C}^M$ and $\mathbf{a}_N(\phi) \in \mathbb{C}^N$ are the array steering vectors of the transmit and the receive array, θ is the corresponding direction of departure at the transmit array, ϕ is the corresponding direction of arrival at the receive array, and α denotes the path loss. In this case, there is only one (line-of-sight) connection between the base station and the terminal, and no virtual subchannels can be created. In this case, the received signals at all antennas experience the same

fading. On the other hand, if there is multipath propagation and/or scattering in the vicinity of the terminal and/or the base station, the propagation matrix $\mathbf{H}$ has a larger rank [21]. If the angular spread is very large, $\mathbf{H}$ might even have full rank, i.e.,

$$\text{rank } \mathbf{H} = \min \{M, N\}.$$

If d is the numerical rank of the estimated propagation matrix $\mathbf{H}$, d virtual subchannels can be created. The parameter d can, for instance, be obtained from a channel estimate via the Akaike information criterion (AIC) or the maximum description length (MDL) criterion [22]. Let us denote the singular value decomposition (SVD) of $\mathbf{H}$ as

$$\mathbf{H} = \mathbf{U} \mathbf{\Sigma} \mathbf{V}^H = [\mathbf{U}_S \quad \mathbf{U}_O] \begin{bmatrix} \mathbf{\Sigma}_S & \\ & \mathbf{\Sigma}_O \end{bmatrix} \begin{bmatrix} \mathbf{V}_S^H \\ \mathbf{V}_O^H \end{bmatrix} \quad (3)$$

where the unitary matrices $\mathbf{U} \in \mathbb{C}^{N \times N}$ and $\mathbf{V} \in \mathbb{C}^{M \times M}$ contain the left and right singular vectors, respectively, the matrix $\mathbf{\Sigma} \in \mathbb{R}^{N \times M}$ contains the singular values of $\mathbf{H}$, the block matrix $\mathbf{\Sigma}_S \in \mathbb{R}^{d \times d}$ is a diagonal matrix that has the d largest singular values of $\mathbf{H}$ on its main diagonal and zeros elsewhere, and the block matrices $\mathbf{U}_S \in \mathbb{C}^{N \times d}$ and $\mathbf{V}_S \in \mathbb{C}^{M \times d}$ consist of the left and right singular vectors that correspond to the largest d singular values of $\mathbf{H}$, respectively.

At the transmitter, the bit stream is coded and modulated, demultiplexed into d subpackets, multiplied by the transmission matrix $\mathbf{V}_S$, and launched into the channel using M transmit antennas, as illustrated in Fig. 8. After the transmission over the wireless channel, the signals are received by N antennas at the receiver and processed to recover the original bit stream. Assume that the column vector $\mathbf{s}(t)$ comprises the d data symbols $s_k(t)$ ($k = 1, 2, \dots, d$) that are transmitted in parallel at time t . The optimum power allocation policy for the d parallel subchannels that satisfies the minimum mean square error (MMSE) criterion under a total average transmitter power constraint has been derived in [23]. Then, the components of the vector $\mathbf{y}(t) = \mathbf{V}_S \mathbf{s}(t) \in \mathbb{C}^M$ are transmitted by the M transmit antennas, as depicted in Fig. 8. In the receiver, the receive array measurements $\mathbf{x}(t)$ in (1) are multiplied by $\mathbf{U}_S^H$ to yield

$$\mathbf{r}(t) = \mathbf{U}_S^H \mathbf{x}(t) = \mathbf{U}_S^H \mathbf{H} \mathbf{V}_S \mathbf{s}(t) + \mathbf{U}_S^H \mathbf{n}(t) \in \mathbb{C}^N \quad (4)$$

as illustrated in Fig. 8. By inserting the SVD of $\mathbf{H}$ in (3) into (4), we find that

$$\mathbf{r}(t) = \mathbf{\Sigma}_S \mathbf{s}(t) + \mathbf{n}'(t) \in \mathbb{C}^N \quad (5)$$

where the transformed interference-plus-noise vector equals $\mathbf{n}'(t) = \mathbf{U}_S^H \mathbf{n}(t)$. Due to the unitary nature of this transformation, the components of $\mathbf{n}'(t)$ are also uncorrelated zero mean random variables.

Hence, the original channel $\mathbf{H}$ between $\mathbf{y}(t)$ and $\mathbf{x}(t)$ has been transformed into d independent virtual channels between $\mathbf{s}(t)$ and $\mathbf{r}(t)$. These are represented by the diagonal elements of $\mathbf{\Sigma}_S$. Note that these d virtual channels should experience independent fading since they are due to independent propagation paths. Hence, we get a d -fold diversity

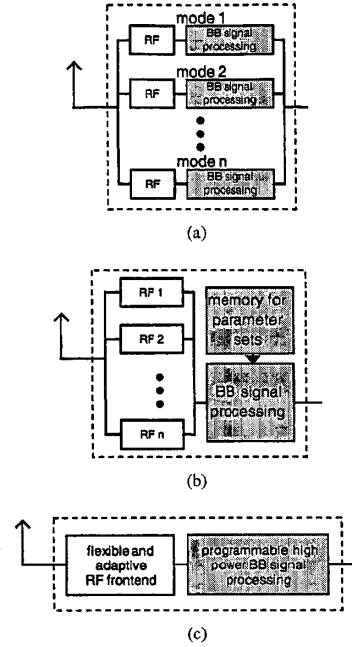


Fig. 9. (a) Illustration of multimode terminals with parallel modes, (b) multimode terminals with software-defined signal processing, and (c) fully adaptive software terminals.

gain on top of the antenna array gains of the transmit array and the receive array.

Due to the high capacity of the MIMO wireless channel [21], the described transceiver structure that uses multiple antennas at the receiver and the transmitter is a promising concept to transmit high data rates in wireless communications. Such concepts have to be evaluated under realistic channel conditions by taking into account fading and estimated channels impulse response matrices.

IV. SOFTWARE RADIO

The seamless future network in Fig. 3 comprises several access systems with seamless interworking for different applications and radio environments. Users will only gain from this flexible concept if multimode and multiband terminals with low power consumption and reasonable size are feasible. A variety of terminal types such as PDAs, notebooks, and handsets support these applications. Other technical challenges include improved display techniques and battery technology. Several concepts for the terminal implementation are under discussion (Fig. 9). Note that these techniques will also be applied to base station equipment. In the simplest concept, several fixed modes are implemented in parallel. However, this straightforward concept is inflexible for future improvements.

There are several terms often used in the context of software radio and, in principle, two concept ideas can be outlined. In the *software-defined radio* concept, many or all of the blocks already implemented in hardware (or maybe in

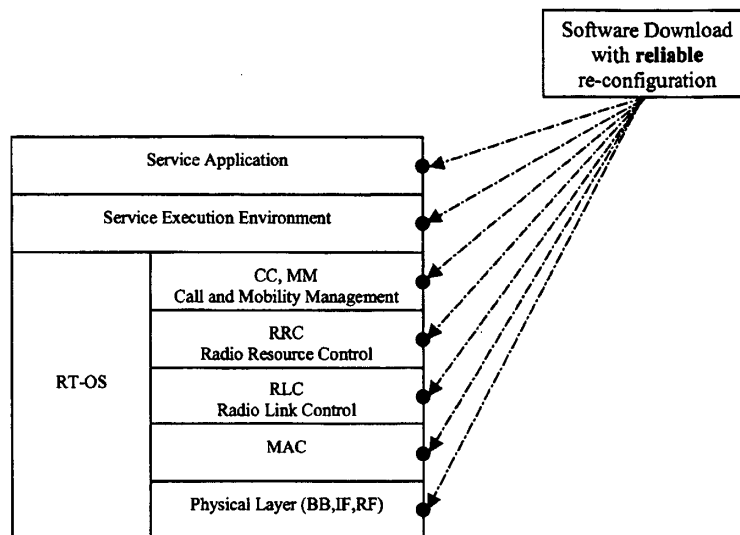


Fig. 10. Reliable software download for the terminal.

software) must be configured by setting certain parameters or by downloading parameter sets of different access systems to the signal processing unit (block diagram in the middle of Fig. 9). The architecture of a software-defined radio needs features outside of the regular design.

The *software radio* shown in the right block diagram of Fig. 9 is the most flexible configuration [24]. Here, all signal processing functions are implemented via programmable digital signal processors (DSPs). It has a great flexibility such that it can be programmed for emerging standards or updated dynamically with new software without any changes in the hardware. The software radio will become feasible due to the progress in semiconductor technology and the increase in available signal processing power.

Concepts of software download at different levels of the protocol stack from applications down to the physical layer have major potential implications not only for terminals and base stations, but also for the whole network. This will determine how applications and services are delivered and in the longer term will influence spectrum usage and applications. A key element of the download is to ensure a reliable reconfiguration over the disturbed air interface. Therefore, research work has to concentrate on this facet. This is illustrated in Fig. 10.

A. Distributed Objects in Future Wireless Networks

The system concepts for mobile communication in the second generation have their main focus on the support of voice communication, which is currently the main traffic type in mobile communications. The development and support of circuit-switched data services in the second-generation mobile networks could be regarded as an addition, as it was in the public wireline networks. Third-generation systems are focused on data services with packet-oriented transmission.

With the advent of computer and data networks (intranet, Internet, extranet) and their rapid growth in the past decade, an alternative approach to the networkcentric application provisioning is required. This approach, known as client-server architecture, differentiates not only by the used protocols, but also by the architectural approach. A basis for the success of the introduction of this architectural type was the development of object-oriented software techniques for distributed systems like COM/DCOM (distributed component object model), JAVA RMI (remote method invocation), CORBA (common object request broker architecture), and mobile agents. Besides the techniques and protocols used to enable web browsing [hyper transfer text protocol (HTTP) and hyper text markup language (HTML, XML)] and transmission protocols (e.g., TCP, UDP, RTP, RSVP, IP, and HTTP), the mentioned technologies are designed to enable the support of distributed systems. But other aspects, such as multithreads and persistent storing, need to be addressed to complete the requirements of new architectures for distributed systems in mobile radio networks.

Another key issue that shall be covered is the increasing demand for open and secure interfaces for the provision of new services and applications to the customer. These new technologies for data networks are mostly driven by computer companies and their fora (e.g., IETF, W3C, OMG, ...). Due to this development, the traditional standardization bodies for telecommunication (e.g., ITU, ETSI, ...) lose some of their influence.

Several new groups, e.g., 3G.IP, MWIF, have started to work on this topic. The question is which technologies will dominate the "mobile Internet." Computer technologies will have a significant impact—they will presumably dominate the "mobile Internet." The reasons for that assumption are as follows. First, with the provision of higher data rates over

the radio link, the subscriber expects the same content in the same or a similar way [same look and feel, virtual home environment (VHE)] as being online over wireline. Therefore, the Internet network technologies will extend to the radio access. Another reason is that today's telecommunications infrastructure is (mostly) a monolithic systems. Proprietary software runs on proprietary hardware. By contrast, computer networks use object-oriented software technologies for distributed systems. They are highly scalable and modular, which enables efficient methods for software provisioning using commercial software products from different vendors. This approach facilitates systems that could be faster deployed with a higher flexibility and, hence, more cost efficiency.

The main principles (object-oriented analysis and design, distribution, decoupling of software components and separation of concern) have already been discussed in the Telecommunications Information Networking Architecture (TINA) consortium [25] during the past years.

However, to provide customers the same grade of service they are used to from telecommunication (e.g., necessary for voice transmission), requirements like the support of QoS, reliability, mobility, and security must be fulfilled. These requirements are a challenge to today's existing data networks (Internet). Moreover, there will be an increasing number of radio technologies, e.g., GSM, ANSI 136, cdmaONE, W-CDMA, TD-CDMA, IEEE 802.11, HiperLAN, that need to be supported in the near future.

From today's perspective, it is foreseeable that the mobile communications networks will evolve toward a client-server architecture. The following major requirements have to be fulfilled by the system, including the network and the terminals:

- QoS with real-time requirements (e.g., video streaming, voice, ...);
- reliability;
- access security;
- support of a wide range of access technologies and easy deployment of new ones (e.g., for operator differentiation);
- scalability of the components;
- self-optimizing networks (to drive down operation, administration, maintenance costs);
- distributed systems; objects may be located on any server in the network or the terminal;
- flexible in introducing new services, e.g., *ad hoc* networking (object oriented);
- secure software up- and download and configuration (of terminals and radio access points);
- storage requirements for thin clients;
- suitable for unreliable links (radio links that fail sometimes).

All these requirements should be addressed in architectures and software concepts that can handle distributed systems, concurrency, and the persistent storage of data throughout the network. These three dimensions are inde-

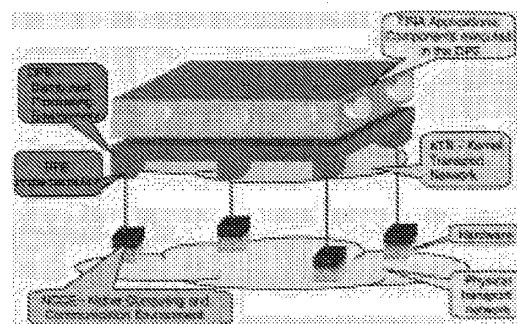


Fig. 11. Usage of the distributed processing environment (DPE), TINA-C.

pendent of each other and can be represented by a three-dimensional (3-D) coordinate system [26].

Concurrency is the actual or apparent parallelism of processes in the same processing unit or in distributed processing units, and a major challenge is the synchronization of concurrent events in a distributed processing environment. JAVA threads is one possibility to implement parallel (concurrent) processes. Distribution means the logical or physical separation of objects. The simplest case for the communication among objects is the simple transfer of bits by sockets without its further interpretation. This is the baseline for advanced processing by adding semantics to the bit stream. More information about the socket technology in TCP/IP networks and its importance (e.g., for JAVA) can be found in [27] and [28]. Advanced concepts for distributed programming as object migration, distributed garbage collection, integration of CORBA and DCOM, mobile agents, and other features can be found in Voyager [29], which is also a middleware. Persistence is the reliable storing of data. This is important to cases where the mobile terminal is temporarily disconnected from the network during the data download. JAVA database connectivity (JDBC) enables the access to relational databases.

Listing these requirements leads to the point that a mobile middleware concept is needed that supports objects or agents to run and interwork in distributed systems. In this context, the support of mobility, QoS, security, support of different radio access technologies, and the usage of radio resources and their management can be interpreted as different objects in the overall network concept. Depending on the user's needs and the operator's requirements, several of these "objects" will be used. Objects that are located on the terminal device will interwork with the specific objects in the network. The basic principle of such an approach was discussed in the TINA architecture depicted in Fig. 11. Today, there are three main middleware technologies that support objects in distributed systems:

- COM/DCOM;
- JAVA RMI;
- CORBA that has been specified by the OMG (Object Management Group).

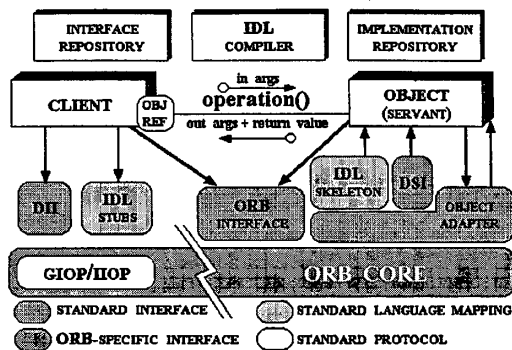


Fig. 12. CORBA ORB architecture.

The CORBA middleware is characterized by the following features.

- *Object oriented:* The definition of “object” within the object management architecture (OMA) is enlarged compared to the standard meaning of objects used in programming languages. The OMA uses “object” to an arbitrary uniquely identified entity within the architecture (see Fig. 12). Each object has a unique reference, even if it moves its location.
- *Object access transparency:* CORBA uses the same access mechanism to local and remote objects as well. The location of the server object is usually not visible to the client object.
- *Efficiency:* The object request broker (ORB) architecture allows efficient implementations, so that in case of local client–server object communication, the effort is only marginally increased compared to functional interfaces.
- *Open interfaces:* The ORB enables the interworking of programs of different vendors. This approach enables the user to use components from different vendors, tailored according to his individual needs. Software developers have the option to participate in tomorrow’s software market and to complement products of large companies with specialized products.
- *Hardware, operating system (OS), and programming language independent:* Components of a CORBA program can be realized using different operating systems, hardware architectures, and programming languages.
- *Security concepts:* For reconfiguration, a reliable software download to the terminal or within the network must be accomplished. CORBA offers many different facets to facilitate this demand. For instance, mobile agents do not currently offer security concepts to fulfil these demands.¹

Most of the characteristics except for the last one, which is CORBA specific, are also at least partly fulfilled by technologies like COM/DCOM and JAVA RMI. However, in contrast to JAVA RMI, COM/DCOM, or Voyager, which are developed and/or owned by one company, CORBA is an open

¹Details explaining Fig. 12 can be found at <http://www.cs.wustl.edu/~schmidt/corba-overview.html>.

standard that is supported from all important computer and software manufacturers.²

Due to intensive research work to develop real-time capable and QoS enabling CORBA during the past years, the required technologies, e.g., TAO ORB from the University of Washington in St. Louis [31]–[33], are now available for wireline networks.

Today, CORBA provides means for the support of the QoS for real-time applications [30]. Moreover, concepts to adapt applications according to the available and changing resources have been developed in the ACTS project OnThe-Move [34], [35], e.g., in case of vertical handover. Further information can be also found in [36].

Today, CORBA is used in wireline data networks. What are the requirements that must be fulfilled by “wireless CORBA” to be suitable as a mobile middleware from the terminal to the network components and server in wireless mobile computing and communication? Addressing use cases, the OMG Telecom Domain Task Force released a whitepaper [8] that addresses the identified questions. A group within the OMG Telecommunication has started work on this topic with the target to finalize a first, out of a bundle, request for proposal (RFP) in May 2000. Other activities concerning this topic have been started in the 5th Framework Program of the European Commission for research projects [37] and are under consideration in the Software Defined Radio Forum (SDR-F) [38], [39].

For user applications, an extension of the current CORBA approach can be seen in the JINI concept, where *ad hoc* networking is facilitated, i.e., the user will be autonomously made aware of new services or network components in the user’s environment. But JINI does not address the security aspects needed for the reconfiguration of terminals or network entities. More detailed information can be found in [40].

A general problem for security aspects is the IPv4 standard, which is used in the present TCP/IP world. There are some specific problems of wireless CORBA as, for example, the overload behavior of TCP/IP and the high load of the TCP headers. However, work has started in IETF to fix this problem.

There will be objects with different tasks in the future networks using the same CORBA technology. They will, however, have different requirements for storage, real-time capability, security, etc.

O&M objects (for network management) will have no specific requirements for storage and usually no real-time requirements, but high security and reliability requirements against fraudulent usage.

1) *Minimum CORBA and MiniORBs:* Very small and embedded devices are typically constrained with respect to resource usage such as main memory and CPU utilization. Full-blown CORBA implementations [41], however, offer a wide range of functionalities that are of limited use in such

²Approximately 800 companies out of a great variety of vertical markets, e.g., telecommunications, transport, aviation, media, are working within the Object Management Group [30].

devices. As a consequence, the Minimum CORBA specification, which essentially constitutes a part of the CORBA 3 standard, offers a reduced profile that even systems with low resources can support without losing interoperability to conventional CORBA systems. For this purpose, Minimum CORBA supports the full set of interface definition language (IDL) features. However, all dynamic aspects of CORBA have been eliminated. Examples for such aspects include the dynamic invocation interface (DII), the dynamic skeleton interface (DSI), the generic data type dynamic any and almost all parts of the interface repository. At the server side the number of policies as well as some of the options in the portable object adapter were removed.

Due to the assumption of a mobile middleware targeting all components from the terminal to the access system (e.g., node B and RNC) and further on to the server, it is needed to consider the required storage of CORBA and ORBs compared to the available storage on mobile terminals. Today's ORBs still require a huge amount of storage compared to the available one in today's mobile terminals.

In the near future, the wireless terminals will differentiate. Many new wireless devices will come to market, from the low-end wireless mobile phone (thin-client terminal) to handheld devices, from notepads up to notebooks. On the high end, there will be no real storage shortage due to fast increasing storage capacity. This will even meet the handheld devices up to a certain point. However, the mass market with the low-end devices and low-storage capacity will be for the near time a problem that must be solved. A way to fix this problem will be the location of a graphical user interface (GUI) on top of the terminal that interworks with an ORB located in the network.

However, for the support of a secure software download to future software radio terminals, it is advantageous to locate the ORB directly in the terminal. Investigations are needed to identify whether the required storage and the available functionality of so-called miniORBs could be provided and will be sufficient with the introduction of SDR terminals, or if some adaptations might be necessary or the definition of a microORB required.

Due to the differentiation of terminal capabilities and customer needs, it is required to develop and implement ORBs with different capabilities, from the full-fledged ORB, to the miniORB as it is implemented in the Netscape navigator, to a microORB (not yet defined), down to only a GUI (for low-end terminals) that interacts with the personal ORB located in the network.

2) *Real-Time CORBA*: Applications running on real-time systems must behave in a deterministic way with respect to their functional behavior as well as their QoS characteristics [42]. Hence, Real-time CORBA introduces many extensions and concepts to guarantee end-to-end predictability and to provide efficient resource management. Although the standard is based on the portable operating system interface (POSIX) real-time extensions, it does not prescribe the availability of a POSIX implementation.

An activity denotes a closely related sequence of actions that is triggered by an external event. Within an activity, dif-

ferent CORBA requests are dispatched or sent. In this context, the specification differentiates between three different states of an activity.

- In-transit: represents the transmission of a request.
- Static: represents a request that is cached in a queue.
- Active: denotes request dispatching by a thread.

A scheduling service is in charge of scheduling activities, i.e., scheduling the threads an activity consists of. Real-time CORBA only supports static scheduling strategies such as rate monotonic scheduling. Dynamic scheduling is (currently) not supported.

For initial configuration of real-time systems developers leverage the interface `RT_CORBA::RTORB`. Using additional APIs, they can create thread pools and change thread priorities. In order to guarantee platform neutrality, Real-time CORBA specifies a priority scheme that can be mapped to the native priority scheme of the underlying operating system. For converting priorities between these schemes, the interface priority mapping is available. Priority inversion is addressed using different strategies. For example, the RT-ORB transmits priority information from the client to the server using Internet inter-ORB protocol (IIOP) packets. This information enables the server to handle the incoming request with the appropriate priority. Special multiplexers are specified to synchronize resource access between parties. In addition, clients might establish multiple communication channels with the servers, where each of them gets assigned its own priority. They might also use dedicated connections that are not multiplexed, as well as specify timeouts for their requests.

B. Reconfiguration of Software Radio Terminals with Wireless CORBA

The client-server methodology for distributed objects is adopted, which can be well described by the CORBA approach.

CORBA provides an open, broadly applicable, and platform-neutral technology that uses object-oriented techniques to hide most of the accidental complexity introduced by distribution.

With the emergence of wireless network technologies, such as GSM, IMT2000/UMTS, and WLAN, it is important that CORBA can be extended to accommodate networks that contain wireless links. Mobile terminals generally have access to fewer local resources than is possible with stationary devices, both in terms of processing power and information. Users increasingly expect to be able to access sophisticated and powerful services from their mobile devices that they currently access from stationary devices. As a consequence, the ability to use services of remote objects become more and more urgent.

The need to change the air interface or basic functionalities of terminals is driven by the assumption that some services might be temporarily or permanently available with a certain air interface.

Wireless CORBA is currently under standardization to consider the wireless scenarios, i.e., temporary disconnections and terminal mobility. It must extend the current CORBA by taking into account the aspects shown in Fig. 13. Wireless

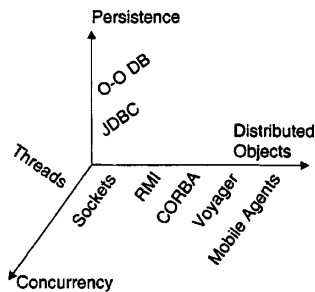


Fig. 13. Architectural and software aspects for future network concepts.

CORBA must be able to cope with migration of objects from one platform to a remote platform, asynchronous RMIs, etc.

Wireless CORBA should be the concept to integrate the handling with distributed objects and concurrent processes, as depicted in Fig. 14.

The virtual processor is an active object and in parallel the run unit for several objects, i.e., the virtual processor controls the objects allocated to it. The middleware can be seen as a virtual blackplane and establishes the communication between remote objects in the terminal, node B, or RNC and supports migration of objects, i.e., objects can roam between different network entities. Depending on the available resources in a terminal, applications can fully run on the terminal or in the network, and remote accesses between the terminal and network must be established.

Dejay [9] is a dialect of JAVA that simplifies the development of distributed software applications. Concurrent processes, distribution of objects and persistence aspects need to be addressed and require the learning of many different techniques like JAVA Threads, JAVA RMI, CORBA, and OODB. Wireless CORBA needs to address all these issues but does not have to lose its security aspects needed for a reliable reconfiguration.

The link between terminal and node B is established via the mobile wireless inter-ORB protocol (MWIOP) and can be seen as extension of the generic interORB protocol (GIOP). The current GIOP as it exists today must be enhanced accordingly, and the new MWIOP shall take into account the wireless requirements to run CORBA. CORBA offers many security facets to make reconfiguration of terminals or networks reliable, and these facets need to be translated into the wireless world. Additionally, CORBA facilitates the interworking of proprietary equipment distributed across the network or within one cabinet.

The software download can be seen as a special application that needs a very high reliability for the reconfiguration process, which can affect the whole functionality within a terminal or network element. In the European Research project TRUST [43], the reliable download is one of the important research areas for terminals, but similar security demands are needed for other network elements such as, e.g., base stations.

To reconfigure basic functionalities within a terminal or base station, a functional framework for a software radio terminal can be outlined, as in Fig. 15.

Proprietary objects as, for instance, the physical layer, communicate via a standardized interface description language (IDL) over a software bus, which consists of the ORB. The communication is related to the reconfiguration management of these objects, but in the future it might be possible to transfer the data stream via the ORB too, if the performance demands are solved. Special objects are needed to handle the download, the installation, and the security check of new software.

Fig. 16 shows the interaction between an application server or a server, provisioning software for a new air interface (later on called "wave server") and a mobile terminal. Here, a JAVA VM (virtual machine) is assumed for the mobile station execution environment (MEXE). The Internet paradigm involves pulling JAVA byte code from a web server to a front-end deployment platform on a terminal.

Combining JAVA and CORBA has several important benefits.

- The CORBA three-tier model combined with the platform independence of JAVA supports the pull paradigm for application distribution, greatly simplifying maintenance of the application-installed base. Furthermore, an application architecture based on CORBA is far more scalable than the traditional two-tier client-server model. Middle-tier logic can be partitioned and dynamically distributed, thereby moving processing closer to data sources and supporting load balancing for downloads.
- Since CORBA facilitates language independence and location transparency, JAVA objects can communicate with other distributed objects. This provides an effective means of web-enabling applications without incurring the bottlenecks experienced with HTTP- and CGI-based approaches.

The client objects for the radio network layer (RNL) on the terminal consist of the physical layer, RLC/MAC, and the RRC layer. The air interface software server, i.e., wave server in the network carries all information for the terminal reconfiguration, which can be established by the software downloader object located in the terminal. The air interface software is hosted on a wave server, which is contacted on demand.

The following phases of a reconfiguration for a terminal can be abstracted into the following phases or states:

- initial software download onto a terminal, e.g., by the SIM Application Toolkit (SAT);
- discovery of new mobile air interface servers, service or applications servers;
- binding to remote servers for initializing the software download;
- follow-up software download onto a terminal;
- installation and activation of new air interface, services, or applications;
- deinstallation of previously accepted air interface, services, or applications;
- remote method invocation;
- unexpected disconnections (and reconnections).

1) *Installation and Activation of a New Air Interface:* Installation can be static or dynamic. Static installa-

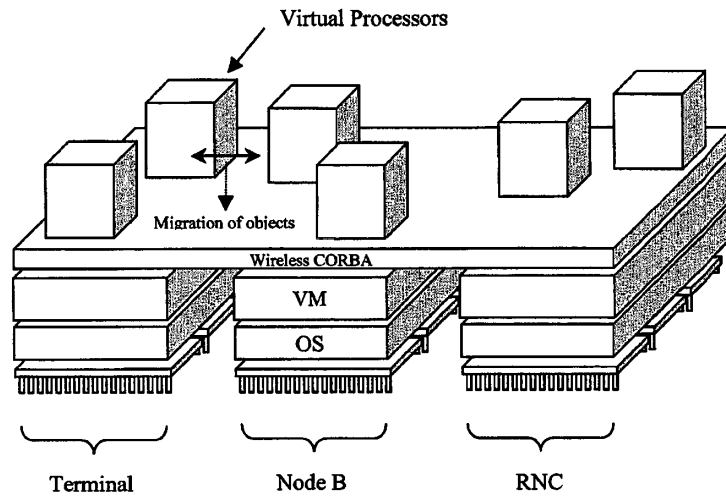


Fig. 14. Abstraction of a future middleware for wireless systems with JAVA.

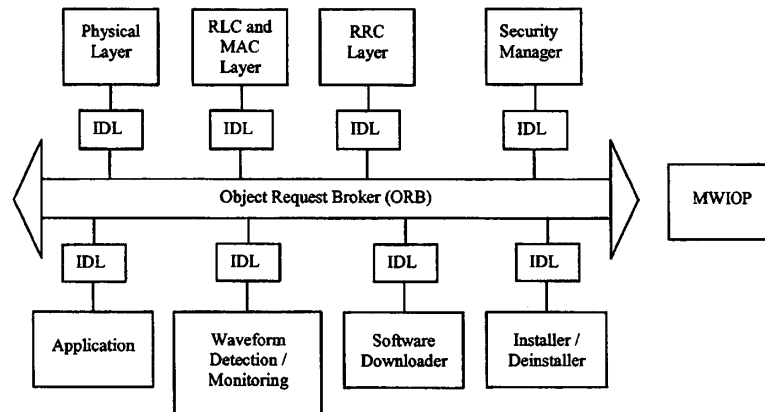


Fig. 15. Functional framework for software radio terminals applying wireless CORBA.

tion and the activation of statically installed applications means, e.g., to do it via the subscriber identity module (SIM card). Further, one has to distinguish whether the download and reconfiguration process are carried out in idle or active terminal mode. In any case, client objects need to get registered first to the server in the network, before the download can start.

Software to be dynamically loaded will be of great importance for terminals for the following reasons.

- Resources available at mobile terminals will, also in the future, be relatively limited.
- Mobile terminals can roam from network to network where different applications are required or offered to the user.
- The faster and faster churn rate of new application software in general and the need to try to take the burden of installing and maintaining new air interface features or user applications, e.g., optimized channel coding

schemes for applications away from the users of mobile terminals.

With the object-by-value (OBV) specification, loading software dynamically should be practical. This solves the problem of getting software dynamically over the over-the-air reconfiguration (OTAR). However, this does not fix the activation problem after a security check. When software for a new air interface is downloaded, it must be configured and tested before it can be used. This involves looking up information on capabilities (e.g., interference situation on measured carriers), terminal resources, and user preferences of the local environment before a download takes place. It might also require fetching software for the new air interface if they are not available locally. For example, if a user in Europe intends to travel to the United States, he might demand to download a new air interface standard before entering the aircraft. What is needed is a standard runtime environment that prompts dynamically loaded CORBA soft-

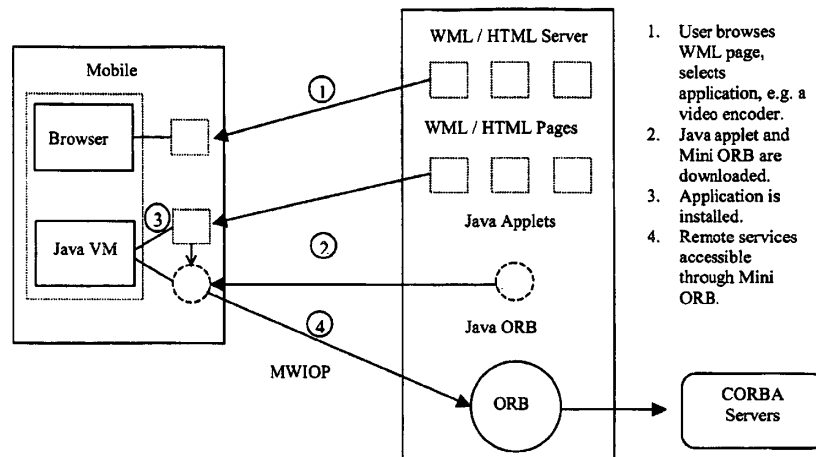


Fig. 16. JAVA ORB on a software radio terminal.

ware to prepare itself after a successful security check and then activates (reconfigure) the terminal, when appropriate.

There are two main aspects to software download: the transport mechanism and the process. The transport mechanism is how the software is entered into the terminal. The process covers for the actions and activities that must take place for the software to be successfully installed into the terminal. Dynamic reconfiguration over the air offers in principle two alternatives: interactive download (dedicated data channel) and broadcast download (common data channel).

Before a download can take place, an alternative air interface must be identified by the terminal. In principle, blind versus bulletin system identification can be addressed. Blind identification means that no prior knowledge of available air interface is given and bulletin system identification utilizes systemwide signaling channels, which gives a pointer to where a local download channel can be located. Download channel schemes need to be specified, i.e., where software is to be transferred to the terminal.

The pure JAVA world has the JAVA Embedded Server API to do this. It also provides some other useful features such as allowing software to be automatically and transparently upgraded when a new mode feature or software application becomes available. The CORBA solution might leverage the work on CORBA mobile agents if this can be made lightweight enough to be used on mobile terminals.

2) *Discovery of New Air Interface Servers*: The identification and monitoring of new air interfaces is carried out by the mode (air interface) identification and monitoring object in the terminal. A successive software download via the air requires to determine the wave server by getting an initial reference to the naming or trader service from the miniORB at the terminal. The naming or trader service are CORBA services that have a reference to the actual server address. Wireless CORBA must be extended in such a way that a simple, standard scheme for advertising and finding air interface or application software servers enables a fluid change of mobile network cells or whole mobile networks. Terminals

that carry, e.g., an out-of-date manufacturer software shall be easily updated when required and appropriate.

In particular, the access gateway should provide a naming and/or trading service, the initial reference of which the miniORB on the terminal gets during the initial access procedure.

3) *Binding to Remote Servers for New Air Interface*: There are binding issues. First, there is the problem of binding to a wave or software server that has a network address that may change during the download. Therefore, some sort of relocatable object reference may be required for this. Another binding issue involves the choice of network download channels when a mobile terminal has more than one choice for the channel that can be used between a client and air interface software server for download.

Presumably, a server would advertise the available means of interacting with it in the tagged profile data in its MWIOP. After this, the client would make the decision about which channel to use and then use the service context list to signal any specific references back to the network. It may be possible that the channel may change due to handover reasons or an interruption time may delay the download.

Yet another binding issue is the versioning, i.e., different configuration software version for possibly different mobile terminals. In traditional CORBA systems on fixed networks, that can be centrally administered. For simplicity reasons, this method should be used also in wireless networks.

4) *Remote Method Invocation*: The software download will be invoked by the terminal, if the radio access network permits it. The download can be considered as a special user application that may tolerate higher data delay but requires a very low bit error rate (BER). In some cases, it will be possible to allocate network or server resources in such a way that the configuration software is faster or more reliable downloaded. To take advantage of this, CORBA applications require a mechanism for expressing their QoS requirements, not only for the download application, but also for others.

In most cases, it would probably be appropriate to configure these requirements for a particular user or terminal

using network QoS policies that are attached to the miniORB through an "ORB QoS Service." If the QoS is insufficient, CORBA needs to give the download mechanism access to the QoS information about the current characteristics of the computing and communication environment and an easy way to modify the download channel or to change the network. In RT-CORBA, end-to-end QoS enabling mechanisms are already specified.

5) *Unexpected Disconnections and Recovery*: Unexpected disconnections are inevitable with wireless radio systems. If an interruption occurs during a download, the client-server needs a global knowledge and control of the download state in order to determine what resources are still in use and to free them appropriately in the network and on the terminal, if the download cannot be resumed within a certain time limit. A garbage collector is then responsible to free unnecessarily occupied resources.

6) *Location-Dependent Software Download*: The location service supports CORBA mobility-aware software download. The download can ask for the current location for a client. The mobility server updates the data in the location register when a terminal has moved to a new location for introducing location-dependent services or applications.

7) *Authentication Service for Software Download*: The authentication service supports the download mechanisms that require a terminal to authenticate itself before allowing it to download certain software. The downloader asks the authentication server to check whether an object is allowed to access a software to be downloaded to the terminal. The authentication server interacts with the terminal (e.g., exchanging authentication keys) to secure that the user (terminal) is the one it claims to be.

V. CONCLUSION

Mobile multimedia applications have already been introduced into evolved second-generation mobile radio systems. The improved wide-band and more flexible radio interfaces of third-generation mobile radio systems provide even more opportunities for mobile multimedia services and applications. Wireless communication systems beyond the third generation will combine many optimized access systems for special purposes that are integrated on a common flexible network platform. These different access systems complement each other in an efficient and optimized way from the user's perspective. Depending on the selected services, the available access systems, and the bearer capabilities, this new system will select the most appropriate access. The different access systems are allocated to different cell layers with respect to cell size, coverage, and mobility for globally optimized seamless service provision. The flexible platform of the medium-access system and the core network will be based on IP technology with transparent transmission to ensure flexibility for all involved players in the new deregulated and liberalized communication environment. In addition, the concept will use algorithms for reconfigurability, self-optimizing networks, and automatic planning so that new network entities and access systems can easily be added.

Key issues of the new concept are the interworking of a variety of access systems on the common platform by horizontal and vertical handover, service negotiation for seamless service provisioning, and global roaming. A new medium-access system and the IP-based core network will handle the interworking and mobility management.

There are many technical challenges that have to be solved to realize this vision. This requires extensive international research activities in the areas of access system improvement, optimization of IP for radio transmission and mobility management as well as the implementation of multimode, multi-band terminals, and, finally, software radio terminals and network entities. International standardization will play an important role to implement this concept on a global basis to ensure global roaming and seamless service provisioning. Besides the conceptual approaches for capacity increase and improved QoS, the reconfigurability of terminals and network components is seen as a major technical challenge. Adequate concepts have been presented, which can be the next major leap forward in the integration of heterogeneous networks for traditional mobile networks as well as computer networks. The demands for new concepts for distributed processing in a wireless environment have been outlined. These new demands can be translated to the integration of managing distributed objects, concurrency, and persistence in a wireless world. In particular, the reliable software download must be realized by, e.g., a new middleware, which takes into account the already available security concepts in CORBA. The requirements on wireless CORBA for a software download have been described. The reliable download is inevitable for the radio network layer (physical layer, MAC/RLC, and RRC), but for crucial user applications, such as home banking, the same security demands must be raised. Capacity enhancing features like multiuser detection and smart antennas will also play an important role.

Finally, economic aspects will determine which access system elements will be implemented. However, the concept should be open and flexible so that new access systems can be introduced later to improve the service to users continuously.

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Adaptive Resource Allocation in SDMA-based Wireless Broadband Networks with OFDM Signaling

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Abstract—The increasing popularity of wireless broadband access in local and wide area networks is the main expression of the need for flexible and ubiquitous wireless connectivity. In order to satisfy user resource requirements in the presence of volatility of the wireless medium, sophisticated multiple access and adaptation techniques are required, which alleviate channel impairments and increase system throughput. The use of multiple antennas at the base station allows intra-cell channel reuse by multiple spatially separable users through Space Division Multiple Access (SDMA) and hence enhances cell capacity. However, the employment of antennas in the physical layer raises significant issues in medium access control (MAC) layer. In this paper, we investigate the impact of antenna arrays on MAC layer channel allocation in the context of Orthogonal Frequency Division Multiplexing (OFDM), which is the predominantly proposed signaling scheme for wireless broadband access. We propose an algorithm to allocate channels to users based on their spatial separability properties, while appropriately adjusting beamforming weights and transmission rates for each user in a channel. The unified consideration of such adaptive techniques yields significant throughput benefits.

I. INTRODUCTION

The proliferation of enhanced telecommunication services, such as multimedia, telecommuting, fast internet access and video conferencing has stimulated unprecedented demand for broadband access to information sources of every kind. While data transmission rates are growing rapidly in backbone fiber networks or other wire-line networks with the development of xDSL and cable modem products, increasingly demanding applications and user expectations have emerged, both for indoor and outdoor environments. The need for ubiquitous coverage and connectivity in local loop, local area and wider area networks, in conjunction with the increasing demand for mobility, flexibility and easiness of system deployment have necessitated wireless broadband access.

Given the inherent volatility of the wireless medium, a challenging issue in the design of wireless networks is that of ensuring fulfillment of quality of service (QoS) requirements for users, which is synonymous to achieving a given data rate, signal-to-interference and noise ratio (SINR) level or bit error rate (BER) at the receiver of each user. The ability of a network infrastructure to fulfill such QoS requirements and ultimately enhance system capacity depends drastically on the employment of multiple access and signaling schemes that encompass procedures which span the medium access (MAC) and physical layers. These include sophisticated resource management and reuse, reliable channel estimation, adaptation of transmission parameters and exploitation of

system diversity attributes. In particular, adaptive physical layer-based transmission techniques provide the potential to adjust parameters such as transmission power, modulation level, symbol rate or forward error correction coding (FEC) rate, based on channel quality. Moreover, the employment of smart antennas in the transmitter constitutes perhaps the most significant means of capacity increase through Space Division Multiple Access (SDMA).

Orthogonal Frequency Division Multiplexing (OFDM) is the predominantly proposed multiple access and signaling scheme for wireless broadband networks [1]. OFDM is included in the IEEE 802.11a and ETSI HIPERLAN/2 standards for wireless LANs [2],[3], the digital audio/video broadcasting (DAB/DVB) standards in Europe and has also been proposed by IEEE 802.16 working group for fixed broadband wireless access. OFDM is based on the principle of multi-carrier transmission, which originally appeared in the design of high speed digital subscriber line (HDSL) modems under the term discrete multi-tone (DMT) [4]. In OFDM, the wide-band spectrum is divided into multiple orthogonal narrow-band subcarriers. Each user symbol is splitted into subsymbols, each subsymbol modulates a different subcarrier and user subsymbols are transmitted in parallel over these low-rate subcarriers. This transmission method results in reduction of effective symbol rate in the channel, mitigation of intersymbol interference (ISI) and thus significant improvements in system capacity and attainable data rates. Adaptive modulation techniques in OFDM provide the potential to vary the number of transmitted bits that constitute a user subsymbol in a subcarrier, according to instantaneous subcarrier quality in order to maintain acceptable BER per subcarrier [5]. A large number of allocated bits in a subcarrier increases subcarrier throughput, but requires better subcarrier quality to maintain a fixed BER and hence this should be applied in good quality subcarriers. The problem of bit allocation for throughput maximization becomes meaningful when studied subject to a total power constraint for symbols. Then, power water-filling across subcarriers provides the optimal solution for the single-user case [6]. For the multi-user case, sub-optimal centralized [7] or distributed [8] modulation and power control algorithms have been proposed. In [9], the authors present an iterative subcarrier, bit and power allocation algorithm for minimizing transmitted power. Channel allocation with modulation level and power adaptation for throughput increase was also studied in [10] for generic multiple access schemes with orthogonal channels.

Space Division Multiple Access (SDMA) with adaptive antennas enables intra-cell bandwidth reuse by multiplexing spatially separable users in the same channel with the use of adaptive antenna arrays at the base station. On the up-link, spatial separation of cochannel users can be performed by applying filtering and detection algorithms which exploit the degrees of freedom and diversity at the receiver. Hence, the separation problem can be decomposed into independent optimization problems, one for each user, for computing the filtering weight vectors [11]. On the down-link, user separation is more cumbersome, since adaptation of transmission parameters of a single user affects interference level at all receivers. Since receivers are distributed and are not primarily expected to be equipped with multiple antennas, they cannot exploit reception diversity or perform joint signal detection. Therefore, spatial separation of cochannel users is performed by beamforming at the base station. The beam patterns of users are adapted, so as to maintain an acceptable SINR at each receiver. In [12], the authors propose an iterative algorithm for power control and receiver beamforming for a set of cochannel links. The algorithm converges to a feasible solution, if there exists one and minimizes total transmitted power. The optimal solution for that problem is also demonstrated in [13]. A similar algorithm in the context of OFDM is presented in [14]. Downlink beamforming for power minimization in a single-cell system is studied in [15].

Some heuristic methods to consider the impact of antennas on resource allocation are presented in [16] and [17]. However, adaptive resource allocation in the context of OFDM or other multiple access schemes has predominantly been studied independently from intra-cell user spatial separation. Different users in the same cell are assigned to different channels and transmission parameter adaptation is performed independently for each user, without any consideration of the impact of a particular assignment on other users. In addition, resource reuse is usually based on static cell sectorization and beam switching methods, which do not fully capture potential adaptability of user rate requirements and dynamicity of wireless channel. As a consequence, intra-cell resource reuse is limited, resource utilization is inefficient and system capacity is decreased. However, with an appropriate transmission strategy at the base station, the issues of resource allocation and spatial separability of users can be studied jointly. The extent to which users are spatially separable can be adjusted by transmit beamforming and selective user assignment in channels. Then, an acceptable SINR level is ensured at each receiver, while spatially separable users achieve high total transmission rate, so that system throughput is increased.

In this paper, we study the joint problem of intra-cell resource allocation and transmit beamforming in the context of an OFDM/SDMA system. We propose an algorithm to allocate spatially separable users in the same subcarriers, while appropriately adjusting beam patterns of individual users at the transmitter. We also consider a simplified version of resource allocation and beamforming, when channel reuse is not applicable and incorporate user minimum rate requirements and power constraints. The main goal of our study is to identify the benefits of this integrated approach and motivate further research on more composite versions of the problem. These encompass constrained resource allocation and spatial separation problems, as well as algorithms that would

be applicable in other multiple access schemes.

The paper is organized as follows. In section II we provide the transmission and channel models and the assumptions used in our approach. In section III we describe the proposed algorithm of subcarrier allocation and user spatial separation, while in section IV we consider constraints for a simplified version of our problem. In section V we derive separability conditions for the case of two users and in section VI we provide numerical results. Finally section VII concludes our study.

II. SYSTEM MODEL

A. Notational remarks

Vectors are assumed to be column ones and are denoted with boldface letters. Superscripts T and H denote the transpose and complex conjugate transpose of a vector or matrix. The notation $\|A\|$ refers to the sum of all entries of matrix A , while $|\mathbf{w}|$ denotes the magnitude of vector $\mathbf{w}$. The cardinality of a set $\mathcal{X}$ is shown as $|\mathcal{X}|$. The dominant generalized eigenvector $\mathbf{u}(A, B)$ for matrix pair (A, B) is a normalized eigenvector that corresponds to the largest positive eigenvalue that solves the generalized eigenproblem $A\mathbf{x} = \lambda B\mathbf{x}$. When A, B are symmetric and positive definite, this problem is equivalent to eigenproblem $C\mathbf{y} = \lambda\mathbf{y}$, with $C = L^{-1}A(L^{-1})^H$ and $\mathbf{y} = L^H\mathbf{x}$, where L is a non-singular lower triangular matrix that appears in the Cholesky decomposition of B , $B = LL^H$.

B. Transmitter model

We consider a base station which provides coverage to a cell and serves K users. The base station has a M -element adaptive linear antenna array, capable of separating at most $M' \leq M$ cochannel users. We will assume that all degrees of freedom of the array are exploited, so that $M' = M$. Each one of the K receivers has a single omni-directional antenna. The base station employs OFDM transmission with N subcarriers.

An underlying slotted transmission scheme is assumed. Packetized data arrive from higher layers for transmission over the radio channel and each packet occupies one time slot of duration T_s . A packet consists of S OFDM information symbols and one training symbol that is used for channel estimation. Each OFDM symbol of a user consists of bits which must be assigned to different subcarriers. If $b_{n,k}$ bits of user k are assigned to subcarrier n , the total number of bits per OFDM symbol for k is $\sum_{n=1}^N b_{n,k}$. These $b_{n,k}$ bits constitute the n -th subsymbol of user k that modulates subcarrier n . User subsymbols can have different number of bits in subcarriers, by using different modulation levels from a set of available QAM constellations. Assuming that the channel is invariant for a slot duration, subsymbols of all symbols of a user within a packet modulate the same subcarriers. The instantaneous transmission rate R_k (in bits/sec) for user k in a slot is,

$$R_k = \frac{1}{T_s} \cdot S \cdot \left(\sum_{n=1}^N b_{n,k} \right). \quad (1)$$

Under SDMA, the base station can transmit up to M subsymbols of M different users in each subcarrier by forming M different beam patterns. The configuration of a K -user OFDM/SDMA

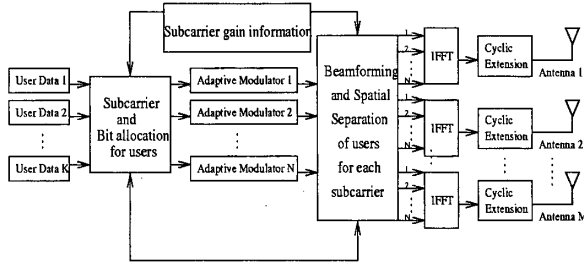


Fig. 1. Block diagram of OFDM/SDMA transmitter with adaptive subcarrier and bit allocation and spatial user separation.

transmitter is depicted in Fig. 1. The serial bit streams of users are inserted into the subcarrier and bit allocation module. This module determines the number of allocated user bits to different subcarriers and the users that share the same subcarriers.

Next, user bits are forwarded into N adaptive modulators. Each modulator modulates the corresponding subcarrier with an appropriate signal that depends on the bits of all users that share the subcarrier. Since linear modulation methods (such as QAM) are assumed, the superposition principle holds and the signal that modulates a subcarrier is given by superimposing the constellation points of users that share the subcarrier. Then, the outputs of modulators enter the beamforming and spatial separation module. For clarity of presentation, the beamforming and spatial separation submodule for subcarrier n is illustrated in Fig. 2. Bits of each of the (at most $M' = M$) users assigned to subcarrier n are forwarded to one of the M parallel beamforming modules. A beamforming vector $\mathbf{w}_{n,k} = [w_{n,k}^1, \dots, w_{n,k}^M]^T$ is computed for each user k . The output of the beamforming and spatial separation module is a set of beamforming vectors $\{\mathbf{w}_{n,k}\}$, for each subcarrier n and each user k assigned to a subcarrier. The resulting (at most NMM') streams are transformed into time domain samples by inverse fast Fourier transform (IFFT). A cyclic extension of time samples is appended to the signal and serves as guard interval for maximum delay spread. Finally, time samples are transmitted from the M antennas.

C. Channel model

The multi-path channel between the m -th antenna and the k -th receiver is modeled as,

$$h_{m,k}(t) = \sum_{\ell=1}^L \beta_k^\ell \alpha_m(\theta_{\ell,k}) \delta(t - \tau_k^\ell), \quad (2)$$

where L is the total number of paths, β_k^ℓ and τ_k^ℓ are respectively the complex gain and time delay for path ℓ and $\alpha_m(\theta_{\ell,k})$ is the m -th element of the $M \times 1$ antenna steering vector at direction $\theta_{\ell,k}$, $\alpha(\theta_{\ell,k})$. The vector $\mathbf{a}_k = \sum_{\ell=1}^L \beta_k^\ell \alpha(\theta_{\ell,k})$ is called spatial signature of user k and captures spatial properties and the multi-path channel of that user.

The complex baseband OFDM signal of user k that is transmitted from antenna m is,

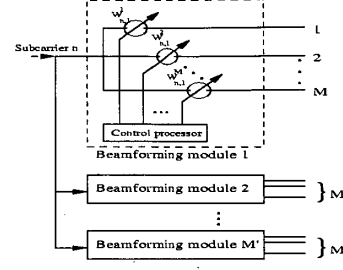


Fig. 2. Beamforming submodule for subcarrier n .

$$s_{m,k}(t) = \sum_{i=-\infty}^{\infty} \sum_{n=0}^{N-1} w_{n,k}^m d_{n,k}^{(i)} g(t - i(T + T_g)) e^{jn(\Delta\omega)t}, \quad (3)$$

where $j = \sqrt{-1}$. The time-domain signal is represented as a sum of rectangular pulses $g(t)$ of duration $T + T_g$, where T and T_g are the symbol and guard interval durations. Each pulse is multiplied by a complex subcarrier coefficient $d_{n,k}^{(i)}$, which denotes the subsymbol of the i -th symbol of user k in subcarrier n . This is shifted in time by i modulation intervals of duration $T + T_g$ and in frequency by $n(\Delta\omega)$, where $\Delta\omega = 2\pi/T$. Assuming that there is no overlap between pulses from different modulation intervals (i.e., different OFDM symbols), we focus on one OFDM symbol, say $i = 0$. It can also be assumed without loss of generality that $T_g = 0$ and that $g(t)$ is normalized to 1. Then, the OFDM symbol of user k that is transmitted from antenna m is,

$$s_{m,k}^0(t) = \sum_{n=0}^{N-1} w_{n,k}^m d_{n,k} e^{jn(\Delta\omega)t}. \quad (4)$$

Let $\mathbf{h}_k(t) = [h_{1,k}(t), \dots, h_{M,k}(t)]^T$ be the channel vector for user k . The signal at receiver k is,

$$y_k(t) = \left(\sum_{j=1}^K \mathbf{s}_j^0(t) \right) * \mathbf{h}_k(t) + \nu(t), \quad (5)$$

where $\mathbf{s}_k^0(t) = [s_{1,k}^0(t), \dots, s_{M,k}^0(t)]^T$ is the transmitted signal of user k from all antennas, $*$ denotes convolution and $\nu(t)$ is thermal noise process at the input of the receiver. Let $\mathbf{H}_{n,k}$ denote the FFT of $\mathbf{h}_k$, evaluated at the n -th subcarrier frequency. This complex quantity captures channel quality in the flat fading environment of a subcarrier. By using the convolution-product property of Fourier transform, we find the received signal of receiver k at subcarrier n as,

$$Y_{n,k} = \mathbf{w}_{n,k}^H \mathbf{H}_{n,k} d_{n,k} + \sum_{j=1, j \neq k}^K \mathbf{w}_{n,j}^H \mathbf{H}_{n,k} d_{n,j} + \nu_{n,k}, \quad (6)$$

where the first two terms are the desired and undesired signals for receiver k and $\nu_{n,k}$ is white Gaussian noise with variance σ^2 . Assuming that coefficients $d_{n,k}$ are normalized, the signal-to-interference and noise ratio (SINR) at the output of the matched

filter at subcarrier n of receiver k is,

$$SINR_{n,k} = \frac{(\mathbf{w}_{n,k}^H \mathbf{H}_{n,k}) (\mathbf{w}_{n,k}^H \mathbf{H}_{n,k})^H}{\sum_{j \neq k} (\mathbf{w}_{n,j}^H \mathbf{H}_{n,k}) (\mathbf{w}_{n,j}^H \mathbf{H}_{n,k})^H + \sigma^2}. \quad (7)$$

Define now the $M \times M$ matrix $\mathcal{H}_{n,k} = \mathbf{H}_{n,k} \mathbf{H}_{n,k}^H$. This matrix captures spatial and temporal characteristics of the link between the base station and receiver k at subcarrier n and will be referred to as spatial covariance matrix. Then,

$$SIR_{n,k} = \frac{\mathbf{w}_{n,k}^H \mathcal{H}_{n,k} \mathbf{w}_{n,k}}{\sum_{j \neq k} \mathbf{w}_{n,j}^H \mathcal{H}_{n,k} \mathbf{w}_{n,j} + \sigma^2}. \quad (8)$$

Link quality for all users, subcarriers and antennas is assumed to be known at the transmitter, which means that matrices $\mathcal{H}_{n,k}$ are available for all n, k . With a bidirectional link and time division duplexing (TDD), each subcarrier can be considered as a reciprocal link. Then, spatial signatures of users at each subcarrier remain unchanged for one up-link and down-link transmission. Link quality estimation can be performed at the base station with training symbols that are included in up-link user packets. A user k sends training symbol e_k , consisting of known complex subcarrier coefficients $\{E_{n,k}\}$, $n = 1, \dots, N$. Antenna m receives N time samples $\{z_{n,k}^m\}$, $n = 1, \dots, N$ and uses FFT to transform them to frequency domain coefficients $\{Z_{n,k}^m\}$, $n = 1, \dots, N$. The received coefficient at antenna m and subcarrier n from user k is $Z_{n,k}^m = E_{n,k} \mathbf{H}_{n,k}^m + N_{n,k}$, where $N_{n,k}$ is the noise component. Then, the MMSE estimate of complex gain is $\hat{H}_{n,k}^m = Z_{n,k}^m / E_{n,k}$. Under the assumption of reciprocity and reasonable time-variance of the link, the transmitter can use these estimates in down-link computations.

The BER of a user that uses M-QAM modulation in a subcarrier is approximated as [18],

$$\text{BER} \approx 0.2e^{-1.5 \frac{SIR}{M-1}}. \quad (9)$$

The minimum SINR to maintain $\text{BER} \leq q$ for M-QAM modulation is the following SINR threshold,

$$\gamma_M = -\frac{\ln(5q)}{1.5} (M-1) \quad (10)$$

A higher SINR (lower interference level) in a subcarrier enables the utilization of high M-QAM modulation levels and yields higher transmission rate.

III. RESOURCE ALLOCATION AND BEAMFORMING FOR OFDM/SDMA: THE RESOURCE REUSE CASE

A. Problem Statement

SDMA enables intra-cell reuse of a conventional channel (frequency, time slot, or code) by multiple users, by exploiting spatial properties of the users with respect to the base station. In the case of an OFDM/SDMA system, channel reuse pertains to simultaneous utilization of a subcarrier by several users for transmission.

Two or more users are called *spatially separable* in a subcarrier if they share the subcarrier and the SIR requirements at corresponding receivers are satisfied. For a given subcarrier, spatial

separability of users is a function of subcarrier spatial covariance matrices of users, which in turn depend on angular and multipath characteristics of users. User separability also depends on the number of bits that constitute user subsymbols, since different M-QAM constellations are associated with different SINR thresholds and hence different amounts of maximum cochannel interference in order to maintain fixed BER. In addition, beamforming vectors of cochannel users affect SINRs of all receivers corresponding to these users. Finally, user separability depends on each individual subcarrier: users that can share one subcarrier, may not be eligible cochannel users in a different subcarrier, or subcarrier reuse may be feasible for different numbers of allocated bits.

Each user in a subcarrier experiences cochannel interference from other users that use this subcarrier. When a larger number of bits (higher subcarrier transmission rate) is assigned to the user subsymbol in a subcarrier, the throughput for that user is increased. If larger numbers of bits are assigned to subcarriers of this user, the user occupies fewer subcarriers to satisfy certain rate requirements. As a result, more users can be accommodated in the system and capacity is increased. However, a larger number of bits for users in a subcarrier render spatial separability more difficult, since maximum sustainable cochannel interference for an acceptable BER is reduced and hence fewer users can reuse the same channel. Non-separable users should in general be assigned to different subcarriers and from that point of view system capacity is not enhanced. On the other hand, with a smaller number of bits per subcarrier (lower subcarrier transmission rate), a user occupies more subcarriers in order to satisfy rate requirements and thus fewer users can be accommodated in the system. However, a smaller number of assigned bits facilitate spatial separability of more users, since users will be less sensitive to cochannel interference. Therefore, smaller number of assigned bits may even increase capacity. In addition, although users may be spatially separable in different subcarriers, total number of allocated bits per subcarrier may be different, due to differences in spatial covariance matrices and beamforming vectors of users in subcarriers.

The existing tradeoff between total number of assigned bits per subcarrier and spatial separability of users affects system throughput. The arising issue is whether there exists a way to perform subcarrier allocation and user spatial separation jointly, so as to maximize total number of assigned bits per subcarrier and ultimately maximize system capacity. This problem is equivalent to identifying cochannel sets of users that yield larger total number of assigned bits for each subcarrier. Ideally, each subcarrier should have a large number of spatially separated users with large number of allocated bits. This is possible if spatial covariance matrices of users and beamforming vectors are such that users do not induce much interference to each other. For instance, spatial separability occurs for users whose spatial signatures are not highly correlated. However, if angular and multipath characteristics of users are such that spatial separation is not facilitated, then subcarrier reuse may be feasible only for a subset of users with small number of assigned bits in the subcarrier.

For a particular subcarrier, the goal is to assign as many spatially separable users as possible, while enabling corresponding receivers to satisfy a fixed BER per subcarrier with as many bits per subsymbol as possible. This policy will yield high through-

put per subcarrier. The cardinality of the set of spatially separable cochannel users is limited by the number of antennas, M . The identification of the set of cochannel users that achieves maximum subcarrier throughput is a hard optimization problem. First, an appropriate subset of spatially separable users with certain number of assigned bits per subsymbol must be identified. Then, beamforming vectors for these users must be computed, so that SINR at each receiver is above the SINR threshold that corresponds to that number of bits. The problem is that the SINR at a receiver depends on beamforming vectors of all other users, i.e., it depends on the cochannel set itself. The enumeration of all possible user assignments in a subcarrier is of exponential complexity. In addition, even if the cochannel set of users is fixed, the computation of beamforming vectors that lead to acceptable SINRs at receivers is not straightforward. Therefore, it is desirable to design a suboptimal heuristic algorithm to construct cochannel sets of spatially separable users and find beamforming vectors, so that a large total number of assigned bits per subcarrier is supported.

In this paper, we consider the problem of resource allocation and spatial separation with the objective to increase system capacity and we propose a greedy algorithm to achieve this goal. The algorithm is based on sequential insertion of spatially separable users in subcarriers. In order to keep the complexity of the algorithm to a reasonable level, user reassignments among subcarriers are not considered. The allocation algorithm is applied for an OFDM symbol of each user and the resulting allocation can be replicated for all S symbols of a user packet. Allocation adjustments can be performed once in a certain number of packets, based on received training symbols in the up-link. We first consider the situation when subcarrier reuse is allowed. For illustrative reasons, we present our algorithm under the assumption that the major limitation is cochannel interference rather than noise, so that SINR can be approximated by SIR.

B. Proposed Algorithm

The basic idea of the algorithm is to assign each user to an appropriate subcarrier, by evaluating the incurred rate benefit of the allocation. This benefit is simply the increase in total number of bits of user subsymbols in the subcarrier. Cochannel users in a subcarrier must be spatially separable, while SIRs at receivers must be as high as possible, so as to exceed the largest possible SIR threshold, which corresponds to a large number of bits per subsymbol. Since joint computation of beamforming vectors of users to increase all receiver SIRs is not straightforward, we focus on the impact of the allocation to each user separately. If inserted users cause the least interference to other users that are already assigned in the channel and receive the least interference from them, then spatial separability with larger numbers of bits per user subsymbol are possible, since SIRs at receivers are higher.

For each subcarrier n and user k , we construct the ratio of desired power for user k over undesired power, caused to other users by user k . The desired power is the useful signal power that reaches receiver k , while the undesired power is a measure of interference induced by user k to receivers of other users that use the same subcarrier n . In fact, we are interested in computing the maximum value of this ratio, $D_{n,k}$, by appropriately adjusting the

direction of beamforming vector $\mathbf{w}_{n,k}$. Thus, we define,

$$D_{n,k} = \max_{\mathbf{w}_{n,k}} \frac{\mathbf{w}_{n,k}^H \mathcal{H}_{n,k} \mathbf{w}_{n,k}}{\mathbf{w}_{n,k}^H \left(\sum_{i \in \mathcal{U}^n} \mathcal{H}_{n,i} \right) \mathbf{w}_{n,k}}, \text{ s.t. } |\mathbf{w}_{n,k}| = c, \quad (11)$$

where c is a constant and $\mathcal{U}^n$ is the set of users that are already assigned to subcarrier n . The vector $\mathbf{w}_{n,k}^*$ that maximizes the ratio above is known to be the generalized eigenvector of matrix pair $(\mathcal{H}_{n,k}, \sum_{i \in \mathcal{U}^n} \mathcal{H}_{n,i})$ and can be computed with the transformation in subsection II.A. A user k should be inserted in subcarrier n if ratio $D_{n,k}$ is maximum. In addition, we take into consideration the impact of insertion of user k on other users that share the subcarrier. For each such user i already assigned in subcarrier n , we compute the following ratios:

$$D_{n,i}^- = \max_{\mathbf{w}_{n,i}} \frac{\mathbf{w}_{n,i}^H \mathcal{H}_{n,i} \mathbf{w}_{n,i}}{\mathbf{w}_{n,i}^H \left(\sum_{j \in \mathcal{U}^n: j \neq i} \mathcal{H}_{n,j} \right) \mathbf{w}_{n,i}} \quad (12)$$

and

$$D_{n,i}^+(k) = \max_{\mathbf{w}_{n,i}} \frac{\mathbf{w}_{n,i}^H \mathcal{H}_{n,i} \mathbf{w}_{n,i}}{\mathbf{w}_{n,i}^H \left(\sum_{j \in \mathcal{U}^n: j \neq i} \mathcal{H}_{n,j} + \mathcal{H}_{n,k} \right) \mathbf{w}_{n,i}}, \quad (13)$$

where in both (12) and (13), we assume $|\mathbf{w}_{n,i}| = c$. The quantity $\Delta D_{n,i}^k = D_{n,i}^- - D_{n,i}^+(k)$ denotes the impact of insertion of new user k on user i that is already assigned in subcarrier n . Insertion of user k causes interference to user i and this is shown in the denominator of $D_{n,i}^+(k)$. A new user k is preferable for the subcarrier if it causes the least total interference to users in the subcarrier, so that quantities $\Delta D_{n,i}^k$ are minimum for as many users i as possible, among all subcarriers n . The Interference Preference Factor (IPF), $I_{n,k}$, is defined as,

$$I_{n,k} = \frac{D_{n,k}}{\sum_{i \in \mathcal{U}^n} \Delta D_{n,i}^k}. \quad (14)$$

In the allocation process, we want to select a user k and assign it to subcarrier n , so that IPF is maximum. The new cochannel set of users is then more likely to be spatially separable.

Let us assume now that user k is tentatively assigned to subcarrier n , according to the criterion above. The beamforming vectors for users in $\mathcal{U}^n$ are then computed as the solutions to appropriate generalized eigenproblems. These beamforming vectors are used to calculate SIR at each receiver. However, it may happen that insertion of new user k decreases SIR at a receiver of a cochannel user in such a way that the number of bits per subsymbol for that user (and thus the corresponding SIR threshold) needs to be reduced in order to maintain acceptable subcarrier BER and spatial separability of all users. The assignment of a user in a subcarrier is beneficial if the total number of user bits for spatially separable users in $\mathcal{U}^n \cup \{k\}$ exceeds that of $\mathcal{U}^n$ before insertion of user k . If the inserted user does not possess desirable spatial or multi-path properties, e.g., it is not sufficiently separated in angle from other users, the resulting total number of user bits in the subcarrier may be reduced. Clearly, the most appropriate allocation pair (n^*, k^*) of user and subcarrier is the one for which the total increase in number of user bits in that subcarrier is maximized. In order to

formalize our arguments, let $b_{n,k}$ denote the number of bits of tentatively inserted user k in subcarrier n . For each user i , already assigned in subcarrier n , let $b_{n,i}^-$ and $b_{n,i}^+(k)$ denote the number of bits for user i before and after insertion of user k . Increase in the number of bits of a user means an increase in rate of that user in the subcarrier. Thus, we define the Rate Increment Factor (RIF) $T_{n,k}$ for user subcarrier n and user k as,

$$T_{n,k} = b_{n,k} + \sum_{i \in \mathcal{U}^n} (b_{n,i}^+(k) - b_{n,i}^-). \quad (15)$$

An efficient allocation of users to subcarriers that leads to spatially separable users and large total number of user bits is one where user insertion in a subcarrier results in least induced or received interference to and from already assigned cochannel users respectively, as well as in maximum increase in total number of user bits. To capture this objective, we define the Assignment Preference Factor (APF) $A_{n,k}$, as

$$A_{n,k} = I_{n,k} T_{n,k}. \quad (16)$$

Among assignments with the same amount of induced or received interference, we prefer the one that results in larger rate increase. In addition, among assignments with the same rate benefit, we consider the one with the least induced or received interference, in order to improve the situation for future allocations. The preference factors for the first assigned user k in an empty subcarrier n in the absence of cochannel users are computed as follows:

- The IPF is given by the maximum achievable SIR at the receiver, subject to a power constraint for the user subsymbol,

$$I_{n,k} = \max_{\mathbf{w}_{n,k}} (\mathbf{w}_{n,k}^H \mathcal{H}_{n,k} \mathbf{w}_{n,k}), \quad \text{s.t. } |\mathbf{w}_{n,k}| = c, \quad (17)$$

where c is a constant. The solution $\mathbf{w}_{n,k}^*$ is the eigenvector that corresponds to the maximum positive eigenvalue of matrix $\mathcal{H}_{n,k}$.

- The RIF is the maximum number of bits per subsymbol, which is determined by the maximum available modulation level.

The algorithm selects the allocation that yields maximum APF and assigns that user to the corresponding subcarrier. The procedure is repeated until no further user assignments in subcarriers can increase the total number of user bits in a subcarrier, that is until $T_{n,k} < 0$ for all subcarriers n and users k , or until the cardinality of cochannel sets of users assigned to all subcarriers is M . The main steps of the algorithm are outlined as follows:

ALGORITHM A

- **STEP 1** : Compute spatial covariance matrices $\mathcal{H}_{n,k}$ for all K users and N subcarriers. Initially all subcarriers are included in list $\mathcal{C}$ of candidate subcarriers for allocation.
- **STEP 2** : Select pair (n^*, k^*) of subcarrier and user that yields maximum APF and perform the assignment.
- **STEP 3** : Update APF factors of cochannel users for n^* .
- **STEP 4** : If $|\mathcal{U}^{\tilde{n}}| = M$ or if $T_{\tilde{n},k} < 0$ for a subcarrier $\tilde{n}$ and all users k , remove subcarrier $\tilde{n}$ from list $\mathcal{C}$.
- **STEP 5** : If list $\mathcal{C}$ is not empty, go to Step 2. Otherwise, terminate the algorithm and go to Step 6.

- **STEP 6** : Repeat the same allocation of users to subcarriers for all packet symbols and all user packets until the next adaptation.

The computationally intense part of the algorithm is the computation of dominant generalized eigenvectors for the APF factors. For one user, this involves Cholesky decomposition of a $M \times M$ matrix and calculation of the maximum eigenvalue of an appropriate matrix, as outlined in II.A. Both of these procedures are known to be of complexity $O(M^3)$. For N subcarriers, K users and M antenna elements, the complexity of the algorithm is $O(NKM^4)$, which is not prohibitive, given that the number of antennas that is used in practice is relatively small (less than 8).

IV. RESOURCE ALLOCATION AND BEAMFORMING FOR OFDM/SDMA: THE CONSTRAINED CASE

A. Motivation and problem statement

In the previous section, we considered the problem of resource allocation with beamforming for spatially separable users and proposed an algorithm for spatial separability with large total number of user bits per subcarrier. However, in a realistic scenario additional constraints may come into stage. For instance, the algorithm generates an allocation of spatially separable users to subcarriers, without any guarantees on total achievable rates for individual users. It may happen that users with certain spatial and multi-path properties, (e.g. spatial covariance matrices) achieve high rates, whereas other users do not. In addition, beamforming power constraints were only utilized to facilitate the assignment. Thus, the only limiting factor in user assignment in a subcarrier was the number of antennas and no statement was made on the impact of beamforming power constraints on the assignment.

Each user k should satisfy a minimum rate requirement ρ_k (in bits/sec), which is usually issued by the MAC layer in order to ensure satisfaction of QoS requirements for users and, to some extent, fairness in resource allocation. In addition, in a multi-carrier transmission scheme such as OFDM, symbol transmission across subcarriers is subject to transmission power constraints per subcarrier. These constraints account for transmission limitations, such as the requirement for low peak-to-average power ratio (PAPR) to avoid symbol distortion [19]. Although the incorporation of constraints in our problem formulation approximates realistic scenarios, the complexity may become prohibitive. For instance, in the assignment procedure of the previous section, user reassignments among subcarriers and additional beamforming calculations should be performed, if the aforementioned constraints are present.

In this section, we consider the impact of these constraints in the context of a simplified problem, where subcarrier reuse is not applicable. In this system, beamforming per subcarrier is used as another dimension to improve subcarrier quality. The OFDM/SDMA transmission system is the one in Figure 1, with the difference that there exists only one beamforming module per subcarrier. Spatial covariance matrices $\mathcal{H}_{n,k}$ are known to the transmitter for each subcarrier n and user k . Due to absence of cochannel interference, the system is assumed to be noise-limited. Noise variance is incorporated in matrix $\mathcal{H}_{n,k}$, so that the SNR at subcarrier n of receiver k is $\mathbf{w}_{n,k}^H \mathcal{H}_{n,k} \mathbf{w}_{n,k}$. Each user k is

assigned to some subcarriers, in order to satisfy minimum rate requirement ρ_k . A fixed BER at each subcarrier must also be satisfied. The number of user bits in a subcarrier depends on the user spatial covariance matrix and the beamforming vector. These determine SNR at the receiver and thus the maximum SNR threshold γ that is satisfied. The beamforming vector for user k in subcarrier n is assumed to have fixed power $P_{n,k}$, i.e., $\mathbf{w}_{n,k}^H \mathbf{w}_{n,k} = P_{n,k}$. A beamforming vector is feasible if it satisfies the power constraint. Clearly, assignment of different users to a subcarrier leads to different feasible beamforming vectors that give a certain SNR at receiver. A subcarrier and bit assignment to users is *admissible*, if there exists a family of feasible beamforming vectors, one for each subcarrier, such that minimum SNR constraints at receivers corresponding to the given number of user bits per subcarrier are satisfied and minimum rate requirements for all users are fulfilled.

The identification of the admissible subcarrier and bit assignment to users that yields maximum total user throughput is not straightforward. It involves selection of the user to be assigned to a subcarrier, computation of the number of user bits in the subcarrier, as well as determination of feasible beamforming vectors. Ideally, each subcarrier should be assigned to the user that can support the largest number of bits in that subcarrier. The problem is that this policy may not lead to an admissible allocation, since some users may not satisfy minimum rate requirements. In the sequel, we propose a heuristic method that identifies an admissible allocation that yields high total user throughput.

B. The proposed approach

Fix attention to a subcarrier n and a user k . The problem of maximizing receiver SNR subject to a beamforming vector power constraint is,

$$\max_{\mathbf{w}_{n,k}} (\mathbf{w}_{n,k}^H \mathcal{H}_{n,k} \mathbf{w}_{n,k}) \text{ s.t. } \mathbf{w}_{n,k}^H \mathbf{w}_{n,k} = P_{n,k}. \quad (18)$$

Since matrix $\mathcal{H}_{n,k}$ is symmetric and invertible, it can be decomposed as $\mathcal{H}_{n,k} = \mathbf{U}_{n,k} \mathbf{\Lambda}_{n,k} \mathbf{U}_{n,k}^H$, where $\mathbf{U}_{n,k}$ is a unitary matrix, whose columns are the eigenvectors of $\mathcal{H}_{n,k}$ and $\mathbf{\Lambda}_{n,k}$ is a diagonal matrix of the corresponding eigenvalues. Thus $\text{SNR}_{n,k} = \tilde{\mathbf{w}}_{n,k}^H \mathbf{\Lambda}_{n,k} \tilde{\mathbf{w}}_{n,k}$, or

$$\text{SNR}_{n,k} = \sum_{m=1}^M \lambda_{n,k}^m (\tilde{w}_{n,k}^m)^2, \quad (19)$$

where $\tilde{\mathbf{w}}_{n,k} = \mathbf{U}_{n,k}^T \mathbf{w}_{n,k}$ and $\{\lambda_{n,k}^m\}_{m=1}^M$ are the eigenvalues of $\mathcal{H}_{n,k}$. Note that $\tilde{\mathbf{w}}_{n,k}^H \tilde{\mathbf{w}}_{n,k} = P_{n,k}$ since $\mathbf{U}_{n,k}$ is unitary. The maximization (19) subject to the power constraint is achieved by vector [20],

$$\tilde{\mathbf{w}}_{n,k}^* = \sqrt{P_{n,k}} [0, \dots, 0, \underbrace{1}_{\mu_{n,k}\text{-elem}}, 0, \dots, 0], \quad (20)$$

where $\mu_{n,k} = \arg \max_m \lambda_{n,k}^m$. Thus, the optimal beamforming vector is $\mathbf{w}_{n,k}^* = \mathbf{U}_{n,k} \tilde{\mathbf{w}}_{n,k}^* = \sqrt{P_{n,k}} \mathbf{u}_{n,k}^{\mu_{n,k}}$, where $\mathbf{u}_{n,k}^{\mu_{n,k}}$ is the eigenvector corresponding to the largest eigenvalue of $\mathcal{H}_{n,k}$ and the maximum SNR value is $P_{n,k} \lambda_{n,k}^{\mu_{n,k}}$.

Consider now the multi-user case. For each user k and subcarrier n , we compute $\text{SNR}_{n,k} = P_{n,k} \lambda_{n,k}^{\mu_{n,k}}$. At each subcarrier n , we assign the user k^* that achieves maximum SNR, namely

$$k^*(n) = \arg \max_{k=1, \dots, K} (P_{n,k} \lambda_{n,k}^{\mu_{n,k}}). \quad (21)$$

The total number of bits (total rate) for each user over all subcarriers is then evaluated by using (1). If all users satisfy the minimum rate requirements, then this is the optimal solution, whereas if no user satisfies minimum rate requirements, then an admissible user and bit allocation does not exist. Assume now that after this initial assignment only a subset of users satisfies minimum rate requirements. Let $\mathcal{S}$ and $\mathcal{U}$ denote the sets of "satisfied" and "unsatisfied" users respectively. Then, the rate of unsatisfied users must be increased, so as to approach and exceed minimum rate requirements. This can be achieved by subcarrier exchange (reassignment) between satisfied and unsatisfied users.

Fix attention to a pair of users $k \in \mathcal{S}$ and $\ell \in \mathcal{U}$ that are initially assigned to subcarriers m and n respectively. Let $r_{n,k}$ denote the number of transmitted bits (rate) for a user k when it is assigned to subcarrier n and let τ_k, τ_ℓ denote the total user rates after the initial assignment. A subcarrier exchange between users k and ℓ is *acceptable*, if the satisfied user does not become unsatisfied and if the rate of the unsatisfied user is increased, or in other words if $r_{m,k} - r_{n,k} \leq \tau_k - \rho_k$ and $r_{m,\ell} \geq r_{n,\ell}$. Subcarrier exchange should cause the *least decrease* in total achievable throughput. For the exchange of subcarriers m and n that are initially occupied by users k and ℓ , we define the reassignment rate cost as,

$$C_{m,n} = (r_{m,k} + r_{n,\ell}) - (r_{m,\ell} + r_{n,k}), \quad (22)$$

where terms in parentheses denote rates before and after reassignment and $C_{m,n} \geq 0$. Another significant parameter is the associated rate benefit for *unsatisfied* users. Rate benefit is captured by the metric,

$$U_{m,n} = (\rho_\ell - \tau_\ell) - [\rho_\ell - (\tau_\ell - r_{n,\ell} + r_{m,\ell})]^+, \quad (23)$$

where the two terms denote the marginal rate that is required in order for ℓ to reach minimum rate ρ_ℓ before and after reassignment and $(x)^+ = x$, if $x > 0$, otherwise it is 0. If the unsatisfied user reaches ρ_ℓ with the subcarrier exchange, then the second term is 0. A preferable reassignment is one with a small reassignment rate cost $C_{m,n}$ and a high rate benefit $U_{m,n}$ for unsatisfied users. We define the Exchange Preference Factor (EPF) as,

$$E_{m,n} = \frac{C_{m,n}}{U_{m,n}}. \quad (24)$$

After initial assignment, admissible subcarrier reassignments with minimum EPF are performed, by selecting appropriate subcarriers occupied by a satisfied and an unsatisfied user. EPFs and user rates are updated after each reassignment. This procedure is iterated until either all users satisfy their minimum rate requirements, or no further acceptable subcarrier reassignments exist. Observe that by requiring maximum rate benefit $U_{m,n}$ for unsatisfied users, we reduce the number of algorithm iterations until user minimum rate requirements are satisfied.

V. SPECIAL CASE: SPATIAL SEPARABILITY FOR TWO USERS

In this section, we consider the special case of two users and study required conditions for spatial separability within a subcarrier, given the number of bits of each user's subsymbol in the subcarrier. Let b_i , $\mathbf{w}_i$ and $\mathcal{H}_i$ respectively be the number of bits, beamforming vector and spatial covariance matrix for user i , $i = 1, 2$. In order to have a fixed BER at each receiver for b_i user bits, the minimum required SIR is γ_i , $i = 1, 2$, where the mapping $b \mapsto \gamma$ is performed by using (10), with $b = \log_2 M$. Vector $\mathbf{w}_i$ is written as $\mathbf{w}_i = |\mathbf{w}_i| \mathbf{u}_i$, where $\mathbf{u}_i$ is a unit vector that specifies the beamforming orientation. Two users with vector of bit numbers (b_1, b_2) are spatially separable if *both* SIRs at corresponding receivers SIR exceed the required thresholds, namely if,

$$SIR_1 = \frac{\mathbf{w}_1^H \mathcal{H}_1 \mathbf{w}_1}{\mathbf{w}_1^H \mathcal{H}_2 \mathbf{w}_1} \geq \gamma_1 \text{ and } SIR_2 = \frac{\mathbf{w}_2^H \mathcal{H}_2 \mathbf{w}_2}{\mathbf{w}_2^H \mathcal{H}_1 \mathbf{w}_2} \geq \gamma_2. \quad (25)$$

Then, the vector of bit numbers is called achievable. The arising spatial separability issue is whether there exist beamforming vectors $\mathbf{w}_1$ and $\mathbf{w}_2$ so that condition (25) is satisfied. The determination of beamforming vectors is not straightforward, since SIR of each user depends on both beamforming vectors. Observe that the product of SIRs can be written as,

$$SIR_1 \cdot SIR_2 = \frac{\mathbf{w}_1^H \mathcal{H}_1 \mathbf{w}_1}{\mathbf{w}_1^H \mathcal{H}_2 \mathbf{w}_1} \cdot \frac{\mathbf{w}_2^H \mathcal{H}_2 \mathbf{w}_2}{\mathbf{w}_2^H \mathcal{H}_1 \mathbf{w}_2} = z_1(\mathbf{w}_1) \cdot z_2(\mathbf{w}_2). \quad (26)$$

Then,

$$\max_{\mathbf{w}_1, \mathbf{w}_2} (SIR_1 \cdot SIR_2) = \max_{\mathbf{w}_1} z_1 \cdot \max_{\mathbf{w}_2} z_2. \quad (27)$$

Let z_1^* , z_2^* denote the maximum values of z_1, z_2 , which can be determined by finding the dominant generalized eigenvectors, $\mathbf{u}_1 = \mathbf{u}(\mathcal{H}_1, \mathcal{H}_2)$ and $\mathbf{u}_2 = \mathbf{u}(\mathcal{H}_2, \mathcal{H}_1)$. These eigenvectors are unit vectors, since vector magnitudes are cancelled in (26). Then, if $z_1^* z_2^* < \gamma_1 \gamma_2$, the vector of bit numbers (b_1, b_2) is not achievable and users are not separable. However, if $z_1^* z_2^* \geq \gamma_1 \gamma_2$, we cannot claim that individual bit numbers are achievable. In this case, if we know the beamforming orientation vectors $\mathbf{u}_1$ and $\mathbf{u}_2$, we can write the SIR constraints in the form of a linear inequality system, $F\mathbf{x} \geq \mathbf{0}$ as,

$$\begin{pmatrix} (\mathbf{u}_1^H \mathcal{H}_1 \mathbf{u}_1)/\gamma_1 & -\mathbf{u}_2^H \mathcal{H}_1 \mathbf{u}_2 \\ -\mathbf{u}_1^H \mathcal{H}_2 \mathbf{u}_1 & (\mathbf{u}_2^H \mathcal{H}_2 \mathbf{u}_2)/\gamma_2 \end{pmatrix} \begin{pmatrix} |\mathbf{w}_1| \\ |\mathbf{w}_2| \end{pmatrix} \geq \begin{pmatrix} 0 \\ 0 \end{pmatrix}. \quad (28)$$

If the system has a solution $(x_1, x_2) = (|\mathbf{w}_1|, |\mathbf{w}_2|)$ with $x_i \geq 0$, $i = 1, 2$, then users are spatially separable for the beamforming orientation $(\mathbf{u}_1, \mathbf{u}_2)$ and the beamforming vectors are given by $\mathbf{w}_i = x_i \mathbf{u}_i$, for $i = 1, 2$. Note that this method is cannot be applied for more than two users, since (27) does not hold.

VI. NUMERICAL RESULTS

A. Simulation setup

We consider a single-cell system with 20 users that are uniformly distributed in the cell area. The system uses OFDM transmission with an array of 8 antennas at 5GHz, in a frequency band which is divided into 50 subcarriers. The received power decreases with distance d from the base station as d^{-4} . Links corresponding to different receivers are uncorrelated. For each such

link, multi-path fading is modeled with a two-ray model. The angle of each path is uniformly distributed in $[0, \pi]$. The delay between paths is uniformly distributed in $[0, T]$, where T is the symbol period. The complex gain of each path is an independent log-normal random variable with standard deviation $\sigma = 6\text{dB}$, which accounts for shadow fading. The array steering vector for angle θ is given by vector,

$$\alpha(\theta) = \left(1, e^{(j2\pi d \sin \theta / \lambda_w)}, \dots, e^{(j2\pi(M-1)d \sin \theta / \lambda_w)}\right), \quad (29)$$

where d is the distance between antenna elements and λ_w is the subcarrier wavelength. The steering vector is thus dependent on subcarrier frequency. Using this model, the spatial covariance matrices $\mathcal{H}_{n,k}$ are determined for each user and subcarrier. A slotted transmission scheme based on TDD is assumed, so that reciprocity between up-link and down-link is ensured. Subcarrier quality estimation is performed by means of training symbols that are transmitted in up-link packets and no estimation errors occur. A target BER of 10^{-3} is assumed for all users and subcarriers and the SINR threshold corresponding to a given number of user bits per subsymbol is computed by (10).

B. Comparative results

The objective of the simulations is to study and compare the performance of different adaptive resource allocation and beamforming techniques. We also consider the effects of intelligent subcarrier and bit allocation and beamforming on system performance. For the problem described in section III, where subcarrier reuse is applicable, the following schemes are compared:

- Subcarrier allocation and spatial separation of users. This is the proposed algorithm in section III. It employs combined subcarrier allocation and beamforming, under the criteria of minimal induced and received interference and large number of transmitted user bits. It will be referred to as Algorithm A.
- Random subcarrier allocation (RSA) and spatial separation of users. This algorithm does not apply the criteria above to assign users to subcarriers. Thus, a user is always assigned to an arbitrary subcarrier. Once user assignment takes place, beamforming vectors are computed as usual and number of user bits per subcarrier are determined. This algorithm is referred to as Algorithm A-RSA.
- Subcarrier allocation with no beamforming (NB). This algorithm does not apply beamforming in the criteria for user insertion in a subcarrier. In the absence of beamforming, preference factors, such as $D_{n,k}$ in (11) are given as

$$D_{n,k} = \frac{\|\mathcal{H}_{n,k}\|}{\sum_{i \in \mathcal{U}^n} \|\mathcal{H}_{n,i}\|}. \quad (30)$$

Other preference factors are computed accordingly. This method is referred to as Algorithm A-NB.

The performance criterion is aggregate subcarrier transmission rate, which is proportional to total number of bits of users in the subcarrier. Different number of bits per subsymbol are achieved by employing 6 different M -QAM modulation levels, which yield up to 6 bits per user OFDM subsymbol in a subcarrier. User

rates were computed over all subcarriers of symbols during transmission of 10,000 data packets, where channel conditions varied randomly between consecutive packets. Results were averaged over 100 such random experiments with different user locations. Figure 3 illustrates the cumulative distribution function of subcarrier rate for the three algorithms above. For a system with 8 antenna elements and 6 modulation levels, the maximum achievable throughput per subcarrier is 48 bits, since at most 8 users can be separated in a subcarrier. Our integrated approach of subcarrier, bit allocation and beamforming has significantly better performance than the other two schemes, whereas algorithm A-NB turns out to provide the lowest total rate per subcarrier. For example, consider a subcarrier throughput value of 20 bits. With algorithm A-NB, only 20% of subcarriers achieve or exceed this rate, whereas with algorithm A this percentage raises to approximately 70%. Based on performance of algorithms A-NB and A-RSA, it is clear that even with random subcarrier allocation, spatial separation based only on adaptive beamforming yields better results than resource allocation schemes that do not include beamforming.

In Figure 4, the performance of the three adaptive schemes is shown as a function of channel quality, i.e., average link SNR, where a link is now a distinct pair of antenna and receiver. Propagation conditions and user positions were calibrated, so as to create different link conditions. Simulation results show that beamforming based on algorithm A-SRA achieves moderate rate, but performance is substantially improved if adaptive subcarrier allocation is incorporated, as in algorithm A. Note that in severe channel conditions (low SNR values), algorithm A is particularly effective in combating interference. For example, for a link SNR of 4dB, the attainable rate for algorithm A is approximately three and four times higher than rates obtained by algorithm A-RSA and A-NB respectively. The performance of these two algorithms improves as channel conditions improve. Figure 5 shows the effect of different number of antennas and modulation levels on the achievable throughput per subcarrier for algorithm A. For m utilized modulation levels, we assume that these are the highest ones, that is, the ones with $6, \dots, 6 - m + 1$ bits per subsymbol. To ensure a fair comparison of rates, the depicted rate for the cases of 4 antennas is actually the rate for two subcarriers, which belong in two consecutive symbols. Spatial separation of users is shown to be more effective for a larger number of antennas. Simulation results demonstrate that the inclusion of more modulation levels in the transmission scheme can yield significant rate benefits and this improvement becomes more evident as channel conditions deteriorate, since lower modulation levels can aid spatial separation of users in poor channel conditions.

For the problem described in section IV, where subcarrier reuse is not applicable, Figure 6 demonstrates the link improvements incurred by beamforming. Average subcarrier rate results are provided for different modulation levels and different number of antenna elements. A larger number of lower modulation levels leads to efficient "quantization" of channel conditions and achievability of appropriate rates.

VII. DISCUSSION

In this paper, we addressed the problem of resource allocation and beamforming for spatial separation of users, with the objec-

tive to increase resource reuse, guarantee user separability and ultimately enhance system capacity. The problem was studied in the context of an OFDM transmission system, which provides a convenient framework for resource allocation and coherent user separation, due to negligible ISI and delay spread. The determination of user and user bit allocation to subcarriers, as well as of the appropriate beamforming vectors that yield large number of transmitted user bits per subcarrier and maintain acceptable BER at the receiver, is a hard optimization problem. In section V, some separability conditions were derived for a simple system with two users and for a given number of user bits, by exploiting the special structure of SIR requirements. Knowledge of beamforming orientations was also assumed, in order to derive acceptable beamforming vectors. It was stated that these conditions are not valid for more than two users. In such a case, the task would be first to consider all possible subsets of users that can share a subcarrier and then consider all possible combinations of number of user bits, in order to find the subset of separable users that yields maximum total number of transmitted bits per subcarrier. The problem is that any claim about spatial separability of a subset of users cannot be proved, since SIR at a receiver depends on beamforming vectors of other users. Even for a fixed assignment of users, the computation of beamforming vectors that maximize receiver SIRs is a computationally intensive non-linear optimization problem. The consideration of constraints renders the problem even more difficult. Therefore some heuristic algorithm must be applied, whose structure should capture desired properties of a good solution and it will provide performance bounds for more general algorithms.

A greedy heuristic algorithm for the unconstrained problem is proposed in section III. Joint consideration of subcarrier and bit allocation together with beamforming for spatial separation of users is shown to increase system throughput. In section IV, we also considered a simplified version of the problem, where subcarrier reuse was not allowed and applied beamforming power constraints and user minimum rate requirements. A heuristic approach to find an admissible allocation with a high total user rate was presented. An interesting topic for investigation would be to devise efficient algorithms for such composite constrained problems.

In our work, we did not consider any limitation on the number of available beamformers, since a separate beam could be formed for each user and subcarrier. However, in a realistic situation, there will be a limited number of beamformers, mainly due to limited infrastructure cost. The assignment algorithm should then perform user allocation both in the frequency (sub-carriers) and in the space (beamformers) dimension. Additional constraints need to be taken into consideration, such as that users cannot be assigned in the same subcarrier and beamformer simultaneously.

Finally, it is worth pointing out the similarity between spatial separation in the context of SDMA and user separation in other multiple access schemes, such as CDMA, which could lead to issues that warrant further investigation. Spatial user signatures and beamforming in SDMA is the analogue of signature sequences and transmission precoding or receiver filtering respectively in CDMA (depending on whether down-link or up-link is considered). Well-studied resource allocation and parameter adaptation methods used in CDMA could constitute the corner-stones for studying analogous problems in SDMA.

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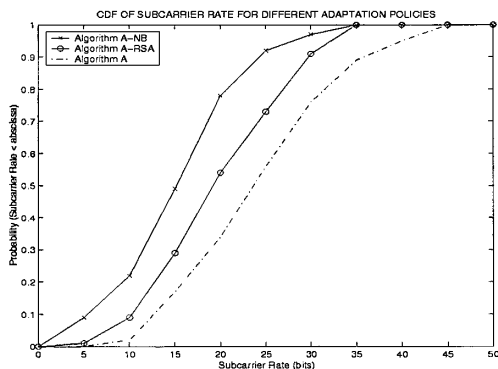


Fig. 3. CDF of subcarrier rate for different adaptive transmission techniques.

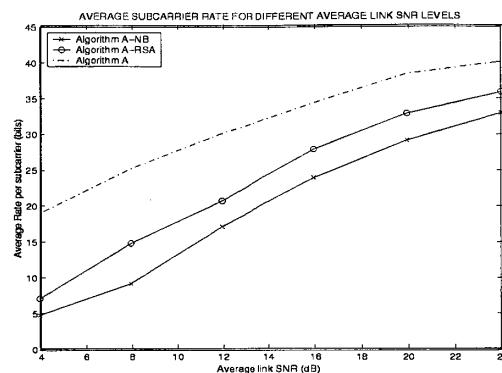


Fig. 4. Subcarrier rate for different channel conditions (SNR values).

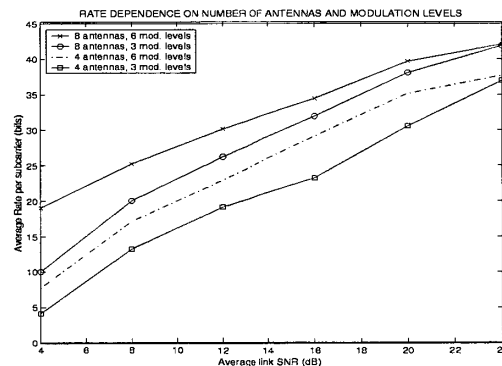


Fig. 5. Subcarrier rate vs. different number of antennas and modulation levels.

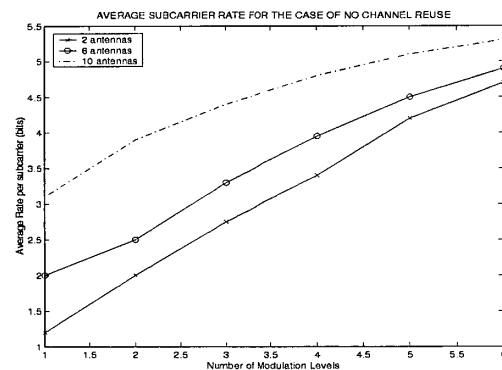


Fig. 6. Subcarrier rate vs. different modulation levels for no subcarrier reuse.

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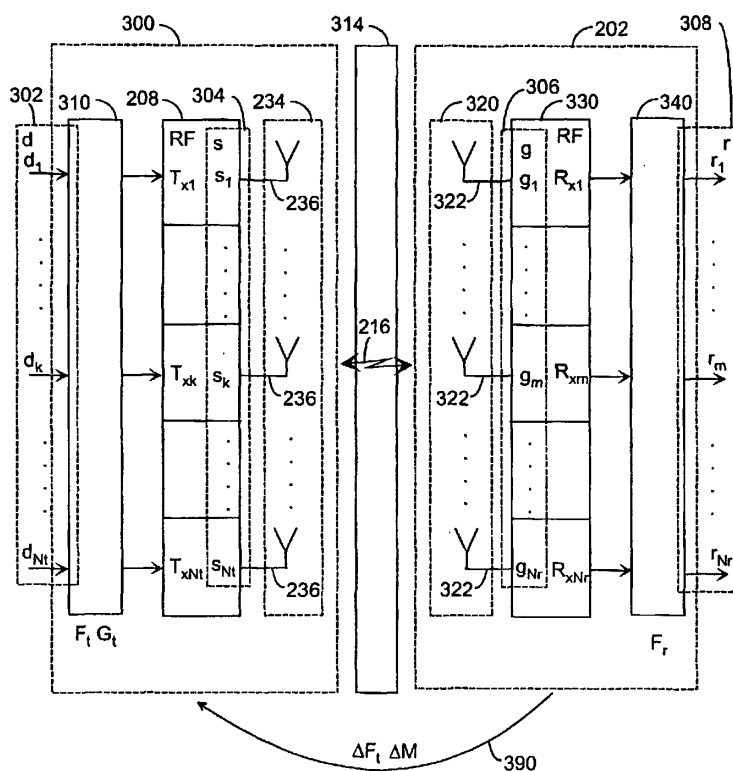
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(54) Title: DATA TRANSFER METHOD IN RADIO SYSTEM

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(57) Abstract: The invention relates to a data transfer method in a radio system utilizing a multiple antenna method, the data transfer method comprising generating, at a receiver, at least part of a change in a variable which contains transmit filter information on a transmitter as compared with a previous value of the variable, transmitting at least part of the change in the variable containing transmit filter information on the transmitter from the receiver to the transmitter and updating, at the transmitter, the transmit filter information on the transmitter on the basis of the received change in the variable containing transmit filter information. The invention further relates to a radio system implementing the method. In the solution, the amount of data used for updating transmit filter information and to be transmitted to a transmitter can be optimised, which enables unnecessary loading of radio capacity to be avoided.



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DATA TRANSFER METHOD IN RADIO SYSTEM

FIELD

[0001] The invention relates to a data transfer method in a radio system. The invention relates particularly to a data transfer method wherein
5 more than one antenna is used both at a transmitter and a receiver for transmitting and receiving signals.

BACKGROUND

[0002] It is generally known that in telecommunication connections, the radio transmission path used for transmitting signals causes interference to
10 telecommunication, the interference typically being functions of time and place. Interference on a radio transmission path includes radio path fading caused to a radio field by the environment, and interference caused by other radio devices, such as multi-use interference of a radio system. In connection with moving terminal equipment in particular, the transmission path quality may of-
15 ten vary considerably between different connections and even during a single connection.

[0003] A solution to the problem is to use different modes of diversity, such as time diversity, frequency diversity and antenna diversity, at a transmitter. Time diversity utilizes interleaving and encoding of a signal to be
20 transmitted, but this causes delay to transmission, particularly to slowly fading channels. In frequency diversity, a signal is simultaneously transmitted at several frequencies; however, frequency diversity is an inefficient method when coherence bandwidth is high.

[0004] In antenna diversity, a signal is transmitted and usually also
25 received by antenna arrays comprising at least two antenna elements, and the aim is to make the mutual correlation between the elements low by means of physical placing and polarization, for example. The radio transmission paths between the antenna elements of transmitting antennas and the antenna elements of receiving antennas then constitute physical radio channels that can
30 be turned into virtual data transfer channels. A way to utilize antenna diversity is a method called MIMO (Multiple Input, Multiple Output) whose theoretical data transfer capacity increases linearly as the number of transmitting antennas and receiving antennas increase. In order to achieve errorless transmission, it is preferable that at least some of the characteristics of the radio path
35 are known to a transmitter; this knowledge enables a possible transmit filter to

be modified. Particularly in FDD (Frequency Division Duplex) systems, a partial knowledge of the radio path is problematic since the physical channels on the uplink and the downlink transmission path are not identical; consequently, the transmit filter information on a transmitter is usually generated at a receiver. In such a case, the receiver must transmit the generated transmit filter information on the transmitter to the transmitter in one way or another.

[0005] In the prior art solutions, the transmit filter information on a transmitter generated by a receiver is as such transmitted to the transmitter, in which case previous transmit filter information on the transmitter is replaced by new transmit filter information in each update. The amount of data to be transmitted is thus in the order of N^2-1 , wherein N is the number of virtual data transmission channels. Drawbacks of the prior art solutions include transfer of unnecessary information and subsequent unnecessary loading of data transfer capacity when the transmit filter information on a transmitter is updated.

BRIEF DESCRIPTION

[0006] An object of the invention is to provide a data transfer method and a radio system implementing the data transfer method so as to enable transmit filter information on a transmitter generated by a receiver to be transferred from the receiver to the transmitter at a low data transfer capacity.

[0007] This is achieved by a data transfer method in a radio system comprising a transmitter comprising at least one antenna array comprising at least two antennas, and at least one receiver comprising at least one antenna array comprising at least two antennas, the radio system comprising a physical radio channel between the transmitter and the receiver, and the data transfer method comprising filtering, by means of transmit filter information, a signal to be transmitted via the antennas of the antenna array of the transmitter and generating, at the receiver, a variable which contains transmit filter information on the transmitter. The method of the invention comprises generating, at the receiver, at least part of a change in the variable containing transmit filter information on the transmitter, transmitting at least part of the change in the variable containing transmit filter information on the transmitter from the receiver to the transmitter, and updating, at the transmitter, the transmit filter information on the transmitter on the basis of the received change in the variable containing transmit filter information.

[0008] The invention further relates to a radio system implementing the data transfer method. The radio system of the invention comprises a transmitter comprising at least one antenna array comprising at least two antennas, and at least one receiver comprising at least one antenna array comprising at least two antennas, the radio system comprising a physical radio channel between the transmitter and the receiver, the radio system comprising means for filtering, by means of transmit filter information, a signal to be transmitted via the antennas of the antenna array of the transmitter, and means for generating, at the receiver, a variable which contains transmit filter information on the transmitter. In the radio system of the invention, the receiver comprises means for generating at least part of a change in the variable containing transmit filter information on the transmitter, the receiver is arranged to transmit at least part of the change in the variable containing transmit filter information on the transmitter to the transmitter, and the means for filtering are arranged to update the transmit filter information on the transmitter on the basis of the received change in the variable containing transmit filter information.

[0009] Preferred embodiments of the invention are disclosed in the dependent claims.

[0010] The invention is based on the idea that a receiver generates a variable which contains transmit filter information on a transmitter, and a change in the variable as compared with a previous value of the variable known to the transmitter and the receiver is transmitted to the transmitter, which updates its transmission filtering on the basis of the received information about the change.

[0011] The method and system of the invention provide several advantages. An essential advantage of the invention is that the amount of data to be transmitted to the transmitter to be used for updating a transmit filter can be optimised, thus enabling unnecessary loading of the radio capacity to be avoided.

LIST OF DRAWINGS

[0012] The invention is now described in closer detail in connection with the preferred embodiments and with reference to the accompanying drawings, in which

[0013] Figure 1 is a simplified block diagram showing a telecommunication system,

[0014] Figure 2a is another simplified block diagram showing a telecommunication system,

[0015] Figure 2b is a simplified block diagram showing terminal equipment, and

5 [0016] Figure 3 is a block diagram showing the present solution.

DESCRIPTION OF EMBODIMENTS

[0017] Since second generation (2G) radio systems and third generation (3G) radio systems as well as different hybrids thereof, i.e. so-called 2.5G radio systems, are already being used all over the world and under constant development, embodiments will be described in a radio system illustrated in Figure 1 wherein network elements of different generations coexist. In the description, the 2G radio system is represented e.g. by a GSM (Global System for Mobile Communications). The 2.5G is represented e.g. by a GPRS (General Packet Radio System). The 3G radio system is represented e.g. by a system which is based on the GSM system and which utilizes 3G EDGE (Enhanced Data Rates for Global Evolution) technology, and systems known at least by the names IMT-2000 (International Mobile Telecommunications 2000) and UMTS (Universal Mobile Telecommunications System). The embodiments are not, however, restricted to these systems described as examples but a person skilled in the art can also apply the teachings to other radio systems comprising corresponding characteristics.

[0018] Figure 1 is a simplified block diagram showing, at a network element level, the most important parts of a radio system and the interfaces therebetween. Being generally known, the structure and functions of the network elements will not be described in greater detail.

[0019] The main parts of a radio system are a core network (CN) 100, a radio access network 130 and user equipment (UE) 170. The term UTRAN is short for UMTS Terrestrial Radio Access Network, i.e. the radio access network 130 belongs to the third generation and is implemented by wideband code division multiple access (WCDMA) technology. Figure 1 also shows a base station system 160 implemented by time division multiple access (TDMA) technology.

[0020] On a general level, the radio system can also be defined to comprise user equipment, which is also known as a subscriber terminal and mobile phone, for instance, and a network part, which comprises the fixed in-

frastructure of the radio system, i.e. the core network, radio access network and base station system.

[0021] The structure of the core network 100 corresponds to a combined structure of the GSM and GPRS systems. The GSM network elements
5 are responsible for establishing circuit-switched connections, and the GPRS network elements are responsible for establishing packet-switched connections; some of the network elements are, however, included in both systems.

[0022] A mobile services switching center (MSC) 102 is the center point of the circuit-switched side of the core network 100. The same mobile
10 services switching center 102 can be used to serve the connections of both the radio access network 130 and the base station system 160. The tasks of the mobile services switching center 102 include: switching, paging, user equipment location registration, handover management, collection of subscriber billing information, encryption parameter management, frequency allocation management, and echo cancellation.
15

[0023] The number of mobile services switching centers 102 may vary: a small network operator may only have one mobile services switching center 102 but large core networks 100 may have several ones. Figure 1 shows a second mobile services switching center 106, but its connections to
20 other network elements are not shown in order to keep Figure 1 sufficiently clear.

[0024] Large core networks 100 may have a separate gateway mobile services switching center (GMSC) 110, which is responsible for circuit-switched connections between the core network 100 and external networks
25 180. The gateway mobile services switching center 110 is located between the mobile services switching centers 102, 106 and the external networks 180. An external network 180 can be for instance a public land mobile network (PLMN) or a public switched telephone network (PSTN).

[0025] A home location register (HLR) 114 comprises a permanent
30 subscriber register, i.e. the following information, for instance: an international mobile subscriber identity (IMSI), a mobile subscriber ISDN number (MSISDN), an authentication key, and when the radio system supports GPRS, a packet data protocol (PDP) address.

[0026] A visitor location register (VLR) 104 contains roaming information on user equipment 170 in the area of the mobile services switching
35 center 102. The visitor location register 104 comprises almost the same information

mation as the home location register 114, but in the visitor location register 104, the information is kept only temporarily.

5 **[0027]** An equipment identity register (EIR) 112 comprises the international mobile equipment identities (IMEI) of the user equipment 170 used in the radio system, and a so-called white list, and possibly a black list and a grey list.

[0028] An authentication center (AuC) 116 is always physically located in the same place as the home location register 114, and it comprises a subscriber authentication key Ki and a corresponding IMSI.

10 **[0029]** The network elements shown in Figure 1 are functional entities whose physical implementation may vary. Usually, the mobile services switching center 102 and the visitor location register 104 constitute one physical device while the home location register 114, equipment identity register 112 and the authentication center 116 constitute another physical device.

15 **[0030]** A serving GPRS support node (SGSN) 118 is the center point of the packet-switched side of the core network 100. The main task of the serving GPRS support node 118 is to transmit and receive packets together with the user equipment 170 supporting packet-switched transmission by using the radio access network 130 or the base station system 160. The serving
20 GPRS support node 118 contains subscriber and location information related to the user equipment 170.

[0031] A gateway GPRS support node (GGSN) 120 is the packet-switched side counterpart to the gateway mobile services switching center 110 of the circuit-switched side with the exception, however, that the gateway
25 GPRS support node 120 must also be capable of routing traffic from the core network 100 to external networks 182, whereas the gateway mobile services switching center 110 only routes incoming traffic. In our example, external networks 182 are represented by the Internet.

[0032] The base station system 160 comprises a base station controller (BSC) 166 and base transceiver stations (BTS) 162, 164. The base station controller 166 controls the base transceiver station 162, 164. In principle, the aim is that the devices implementing the radio path and their functions reside in the base transceiver station 162, 164 while control devices reside in the base station controller 166.

35 **[0033]** The base station controller 166 is responsible for the following tasks, for instance: radio resource management of the base transceiver

station 162, 164, intercell handovers, frequency control, i.e. frequency allocation to the base transceiver stations 162, 164, management of frequency hopping sequences, time delay measurement on the uplink, implementation of the operation and maintenance interface, and power control.

5 **[0034]** The base transceiver station 162, 164 comprises at least one transceiver which implements one carrier, i.e. eight time slots, i.e. eight physical channels. Typically, one base transceiver station 162, 164 serves one cell, but a solution is also possible wherein one base transceiver station 162, 164 serves several sectorized cells. The diameter of a cell may range between a few
10 meters and dozens of kilometers. The base transceiver station 162, 164 also comprises a transcoder for converting the speech coding format used in the radio system to that used in the public switched telephone network. In practice, however, the transcoder is physically located in the mobile services switching center 102. The tasks of the base transceiver station 162, 164 include: calcula-
15 tion of timing advance (TA), uplink measurements, channel coding, encryption, decryption, and frequency hopping.

[0035] The radio access network 130 comprises radio network subsystems 140, 150. Each radio network subsystem 140, 150 comprises radio network controllers (RNC) 146, 156 and nodes B 142, 144, 152, 154. Node B
20 is a rather abstract concept; the term 'base transceiver station' is often used instead.

[0036] Operationally, the radio network controller 140, 150 corresponds approximately to the base station controller 166 of the GSM system, and node B 142, 144, 152, 154 corresponds approximately to the base trans-
25 ceiver station 162, 164 of the GSM system. Solutions also exist in which the same device is both the base transceiver station and node B, i.e. the device is capable of implementing both the TDMA and WCDMA radio interfaces simultaneously.

[0037] The user equipment 170 comprises two parts: mobile equipment (ME) 172 and a UMTS subscriber identity module (USIM) 174. The GSM
30 system naturally uses its own identity module. The user equipment 170 comprises at least one transceiver for establishing a radio link to the radio access network 130 or base station system 160. The user equipment 170 may comprise at least two different subscriber identity modules. The user equipment
35 170 further comprises an antenna, a user interface and a battery. Today, dif-

ferent types of user equipment 170 exist, for instance equipment installed in cars and portable equipment.

[0038] The USIM 174 comprises user-related information and information related to information security in particular, for instance an encryption algorithm.

[0039] Finally, the interfaces between different network elements shown in Figure 1 are listed in Table 1. In the UMTS, the most important interfaces are the lu interface between the core network and the radio access network, which is divided into the luCS (CS = Circuit Switched) interface on the circuit-switched side and the luPS (PS = Packet Switched) interface on the packet-switched side, and the Uu interface between the radio access network and the user equipment. In the GSM, the most important interfaces are the A interface between the base station controller and the mobile services switching center, the Gb interface between the base station controller and the serving GPRS support node, and the Um interface between the base transceiver station and the user equipment. The interface defines what kind of messages different network elements can use in communicating with each other. The aim is to provide a radio system which enables the network elements of different manufacturers to interwork adequately enough to provide a working radio system. In practice, however, some of the interfaces are vendor-dependent.

Interface	Between network elements
Uu	UE-UTRAN
lu	UTRAN-CN
luCS	UTRAN-MSC
luPS	UTRAN-SGSN
Cu	ME-USIM
lur	RNC-RNC
lub	RNC-B
A	BSS-MSC
Gb	BSC-SGSN
A-bis	BSC-BTS
Um	BTS-UE
B	MSC-VLR
E	MSC-MSC

9

D	MSC-HLR
F	MSC-EIR
Gs	MSC-SGSN
PSTN	MSC-GMSC
PSTN	GMSC-PLMN/PSTN
G	VLR-VLR
H	HLR-AUC
Gc	HLR-GGSN
Gr	HLR-SGSN
Gf	EIR-SGSN
Gn	SGSN-GGSN
Gi	GGSN-INTERNET

Table 1

[0040] The description shown in Figure 1 is quite general, so Figure 2a shows a more detailed example of a cellular radio system. Figure 2a only comprises the most essential blocks, but it is obvious to one skilled in the art that a conventional cellular radio network also comprises other functions and structures that need not be explained in closer detail herein. The details of a cellular radio system may differ from those shown in Figure 2a, but these differences are irrelevant to the invention.

[0041] Figure 2a shows a mobile services switching centre 106, a gateway mobile services switching centre 110, which is responsible for the connections of the mobile communication system to the external world, herein to the public telephone network 180, and a network part 200 and terminal equipment 202.

[0042] A cellular radio network typically comprises a fixed network infrastructure, i.e. a network part 200, and terminal equipment 202, which may be fixedly mounted, vehicle mounted, or portable terminal equipment, such as mobile telephones or portable computers, which enable communication with a radio communications system. The network part 200 comprises base transceiver stations 204. A base transceiver station corresponds with node B in the previous figure. A plurality of base transceiver stations 204, in turn, is controlled in a centralized manner by a radio network controller 146 communicating with the base transceiver stations and comprising a group switching field 220 and a control unit 222. The group switching field 220 is used for switching

speech and data and for connecting signalling circuits. The control unit 222, in turn, carries out call control, mobility management, collection of statistical data, signalling and control and management of resources.

[0043] The base transceiver station 204 and the radio network controller 146 constitute a radio network subsystem 140, which further comprises a transcoder 226, which converts different digital speech encoding formats used between a public telephone network and a radio telephone network into compatible ones, e.g. from the format of the fixed network into another format of the cellular radio network, and vice versa. The transcoder 226 is usually located as close to a mobile services switching centre 106 as possible because this allows speech to be transmitted between the transcoder 226 and the radio network controller 146 in a cellular radio network form, which saves transmission capacity.

[0044] The base transceiver station 204 further comprises a multiplexer unit 212, transceivers 208 and a control unit 210, which controls the operation of the transceiver 208 and the multiplexer 212. The multiplexer 212 is used for arranging the traffic and control channels used by a plurality of transceivers 208 onto a single transmission connection 214. The transmission connection 214 constitutes an interface lub. Furthermore, the multiplexer unit 212 carries out error correction operations and, possibly, bit interleaving and deinterleaving.

[0045] The transceivers 208 of the base transceiver station 204 are connected to an antenna array 234 comprising at least two antennas 236 and 238. The antenna array 234 is used for implementing at least one radio connection 216 to at least one terminal 202. The structure of the frames transmitted on the at least one radio connection 216 is determined system-specifically, and it is called an air interface Uu.

[0046] Figure 2b shows the structure of the terminal equipment 202 by means of a block diagram. The terminal equipment 202 comprises a user interface UI 370, a source codec unit SC 360 SC, a baseband part BB 350, a transceiver 330, an antenna array 320 and a control unit 380.

[0047] The user interface 370 of the terminal equipment 202 comprises e.g. the terminal's keyboard and audiovisual means, such as a display, microphones and earphones. The user interface 370 enables the operation of the terminal equipment 202 to be controlled, and the user interface 370 is also responsible for delivering a signal 372 produced by a user and directed to the

terminal equipment 202 and for converting a signal 374 supplied from the terminal equipment 202 and directed to the user into a form understood by the user. The user interface 370 may also be located in a peripheral device, such as a computer, connected to the terminal equipment 202. A source encoding
5 unit 360 comprises source encoding and carries out digital signal processing.

[0048] The baseband part 350 comprises signal processors and necessary memory means for processing the signals to be transmitted to and received from the transceiver 330. The baseband part 350 is, for example, used for carrying out the digital transmitter and receiver filtering of the terminal
10 equipment 202. Furthermore, a signal to be transmitted is spread with a spreading code and a received signal is despread at the baseband part.

[0049] The transceiver 330 converts a received radio-frequency signal into a baseband one and a baseband signal to be transmitted into a radio-frequency one. The transceiver 330 further comprises amplifiers for amplifying and possibly for phasing the signals to be transmitted from and received
15 by antennas 322 according to control commands issued by the control unit 380. Signals are amplified and phased at the transceiver in analogue form. The transceiver 330 also comprises duplex filters to enable a signal to be transmitted and a signal to be received to be separated.

[0050] The control unit 380 controls the operation of the transceiver 380, baseband part 350 and the source encoding unit 360. The control unit 380 gives the transceiver 380 and the baseband part 380, for example, control commands determining the settings of transmit filters, on the basis of which the transceiver 380 and the baseband part 380 implement the physical filtering of a
25 signal. Furthermore, the control unit 380 is responsible for the higher layer signalling, which is associated with connection setup and maintenance and resource allocation, for example. The control unit 380 further comprises a processor and memory means to enable execution of processes, such as calculation procedures, programmed in the control unit.

[0051] The antenna array 320 comprises at least two antennas 322 arranged, utilizing physical disposition, for example, to enable low correlation between the antennas 322. The distance between the antennas is then typically 0.5 – 1.5 times the length of the carrier used. Some of the antennas may also be in different polarizations, which means that the distance therebetween
35 may typically be less than 0.5 times the carrier length.

[0052] The solution set forth is not restricted to be implemented in the radio system disclosed above but it can be applied to any radio system that allows the multiple antenna technology to be utilized. Such systems include wireless local area networks (W-LAN), wireless personal area networks (W-PAN) and Bluetooth networks, for example.

[0053] For the sake of simplicity, Figure 3 is restricted to view at least one transmitter 300 and at least one receiver 202 according to a preferred embodiment of the present solution. The transmitter 300, which is usually a base transceiver station 204, comprises a transceiver 208, an antenna array 234 and a transmit filter 310. The number N_t of transmitting antennas 236 in the antenna array 234 is $N_t > 1$. Transmit filtering can preferably be implemented at the transceiver 208 of the base transceiver station 204 or at a multiplexer unit 212.

[0054] In Figure 3, the terminal equipment 202 serves as a receiver comprising an antenna array 320 which, in turn, comprises antennas 322 whose number is $N_r > 1$. The receiver 202 further comprises a receive filter 340, which carries out signal filtering, preferably at the transceiver 330 of the terminal equipment 202 or at the baseband part 350.

[0055] Above, the radio system parts have been named as a transmitter 300 and a receiver 202 only for the sake of simplicity; the present solution is thus not restricted to the appellations used.

[0056] The radio connection 216 between the transmitter 300 and the receiver 202 is set up using a radio transmission path 314. The radio transmission path 314 comprises an environment which may cause changes in the phases and amplitudes of the radio signals to be transmitted.

[0057] Figure 3 also shows how the signal propagates at the transmitter 300, on the radio transmission path 314 and at the receiver 202. In Figure 3, a data signal 302, which can preferably be presented by a signal vector $d = (d_1, d_2, \dots, d_k, d_{N_t})$, is directed to the transmit filter 310. The signal vector can be directed at the transmitter as separated e.g. in terms of location, time or encoding; the point is to enable the data signal components d_k to be processed at the transmitter 300 independently of each other. The elements d_k of the data signal vector d are typically complex numbers that comprise the information to be transmitted possibly in an encoded form. The information to be transmitted may also be in an interleaved form. The transmit filter 310 directs filtering to the data signal 302, the filtering preferably being presented by a transmit filter

matrix F_t . The transmit filter matrix may comprise implicitly normalized weighting, which comprises the ratios of the weights of the signals transmitted from each antenna 236. A weighted transmit filter matrix can be presented in a matrix form $F_t = G_t F_{t,nw}$, wherein G_t is a normalized weight matrix comprising as its

5 diagonal elements the ratios of the weights of the signals transmitted from each antenna 236, and $F_{t,nw}$ is an unweighted transmit filter matrix. The transmit filter matrix can preferably be generated at the radio network controller 146 or the base transceiver station 204. Preferably, the physical transmit filtering of the signal can be implemented at the transceivers 208 of the base transceiver

10 station, in which case analogue filtering is carried out. Transmit filtering can also preferably be implemented at the multiplexer unit 212 of the base transceiver station, in which case the transmit filtering is carried out digitally.

[0058] As a result of the filtering carried out by the transmit filter 310, the data signal 302 is converted into a new signal 304, which can preferably be presented by a signal vector $s = (s_1, s_2, \dots, s_k, s_{Nt})$. The signal vector s

15 is obtained by means of the signal vector d , transmit filter matrix F_t and a noise vector Q_t in the following manner: $s^T = F_t d + Q_t$, wherein the superscript T refers to the transpose of the matrix. Each element s_k of the signal vector s represents the strength and phase of a signal supplied from each antenna k of the

20 antenna array 234 of the transmitter 300. The signal 304 presented by the signal vector s is transmitted to the radio transmission path 314 by using at least two antennas 236. Q_t is the noise generated at the transmit filter.

[0059] The receiver 202 receives a signal 306, which can preferably be presented by means of a signal vector $g = (g_1, g_2, \dots, g_m, g_{Nr})$. Each element

25 g_m of the signal vector represents the strength and phase of a signal received by each antenna m of the antenna array 320. The signal vector g can be presented e.g. by means of a channel matrix H and the signal vector s in the following manner:

$$g^T = Hs + Q_H, \quad (1)$$

30 wherein the superscript T refers to the transpose of the matrix, and Q_H presents a noise vector generated on the radio transmission path 314. In this description, the matrix H may contain echoes, which is why the signal vector s may comprise several copies of the signal vector transmitted by the transmitter.

[0060] The channel matrix H presents a physical radio channel, i.e. a channel estimate, between the transmitter 300 and the receiver 202. The channel matrix H can be written e.g. in the form

$$H = \begin{pmatrix} H_{11} & \dots & \dots & H_{1,N_r} \\ \vdots & \ddots & \dots & \vdots \\ \vdots & \dots & H_{mk} & \vdots \\ H_{N_t,1} & \dots & \dots & H_{N_t,N_r} \end{pmatrix}, \quad (2)$$

5 wherein each element H_{mk} of the channel matrix H represents the effect, such as attenuation, phase shift and radio echo, of the radio transmission path 314 between the transmitting antenna k and the receiving antenna m on the signal 216 between the transmitting antenna k and the receiving antenna m . Let us first confine ourselves to a situation wherein no radio echo exists.

10 [0061] The signal 306 is supplied to the receive filter 340, which converts the signal 306 into a signal 308. Receive filtering can preferably be implemented at the transceiver 330 of the receiver 202, in which case analogue filtering is carried out. In an embodiment, receive filtering is implemented digitally at the baseband part 350 of the receiver 202. The filtering carried out on
15 the signal 306 by the receive filter 340 can be presented using a receive filter matrix F_r in the following manner: $r^T = F_r^{-1}g + Q_r$, wherein F_r^{-1} is the inverse matrix of the filter matrix F_r , and the noise vector Q_r represents the noise generated at the receiver 202. The receive filter matrix is preferably generated at the control unit 380 of the receiver 202.

20 [0062] In an embodiment of the present solution, the matrix $F_{t,nw}$ representing the unweighted transmit filter 310 and the matrix F_r representing the receive filter are unitary-like complex matrices, and when they are directed at a vector, the direction of the vector is changed but the length of the vector is changed only by small amounts. In addition, variables $F_{t,nw}^\dagger F_{t,nw}$ and $F_r^\dagger F_r$ resemble a unit matrix, wherein $F_{t,nw}^\dagger$ is the conjugate transpose of the matrix $F_{t,nw}$ and wherein $F_r^\dagger$ is the conjugate transpose of the matrix F_r .
25

[0063] After passing through the transmitter 300, radio transmission path 314 and the receiver 202, the data signal 302 has become the signal 308. In a preferred embodiment of the present solution, the signal vector r representing the signal 308 generated by the receive filter 340 can be presented
30 using the transmitted data signal vector d , the inverse matrix F_t^{-1} of the transmit filter matrix F_t , the channel matrix H and the receive filter matrix F_r by using the matrix equation

15

$$r = F_t^{-1} H F_r d + Q, \quad (3)$$

wherein Q is a noise vector comprising the noise generated at the transmitter 300, on the radio transmission path 314 and at the receiver 202. In theory, a radio system applying a multiple antenna system and comprising N_t transmitting antennas and N_r receiving antennas, wherein $N_t > 1$ and/or $N_r > 1$, is capable of setting up at most N_c parallel channels, each parallel channel operating as an independent channel. The theoretical maximum number N_c of parallel channels between each transceiver pair is either the number N_t of transmitting antennas or the number N_r of receiving antennas such that the lower one is selected from N_t and N_r . For example, if $N_t = 3$ and $N_r = 2$, the maximum number of parallel channels is $N_c = 2$. A parallel channel matrix representing the parallel channels can be presented in the form

$$V = F_t^{-1} H F_r. \quad (4)$$

When the transmit and receive filters are optimized without weighting G_t , the parallel channel matrix V comprises, as its diagonal elements, the weight σ_n of each parallel channel n, which describes the data transfer capacity of each parallel channel n. As far as the operation of the radio system is concerned, it is preferable that the characteristics, such as data transfer capacity, of the parallel channels can be influenced. The characteristics of the parallel channels can preferably be affected by adjusting e.g. the transmit filter 310 or the receive filter 340, or both. The capacity to be transmitted over parallel channels can preferably be adjusted using the weighting matrix G_t , for example.

[0064] When the filters 310 and 340 are adjusted, it is often preferable to know at least something about a channel estimate. Particularly in FDD systems, the channel estimate of the radio channel between the transmitter 300 and the receiver 202 is generated at the receiver 202. The channel estimate and the matrix H representing the channel estimate are preferably generated at the control unit 380 of the receiver 202. As far as the generation of a channel estimate is concerned, it is preferable that the receiver 202 is provided with information on the physical radio transmission path between the transmitter 300 and the receiver 202 or about the general characteristics of the radio transmission path. As far as the matrix presentation is concerned, determining a channel estimate means determining at least one matrix element of the channel matrix H.

[0065] The matrix elements of the channel matrix H can be estimated using known technology. For example, a WCDMA standard titled "3rd Generation Partnership Project; Technical Specification Group Radio Access Network" discloses channel estimation with a so-called common and/or dedicated pilot signal. In multiple antenna reception, a channel is estimated possibly on several receive channels simultaneously.

[0066] In a preferred embodiment of the present solution, at least part of the channel estimate is generated using a signal transmitted from the transmitter 300 to the receiver 202, the signal comprising predetermined information known to the transmitter 300 and the receiver 202. The predetermined information may comprise a sequence which determines the order in time in which the transmitter 300, using each antenna 236, transmits the signal at a previously known, antenna-specific amplitude and phase, and the receiver 202 receives the signal by each antenna 322. In an embodiment, the transmitter 300 transmits at least one training sequence to the receiver 202, the training sequence comprising mutually orthogonal or almost orthogonal training sequence components. In a preferred embodiment of the use of a training sequence, the transmitter 300 transmits a set of mutually orthogonal training sequence components to the receiver 202 by transmit filters 310 known to the receiver. At least part of the channel estimate can then be determined from equation (3). The orthogonality of the training sequence components can be generated e.g. by arranging the transmit filter 310 and the receive filter 340 appropriately. In an embodiment, the orthogonal training sequence components are implemented such that the transmitter 300 transmits a signal s_k by one antenna k of the transmitting antenna array 234 at a time, which signal is received by each antenna m of the receiving antenna array 320 separately; this results in a signal g_m . The element H_{mk} of the matrix representing the channel estimate can then be determined from the ratio g_m/d_k . If necessary, the transmission and reception are continued until the desired channel estimate parts have been determined. The orthogonality of the training sequence components can also be implemented by encoding the signal directed to the transmitter such that the receiver, knowing the code, is capable of determining the settings of the filters 310 and 340 corresponding with each received signal, and at least part of the channel estimate.

[0067] Examine, by way of example, a training sequence implemented by orthogonal training sequence components when $N_t=4$. The trans-

mitter 300 then transmits signals $s_1 = (1,1,1,1)$, $s_2 = (1,-1,1,-1)$, $s_3 = (1,1,-1,-1)$ and $s_4 = (1,-1,-1,1)$ such that the signal s_1 is transmitted at a point of time t_1 , signal s_2 at a point of time t_2 , signal s_3 at a point of time t_3 , and the signal s_4 at a point of time t_4 . This can be interpreted to mean that the transmit filters are selected in four different ways at four different points of time. At each point of time t_1 , t_2 , t_3 and t_4 , each receiving antenna 322 receives a signal transmitted at a particular point of time such that a received signal is measured simultaneously by each receiving antenna 322. Next, the receiver 202 is able to generate, as linear combinations of the signals s_1 , s_2 , s_3 and s_4 , signals $s'_1 = (1,0,0,0)$, $s'_2 = (0,1,0,0)$, $s'_3 = (0,0,1,0)$ and $s'_4 = (0,0,0,1)$, for example, as in a situation wherein each transmitting antenna k had sent signals s'_1 , s'_2 , s'_3 and s'_4 at points of time $t_1 - t_4$, each signal being received separately by each receiving antenna 322.

[0068] The above-mentioned signal used for channel estimation and comprising previously known information, such as training sequences, can be intended for channel estimation exclusively. The signal may be intended for several users simultaneously, or for one user only. These are exemplified by the above-mentioned common and dedicated pilots of the WCDMA standard. A signal used for channel estimation may also have other functions. A signal intended for channel estimation may be part of the actual data signal but in such a case, the signal intended for channel estimation can be separated from the data signal in terms of time, frequency or code.

[0069] An essential step of the present solution is to generate, at the receiver 202, a variable which contains transmit filter information on the transmit filter 310 of the transmitter 300. The variable containing transmit filter information can be generated e.g. such that it is possible to divide the variable into parts whose effects on a channel's data transfer capacity can be separated easily. Each part can then be prioritized based e.g. on the way in which a change in a particular part affects the data transfer capacity of a radio system. When the variable containing transmit filter information on the transmitter 300 has been generated at the receiver 202, the next step is to generate at least part of a change in the variable containing transmit filter information as compared with a value of the variable containing transmit filter information previously transmitted to the receiver 202. Next, the change in the variable containing transmit filter information or a part thereof is transmitted from the receiver 202 to the transmitter 300. In Figure 3, a change in the variable containing

transmit filter information or a part thereof is designated by an arrow 390 directed from the receiver 202 to the transmitter 300.

[0070] In an embodiment, the effect of the change in the variable containing transmit filter information about the transmitter 300 on the data transfer capacity directed from the transmitter 300 to the receiver 202 is determined at the receiver 202 and, on the basis of the determined effect, the part to be transmitted from the receiver to the transmitter is selected from among the change in the variable containing transmit filter information on the transmitter 300. The part of the change in the transmit filter information can then be selected e.g. to enable the data transfer capacity to be maximized.

[0071] In another embodiment, the effect of the change in the variable containing transmit filter information about the transmitter 300 on the number of parallel channels directed from the transmitter 300 to the receiver 202 that are connected is determined at the receiver 202, and the part of the change in the variable containing transmit filter information on the transmitter 300 to be transmitted from the receiver 202 to the transmitter 300 is selected such that a desired number of available parallel channels is achieved.

[0072] Let us next view the present solution by means of matrix presentations. In a preferred embodiment of the present solution, at least part of a transmit filter matrix $F_{t,opt}$ containing transmit filter information, at least part of an inverse matrix $F_{r,opt}^{-1}$ of the receive filter matrix representing the receive filter matrix 340, and at least part of a singular value matrix W of the channel matrix H are generated at the receiver 202 by using at least part of the determined channel matrix H and the singular value decomposition

$$H = F_{t,opt} W F_{r,opt}^{-1}. \quad (5)$$

On its main diagonal, the singular value matrix W comprises the singular values of the channel matrix H , which are the square roots of the eigenvalues of a matrix $H^H H$. The matrix $F_{r,opt}$ does not necessarily have to be interpreted as an optimised receive filter but $F_{r,opt}$ can be any matrix that fulfils equation (5) with acceptable accuracy. In a preferred embodiment, the numbers of transmitting antennas 236 and receiving antennas 322 are equal, i.e. $N_c = N_t = N_r$, in which case the channel matrix H is a square matrix of dimension N_c , and the square roots of the singular values reside on the diagonal of the singular value matrix W .

[0073] In the above-described embodiment, the transmit filter matrix $F_{t,opt}$ corresponds with the variable containing transmit filter information. After

the transmit filter matrix $F_{t,opt}$ has been generated, a change in the transmit filter matrix or a part thereof is generated at the receiver 202. A part of the transmit filter matrix can be at least one row or column of the matrix, or a matrix element of at least one row or column. The change in the transmit filter matrix or a part thereof can be generated using at least part of the determined transmit filter matrix $F_{t,opt}$ and at least part of a transmit filter matrix $F_{t,ob}$ previously known to the receiver 202.

[0074] In a preferred embodiment of the present solution, the receiver 202 stores at least part of the transmit filter matrix $F_{t,ob}$ transmitted to the transmitter 300 by the receiver. After generating the updated transmit filter matrix $F_{t,opt}$, the receiver 202 generates a change between the new and the old transmit filter matrix, which can be e.g. a difference $\Delta F_t = F_{t,opt} - F_{t,ob}$. Next, at least part of the change ΔF_t in the transmit filter matrix is transmitted from the receiver 202 to the transmitter 300, and a completely or partly updated transmit filter matrix $F'_{t,opt}$ is generated at the transmitter 300 by using at least part of the change ΔF_t transmitted to the transmitter 300 and the current transmit filter matrix $F_{t,ob}$ of the transmitter 300. If the change in the transmit filter information is presented by the above-described difference between the matrices, for example, a completely or partly updated transmit filter matrix $F'_{t,opt}$ is obtained from the expression $F'_{t,opt} = F_{t,ob} + \Delta F_t$. It is to be noted then that the matrices $F'_{t,opt}$ and $F_{t,opt}$ are not necessarily identical since in another embodiment, only a desired part of the change in the transmit filter information has been transmitted to the transmitter 300, which corresponds with a partial update of the transmit filter information.

[0075] The change in the transmit filter matrix can also be presented using a unitary transformation matrix Φ , which fulfils a relation $F_{t,opt} = F_{t,ob}\Phi$. At least part of the matrix Φ is then generated, the at least part of the matrix Φ being transmitted from the receiver 202 to the transmitter 300. Next, the updated at least part of the transmit filter matrix $F_{t,opt}$ is generated using the matrix Φ delivered to the transmitter or a part thereof, at least part of the current transmit filter matrix $F_{t,ob}$ of the transmitter 300 and the equation $F_{t,opt} = F_{t,ob}\Phi$. The above-described method enables the transmit filter information generated at the receiver 202 to be preferably updated at the transmitter 300. If the change is small, which is likely in a slowly changing channel, the change can also be presented in the form $F_{t,opt} = F_{t,ob} + \Pi$, wherein the elements of the matrix Π are small.

[0076] Another way to utilize the matrix presentation is to determine a matched filter matrix M by means of the channel matrix H or a part thereof by using the expression

$$M = H^H H, \quad (6)$$

5 wherein H^H is the Hermitian conjugate of the matrix H . The matched filter matrix M then corresponds with the variable containing transmit filter information. The definition according to equation (6) of the matched filter matrix M is characterized in that the eigenvalues of the matched filter matrix are obtained directly as the squares of the singular values of the channel matrix H . The matched filter matrix M according to definition (6) then also comprises information about the optimised transmit filter matrix $F_{t,opt}$ and the weighting coefficients σ_n of the parallel channels as well as about a weighting matrix G_t possibly generated utilizing the same. A matrix ΔM characterizing the change in the matched filter matrix M is generated at the receiver 202 by using at least part of the determined matched filter matrix M and at least part of a matched filter matrix M_0 previously known to the receiver 202. In a preferred embodiment, the change in the matched filter matrix can be presented as a difference $\Delta M = M - M_0$, which in this case corresponds with the change in the variable containing transmit filter information. The change ΔM in the filter matrix can preferably be presented as the eigenvalue decomposition

$$\Delta M = U_t D U_t^H, \quad (7)$$

wherein the matrix D comprises the eigenvalues λ_k of the change ΔM in the filter matrix and the columns in the matrix U_t comprise the eigenvectors $u_{t,k}$ corresponding with the eigenvalues λ_k ; using these designations, equation (6) can be written in the form

$$\Delta M = \begin{bmatrix} u_{t,1} \sqrt{\lambda_1} & u_{t,2} \sqrt{\lambda_2} & \dots & u_{t,N} \sqrt{\lambda_N} \end{bmatrix} \begin{bmatrix} u_{t,1}^H \sqrt{\lambda_1} \\ u_{t,2}^H \sqrt{\lambda_2} \\ \vdots \\ u_{t,N}^H \sqrt{\lambda_N} \end{bmatrix}. \quad (8)$$

[0078] After eigenvalue decomposition (7) or (8) of the change ΔM in the filter matrix has been generated, at least one eigenvalue λ_k of the matrix ΔM and at least part of the eigenvector $u_{t,k}$ associated with the particular eigenvalue are transmitted from the receiver 202 to the transmitter 300, the eigenvalue-eigenvector pair being designated by $(\lambda, u)_k$.

[0079] In an embodiment of the present solution, at least part of the change in the variable containing transmit filter information, such as part of the

matrix ΔF_t or part of the $(\lambda, u)_k$ pair, is transmitted from the receiver 202 to the transmitter 300. The parts to be transmitted and the order of transmission can then be selected based on the effect of the transmission order on the data transfer capacity of parallel channels or the effect of the transmission order on the number of available parallel channels. In another embodiment, the change in the variable containing transmit filter information is transmitted from the receiver 202 to the transmitter 300 in the order of magnitude of the eigenvalues λ_k . This is a preferred embodiment especially when the transmitter 300 does not have any previous transmit filter information when, for example, a new radio connection is being set up.

[0080] In another embodiment, the effect of the change in the variable containing transmit filter information about the transmitter 300 on the number of available parallel channels directed from the transmitter 300 to the receiver 202 is determined at the receiver 202 and the $(\lambda, u)_k$ pair to be transmitted from the receiver 202 to the transmitter 300 is selected such that a desired number of available parallel channels is achieved.

[0081] When at least part of the change in the transmit filter information on the transmitter 300, such as a $(\lambda, u)_k$ pair, has been transmitted from the receiver 202 to the transmitter 300, at least part of the matched filter matrix M is updated at the transmitter 300 by using at least one $(\lambda, u)_k$ pair transmitted to the transmitter 300 by the receiver 202 and at least part of a previous matched filter matrix M_0 of the transmitter by using the equation

$$M = M_0 + \sum u_{t,k} \sqrt{\lambda_k} (u_{t,k} \sqrt{\lambda_k})^T, \quad (9)$$

wherein the summing comprises the $(\lambda, u)_k$ pairs transmitted from the receiver 202 to the transmitter 300. When the matched filter matrix M of the transmitter 300 has been updated at least once using e.g. equation (9), at least part of the transmit filter matrix $F_{t,opt}$ can be generated at the receiver 300 by using the updated matched filter matrix M and the eigenvalue decomposition

$$M = F_{t,opt}^{-1} \Lambda F_{t,opt}, \quad (10)$$

wherein Λ comprises the eigenvalues of the updated matched filter matrix M . Eigenvalue decomposition (10) can also be used while determining a previous matched filter matrix M_0 to be used e.g. for updating the matched filter matrix M of equation (9), provided that the transmit filter matrix $F_{t,ob}$ equivalent to the matrix M_0 is known to the transmitter 300. The above-described method enables the transmit filter information generated at the receiver 202 to be updated at the transmitter 300 with no need for the transmitter 300 to store sev-

eral matrices in memory. If the transmit filter information on the transmitter 300 is generated for the first time e.g. after a radio connection has been disconnected, the matched filter matrix previously known to the transmitter 300 and the receiver 202 is $M_0 = 0$, and the updated matched filter matrix M is generated in the above-described manner, using expressions (9) and (10).

[0082] Examine the selection of the weighting matrix G_t possibly contained in the transmit filter F_t . This can be generated e.g. by using the eigenvalues Λ of the updated matched filter matrix M , whose square roots are singular values σ_n . According to the prior art, the weighting matrix G_t can be selected e.g. based on a so-called water-filling method (I.E. Telatar, "Capacity of multi-antenna gaussian channels", Eur.Trans. Telecomm., vol. 10, no. 6, pp. 585 to 595), which is advantageous if the telecommunication system allows several modulation alphabets to be used simultaneously. When only one modulation alphabet is used, a so-called inverse water-filling (J. Saltz, Digital transmission over cross-coupled linear channels", Bell Labs Tech. J. July-Aug. 1985) can be applied, which comprises selecting some of the strongest parallel virtual data transfer channels.

[0083] In an embodiment, a correlation matrix C can be generated from the measured channel information to describe the correlation between the transmitting and receiving elements. This requires a channel estimate to be obtained from more than one measuring occasion. The covariance of measured matrix elements of the channel matrix H is calculated utilizing these several measurement results by calculating e.g. the expectation values of the products of separate matrix elements. A reference titled "Wireless Communication using dual antenna arrays" by Da-Shan Shiu, Kluwer Academic Publishers, Boston 2000, discusses the calculation of a channel correlation matrix. In the wireless communication systems, no correlation exists between the transmitting antennas and the receiving antennas; the highest correlation occurs between different transmitting antennas or between different receiving antennas. The correlation between the transmitting antennas can then be presented as a matrix C_t , and the correlation between the receive matrices can be presented as a matrix C_r . The receiver 202 measures at least some of these matrices. In a preferred embodiment, the information thus measured is utilized when generating as independent parallel data transfer channels as possible. If the information about the transmit filter matrix transmitted to the transmitter 300 by the receiver 202 is based directly on the channel matrix H , at least a

portion of the matrices A_r and A_t for which $C_t = A_t^H A_t$ and $C_r = A_r^H A_r$ are valid are preferably generated. These matrices can be called long-term transmit and receive filters. These parts enable at least part of a matrix $\tilde{H} = A_t^H H A_r$ to be generated. The transmit and receive filters and the change therein are now
 5 calculated from this matrix in a similar manner to that used in the above-disclosed embodiments when they were calculated from the matrix H . If the information on the transmit filter matrix transmitted to the transmitter 300 by the receiver 202 is based on the matched filter M , at least part of a matrix $\tilde{M} = H_t^H C_r H C_t$ is generated using correlation matrices. The transmit and re-
 10 ceive filters and the change therein are now calculated from this matrix in a similar manner to that used in the above-described embodiments when they were calculated from the matrix M .

[0084] In an embodiment, transmit and receive filters can be calculated from channel information measured at more than one point of time
 15 by using a so-called independent components analysis.

[0085] The change in the transmit filter information on the transmitter 300 can be transmitted from the receiver 202 to the transmitter by using prior art methods. The above-described WCDMA standard describes so-called feedback-mode signalling on so-called control channels of the uplink. It is ob-
 20 vious to one skilled in the art that corresponding logical channel structures can be used for transmitting transmit filter information described in the present invention.

[0086] In an embodiment, at predetermined intervals or possibly at the request of the transmitter 300, the receiver 202 transmits information about
 25 a change in the channel matrix H , matched filter matrix M , transmit filter F_t and/or the long-term filters A_r and/or A_t or corresponding correlation matrices to the transmitter 300. Preferably, this information can be transmitted e.g. on a control channel of the uplink. In another preferred embodiment, at predetermined intervals or possibly at the request of the transmitter, the receiver 202
 30 also transmits information concerning the main part of the channel matrix H , matched filter matrix M , transmit filter F_t and/or the long-term filters A_r and/or A_t or corresponding correlation matrices. Preferably, this main part, which is transmitted more seldom, comprises information on almost the entire matrix and is possibly protected by an error correction code. Preferably, this informa-
 35 tion can be transmitted in packet-switched form e.g. on a common packet channel CPCH of the uplink, or on a channel RACH randomly used.

[0087] In a preferred embodiment of the present solution, the change in the variable containing transmit filter information to be transmitted from the receiver 202 to the transmitter 300 is quantised using e.g. a method according to the radio system standard. The above-described WCDMA standard discloses two methods: Mode 1 and Mode 2. Alternatively, vector quantising can be used. A publication titled "Closed loop transmit diversity for FDD WCDMA systems" by J. Hämäläinen, R. Wichman, Asilomar conference on signals, systems and computers, 2000, vol. 1, pp. 111 to 115, describes other methods for selecting quantising. The bits obtained on the basis of quantising are then transmitted to a transmitter on a radio path.

[0088] Quantising involves a rounding error. The rounding error is part of the concept "filter matrix part" used above.

[0089] Examine errors and error correction possibly occurred in the transmit filter information to be transmitted. In the prior art verification systems, the above-mentioned WCDMA standard comprises examining the estimates of so-called dedicated channels, which are thus channel estimates from the filtered channels, and the estimates of common pilot channels. On the basis of the difference therebetween, the receiver 202 is often able to infer whether the transmitter 300 has used a correct transmit filter or whether an error has occurred in the delivery of transmit filter information. Preferably, if the receiver 202 recognizes that an error has occurred, the error can be inferred from the above-mentioned channel estimates, and the erroneous information can be taken into account while determining future variables indicating a change in a channel. In an alternative embodiment, at predetermined intervals or possibly at the request of the receiver 202, the transmitter 300 transmits information on the transmit filter used by the transmitter. This information enables the receiver 202 to infer whether an error has occurred in the delivery of the transmit filter information. Preferably, this can be implemented by transmitting e.g. cyclic redundancy checking bits generated from the description of the transmit filter known to the transmitter 300 and the receiver 202 by using the bits. If the receiver 202 detects that the transmitter 300 uses an erroneous filter, the receiver 202 may either try to estimate the error as described above or to transmit a nulling command to the transmitter 300. After the nulling command, the transmitter will no longer use the old information on the channel. The receiver 202 delivers information on the transmit filter to the transmitter 300 by using e.g. one of the above-mentioned embodiments.

[0090] Examine the embodiments of the invention in connection with channels wherein echoes occur. The channel matrix H can be presented as a matrix which, on its block diagonal, comprises single channel matrices corresponding with different delays. This matrix cannot be diagonalized using transmit and receive filters. In a preferred embodiment, the filters are selected to enable the data transfer capacity of a channel to be maximized. Depending on the structure of the receiver, this maximization can be carried out in different ways. In the case of one receiving antenna, the problem is discussed in a publication titled "Feedback Schemes for FDD WCDMA systems in multipath environment" by J. Hämäläinen and R. Wichman, VTC Spring 2001, vol. 1, pp. 238 to 242. Alternatively, a so-called independent components analysis can be used. It is obvious to one skilled in the art that similar methods can be utilized in multiple antenna reception. The inventive solution comprises forwarding parts of a change in a transmit filter.

[0091] The singular value decomposition disclosed in equation (5) and the eigenvalue decomposition disclosed in equations (7) and (10) can be implemented by numerical algorithms according to the prior art that are typically iterative and based on the unitary matrices found in equations (5), (7) and (10), such as successive operations on the filter matrices $F_{t,opt}$ and $F_{r,opt}$ and the eigenvalue matrix U_t , such as Jacobian rotations. Every time, the successive operations then result in a more accurate singular value decomposition or eigenvalue decomposition. As far as calculation is concerned, numerical iteration is relatively heavy, and a reduction in the number of iteration cycles enables the processor power consumption e.g. of the terminal equipment 202 to be reduced. However, the reduction in the number of iteration cycles results in inaccuracy of the unitary matrices obtained from the singular value decomposition or eigenvalue decomposition, such as the filter matrices $F_{t,opt}$ and $F_{r,opt}$ and the eigenvalue matrix U_t , and in inaccuracy of the singular values and eigenvalues associated with the above-mentioned unitary matrices. In such a case, the iteration can more often than not be interrupted when the inaccuracy caused by an interrupted iteration to the above-mentioned unitary matrices and the singular values and eigenvalues associated therewith is covered with other sources of error. Such other sources of error include e.g. an error caused by quantising of transmit filter information, and the signal-to-noise ratio of the signals to be transmitted.

[0092] In a preferred embodiment of the present solution, the iteration of the singular value decomposition or eigenvalue decomposition is interrupted when a desired accuracy of the singular value decomposition or eigenvalue decomposition has been achieved. The desired accuracy can be
5 determined e.g. by a model error in a channel estimate or a restricted number of bits.

[0093] In another embodiment, the effect of the inaccuracy of the singular value decomposition or eigenvalue decomposition on the inaccuracy of each parallel channel is determined at the receiver 202, which can be carried out e.g. using equation (3). In addition, SINR (Signal-to-Interference and Noise Ratio) estimates for each parallel channel are generated at the receiver
10 202, and the iteration of the singular value decomposition or eigenvalue decomposition is interrupted at the inaccuracy determined by an SINR estimate. An SINR estimate can be generated e.g. at the control unit 380 of the terminal equipment 202.
15

[0094] In another embodiment, the effect of the inaccuracy of the singular value decomposition or eigenvalue decomposition on the accuracy of the change in the variable containing transmit filter information on the transmitter 300 is determined at the receiver 202 and the determined change in the
20 variable containing transmit filter information is quantised by the quantising method used. Furthermore, the inaccuracy caused by the quantising method used to the accuracy of the change in the variable containing transmit filter information is determined, and the iteration of the singular value decomposition or eigenvalue decomposition is interrupted at the inaccuracy determined by the
25 quantising method. In connection with interrupting the iteration, it is to be noted that the inaccuracy caused by interrupting the iteration of the variables to be quantised, such as the eigenvalues λ_k , does not result in erroneous quantising of the variable. The change in each variable must then be monitored during iteration in order to ensure that the variable becomes rounded in a correct di-
30 rection.

[0095] In a preferred embodiment of the present solution, eigenvalue decompositions (7) and (10) can be generated by diagonalizing the matrices ΔM and M on the left of equations (7) and (10), the result of the diagonalization being the eigenvalues and eigenvector matrices of the above-mentioned matrices. Diagonalization can be carried out as unitary matrix operations on the matrices found in equations (7) and (10) to be diagonalized.
35

The diagonalization can then be carried out in an exact manner if the dimension of a matrix to be diagonalized is less than or equal to 4. In practice, an analytic solution is preferred when the dimension of a matrix to be diagonalized is 2. In a preferred embodiment of the present solution, the matrices ΔM and M are diagonalized approximatively at the receiver 202 and the transmitter 300 by utilizing a perturbation theory known per se, which is used e.g. in quantum mechanics for approximatively determining the eigenvalues and eigenvectors of matrices.

[0096] Although the invention has been described above with reference to the example according to the accompanying drawings, it is obvious that the invention is not restricted thereto but can be modified in many ways within the scope of the inventive idea disclosed in the claims.

CLAIMS

1. A data transfer method in a radio system comprising a transmitter (300) comprising at least one antenna array (234) comprising at least two antennas (236), and at least one receiver (202) comprising at least one antenna array (320) comprising at least two antennas (322), the radio system comprising a physical radio channel between the transmitter (300) and the receiver (202); the method comprising
 - filtering, by means of transmit filter information, a signal to be transmitted via the antennas (236) of the antenna array (234) of the transmitter (300); and
 - generating, at the receiver (202), a variable which contains transmit filter information on the transmitter (300), **characterized** by
 - generating, at the receiver (202), at least part of a change in the variable containing transmit filter information on the transmitter (300);
 - transmitting at least part of the change in the variable containing transmit filter information on the transmitter (300) from the receiver (202) to the transmitter (300); and
 - updating, at the transmitter (300), the transmit filter information on the transmitter (300) on the basis of the received change in the variable containing transmit filter information.
2. A method as claimed in claim 1, **characterized** by generating, at the receiver (202), at least part of the change in the variable containing transmit filter information on the transmitter (300) as compared with a value of the variable containing transmit filter information previously transmitted to the receiver (202).
3. A method as claimed in claim 1, **characterized** by transmitting the signal to the receiver (202) by the transmitter (300) via the physical radio channel;
 - determining, at the receiver (202), at least part of a channel estimate of the physical channel on the basis of the received signal;
 - determining, at the receiver (202), at least part of the change in the variable containing transmit filter information on the transmitter (300) by using at least part of the determined channel estimate.

4. A method as claimed in claim 1, **characterized** by transmitting the signal to the receiver (202) by the transmitter (300) via the physical radio channel, the signal comprising predetermined information,

5 determining, at the receiver (202), at least part of a channel estimate of the physical channel by means of the predetermined information contained in the received signal;

determining, at the receiver (202), at least part of the change in the variable containing transmit filter information on the transmitter (300) by using at least part of the determined channel estimate.

10 5. A method as claimed in claim 1, **characterized** by transmitting at least one training sequence comprising at least one previously known symbol sequence to the receiver (202) by the transmitter (300);

determining, at the receiver (202), at least one matrix element of a channel matrix H by means of the received at least one training sequence;

15 generating, at the receiver (202), at least part of a transmit filter matrix $F_{t,opt}$ which contains transmit filter information, at least part of an inverse matrix $F_{r,opt}^{-1}$ of a receive filter matrix which contains a receive filter (340), and at least part of a singular value matrix W of the channel matrix H by using at least part of the determined channel matrix H and the singular value decomposition

20

$$H = F_{t,opt} W F_{r,opt}^{-1};$$

generating, at the receiver (202), the change in the transmit filter matrix representing the transmit filter information by using at least part of the determined transmit filter matrix $F_{t,opt}$ and at least part of a transmit filter matrix previously known to the receiver (202);

25

transmitting at least part of the matrix which contains the change in the transmit filter information from the receiver (202) to the transmitter (300);

30 updating, at the transmitter (300), at least part of the transmit filter matrix by using at least part of the change in the transmit filter matrix transmitted to the transmitter (300) by the receiver (200) and at least part of a transmit filter matrix previously known to the transmitter (300).

6. A method as claimed in claim 1, **characterized** by transmitting at least one training sequence comprising at least one previously known symbol sequence to the receiver (200) by the transmitter (300);

35 determining, at the receiver (202), at least one matrix element of the channel matrix H by means of the received at least one training sequence;

30

generating a matched filter matrix M from the channel matrix H by using the equation

$$M = H^H H;$$

generating, at the receiver (202), a matrix ΔM characterizing a change in the matched filter matrix M by using at least part of the determined matched filter matrix M and at least part of a matched filter matrix M_0 previously known to the receiver (202);

generating, at the receiver (300), at least part of an eigenvalue matrix D of the matrix ΔM characterizing the change in the matched filter matrix and at least part of the above-generated eigenvalue matrix D from a corresponding eigenvector matrix U_t by using the eigenvalue decomposition

$$\Delta M = U_t D U_t^H;$$

transmitting at least one eigenvalue λ_k of the matrix ΔM and at least part of an eigenvector $u_{t,k}$ associated with said eigenvalue from the receiver (202) to the transmitter (300);

updating, at the transmitter (300), at least part of the matched filter matrix M by using at least one eigenvalue λ_k of the matrix ΔM characterizing the change in the matched filter matrix and transmitted to the transmitter (300) by the receiver (202), at least part of the eigenvector $u_{t,k}$ associated with said eigenvalue and at least part of a previous matched filter matrix M_0 of the transmitter by using the equation

$$M = M_0 + u_{t,k} \sqrt{\lambda_k} (u_{t,k} \sqrt{\lambda_k})^T;$$

updating, at the transmitter (300), at least part of the transmit filter matrix $F_{t,opt}$ containing transmit filter information by using the updated matched filter matrix M and Λ eigenvalue decomposition

$$M = F_{t,opt}^{-1} \Lambda F_{t,opt},$$

wherein Λ comprises the eigenvalues of the matched filter matrix M .

7. A method as claimed in claims 5 and 6, **characterized** by generating, at the receiver (202) and the transmitter (300), singular value decompositions or eigenvalue decompositions by using numerical iteration; and

interrupting the iteration of a singular value decomposition or eigenvalue decomposition at a desired accuracy of singular values or eigenvalues.

8. A method as claimed in claims 5 and 6, **characterized** by generating, at the receiver (202), singular value decompositions or eigenvalue decompositions by using numerical iteration;

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determining, at the receiver (202), the effect of the inaccuracy of a singular value decomposition or eigenvalue decomposition on the inaccuracy of each parallel channel;

5 generating, at the receiver (202), SINR estimates for each parallel channel;

interrupting, at the receiver (202), the iteration of the singular value decomposition or eigenvalue decomposition at the inaccuracy determined by an SINR estimate.

10 9. A method as claimed in claims 5 and 6, **characterized** by generating a singular value decomposition or eigenvalue decomposition at a predetermined accuracy by using numerical iteration;

determining the effect of the inaccuracy of the singular value decomposition or eigenvalue decomposition on the accuracy of the change in the variable containing transmit filter information on the transmitter (300);

15 quantising the determined change in the variable containing transmit filter information by the quantising method used;

determining the inaccuracy caused by the quantising method used on the accuracy of the change in the variable containing transmit filter information; and

20 interrupting the iteration of the singular value decomposition or eigenvalue decomposition at the inaccuracy determined by the quantising method such that the change in the variable containing transmit filter information becomes rounded in a correct direction.

25 10. A method as claimed in claims 5 and 6, **characterized** by

generating, at the receiver (202) and the transmitter (300), singular value decompositions or an eigenvalue decomposition by means of a perturbation theory.

30 11. A method as claimed in claim 1, **characterized** by generating, at the receiver (202), at least part of the change in the variable containing transmit filter information on the transmitter (300);

quantising at least part of the change in the variable containing transmit filter information on the transmitter (300); and

35 transmitting at least part of the quantised change in the variable containing transmit filter information on the transmitter (300) from the receiver (202) to the transmitter (300).

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12. A method as claimed in claim 1, **characterized** by
generating, at the receiver (202), at least part of the change in the
variable containing transmit filter information on the transmitter (300);

quantising at least part of the change in the variable containing
5 transmit filter information on the transmitter (300) by using a Mode 1 standard;
and

transmitting at least part of the quantised change in the variable
containing transmit filter information on the transmitter (300) from the receiver
(202) to the transmitter (300).

10 13. A method as claimed in claim 1, **characterized** by
generating, at the receiver (202), at least part of the change in the
variable containing transmit filter information on the transmitter (300);

quantising at least part of the change in the variable containing
transmit filter information on the transmitter (300) by using a Mode 2 standard;
15 and

transmitting at least part of the quantised change in the variable
containing transmit filter information on the transmitter (300) from the receiver
(202) to the transmitter (300).

20 14. A method as claimed in claim 1, **characterized** by
determining, at the receiver (202), the effect of the change in the
variable containing transmit filter information on the transmitter (300) on the
data transfer capacity directed from the transmitter (300) to the receiver (202),
and

selecting, on the basis of the determined effect, the part of the
25 change in the variable containing transmit filter information on the transmitter
(300) to be transmitted from the receiver (202) to the transmitter (300).

15. A method as claimed in claim 1, **characterized** by
determining, at the receiver (202), the effect of the change in the
variable containing transmit filter information on the transmitter (300) on the
30 data transfer capacity directed from the transmitter (300) to the receiver (202),
and

selecting the part of the change in the variable containing transmit
filter information on the transmitter (300) to be transmitted from the receiver
(202) to the transmitter (300) in order to enable said data transfer capacity to
35 be maximized.

16. A method as claimed in claim 1, **characterized** by

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determining, at the receiver (202), the effect of the change in the variable containing transmit filter information about the transmitter (300) on the number of available parallel channels; and

5 selecting the part of the change in the variable containing transmit filter information on the transmitter (300) to be transmitted from the receiver (202) to the transmitter (300) such that a desired number of available parallel channels is achieved.

10 17. A radio system comprising a transmitter (300) comprising at least one antenna array (234) comprising at least two antennas (236), and at least one receiver (202) comprising at least one antenna array (320) comprising at least two antennas (322), the radio system comprising a physical radio channel between the transmitter (300) and the receiver (202); the radio system comprising

15 means (208, 212) for filtering, by means of transmit filter information, a signal to be transmitted via the antennas (236) of the antenna array (234) of the transmitter (300); and

means (380) for generating, at the receiver (202), a variable which contains transmit filter information on the transmitter (300), **characterized** in that

20 the receiver (202) comprises means (380) for generating at least part of a change in the variable containing transmit filter information on the transmitter (300);

the receiver (202) is arranged to transmit at least part of the change in the variable containing transmit filter information on the transmitter (300) from the receiver (202) to the transmitter (300); and

25 the means (208, 212) for filtering are arranged to update the transmit filter information on the transmitter (300) on the basis of the received change in the variable containing transmit filter information.

30 18. A radio system as claimed in claim 17, **characterized** in that

the receiver (202) comprises means (380) for generating at least part of the change in the variable containing transmit filter information on the transmitter (300) as compared with a value of the variable containing transmit filter information previously transmitted to the receiver (202).

35 19. A radio system as claimed in claim 17, **characterized** in that

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the transmitter (300) comprises means (236) for transmitting the signal to the receiver via the physical radio channel;

the receiver (202) comprises means (380) for determining at least part of a channel estimate of the physical channel on the basis of the received signal;

the receiver (202) comprises means (380) for determining at least part of the change in the variable containing transmit filter information on the transmitter (300) by using at least part of the determined channel estimate.

20. A radio system as claimed in claim 17, **characterized** in that

the transmitter (300) comprises means (236) for transmitting the signal to the receiver (202) via the physical radio channel, the signal comprising predetermined information;

the means (380) for generating, at the receiver (202), a variable containing transmit filter information on the transmitter (300) are arranged to determine at least part of the channel estimate of the physical channel by means of the predetermined information contained in the received signal;

the means (380) for generating, at the receiver (202), a variable containing transmit filter information on the transmitter (300) are arranged to determine at least part of the change in the variable containing transmit filter information on the transmitter (300) by using at least part of the determined channel estimate.

21. A radio system as claimed in claim 17, **characterized** in that

the transmitter (300) is arranged to transmit at least one training sequence comprising at least one previously known symbol sequence to the receiver (202);

the means (380) for generating, at the receiver (202), a variable containing transmit filter information on the transmitter (300) are arranged to determine at least one matrix element of a channel matrix H by means of the received at least one training sequence;

the means (380) for generating, at the receiver (202), a variable containing transmit filter information on the transmitter (300) are arranged to generate at least part of a transmit filter matrix $F_{t,opt}$ which contains transmit filter information, at least part of an inverse matrix $F_{r,opt}^{-1}$ of a receive filter matrix which contains a receive filter (340), and at least part of a singular value

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matrix W of the channel matrix H by using at least part of the determined channel matrix H and the singular value decomposition

$$H = F_{t,opt} W F_{r,opt}^{-1};$$

the means (380) for generating, at the receiver (202), a variable
5 containing transmit filter information on the transmitter (300) are arranged to generate a change in a transmit filter matrix representing the transmit filter information by using at least part of the determined transmit filter matrix $F_{t,opt}$ and at least part of a transmit filter matrix previously known to the receiver (202);

the receiver (202) is arranged to transmit at least part of the matrix
10 containing the change in the transmit filter information to the transmitter (300);

the means (208, 212) for filtering, at the transmitter (300), are arranged to update at least part of the transmit filter matrix by using at least part of the change in the transmit filter matrix transmitted to the transmitter (300) by the receiver (200) and at least part of a transmit filter matrix previously known
15 to the transmitter (300).

22. A radio system as claimed in claim 17, **characterized** in that

the transmitter (300) is arranged to transmit at least one training sequence comprising at least one previously known symbol sequence to the receiver (202);
20

the means (380) for generating, at the receiver (202), a variable containing transmit filter information on the transmitter (300) are arranged to determine at least one matrix element of the channel matrix H by means of the received at least one training sequence;

25 the means (380) for generating, at the receiver (202), a variable containing transmit filter information on the transmitter (300) are arranged to generate a matched filter matrix M from the channel matrix H by using the equation

$$M = H^H H;$$

30 the means (380) for generating, at the receiver (202), a variable containing transmit filter information on the transmitter (300) are arranged to generate a matrix ΔM characterizing the change in the matched filter matrix M by using at least part of the determined matched filter matrix M and at least part of a matched filter matrix M_0 previously known to the receiver (202);

35 the means (380) for generating, at the receiver (202), a variable containing transmit filter information on the transmitter (300) are arranged to

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generate at least part of an eigenvalue matrix D of the matrix ΔM characterizing the change in the matched filter matrix and at least part of the above-generated eigenvalue matrix D from a corresponding eigenvector matrix U_t by using the eigenvalue decomposition

$$\Delta M = U_t D U_t^H ;$$

the receiver (202) is arranged to transmit at least one eigenvalue λ_k of the matrix ΔM and at least part of an eigenvector $u_{t,k}$ associated with said eigenvalue to the transmitter (300);

the means (208, 212) for filtering, at the transmitter (300), are arranged to update at least part of the matched filter matrix M by using at least one eigenvalue λ_k of the matrix ΔM characterizing the change in the matched filter matrix and transmitted to the transmitter (300) by the receiver (202), at least part of the eigenvector $u_{t,k}$ associated with said eigenvalue, and at least part of a previous matched filter matrix M_0 of the transmitter by using the equation

$$M = M_0 + u_{t,k} \sqrt{\lambda_k} (u_{t,k} \sqrt{\lambda_k})^T ;$$

the means (208, 212) for filtering, at the transmitter (300), are arranged to update at least part of the transmit filter matrix $F_{t,opt}$ containing transmit filter information by using the updated matched filter matrix M and Λ eigenvalue decomposition

$$M = F_{t,opt}^{-1} \Lambda F_{t,opt} ,$$

wherein Λ comprises the eigenvalues of the matched filter matrix M.

23. A radio system as claimed in claims 21 and 22, **characterized** in that

the means (380) for generating, at the receiver (202), a variable containing transmit filter information on the transmitter (300) and the means (208, 212) for filtering, at the transmitter (300), are arranged to generate singular values decompositions or eigenvalue decompositions by using numerical iteration; and

the means (380) for generating, at the receiver (202), a variable containing transmit filter information on the transmitter (300) and the means (208, 212) for filtering, at the transmitter (300), are arranged to interrupt the iteration of a singular value decomposition or eigenvalue decomposition at a desired accuracy of singular values or eigenvalues.

24. A radio system as claimed in claims 21 and 22, **characterized** in that

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the means (380) for generating, at the receiver (202), a variable containing transmit filter information on the transmitter (300) are arranged to generate singular value decompositions or eigenvalue decompositions by using numerical iteration;

5 the means (380) for generating, at the receiver (202), a variable containing transmit filter information on the transmitter (300) are arranged to determine the effect of the inaccuracy of a singular value decomposition or eigenvalue decomposition on the inaccuracy of each parallel channel;

10 the means (380) for generating, at the receiver (202), a variable containing transmit filter information on the transmitter (300) are arranged to generate SINR estimates for each parallel channel;

the means (380) for generating, at the receiver (202), a variable containing transmit filter information on the transmitter (300) are arranged to interrupt the iteration of the singular value decomposition or eigenvalue decomposition at the inaccuracy determined by an SINR estimate.

15 25. A radio system as claimed in claims 21 and 22, **characterized** in that

the means (380) for generating, at the receiver (202), a variable containing transmit filter information on the transmitter (300) are arranged to generate a singular value decomposition or eigenvalue decomposition at a predetermined accuracy by using numerical iteration;

20 the means (380) for generating, at the receiver (202), a variable containing transmit filter information on the transmitter (300) are arranged to determine the effect of the inaccuracy of the singular value decomposition or eigenvalue decomposition on the accuracy of the change in the variable containing transmit filter information on the transmitter (300);

25 the means (380) for generating, at the receiver (202), a variable containing transmit filter information on the transmitter (300) are arranged to quantise the determined change in the variable containing transmit filter information by the quantising method to be used;

30 the means (380) for generating, at the receiver (202), a variable containing transmit filter information on the transmitter (300) are arranged to determine the inaccuracy caused by the quantising method used to the accuracy of the change in the variable containing transmit filter information; and

35 the means (380) for generating, at the receiver (202), a variable containing transmit filter information on the transmitter (300) are arranged to

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interrupt the iteration of the singular value decomposition or eigenvalue decomposition at the inaccuracy determined by the quantising method such that the change in the variable containing transmit filter information becomes rounded in a correct direction.

5 26. A radio system as claimed in claims 21 and 22, **characterized** in that

the means (380) for generating, at the receiver (202), a variable containing transmit filter information on the transmitter (300) and the means (208, 212) at the transmitter (300) are arranged to generate a singular value
10 decomposition or eigenvalue decomposition by means of a perturbation theory.

27. A radio system as claimed in claim 17, **characterized** in that

the means (380) for generating, at the receiver (202), a variable containing transmit filter information on the transmitter (300) are arranged to
15 generate at least part of the change in the variable containing transmit filter information on the transmitter (300);

the means (380) for generating, at the receiver (202), a variable containing transmit filter information on the transmitter (300) are arranged to quantise at least part of the change in the variable containing transmit filter
20 information on the transmitter (300); and

the receiver (202) is arranged to transmit at least part of the quantised change in the variable containing transmit filter information on the transmitter (300) to the transmitter (300).

25 28. A radio system as claimed in claim 17, **characterized** in that

the means (380) for generating, at the receiver (202), a variable containing transmit filter information on the transmitter (300) are arranged to generate at least part of the change in the variable containing transmit filter information on the transmitter (300);

30 the means (380) for generating, at the receiver (202), a variable containing transmit filter information on the transmitter (300) are arranged to quantise at least part of the change in the variable containing transmit filter information on the transmitter (300) by using a Mode 1 standard; and

35 the receiver (202) is arranged to transmit at least part of the quantised change in the variable containing transmit filter information on the transmitter (300) to the transmitter (300).

29. A radio system as claimed in claim 17, **characterized** in that

the means (380) for generating, at the receiver (202), a variable containing transmit filter information on the transmitter (300) are arranged to generate at least part of the change in the variable containing transmit filter information on the transmitter (300);

the means (380) for generating, at the receiver (202), a variable containing transmit filter information on the transmitter (300) are arranged to quantise at least part of the change in the variable containing transmit filter information on the transmitter (300) by using a Mode 2 standard; and

the receiver (202) is arranged to transmit at least part of the quantised change in the variable containing transmit filter information on the transmitter (300) to the transmitter (300).

30. A radio system as claimed in claim 17, **characterized** in that

the means (380) for generating, at the receiver (202), a variable containing transmit filter information on the transmitter (300) are arranged to determine the effect of the change in the variable containing transmit filter information on the transmitter (300) on the data transfer capacity directed from the transmitter (300) to the receiver (202), and

the means (380) for generating, at the receiver (202), a variable containing transmit filter information on the transmitter (300) are arranged to select, on the basis of the determined effect, the part of the change in the variable containing transmit filter information on the transmitter (300) to be transmitted from the receiver (202) to the transmitter (300).

31. A radio system as claimed in claim 17, **characterized** in that

the means (380) for generating, at the receiver (202), a variable containing transmit filter information on the transmitter (300) are arranged to determine the effect of the change in the variable containing transmit filter information on the transmitter (300) on the data transfer capacity directed from the transmitter (300) to the receiver (202), and

the means (380) for generating, at the receiver (202), a variable containing transmit filter information on the transmitter (300) are arranged to select the part of the change in the variable containing transmit filter information on the transmitter (300) to be transmitted from the receiver (202) to the

40

transmitter (300) in order to enable said data transfer capacity to be maximized.

32. A radio system as claimed in claim 17, **characterized** in that

5 the means (380) for generating, at the receiver (202), a variable containing transmit filter information on the transmitter (300) are arranged to determine the effect of the change in the variable containing transmit filter information about the transmitter (300) on the number of available parallel channels; and

10 the means (380) for generating, at the receiver (202), a variable containing transmit filter information on the transmitter (300) are arranged to select the part of the change in the variable containing transmit filter information on the transmitter (300) to be transmitted from the receiver (202) to the transmitter (300) such that a desired number of available parallel channels is
15 achieved.

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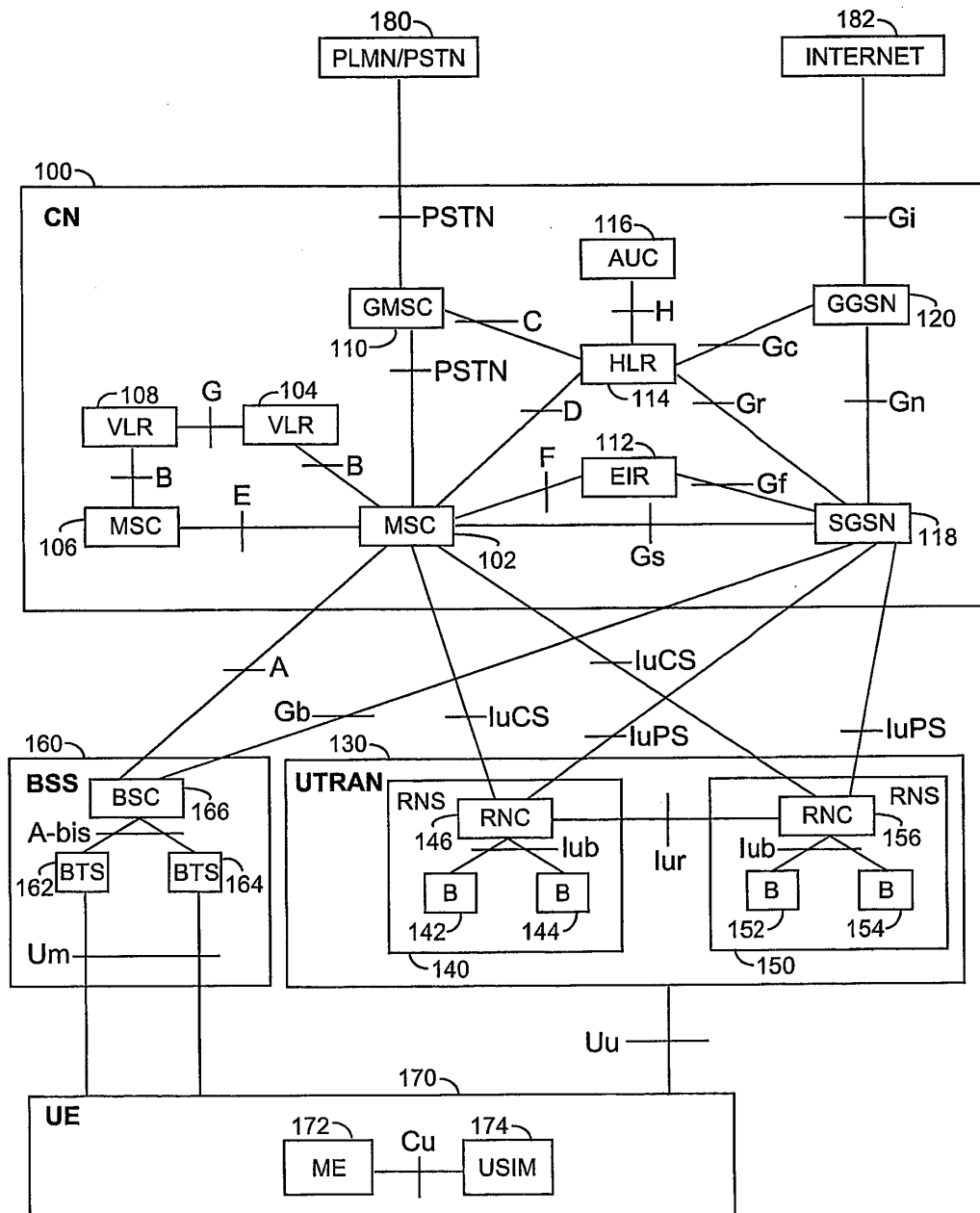


Fig. 1

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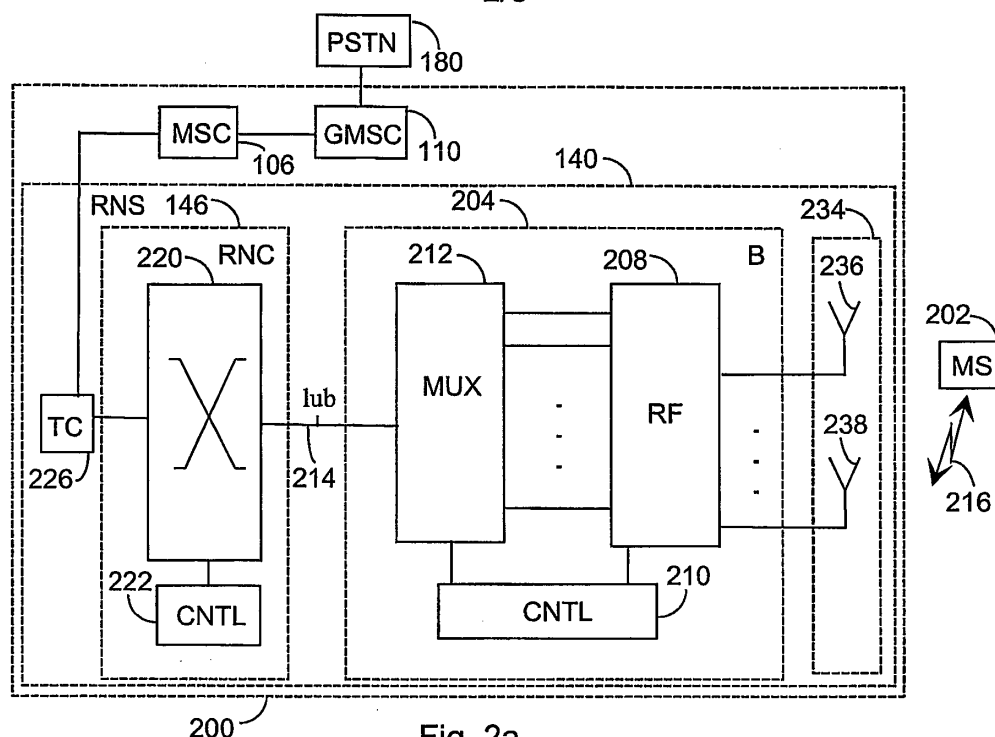


Fig. 2a

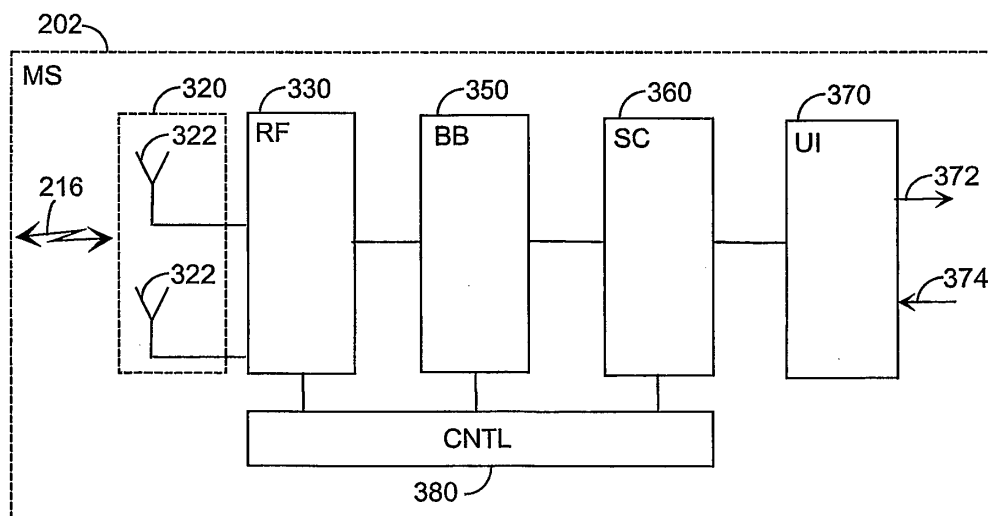


Fig. 2b

3/3

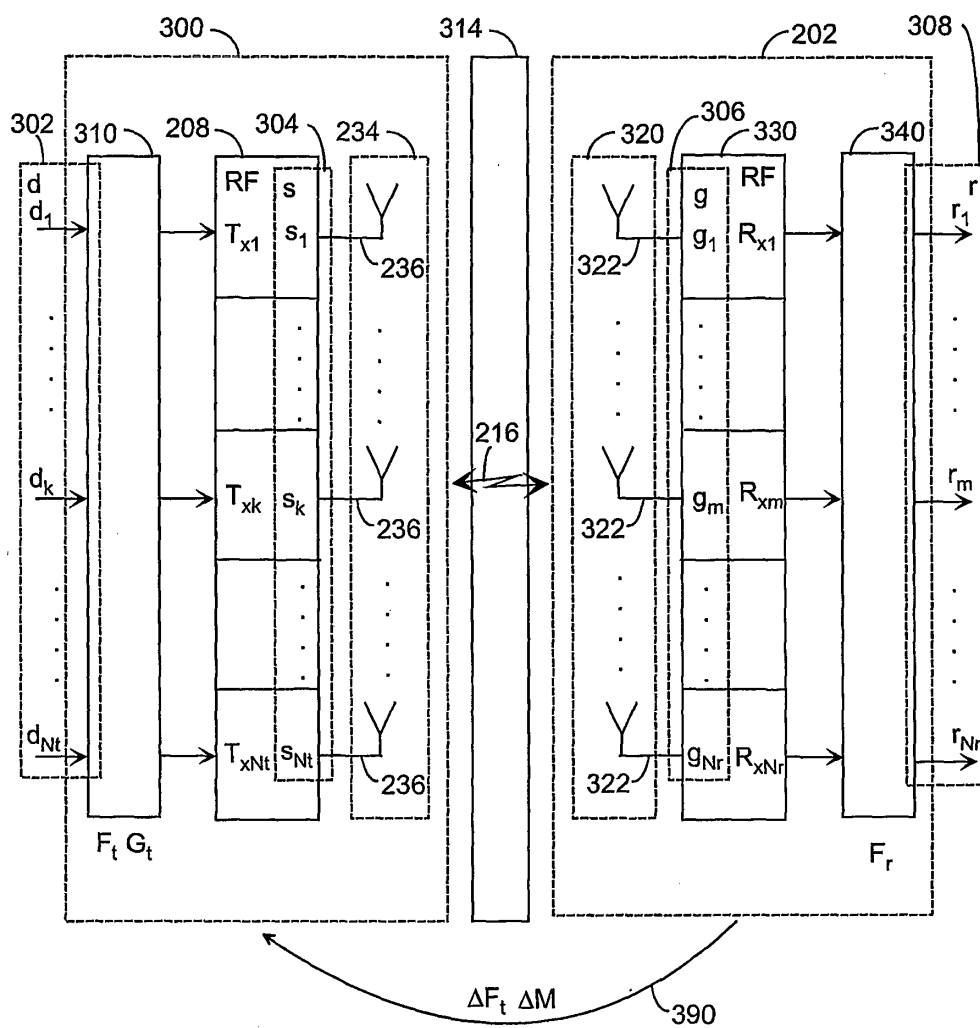


Fig. 3

INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI 02/00065

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H04B 7/04 // H 04L 1/12

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H04B, H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA, PAJ, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 1143636 A2 (SAMSUNG ELECTRONICS CO. LTD.), 10 October 2001 (10.10.01), abstract --	1-32
A	US 5634199 A (D. GERLANCH ET AL.), 27 May 1997 (27.05.97), column 2, line 60 - column 3, line 9 --	1-32
A	WO 0072465 A1 (NOKIA NETWORKS OY), 30 November 2000 (30.11.00), page 12, line 28 - line 29, abstract --	1-32

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

26 August 2002

Date of mailing of the international search report

17 -09- 2002

Name and mailing address of the ISA/

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Form PCT/ISA/210 (second sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI 02/00065

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JONGREN G. et al, Utilizing quantized feedback information in orthogonal space-time block coding. IEEE Global Telecommunications Conference, 2000. GLOBECOM'00, 27 Nov.-1 Dec. 2000, vol. 22, pages 995-999, ISBN: 0-7803-6451-1, paragraph II.B --	1-32
A	HOTTINEN, A. et al, Transmit diversity using filtered feedback weights in the FDD/WCDMA system, International Zurich Seminar on Broadband Communications, 2000. Proceedings. 2000, 15-17 Feb. 2000, pages 15-21, ISBN: 0-7803-5977-1, paragraph 2.2 -- -----	1-32

Form PCT/ISA/210 (continuation of second sheet) (July 1998)

INTERNATIONAL SEARCH REPORT
Information on patent family members

06/07/02

International application No.
PCT/FI 02/00065

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 1143636 A2	10/10/01	CN 1326274 A	12/12/01
		JP 2001352283 A	21/12/01
		KR 206252 Y	01/12/00
		US 2002006168 A	17/01/02

US 5634199 A	27/05/97	US 5471647 A	28/11/95

WO 0072465 A1	30/11/00	AU 2548200 A	12/12/00
		AU 4144799 A	12/12/00
		BR 9917298 A	19/02/02
		CN 1304587 T	18/07/01
		EP 1097525 A	09/05/01
		EP 1179230 A	13/02/02
		NO 20010290 A	18/01/01
		US 2002009156 A	24/01/02
		WO 0072464 A	30/11/00

Form PCT/ISA/210 (patent family annex) (July 1998)

Application No. :

04 773 142.7

Minutes of the oral proceedings before the EXAMINING DIVISION

The proceedings were not public.

Proceedings opened on 08.10.2013 at 09:00 hours

Examining Division:

Chairman: Pinilla-Ariza, D
1st member: Lastoria, Gianluca
2nd member: Volpato, Andrea
Minute writer: Volpato, Andrea

Present as/for the applicant/s:

L. von Kurowski (Hoffmann Eitle)
accompanied by: R. Schiere (Trainee - Hoffmann Eitle)

The identity of the person/s present and, where necessary, the authorisation to represent/authority to act were checked.

Essentials of the oral proceedings and the relevant statements of the applicant/s:

The chairman informed the applicant/s as follows:

The examining division intends to grant a European patent based on the following application documents:

Auxiliary Request 1

Description, Pages

1-4, 8-20	filed with entry into the regional phase before the EPO	
5, 5a, 5b, 6, 7	filed during Oral proceedings on	08-10-2013

Claims, Numbers

1-8	filed during Oral proceedings on	08-10-2013

Drawings, Sheets

1/12-12/12	filed with entry into the regional phase before the EPO	

With the following amendments to the above-mentioned documents proposed by the division

Drawings, Sheets 10/12

The examining procedure will be continued by issuing a communication under Rule 71(3) EPC on the basis of the above documents.

The chairman **closed the proceedings** on 08.10.2013 at 11:25 hours.



signed:

Pinilla-Ariza, D

.....
Chairman

signed:

Volpato, Andrea

.....
Minute Writer

Enclosure(s):

page 5,5a,5b,6,7 of the description and claims 1-8 as filed during the oral proceedings

The chairman informed the applicant/s as follows:

The examining division intends to grant a European patent based on the following application documents:

Auxiliary Request 1

Description, Pages

1-4, 8-20	filed with entry into the regional phase before the EPO	
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Claims, Numbers

1-8	filed during Oral proceedings on	08-10-2013

Drawings, Sheets

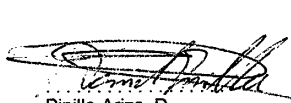
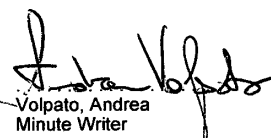
1/12-12/12	filed with entry into the regional phase before the EPO	

With the following amendments to the above-mentioned documents proposed by the division

Drawings, Sheets 10/12

The examining procedure will be continued by issuing a communication under Rule 71(3) EPC on the basis of the above documents.

The chairman **closed the proceedings** on 08.10.2013 at 11:25 hours.

	
Pinilla-Ariza, D Chairman	Volpato, Andrea Minute Writer

Annex(es):

page 5,5a,5b,6,7 of the description and claims 1-8 as filed during the oral proceedings

1. The **chairman** opened the oral proceedings at 9:00 and introduced the members of the examining division after the identity of the representative (hereinafter referred to as the applicant) had been checked.
2. At the chairman's request, the **applicant** confirmed the maintenance of the set of claims of the Main Request, submitted with letter of 12 Juli 2013.
3. The **chairman** asked the first examiner to present the opinion of the Examining Division regarding clarity (Art. 84 EPC).
4. The **first examiner** presented the clarity issue in claim 1: the wording "*multiple channels ...determined to be idle ... and the MIMO*" would make one understand that there is a process for determining whether a channel is MIMO which has no sense from a technical point of view since a channel is neutral and can be used for a transmission according to a plurality of different technologies like e.g. MIMO, GSM, UMTS etc..
5. The **applicant** acknowledges the issue and propose the use of the wording "and by using MIMO" giving as basis for the change fig. 14 and the passages at page 2, lines 16-18.
6. The proceedings were adjourned at 9:10 for consultation among the Examining Division. The proceedings were resumed at 9:15.
7. The **chairman** objected that the given basis for the changes were not really substantive since they belonged to a passage in the description presenting the background art and suggested that a more solid basis could be found in i.e. fig. 6 and the passage at page 12, lines 16-23 which belong to an embodiment in the description. The applicant agreed. After this, the clarity issue was declared as overcome.
8. The **chairman** invited the applicant to present the invention. The applicant made reference to figures 15 and 16 to explain that the problem challenged by the application was to improve the case of a transmission over multiple channels by multiple stations where in the case of non synchronized packets the power leakage from a channel to the other channels could degrade the packets transmission procedure in general. The applicant indicated fig. 2 and the passages at page 9, lines 4-12 as the most relevant part of the invention, where it is disclosed that a first device transmitting over multiple channels elect one of the transmitting channels as a mandatory channel and that in case another device wanted to transmit on a potential available idle channel should check where the channel marked as mandatory is idle prior transmitting, all this in order to avoid interference / power leakage into the channels used by the first device.
9. The proceedings were adjourned at 9:25 for consultation among the Examining Division. The proceedings were resumed at 9:45.

10. The **examining division** acknowledged that the inventive concept pointed out was not present in the cited prior art, nevertheless there were still two missing essential features in the current formulation of independent claim 1 (Art. 84 EPC and Rules 43(1) and 43(3)):

- the presence of multiple devices which transmit simultaneously;
- the fact that the device which would potentially interfere should refrain to transmit on his idle available channel if the channel marked as "mandatory" is in use (busy) .

11. The proceedings were adjourned at 10:20 for the Applicant to try to fix the issue. The proceedings were resumed at 10:55.

12. The **applicant** filed a new set of amended claims replacing the first Auxiliary Request which were overcoming the defects as presented under point 10 and some clerical errors. Moreover, amended description pages 5, 5a, 5b, 6 and 7 have been submitted in order to render the description compliant with the new claim formulation and to acknowledge the prior art.

13. The **chairman** informed the applicant that the Examining Division intended to grant a patent on the basis of the newly filed set of claims of the first Auxiliary Request because the subject-matter of the independent claims was not rendered obvious by any of the prior art documents and that the minutes of the Oral Proceeding were going to be delivered as soon as possible.

14. The proceedings were closed at 11:25.

channel #3 because of leakage power from the wireless channels #1 and #2. In other words, the STA in transmission cannot receive a wireless packet transmitted on a wireless channel that is adjacent to the wireless channel being in transmission. This problem occurs not only in case of simultaneous transmission using multiple wireless channels but also in a conventional case where wireless packets are transmitted by using one wireless channel and an adjacent wireless channel that is affected by leakage power receives the wireless packets.

WO 2004/114561 A1 relates to a radio packet communication method and radio packet communication apparatus. Data packets are transmitted between two stations capable of using plural radio channels and MIMO together, by using idle channels and MIMO. When at least one idle channel has been detected, plural data packets are generated in the same number as the sum of MIMO numbers of the respective idle channels, in which the data packets are generated from one or plural data frames, and plural data packets having the same packet time length are transmitted simultaneously between the two stations by using the idle channels and MIMO.] < page 56 >

It is an object of the present invention to avoid leakage power from affecting an adjacent channel so as to improve throughput by simultaneous transmission.

<->] This object is accomplished by the independent claims. Advantageous embodiments are described in the dependent claims.

<DISCLOSURE OF THE INVENTION>

A first ^{example} aspect of the invention provides a wireless packet communication method for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, or the multiple wireless channels and the MIMO. The wireless packet communication method includes setting a mandatory channel that is always used for

2.10.12 v. Amoral

transmission and transmitting the wireless packets by using a wireless channel or wireless channels that includes/include the mandatory channel, only when the mandatory channel is idle.

In other words, for transmitting a plurality of wireless packets simultaneously, transmission is performed by using the wireless channel(s) including the mandatory channel. Transmission is not performed when the mandatory channel is not idle. Moreover, wireless packets are always transmitted via wireless channels including the mandatory channel, and when the mandatory channel is busy, transmission is not performed even if there is another wireless channel. In other words, the mandatory channel can be regarded as a wireless

[continue on page 6]

8.10.13 v. Amstel.

8-10-13 v. Cusack

is transmitted as data packets each having the same packet length. adjacent channel while reducing interference between stations. The transmission data communicate with the plurality of stations via the substantially same channel or arbitrarily two or more. By means of the antenna beams, the access point can beams and the number of stations carrying out simultaneous communication may be comparatively narrow directivities to a plurality of stations. The number of antenna comprises an adaptive array antenna generating a plurality of radio waves with transmitting the packet to a wireless station. The wireless communication apparatus In CSMA an access point senses a carrier for transmitting the packet prior to a wireless communication system employing CSMA (carrier sense multiple access). a wireless communication apparatus in

EP 1 263 168 A2

channel having the highest priority among wireless channels that have a plurality of priorities. ~~example~~ A second aspect of the invention provides a wireless packet communication method for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, or the multiple wireless channels and the MIMO. The wireless packet communication method includes distinguishing an STA A, for which a mandatory channel always used for transmission is set, from an STA B for which no mandatory channel is set. Wireless packets addressed to the STA A are transmitted by using the wireless channel(s) including the mandatory channel, only when the mandatory channel is idle. Wireless packets addressed to the STA B are transmitted by using the idle wireless channel(s).

The STA A has a similar function as that of the invention of claim 1. The STA B for which no mandatory channel is set, is made transmittable even when the mandatory channel is busy. ~~example~~ Another aspect of the invention is such that the plurality of wireless packets transmitted simultaneously are set to have the same or equivalent packet time length that corresponds to a packet size or a transmission time. ~~example~~ Another aspect of the invention is such that wireless packets are simultaneously transmitted selectively using the multiple wireless channels or MIMO in accordance with the number of pieces of data or the number of MIMOs that depends on a channel condition. ~~example~~ Another aspect of the invention provides a wireless packet communication apparatus for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels determined to be idle and MIMO, or the multiple wireless channels and the MIMO. The wireless packet

8.10.11 v. 1.1

communication apparatus includes a unit setting a mandatory channel that is always used for transmission and transmitting the wireless packets by using the multiple wireless channels or the wireless channel that include/includes the mandatory channel, only when the mandatory channel is idle.

Another ^{example} ~~aspect of the invention~~ provides a wireless packet communication apparatus for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, or the multiple wireless channels and the MIMO. The wireless packet communication apparatus includes a unit distinguishing an STA A, for which a mandatory channel that is always used for transmission is set, from an STA B for which no mandatory channel is set, and determining destinations of the wireless packets. In case of wireless packets addressed to the STA A, the unit transmits the wireless packets by using the multiple wireless channels or the wireless channel that include/includes the mandatory channel, only when the mandatory channel is idle. In case of wireless packets addressed to the STA B, the unit transmits the wireless packets by using idle wireless channel or channels.

Another ^{example} ~~aspect of the invention~~ is such that the plurality of wireless packets transmitted simultaneously are set to have the same or equivalent packet time length that corresponds to a packet size or a transmission time.

Another ^{example} ~~aspect of the invention~~ is such that wireless packets are simultaneously transmitted selectively using the multiple wireless channels or MIMO in accordance with the number of pieces of data or the number of MIMOs that depends on a channel condition.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a flowchart according to a first embodiment of the present invention.

October 8, 2013

Claims
auxiliary
 (Main Request)

1. A wireless packet communication method for transmitting a plurality of wireless packets having equal packet time lengths simultaneously by using multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense and MIMO, the method characterized by comprising:

by using

setting a mandatory channel among multiple wireless channels that is always used for transmission and has the highest priority among wireless channels that have a plurality of priorities; ~~and~~

transmitting the wireless packets by using wireless channels (Ch#1, Ch#2) that include the mandatory channel, only when the mandatory channel is idle; ~~and~~

- ①
 2. ~~A~~ Wireless packet communication method *according to claim 1* ~~for transmitting~~ a plurality of wireless packets having equal packet time lengths simultaneously ~~by using multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense and MIMO, the method characterized by,~~ comprising:

by using

distinguishing an STA A from an STA B, the STA A for which ~~the~~ mandatory channel ~~among multiple wireless channels~~ is set, the STA B for which no mandatory channel ~~among multiple wireless channels~~ is set, ~~the~~ mandatory channel being always used for transmission and having the highest priority among wireless channels that ~~have a plurality of priorities;~~ and

when wireless packets are addressed to said STA A, transmitting the wireless packets to said STA A by using wireless channels (Ch#1, Ch#2) that include the

8.10.13 *alms*

- ① = refraining from transmitting wireless packets by another station on a channel (Ch#3) determined to be idle, when the mandatory channel is busy.
- ② = refraining from transmitting wireless packets on a channel (Ch#3) determined to be idle, when the mandatory channel is busy.

8.10.13 v. Murat.

mandatory channel, only when the mandatory channel is idle; and

when wireless packets are addressed to said STA B, transmitting the wireless packets to said STA B by using idle wireless channel(s) (Ch#1, Ch#2).

3. The wireless packet communication method according to claim 1 or 2, characterized in that

the packet time length corresponds to a packet size or a transmission time.

4. The wireless packet communication method according to claim 1 or 2, characterized by further comprising

simultaneously transmitting wireless packets selectively using the multiple wireless channels (Ch#1, Ch#2) or the MIMO in accordance with a number of pieces of data or a number of MIMOs that depends on a channel condition.

5. A wireless packet communication ^{system} ~~apparatus~~ for transmitting a plurality of wireless packets having equal packet time lengths simultaneously by using multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense and ^{by using} MIMO, the apparatus characterized by comprising

a unit (23) setting a mandatory channel among multiple wireless channels that is always used for transmission and has the highest priority among wireless channels that have a plurality of priorities, and transmitting the wireless packets only when the mandatory channel is idle by using wireless channels (Ch#1, Ch#2) that include the mandatory channel; and

^{station}
a ~~unit~~ ②

8.10.13 v. *Chen*

system according to claim 5

6. ~~A~~ Wireless packet communication ~~apparatus~~ ^{for} transmitting a plurality of wireless packets having equal packet time lengths simultaneously by using multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense and ^{by using} MIMO, the apparatus ~~characterized by~~, comprising

a unit (23) distinguishing an STA A from an STA B and determining destinations of the wireless packets so as to transmit wireless packets addressed to said STA A only when ^{the} ~~a~~ mandatory channel ~~among multiple wireless channels having the highest priority among wireless channels that have a plurality of priorities~~ is idle by using wireless channels (Ch#1, Ch#2) that include a mandatory channel, and to transmit wireless packets addressed to said STA B by using idle wireless channel or channels (Ch#1, Ch#2), ~~the mandatory channel being always used for transmission,~~ the STA A for which the mandatory channel is set, the STA B for which no mandatory channel is set.

7. The wireless packet communication apparatus according to claim 5 or 6, characterized in that

the packet time length corresponds to a packet size or a transmission time.

8. The wireless packet communication apparatus according to claim 5 or 6, characterized by further comprising:

a unit simultaneously transmitting wireless packets selectively using the multiple wireless channels (Ch#1, Ch#2) or the MIMO in accordance with a number of pieces of data or a number of MIMOs that depends on a channel condition.

8.10.13 v. *Arndt*

~~Amendments pursuant to Rule 86(2) to (4) EPC~~

~~WIRELESS PACKET COMMUNICATION METHOD AND
WIRELESS PACKET COMMUNICATION APPARATUS~~

TECHNICAL FIELD

The present invention relates to a wireless packet communication method and a wireless packet communication apparatus for simultaneously transmitting a plurality of wireless packets by using multiple wireless channels or Multiple Input Multiple Output (hereinafter, MIMO).

BACKGROUND ART

In a conventional wireless packet communication apparatus, a wireless channel to be used is determined in advance. Prior to transmission of a data packet, the wireless packet communication apparatus performs carrier sense to detect whether or not that wireless channel is idle. Only when that wireless channel is idle, the wireless packet communication apparatus transmits one data packet. This management allows a plurality of stations (hereinafter, STA) to share one wireless channel in a staggered manner ((1) "International Standard ISO/IEC 8802-11 ANSI/IEEE Std 802.11, 1999 edition, Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications", (2) "Low-powered Data Communication System/Broadband Mobile Access Communication System (CSMA) Standard", ARIB STD-T71 version 1.0, Association of Radio Industries and Businesses, settled in 2000).

On the other hand, a wireless packet communication method is known in which, when multiple wireless channels are found idle by carrier sense, a plurality of wireless packets are transmitted simultaneously by using the wireless channels. This method is generally described with reference to Figs. 13 and 14.

Fig. 13(1) shows a case where two wireless channels are idle for three wireless

packets. Two of the three wireless packets are transmitted simultaneously by using the two wireless channels. Fig. 13(2) shows a case where three wireless channels are idle for two wireless packets. All (two) wireless packets are transmitted simultaneously by using the two wireless channels.

5 Fig. 14 shows a case where a known MIMO technique (Kurosaki et al., "100Mbit/s SDM-COFDM over MIMO Channel for Broadband Mobile Communications", Technical Reports of the Institute of Electronics, Information and Communication Engineers, A · P 2001-96, RCS2001-135(2001-10)) is used together. In MIMO, different wireless packets are transmitted from a plurality of antennas at the same time on the same wireless channel.

10 Those wireless packets transmitted at the same time on the same wireless channel are separated from each other by digital signal processing that can deal with a difference between propagation coefficients of the wireless packets received by a plurality of antennas in an opposed STA. The number of MIMOs is determined in accordance with the propagation coefficients and the like.

15 Fig. 14(1) shows a case where three wireless channels are idle for seven wireless packets when the number of MIMOs of each wireless channel is two. When MIMO is applied to each of the three wireless channels, up to six wireless packets can be transmitted simultaneously. Therefore, six of the above seven wireless packets are transmitted simultaneously by using the three wireless channels.

20 Figs. 14(2) and (3) show cases where three wireless channels are idle for four wireless packets when the Number of MIMOs of each wireless channel is two. When MIMO is applied to each of the three wireless channels, up to six wireless packets can be transmitted simultaneously. However, the number of transmission-standby wireless packets is four. Therefore, MIMO is applied to a part of the three wireless channels. For

25 example, one of the wireless channels transmits two wireless packets by using MIMO, while

each of the remaining two wireless channels transmits one wireless packet without using MIMO, as shown in Fig. 14(2). Thus, four wireless packets are transmitted simultaneously by using the three wireless channels in total. Alternatively, four wireless packets are transmitted simultaneously on two wireless channels each using MIMO, as show in Fig.

5 14(3).

In the case where center frequencies of multiple wireless channels used at the same time are close to each other, an effect of leakage power from one wireless channel to a frequency region used by another wireless channel becomes large. In general, in case of transferring a wireless packet, a transmit-side STA transmits the wireless packet and
10 thereafter a receive-side STA transmits an acknowledgment packet (Ack) for the received wireless packet to the transmit-side STA. When the transmit-side STA tries to receive this acknowledgment packet (hereinafter, ACK packet), the effect of leakage power from another wireless channel used for simultaneous transmission becomes a problem.

For example, a case is considered where center frequencies of wireless channels #1
15 and #2 are close to each other and transmission times of wireless packets transmitted simultaneously from the respective wireless channels are different from each other, as shown in Fig. 15. In this case, the wireless packet transmitted on the wireless channel #1 is shorter. Thus, when an ACK packet (Ack1) for that wireless packet is received, the wireless channel #2 is performing transmission. Therefore, the wireless channel #1 may not receive
20 that ACK packet (Ack1) because of leakage power from the wireless channel #2. In this situation, throughput cannot be improved even if simultaneous transmission is performed using multiple wireless channels at the same time.

In a wireless LAN system, for example, data sizes of data frames input from a network are not constant. Thus, in case of sequentially converting the input data frames
25 into wireless packets for transmission, packet time lengths of the wireless packets are also

different. Therefore, even when a plurality of wireless packets are transmitted simultaneously at the same time, as shown in Fig. 15, the transmission time of each wireless packet is different. This increases a possibility of unsuccessful receiving of the ACK packet.

5 In order to overcome the above problem, there is a known method in which transmission of a plurality of wireless packets is terminated at the same time or substantially at the same time by making equal or equivalent packet time lengths (time required to transmit the wireless packets) of the wireless packets transmitted simultaneously. In this case, a transmit-side STA is not performing transmission at a
10 timing at which ACK packets for the respective wireless packets reach the transmit-side STA. Thus, the transmit-side STA can receive all the ACK packets without being affected by leakage power between wireless channels or the like. Therefore, the throughput can be improved.

However, even if the packet time lengths of the wireless packets transmitted
15 simultaneously are made the same, the effect of leakage power may become a problem. This case is now described with reference to Fig. 16.

At timing t1, wireless channels #1 and #2 of a transmit-side STA are idle, while a wireless channel #3 is busy. Thus, the transmit-side STA transmits wireless packets having the same packet time length by using the idle wireless channels #1 and #2. Therefore, the
20 effect of leakage power can be avoided between the wireless channels #1 and #2. When the wireless channel #3 becomes idle during transmission of those wireless packets (at timing t2), another STA may determine that the wireless channel #3 is idle and may transmit a wireless packet to the above transmit-side STA by using the wireless channel #3. However, the transmit-side STA is transmitting the wireless packets by using the wireless
25 channels #1 and #2 and therefore cannot receive the wireless packet on the wireless

channel #3 because of leakage power from the wireless channels #1 and #2. In other words, the STA in transmission cannot receive a wireless packet transmitted on a wireless channel that is adjacent to the wireless channel being in transmission. This problem occurs not only in case of simultaneous transmission using multiple wireless channels but also in a conventional case where wireless packets are transmitted by using one wireless channel and an adjacent wireless channel that is affected by leakage power receives the wireless packets.

WO 2004/114561 A1 relates to a radio packet communication method and radio packet communication apparatus. Data packets are transmitted between two stations capable of using plural radio channels and MIMO together, by using idle channels and MIMO. When at least one idle channel has been detected, plural data packets are generated in the same number as the sum of MIMO numbers of the respective idle channels, in which the data packets are generated from one or plural data frames, and plural data packets having the same packet time length are transmitted simultaneously between the two stations by using the idle channels and MIMO. < page 5b >

It is an object of the present invention to avoid leakage power from affecting an adjacent channel so as to improve throughput by simultaneous transmission.

➡ This object is accomplished by the independent claims. Advantageous embodiments are described in the dependent claims.

<DISCLOSURE OF THE INVENTION>

A first ^{example} ~~aspect of the invention~~ provides a wireless packet communication method for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, or the multiple wireless channels and the MIMO. The wireless packet communication method includes setting a mandatory channel that is always used for

[→ sa]

2.10.12 v. *Amend.*

< please insert the text in
 page 5 between lines 21
 and 22, as indicated
 on page 5 >

EP 1 263 168 42

- 1-1 ~~Newly cited prior-art document D2~~ relates to a wireless communication apparatus in a wireless communication system employing CSMA (carrier sense multiple access). In CSMA an access point senses a carrier for transmitting the packet prior to transmitting the packet to a wireless station. The wireless communication apparatus comprises an adaptive array antenna generating a plurality of radio waves with comparatively narrow directivities to a plurality of stations. The number of antenna beams and the number of stations carrying out simultaneous communication may be arbitrarily two or more. By means of the antenna beams, the access point can communicate with the plurality of stations via the substantially same channel or adjacent channel while reducing interference between stations. The transmission data is transmitted as data packets each having the same packet length.

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transmission and transmitting the wireless packets by using a wireless channel or wireless channels that includes/include the mandatory channel, only when the mandatory channel is idle.

In other words, for transmitting a plurality of wireless packets simultaneously, transmission is performed by using the wireless channel(s) including the mandatory channel. Transmission is not performed when the mandatory channel is not idle. Moreover, wireless packets are always transmitted via wireless channels including the mandatory channel, and when the mandatory channel is busy, transmission is not performed even if there is another wireless channel. In other words, the mandatory channel can be regarded as a wireless

[continue on page 6]

[-26]

5a

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channel having the highest priority among wireless channels that have a plurality of priorities.

~~example~~
A second ~~aspect of the invention~~ provides a wireless packet communication method for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, or the multiple wireless channels and the MIMO. The wireless packet communication method includes distinguishing an STA A, for which a mandatory channel always used for transmission is set, from an STA B for which no mandatory channel is set. Wireless packets addressed to the STA A are transmitted by using the wireless channel(s) including the mandatory channel, only when the mandatory channel is idle. Wireless packets addressed to the STA B are transmitted by using the idle wireless channel(s).

The STA A has a similar function as that of the invention of claim 1. The STA B for which no mandatory channel is set, is made transmittable even when the mandatory channel is busy.

~~example~~
Another ~~aspect of the invention~~ is such that the plurality of wireless packets transmitted simultaneously are set to have the same or equivalent packet time length that corresponds to a packet size or a transmission time.

~~example~~
Another ~~aspect of the invention~~ is such that wireless packets are simultaneously transmitted selectively using the multiple wireless channels or MIMO in accordance with the number of pieces of data or the number of MIMOs that depends on a channel condition.

~~example~~
Another ~~aspect of the invention~~ provides a wireless packet communication apparatus for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels determined to be idle by carrier sense, a wireless channel determined to be idle and MIMO, or the multiple wireless channels and the MIMO. The wireless packet

communication apparatus includes a unit setting a mandatory channel that is always used for transmission and transmitting the wireless packets by using the multiple wireless channels or the wireless channel that include/includes the mandatory channel, only when the mandatory channel is idle.

Another ^{example} ~~aspect of the invention~~ provides a wireless packet communication apparatus for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, or the multiple wireless channels and the MIMO. The wireless packet communication apparatus includes a unit distinguishing an STA A, for which a mandatory channel that is always used for transmission is set, from an STA B for which no mandatory channel is set, and determining destinations of the wireless packets. In case of wireless packets addressed to the STA A, the unit transmits the wireless packets by using the multiple wireless channels or the wireless channel that include/includes the mandatory channel, only when the mandatory channel is idle. In case of wireless packets addressed to the STA B, the unit transmits the wireless packets by using idle wireless channel or channels.

Another ^{example} ~~aspect of the invention~~ is such that the plurality of wireless packets transmitted simultaneously are set to have the same or equivalent packet time length that corresponds to a packet size or a transmission time.

Another ^{example} ~~aspect of the invention~~ is such that wireless packets are simultaneously transmitted selectively using the multiple wireless channels or MIMO in accordance with the number of pieces of data or the number of MIMOs that depends on a channel condition.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a flowchart according to a first embodiment of the present invention.

Fig. 2 is a time chart of an exemplary operation in the first embodiment of the present invention.

Fig. 3 explains methods for reconstructing a data packet.

Fig. 4 is a flowchart according to a second embodiment of the present invention.

5 Fig. 5 is a time chart of an exemplary operation in the second embodiment of the present invention.

Fig. 6 is a flowchart according to a third embodiment of the present invention.

Fig. 7 is a flowchart according to a fourth embodiment of the present invention.

Fig. 8 is a flowchart according to a fifth embodiment of the present invention.

10 Fig. 9 is a flowchart according to a sixth embodiment of the present invention.

Fig. 10 is a flowchart according to a seventh embodiment of the present invention.

Fig. 11 is a flowchart according to an eighth embodiment of the present invention.

Fig. 12 is a block diagram of an exemplary wireless packet communication apparatus according to the present invention.

15 Fig. 13 explains exemplary methods for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels.

Fig. 14 explains exemplary methods for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels (and MIMO).

Fig. 15 explains an effect of leakage power of a wireless channel.

20 Fig. 16 explains a case where the effect of leakage power becomes a problem even if packet time lengths of wireless packets transmitted simultaneously are made the same.

Fig. 17 shows a structure of a wireless packet used in the wireless packet communication apparatus of the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

[First Embodiment]

Fig. 1 is a flowchart of a wireless packet communication method according to the first embodiment of the present invention. Fig. 2 is a time chart of the wireless communication method according to the first embodiment of the present invention. In this embodiment, wireless channels #1, #2, and #3 are provided, and the wireless channel #1 is set as a mandatory channel for every STA. Each STA is regularly notified of the mandatory channel. When the mandatory channel is busy, each STA does not perform transmission even if there is other idle wireless channel. That is, no transmission is performed. It is assumed that the wireless channels #1, #2, and #3 affect each other due to a leakage and that when one of the wireless channels is in transmission, the other channels cannot receive data.

When data is stored in a transmission buffer, an idle wireless channel is searched by carrier sense (S1 and S2). In this example, it is found that the wireless channel #3 is busy at a timing data is generated (1), and the wireless channels #1 and #2 are idle. Then, it is determined whether or not the mandatory channel is idle (S3). When the mandatory channel is busy, a procedure goes back to the search of an idle wireless channel. On the other hand, when the mandatory channel is idle, data packets are reconstructed to data packets having the same packet time length for every wireless channel in accordance with the number of idle channels and the number of transmission stand-by data packets. The reconstructed data packets are transmitted (simultaneously) (S4). In this example, since the wireless channel #1 as the mandatory channel is idle, the wireless packets is simultaneously transmitted by using two wireless channels as the wireless channels #1 and #2.

The following three methods are known data packet reconstruction methods. In

the case where there is one data packet and two idle channels, for example, two data packets having the same packet time length are generated by fragmenting the data packet, as shown in Fig. 3(1). In the case where there are three data packets and two idle channels, a data packet 2 is divided into two portions and the two portions are connected to data packets 1 and 3, respectively, for example, as shown in Fig. 3(2). In this manner, two data packets having the same packet time length are generated. Alternatively, the two data packets having the same packet time length can be generated by connecting the three data packets into one block and then dividing the block into two. Alternatively, the data packets 1 and 2 may be aggregated to each other and dummy data is added to the data packet 3, as shown in Fig. 3(3), thereby obtaining two data packets having the same packet time length. Moreover, in the case where multiple wireless channels having different transmission rates are used, the packet time lengths of data packets are adjusted to be the same by associating a size ratio of each data packet with a ratio of the transmission rates.

Even when the wireless channel #3 becomes idle, another STA does not perform transmission because the wireless channel #1 set as the mandatory channel is busy. On the other hand, at a timing data is generated (2), all the wireless channels including the wireless channel #1 set as the mandatory channel are idle. Therefore, each STA becomes transmittable. For example, in the case where an STA transmits the wireless packets at the timing data is generated (1), another STA transmits a wireless packet to the STA having transmitted at the timing data is generated (2).

[Second Embodiment]

Fig. 4 is a flowchart of a wireless packet communication method according to the second embodiment of the present invention. Fig. 5 is a time chart of that wireless packet communication method. In this embodiment, there are an STA A for which a mandatory channel is set and an STA B for which no mandatory channel is set. There is no specific

limitation to transmission to the STA B, while transmission to the STA A is allowed only when the mandatory channel is idle, and is not performed when the mandatory channel is busy even if another wireless channel is idle. Please note that in the first embodiment a mandatory channel is set for every STA so that packet transmission is always performed via
5 wireless channels including the mandatory channel without an address of a wireless packet being considered.

First, when data is stored in a transmission buffer, an idle wireless channel is searched by carrier sense (S1 and S2). In this example, it is found that at a timing data is generated (I), a wireless channel #3 is busy and wireless channels #1 and #2 are idle.
10 Then, an address of one data packet stored in the transmission buffer is decoded (S11), and it is determined whether or not any mandatory channel is set for an STA that is the decoded address (S12). When a mandatory channel is set for the receive-side STA, it is determined whether or not that mandatory channel is idle (S13). When that mandatory channel is idle, transmission stand-by data packets are reconstructed to have the same packet time length
15 for every wireless channel in accordance with the number of idle channels and the number of the transmission stand-by data packets. The reconstructed data packets are transmitted (simultaneously) (S4). In this example, for wireless packets addressed to the STA A, simultaneous transmission is performed using two wireless channels as the wireless channels #1 and #2 because the wireless channel #1 set as the mandatory channel is idle.

20 On the other hand, when no mandatory channel is set for the receive-side STA in S12, the state of the mandatory channel need not be considered so that the transmission stand-by data packets are reconstructed to have the same packet time length for every wireless channel in accordance with the number of idle channels and the number of the transmission stand-by data packets. The reconstructed data packets are transmitted
25 (simultaneously) (S4). Moreover, when the mandatory channel is not idle in S13, the

wireless packet cannot be transmitted to the STA A for which the mandatory channel is set. Therefore, it is then determined whether or not there is another data packet in the transmission buffer (S14). With a presence of a data packet therein, a procedure returns to decoding of an address of the data packet in S11. With no data packet, an idle channel is
5 searched in S2.

In this example, when the wireless channel #3 becomes idle, transmission of a wireless packet to the STA B in which no mandatory channel is set using the wireless channel #3 becomes possible. On the other hand, transmission of a wireless packet to the STA A using the wireless channel #3 is not performed because the wireless channel #1 is
10 busy, and has to wait until the wireless channel #1 becomes idle.

At a timing data is generated (2), the wireless channels #1 and #2 are idle. Therefore, wireless packets addressed to the STA A for which the mandatory channel is set and to the STA B for which no mandatory channel is set can be transmitted by using the wireless channels #1 and #2.

15 [Third Embodiment]

Fig. 6 is a flowchart of a wireless packet communication method according to the third embodiment of the present invention. This embodiment has a feature in using MIMO additionally for simultaneous transmission of wireless packets in the first embodiment as well as in reconstructing wireless packets in S4 in the first embodiment such that
20 reconstructed wireless packets have the same packet time length for the number of simultaneous transmissions that corresponds to a total number of MIMOs of idle channels (S5). Except for the above, this embodiment is the same as the first embodiment.

[Fourth Embodiment]

Fig. 7 is a flowchart of a wireless packet communication method according to the
25 fourth embodiment of the present invention. This embodiment has the following feature.

In case of applying MIMO to simultaneous transmission of wireless packets, antenna correlation is obtained from propagation coefficients prior to reconstruction of wireless packets to wireless packets having the same packet time length for the number of simultaneous transmissions that corresponds to a total number of MIMOs of idle channels in S5 in the third embodiment. Then, the number of MIMOs that that can be multiplexed in one channel is obtained by using a predetermined threshold value (S6). Except for the above, this embodiment is the same as the third embodiment.

[Fifth Embodiment]

Fig. 8 is a flowchart of a wireless packet communication method according to the fifth embodiment of the present invention. This embodiment has a feature that simultaneous transmission using multiple wireless channels as described in the first embodiment or simultaneous transmission using MIMO as described in the third embodiment is selected in accordance with the number of pieces of data stored in the transmission buffer or the number of MIMOs as described in the fourth embodiment that depends on a channel condition (S7). In accordance with this selection, wireless packets are reconstructed to have the same packet time length for the number of idle channels or the Number of MIMOs. The reconstructed packets are transmitted simultaneously (S4 and S8). Except for the above, this embodiment is the same as the first embodiment.

[Sixth Embodiment]

Fig. 9 is a flowchart of a wireless packet communication method according to the sixth embodiment of the present invention. This embodiment has a feature that MIMO is applied to simultaneous transmission of wireless packets in the second embodiment. More specifically, wireless packets in S4 in the second embodiment is reconstructed in such a manner that reconstructed wireless packets have the same packet time length for the number of simultaneous transmissions that corresponds to a total number of MIMOs of idle

channels (S5). Except for the above, this embodiment is the same as the second embodiment.

[Seventh Embodiment]

Fig. 10 is a flowchart of a wireless packet communication method according to the seventh embodiment of the present invention. This embodiment has the following feature. In case of applying MIMO to simultaneous transmission of wireless packets, antenna correlation is obtained from propagation coefficients prior to reconstruction of wireless packets to wireless packets having the same packet time length for the number of simultaneous transmissions that corresponds to a total number of MIMOs of idle channels in S5 in the sixth embodiment. Then, the number of MIMOs that can be multiplexed in one channel is obtained by using a predetermined threshold value (S6). Except for the above, this embodiment is the same as the sixth embodiment.

[Eighth Embodiment]

Fig. 11 is a flowchart of a wireless packet communication method according to the eighth embodiment of the present invention. This embodiment has a feature that simultaneous transmission using multiple wireless channels as described in the second embodiment or simultaneous transmission using MIMO as described in the sixth embodiment is selected in accordance with the number of pieces of data stored in the transmission buffer or the number of MIMOs described in the seventh embodiment that depends on a channel condition (S7). In accordance with this selection, reconstruction of wireless packets is performed in such a manner that reconstructed wireless packets have the same packet time length for the number of idle channels or the Number of MIMOs. The reconstructed wireless packets are transmitted simultaneously (S4 and S8). Except for the above, this embodiment is the same as the second embodiment.

[Exemplary structure of a wireless packet communication apparatus]

Fig. 12 shows an exemplary structure of a wireless packet communication apparatus of the present invention. Although the following description will be directed to the structure of the wireless packet communication apparatus capable of transmitting and receiving three wireless packets simultaneously by using three wireless channels #1, #2, and #3, the number of simultaneously transmittable/receivable wireless packets may be set arbitrarily. Where MIMO is used for each wireless channel, wireless packets can be transmitted and received simultaneously in the number of simultaneous transmissions that is equal to the sum of MIMO numbers of multiple wireless channels. However, the MIMO will not be taken into consideration in the following description as well as a case where multiple wireless channels are independently used.

In Fig. 12, the wireless packet communication apparatus includes a transmission/reception block 10-1, 10-2, and 10-3, a transmission buffer 21, a data packet generating block 22, a data frame management block 23, an analyzer of channels' occupation status 24, a packet switching block 25, a packet order management block 26, and a data frame extraction block 27.

The transmission/reception blocks 10-1, 10-2, and 10-3 perform wireless communication via different wireless channels #1, #2, and #3, respectively. These wireless channels are independent of each other because they have different wireless frequencies from each other, therefore, the blocks can perform wireless communication using multiple wireless channels at the same time. Each transmission/reception block 10 includes a modulator 11, a transmitter 12, an antenna 13, a receiver 14, a demodulator 15, a frame selection block 16, and a carrier sense block 17.

Radio frequency signals transmitted from another wireless packet communication apparatus via different wireless channels #1, #2, and #3 are input to the receivers 14 through the antennas 13 of the transmission/reception block 10-1, 10-2, and 10-3,

respectively. Each receiver 14 corresponding to each wireless channel performs a reception processing on the input radio frequency signal. The reception processing contains frequency conversion, filtering, quadrature detection, and AD conversion. A radio frequency signal on a wireless propagation path of each wireless channel is always input to the corresponding receiver 14 except during periods the antenna 13 connected to the receiver 14 is used for transmission. The receiver 14 outputs, to the carrier sense block 17, an RSSI signal indicating a received electric field strength of each wireless channel. When receiving a radio frequency signal on the corresponding wireless channel, the receiver 14 outputs to the demodulator 15 a baseband signal for which the reception processing is performed.

The demodulator 15 performs a demodulation processing on the baseband signal input from the receiver 14, and outputs a resulting data packet to the frame selection block 16. The frame selection block 16 performs CRC check on the input data packet. In the case where the data packet has been received correctly, the frame selection block 16 determines whether or not the data packet is directed to an own STA. More specifically, the frame selection block 16 determines whether or not a receive-side STA ID of the data packet is coincident with ID of the own STA. Then, the frame selection block 16 outputs the data packet addressed to the own STA to the packet order management block 26 while transmitting to the modulator 11 an ACK packet generated in an ACK packet generating block (not shown) and performs a reply processing. In transmission of the ACK packet, a transmission mode may be set in such a manner that a transmission rate is set or MIMO is not applied. On the other hand, when the data packet is not directed to the own STA, the frame selection block 16 discards the data packet.

The packet order management block 26 checks sequence numbers added to received data packets and rearranges the received data packets in an appropriate order, i.e.,

in order of sequence numbers. The rearranged data packets are output to the data frame extraction block 27 as received data packets. The data frame extraction block 27 removes a packet header from each of the data packets contained in the received data packets, and outputs the resulting data packets as received data frames.

5 When receiving an RSSI signal, the carrier sense block 17 compares a value of a received electric field strength represented by the RSSI signal with a preset threshold value. When a state where the received electric field strength is smaller than the threshold value continues for a predetermined period, the carrier sense block 17 determines that the assigned wireless channel is idle. Otherwise, the carrier sense block 17 determines that the
10 assigned wireless channel is busy. The carrier sense blocks 17 corresponding to the respective wireless channels output the determination results as carrier sense results CS1 to CS3. Please note that in each transmission/reception block 10, no RSSI signal is input to the carrier sense block 17 while the antenna 13 is in transmission. Moreover, in the case where the antenna 13 has already been in a transmission state, it is not possible to
15 simultaneously transmit another data packet as a radio frequency signal by means of the same antenna 13. Therefore, when receiving the RSSI signal, each carrier sense block 17 outputs the carrier sense result indicating that the wireless channel assigned thereto is busy.

The carrier sense results CS1 to CS3 that are output from the carrier sense blocks 17 corresponding to the respective wireless channels are input to the analyzer of channels' occupation status 24. The analyzer of channels' occupation status 24 manages an idle
20 status of each wireless channel based on the corresponding carrier sense result and notifies the data frame management block 23 of information on an idle wireless channel, the number of idle channels, and the like (Fig. 12, a).

On the other hand, sent data frames to be transmitted are input to and buffered in
25 the transmission buffer 21. The sent data frames consists one or more data frames. The

transmission buffer 21 successively notifies the data frame management block 23 of the number of data frames the transmission buffer 21 currently stores, ID information of a receive-side wireless packet communication apparatus, a data size, address information indicating a position in the buffer, and other information (b).

5 The data frame management block 23 determines how to generate data packets from which data frame and on which wireless channel to transmit, according to information about data frames for each receive-side STA ID from the transmission buffer 21 and information about the wireless channels from the analyzer of channels' occupation status 24. The data frame management block 23 then notifies the transmission buffer 21, the
10 data packet generating block 22, and the data packet switching block 25 of the determined data frame, generation manner, and wireless channel, respectively (c, d, and e). For example, in the case where the number N of idle wireless channels including the mandatory channel is smaller than the number K of transmission stand-by data frames in the transmission buffer 21, the number N of idle wireless channels including the mandatory
15 channel is determined as the number of data packets transmitted simultaneously. The transmission buffer 21 is notified of address information to designate N data frames from the K data frames (c). The data packet generating block 22 is notified of information necessary for generating N data packets from data frames input from the transmission buffer 21 (d). The packet switching block 25 is instructed to associate the N data packets
20 generated by the data packet generating block 22 with the idle wireless channels (e).

 According to an output instruction, the transmission buffer 21 outputs the data frames to the data packet generating block 22 (f). The data packet generating block 22 extracts data fields from the respective data frames to generate a plurality of data blocks having the same packet time length, and adds a packet header and a CRC code (FCS region)
25 to each of the data blocks to generate data packets shown in Fig. 17. The packet header

contains ID information on a receive-side STA as a destination of the corresponding data packet, control information such as a sequence number indicating an order of the data frame, and other information. The control information also contains information required for a receive-side STA to convert a data packet into the original data frame when it receives
5 the data packet. The packet switching block 25 associates the data packets input from the data packet generating block 22 with the respective wireless channels.

As a result, the data packet associated with the wireless channel #1 is input to the modulator 11 in the transmission/reception block 10-1; the data packet associated with the wireless channel #2 is input to the modulator 11 in the transmission/reception block 10-2;
10 and the data packet associated with the wireless channel #3 is input to the modulator 11 in the transmission/reception block 10-3. When receiving a data packet from the packet switching block 25, each modulator 11 performs a predetermined modulation processing on the data packet and outputs the processed data packet to the transmitter 12. Each transmitter 12 performs a transmission processing on the modulated data packet input
15 from the modulator 11. The transmission processing contains DA conversion, frequency conversion, filtering, and power amplification. After the transmission processing, each transmitter 12 transmits the processed data packet as a wireless packet on the corresponding wireless channel via the corresponding antenna 13.

The processings described in the first to eight embodiments are performed under a
20 control of the data frame management block 23 with the mandatory channel taken into consideration. This can prevent a situation that a wireless packet cannot be received by use of multiple wireless channels because of leakage of power from one channel to an adjacent channel.

25

INDUSTRIAL AVAILABILITY

According to the present invention, while a transmit-side STA is in transmission using one or more wireless channels including a mandatory channel, the other STAs do not perform transmission to the transmit-side STA. Thus, it is possible to avoid a situation
5 that the transmit-side STA cannot receive a wireless packet addressed to an own STA. On the other hand, the other STAs can surely transfer a wireless packet to the transmit-side STA by transmitting the wireless packet after the mandatory channel becomes idle. Thus, throughput can be improved.

Moreover, in the case where there is an STA for which no mandatory channel is set,
10 transmission is enabled between STAs including the STA even when the mandatory channel is busy. Thus, reduction of the throughput can be suppressed.

②

Claims

~~auxiliary~~
~~(Main Request)~~

1. A wireless packet communication method for transmitting a plurality of wireless packets having equal packet time lengths simultaneously by using multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense and MIMO, the method characterized by comprising:

by using

setting a mandatory channel among multiple wireless channels that is always used for transmission and has the highest priority among wireless channels that have a plurality of priorities; ~~and~~

transmitting the wireless packets by using wireless channels (Ch#1, Ch#2) that include the mandatory channel, only when the mandatory channel is idle; ~~and~~

①

2. ~~A~~ ^{*according to claim 1*} Wireless packet communication method ~~for transmitting~~ a plurality of wireless packets having equal packet time lengths simultaneously ~~by using~~ multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense and MIMO, ~~the method characterized by~~ comprising:

by using

distinguishing ~~a~~ STA A from ~~a~~ STA B, the STA A for which ~~the~~ mandatory channel ~~among multiple wireless channels~~ is set, the STA B for which no mandatory channel ~~among multiple wireless channels~~ is set, ~~the~~ mandatory channel being always used for transmission and having the highest priority among wireless channels that ~~have a plurality of priorities~~; and

when wireless packets are addressed to said STA A, transmitting the wireless packets to said STA A by using wireless channels (Ch#1, Ch#2) that include the

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- ① = refraining from transmitting wireless packets by another station on a channel (Ch#3) determined to be idle, when the mandatory channel is busy.
- ② = refraining from transmitting wireless packets on a channel (Ch#3) determined to be idle, when the mandatory channel is busy.

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mandatory channel, only when the mandatory channel is idle; and

when wireless packets are addressed to said STA B, transmitting the wireless packets to said STA B by using idle wireless channel~~set~~ ^{or channels} (Ch#1, Ch#2).

3. The wireless packet communication method according to claim 1 or 2, characterized in that

the packet time length corresponds to a packet size or a transmission time.

4. The wireless packet communication method according to claim 1 or 2, characterized by further comprising

simultaneously transmitting wireless packets selectively using the multiple wireless channels (Ch#1, Ch#2) or the MIMO in accordance with a number of pieces of data or a number of MIMOs that depends on a channel condition.

5. A wireless packet communication ^{system} ~~apparatus~~ for transmitting a plurality of wireless packets having equal packet time lengths simultaneously by using multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense and ^{by using} MIMO, the apparatus characterized by comprising

a unit (23) setting a mandatory channel among multiple wireless channels that is always used for transmission and has the highest priority among wireless channels that have a plurality of priorities, and transmitting the wireless packets only when the mandatory channel is idle by using wireless channels (Ch#1, Ch#2) that include the mandatory channel~~it~~ ; and

a ^{station} ~~unit~~ ②

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system according to claim 5

6. ~~A~~ Wireless packet communication ~~apparatus for~~ transmitting a plurality of wireless packets having equal packet time lengths simultaneously by using multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense and ^{by using} MIMO, the apparatus characterized by, comprising

a unit (23) distinguishing ~~a~~ STA A from ~~a~~ STA B and determining destinations of the wireless packets so as to transmit wireless packets addressed to said STA A only when ^{the} ~~a~~ mandatory channel ~~among multiple wireless channels having the highest priority among wireless channels that have a plurality of priorities~~ is idle by using wireless channels (Ch#1, Ch#2) that include a mandatory channel, and to transmit wireless packets addressed to said STA B by using idle wireless channel or channels (Ch#1, Ch#2), ~~the mandatory channel being always used for transmission,~~ the STA A for which the mandatory channel is set, the STA B for which no mandatory channel is set.

7. The wireless packet communication apparatus according to claim 5 or 6, characterized in that

the packet time length corresponds to a packet size or a transmission time.

8. The wireless packet communication apparatus according to claim 5 or 6, characterized by further comprising:

a unit simultaneously transmitting wireless packets selectively using the multiple wireless channels (Ch#1, Ch#2) or the MIMO in accordance with a number of pieces of data or a number of MIMOs that depends on a channel condition.

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FIG. 1

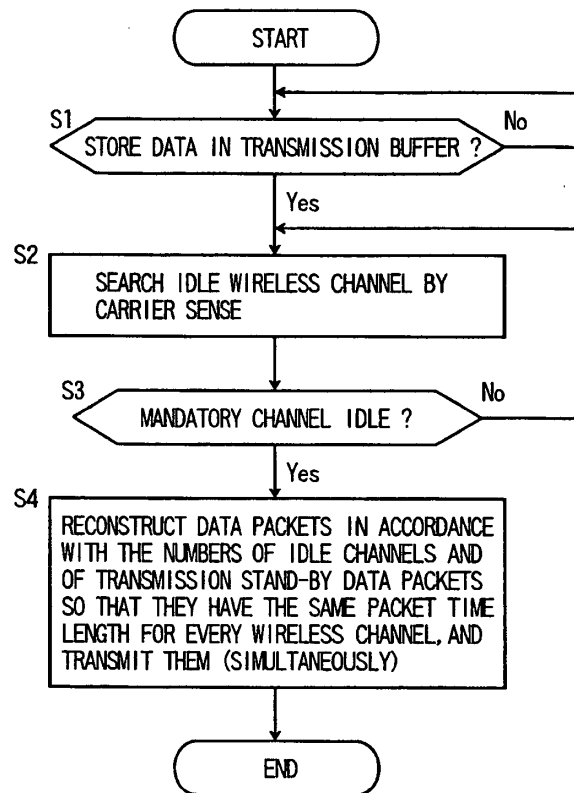
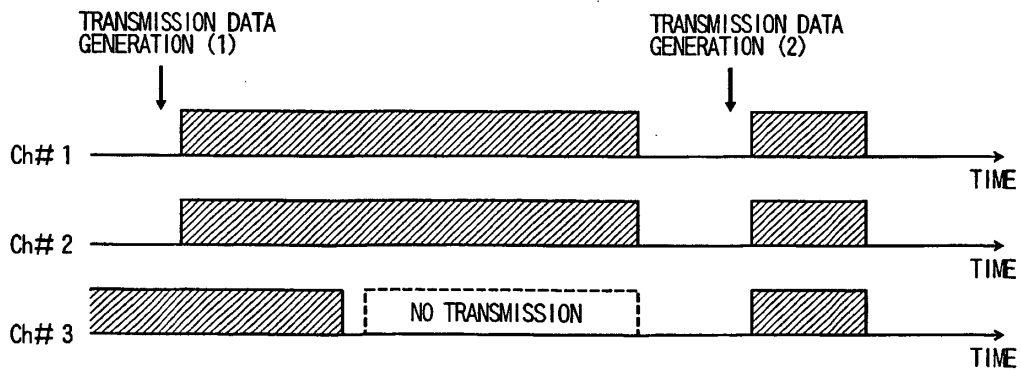
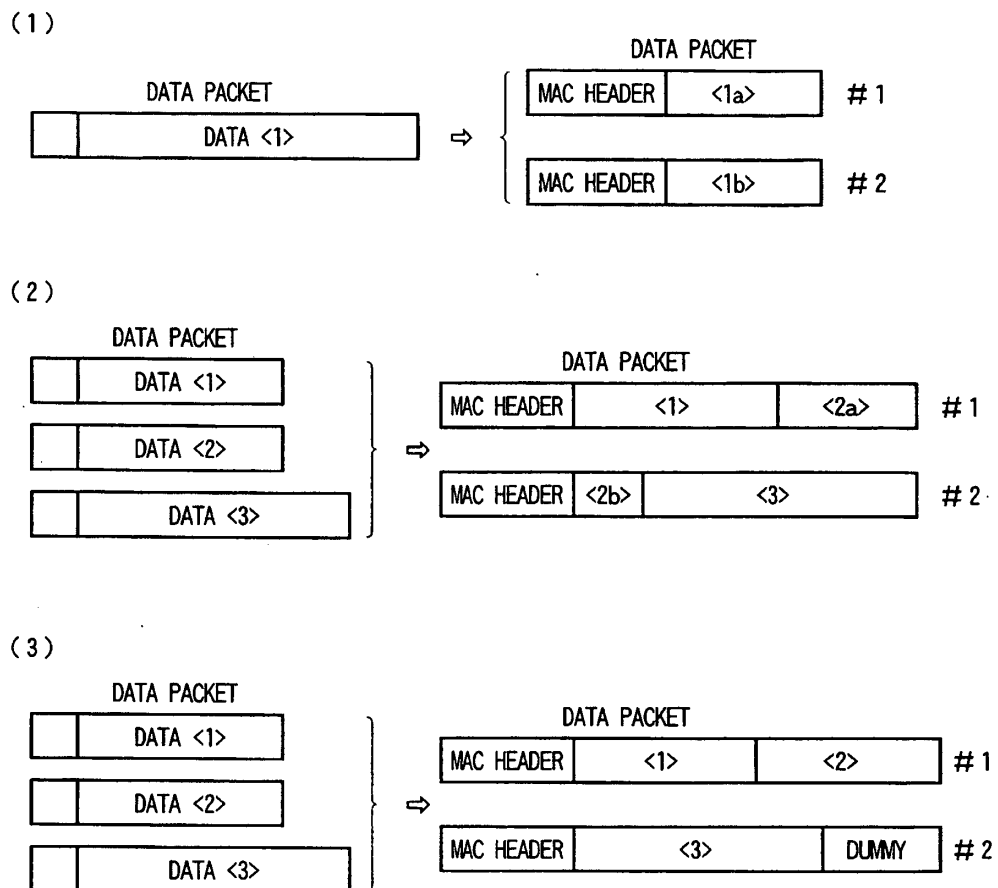


FIG. 2



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FIG. 3



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FIG. 4

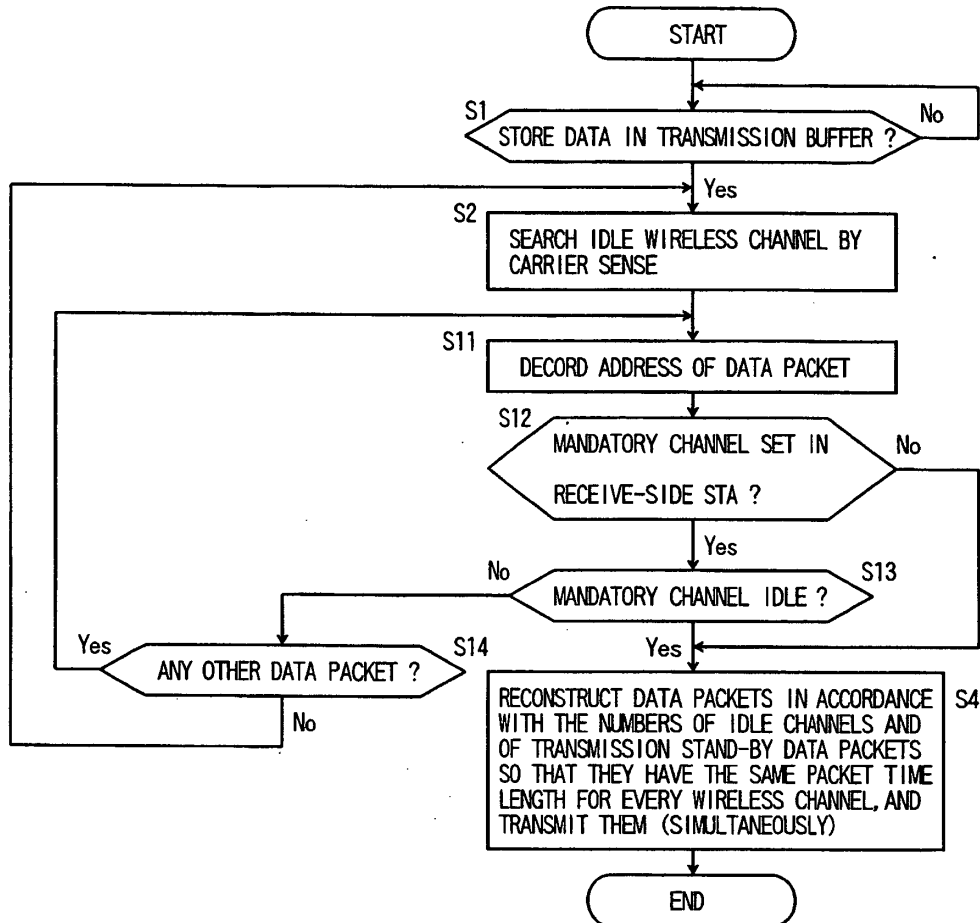
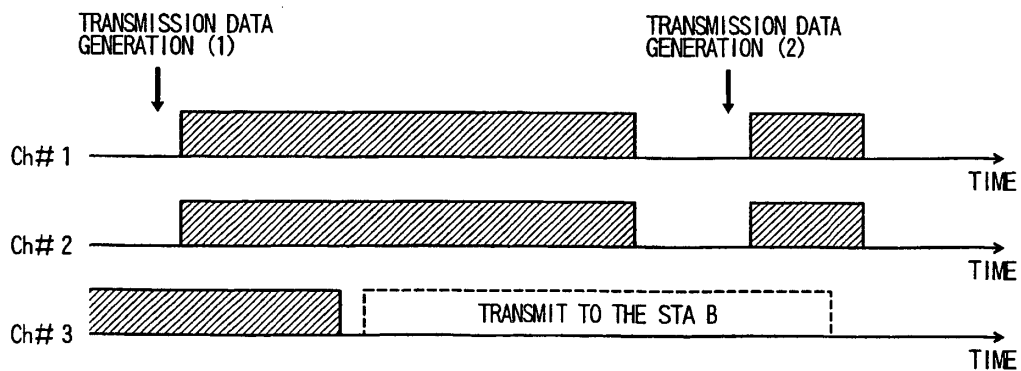
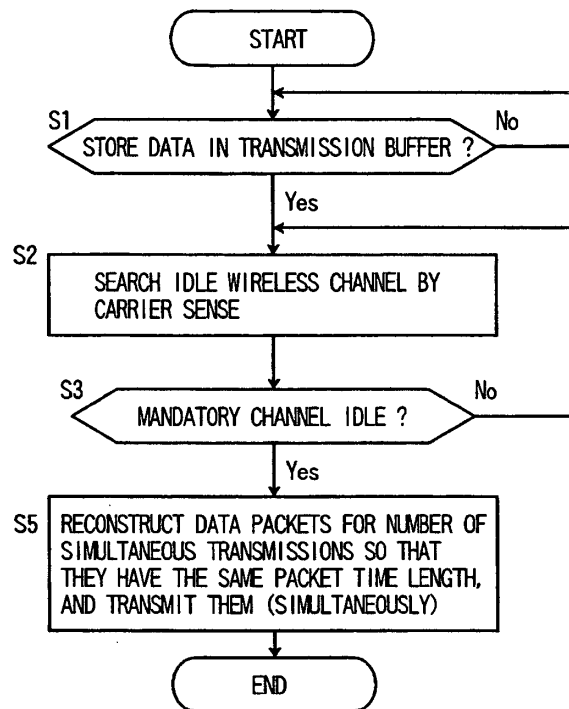


FIG. 5



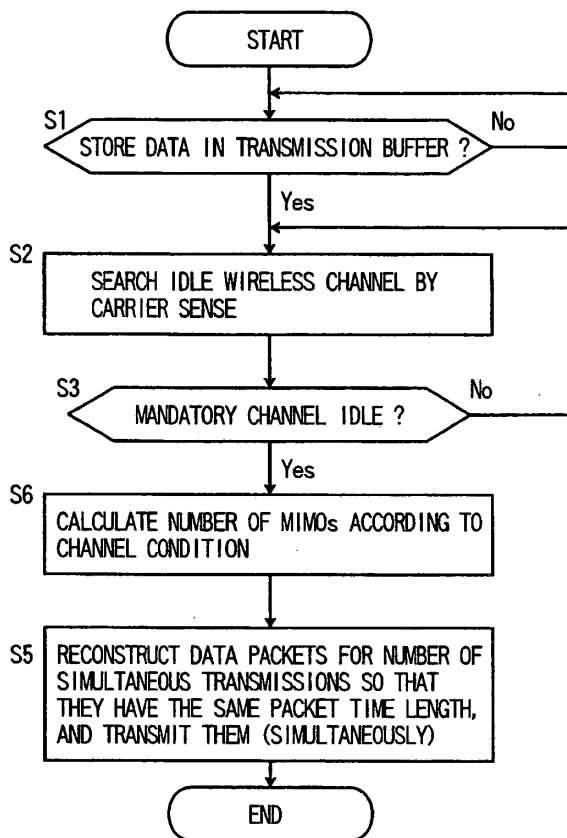
4 / 1 2

FIG. 6



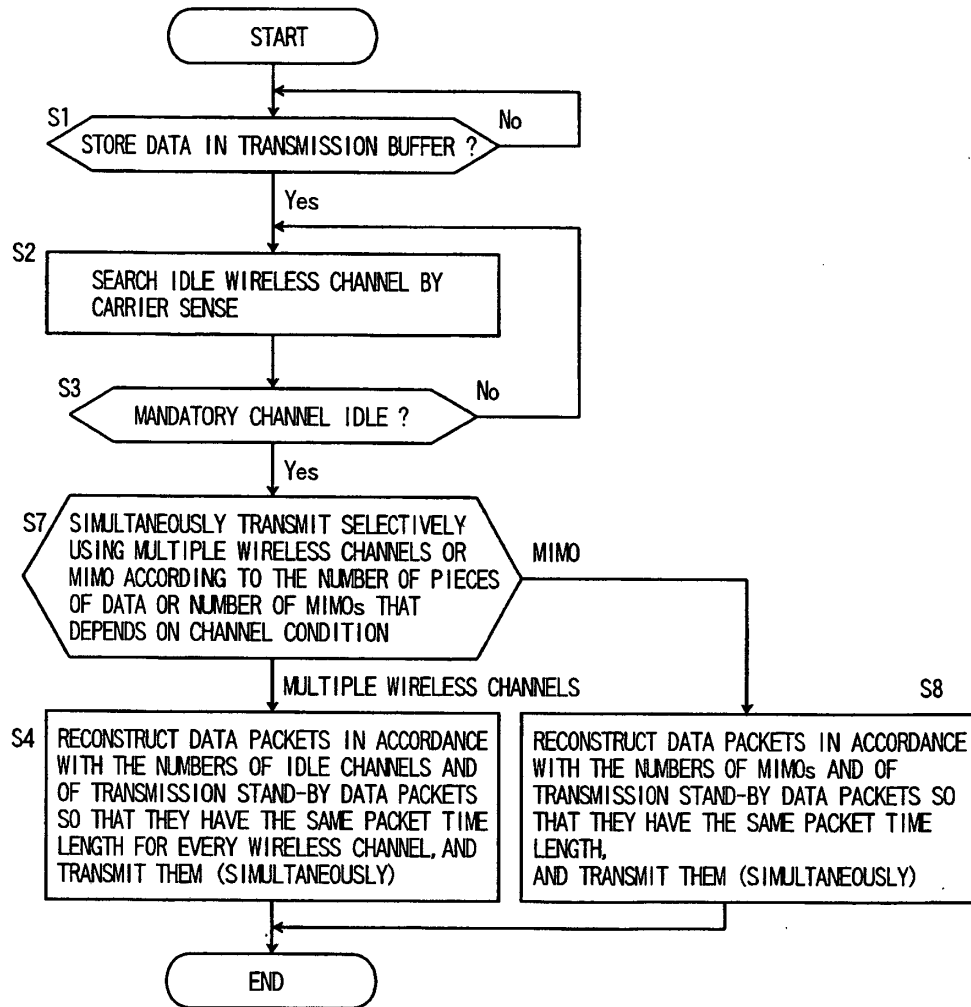
5 / 1 2

FIG. 7



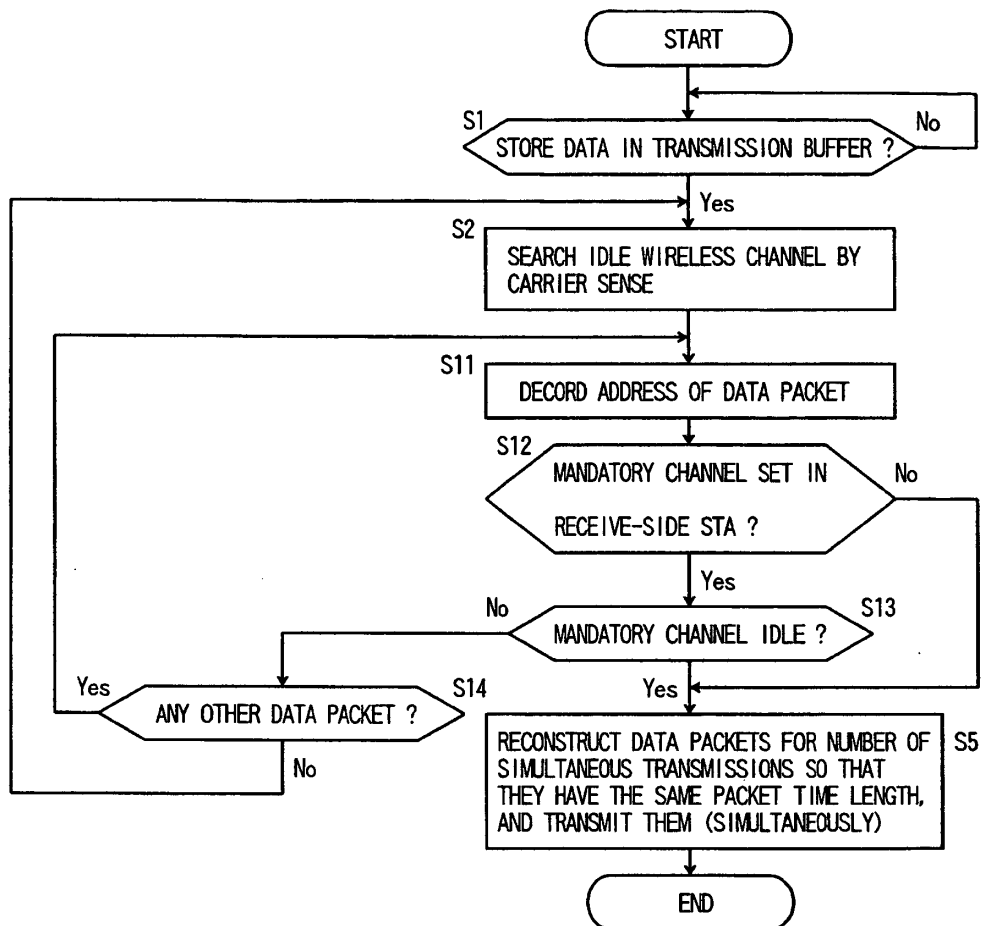
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FIG. 8



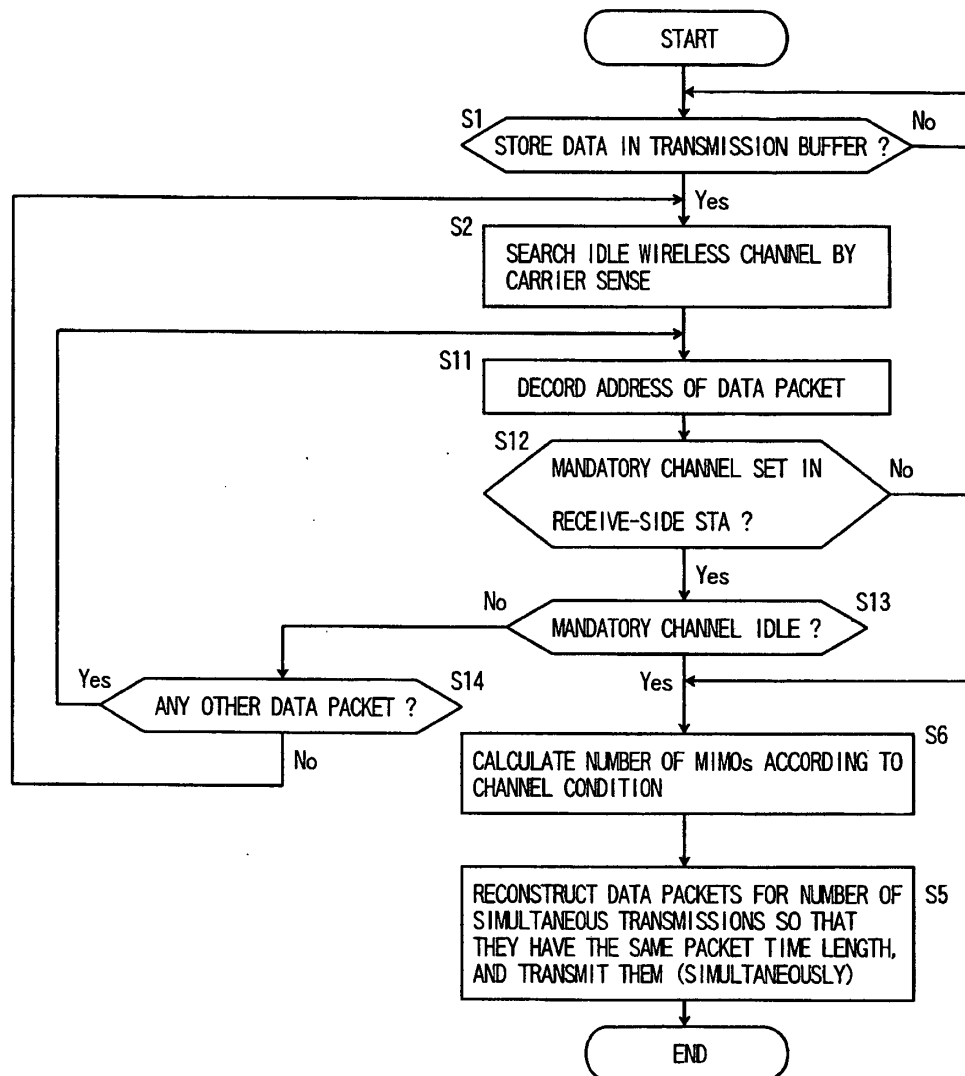
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FIG. 9



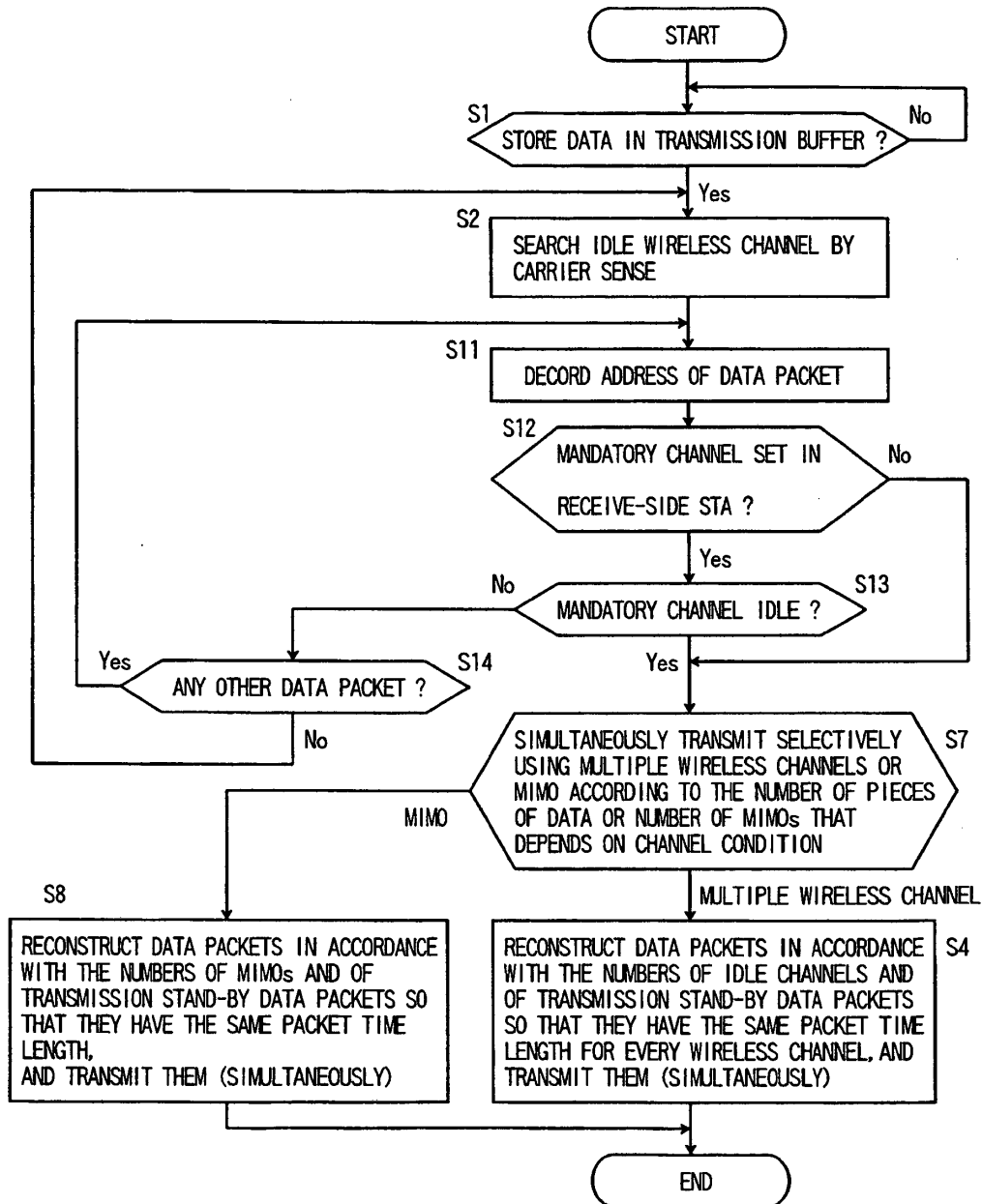
8/12

FIG. 10

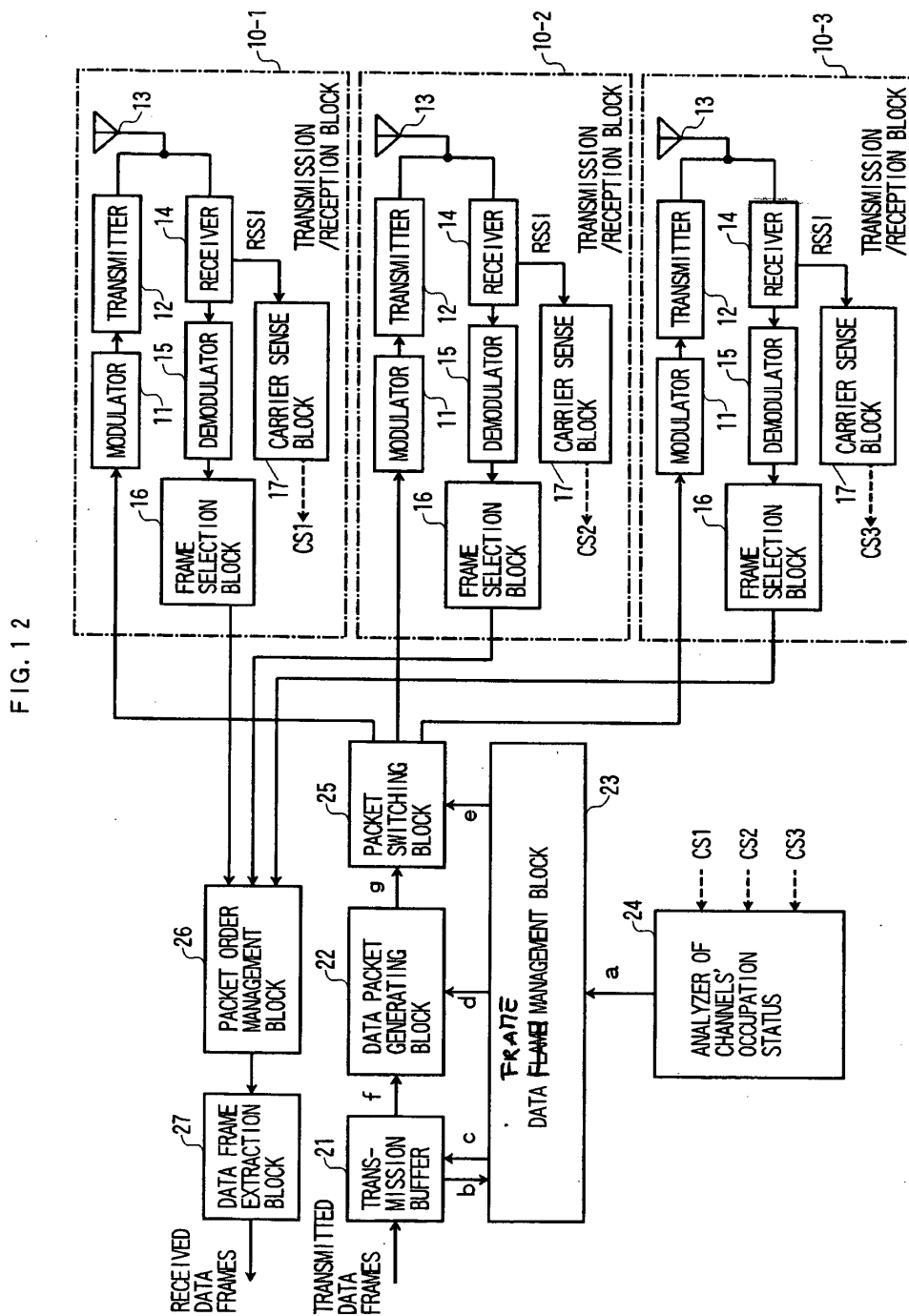


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FIG. 11



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FIG. 13

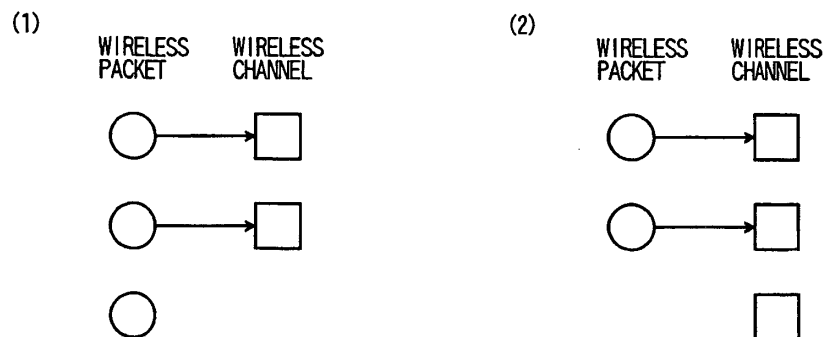
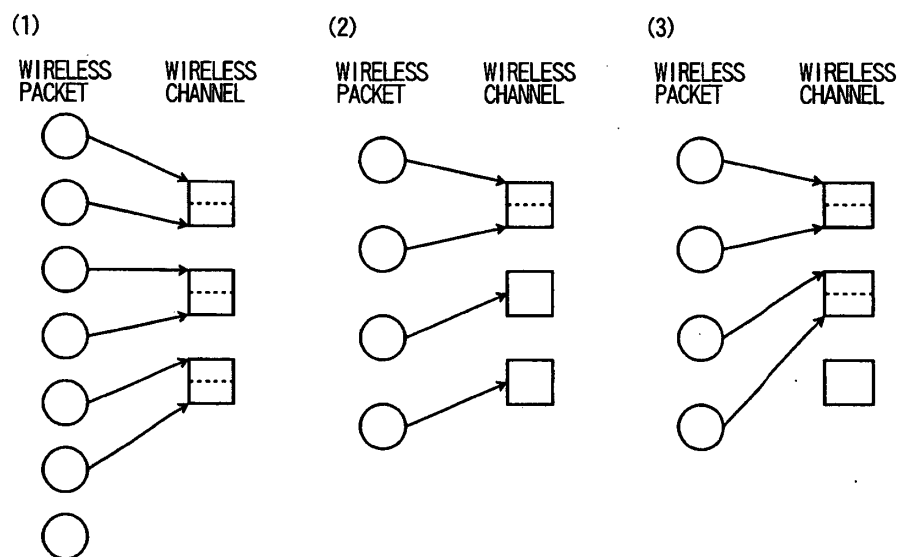


FIG. 14



12 / 12

FIG. 15

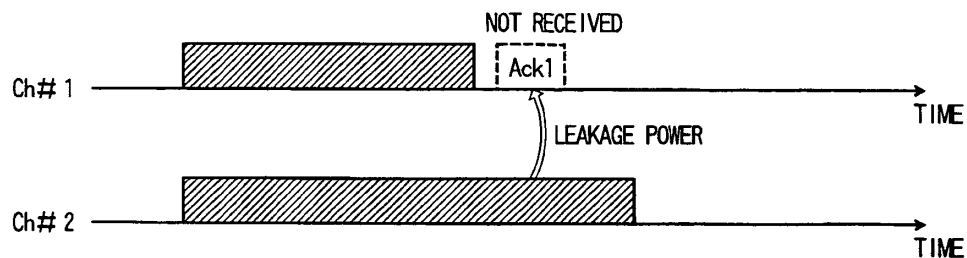


FIG. 16

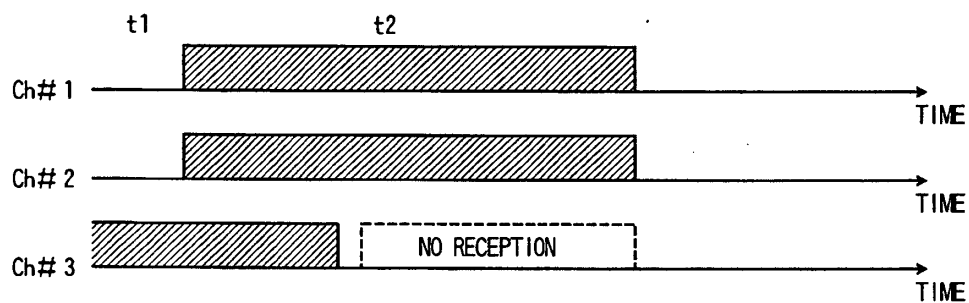
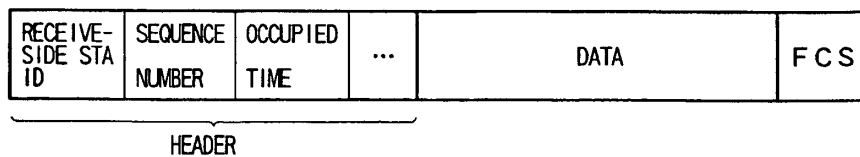


FIG. 17



Application No.:

04 773 142.7

IV.2. Patent classification

The classification has been changed. It now is as follows:

INV. H04W74/08 ADD. H04W72/02

IV.3. Title of the invention ✓

The title indicated on the published patent application remains unchanged. It reads as follows:

FUNKPAKETKOMMUNIKATIONSVERFAHREN UND
FUNKPAKETKOMMUNIKATIONSVORRICHTUNG

RADIO PACKET COMMUNICATION METHOD AND RADIO PACKET
COMMUNICATION APPARATUS

PROCEDE DE COMMUNICATION DE PAQUETS RADIO ET APPAREIL DE
COMMUNICATION DE PAQUETS RADIO

IV.4. Documentation

CDOC The following documents not mentioned in the Search Report were cited during the Examination Procedure:

EP 1 263 168 A2 (TOSHIBA KK [JP]) 4 December 2002 (2002-12-04)

US 2002/176386 A1 (SINGH GURPREET [US] SINGH GURPRETT [US])
28 November 2002 (2002-11-28)

WO 03/069800 A1 (NOKIA CORP [FI]; TIRKKONEN OLAV [FI];
SOININEN PEKKA [US]) 21 August 2003 (2003-08-21)

REINHARD BECHER ET AL: "Broad-Band Wireless Access and Future
Communication Networks",
PROCEEDINGS OF THE IEEE, IEEE, NEW YORK, US,
vol. 89, no. 1, 1 January 2001 (2001-01-01), XP011044465,
ISSN: 0018-9219

YA-HAN PAN ET AL: "Dynamic sub-channel allocation with adaptive
beamforming for broadband ofdm wireless systems",
GLOBECOM'02. 2002 - IEEE GLOBAL TELECOMMUNICATIONS

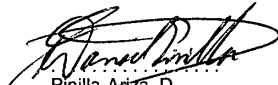
Application No.:

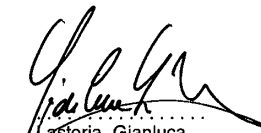
04 773 142.7

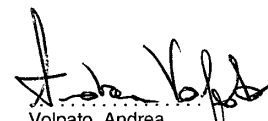
CONFERENCE. CONFERENCE PROCEEDINGS. TAIPEI, TAIWAN,
NOV. 17 - 21, 2002; [IEEE GLOBAL TELECOMMUNICATIONS
CONFERENCE], NEW YORK, NY : IEEE, US,
vol. 1, 17 November 2002 (2002-11-17), pages 711-715, XP010636043,
DOI: 10.1109/GLOCOM.2002.1188171
ISBN: 978-0-7803-7632-8

KOUTSOPOULOS I ET AL: "Adaptive resource allocation in SDMA-based
wireless broadband networks with OFDM signaling",
PROCEEDINGS IEEE INFOCOM 2002. THE CONFERENCE ON
COMPUTER COMMUNICATIONS. 21ST. ANNUAL JOINT
CONFERENCE OF THE IEEE COMPUTER AND COMMUNICATIONS
SOCIETIES. NEW YORK, NY, JUNE 23 - 27, 2002; [PROCEEDINGS
IEEE INFOCOM. THE CONFERENCE ON COMPUTER COMMUNI,
vol. 3, 23 June 2002 (2002-06-23), pages 1376-1385, XP010593704,
DOI: 10.1109/INFCOM.2002.1019388
ISBN: 978-0-7803-7476-8

16.10.13
Date


Pinilla-Ariza, D
Chairman


Astoria, Gianluca
1st examiner


Volpato, Andrea
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Enclosure(s):
XP011044465,XP010636043,XP010593704,WO-03069800-A1

Form 2906



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Application No. 04 773 142.7 - 1858	Ref. 110 895 a/me	Date 31.10.2013
Applicant NIPPON TELEGRAPH AND TELEPHONE CORPORATION		

Communication under Rule 71(3) EPC

1. Intention to grant

You are informed that the Examining Division intends to grant a European patent on the basis of the above application with the text and drawings and the related bibliographic data as indicated below.

A copy of the relevant documents is enclosed.

1.1 Auxiliary Request 1

In the text for the Contracting States:
DE FR GB

Description, Pages

1-4, 8-20	filed with entry into the regional phase before the EPO	
5, 5a, 5b, 6, 7	filed during Oral proceedings on	08-10-2013

Claims, Numbers

1-8	filed during Oral proceedings on	08-10-2013

Drawings, Sheets

1/12-12/12	filed with entry into the regional phase before the EPO

With the following amendments to the above-mentioned documents proposed by the division

Drawings, Sheets	10/12

Comments

Clerical mistake in figure 12 has been corrected

See also comments on the enclosed EPO Form 2906.

1.2 Bibliographic data

The title of the invention in the three official languages of the European Patent Office, the international patent classification, the designated Contracting States, the registered name(s) of the applicant(s) and the other bibliographic data are shown on the **enclosed EPO Form 2056**.

2. Invitation

You are invited, **within a non-extendable period of four months** of notification of this communication,

2.1 to EITHER approve the text communicated above and verify the bibliographic data (R. 71(5) EPC)

(1) by filing a translation of the claim(s) in the other two official languages of the EPO

	Fee code	EUR
(2a) by paying the fee for grant including the fee for printing (Art. 2(2) RFees):	007	875.00
minus any amount already paid (R. 71a(5) EPC):		0.00
(2b) by paying the printing fee (Art. 2(2) RFees) for the 36th and each subsequent page; number of pages payable: 3	008	42.00
minus any amount already paid (R. 71a(5) EPC):		0.00
Total amount:		917.00
(3) by paying additional claims fees under Rule 71(4) EPC; number of claims fees payable: 0	016	0.00
minus any amount already paid (R. 71a(5) EPC):		0.00
Total amount:		0.00

Important: If the translations of the claims and fees have already been filed and paid respectively in reply to a previous communication under Rule 71(3) EPC, e.g. in the case of resumption of examination after approval (see Guidelines C-V, 6), **agreement as to the text to be granted** (R. 71a(1) EPC) must be expressed within the same time limit (e.g. by approving the text and verifying the bibliographic data, by confirming that grant proceedings can go ahead with the documents on file and/or by stating which translations of the claims already on file are to be used).

Note 1: See "Important notes concerning fee payments" below.

Note 2: Any overpaid "minus" amounts will be refunded when the decision to grant (EPO Form 2006A) has been issued.

2.2 OR, in the case of disapproval, to request reasoned amendments or corrections to the text communicated above or keep to the latest text submitted by you (R. 71(6) EPC).

In this case the translations of the claims and fee payments mentioned under point 2.1 above are NOT due.

The terms "amendment(s)" and "correction(s)" refer only to amendments or corrections of the application documents and not of other documents (e.g. bibliographic data, the designation of the inventor, etc.).

If filing amendments, you must identify them and indicate the basis for them in the application as filed. Failure to meet either requirement may lead to a communication from the Examining Division requesting that you correct this deficiency (R. 137(4) EPC).

2.3 Bibliographic data

Where you request a change or correction of bibliographic data in response to the Rule 71(3) communication, this will **not** cause the sending of a second communication under Rule 71(3) EPC. You will still have to pay the fees and file translations in reply to the Rule 71(3) communication in the case of 2.1 above, unless you also file a reasoned request for amendments or corrections in response to the Rule 71(3) communication (see case 2.2 above).

3. Loss of rights

If neither of the two possible actions above (see points 2.1 or 2.2) is performed in due time, the European patent application will be deemed to be withdrawn (R. 71(7) EPC).

4. Further procedure

4.1 In the case of point 2.1 above

- 4.1.1** The decision to grant the European patent will be issued, and the **mention of the grant** of the patent will be published in the European Patent Bulletin, if the requirements concerning the translation of the claims and the payment of all fees are fulfilled and there is agreement as to the text to be granted (R. 71a(1) EPC).

Note on payment of the renewal fee:

If a renewal fee becomes due before the next possible date for publication of the mention of the grant of the European patent, publication will be effected only after the renewal fee and any additional fee have been paid (R. 71a(4) EPC).

Under Article 86(2) EPC, the obligation to pay renewal fees to the European Patent Office terminates with the payment of the renewal fee due in respect of the year in which the mention of the grant of the European patent is published.

Note on payment of the designation fee(s):

If the designation fee(s) become(s) due after the communication under Rule 71(3) EPC, the mention of the grant of the European patent will not be published until the designation fee(s) has/have been paid (R. 71a(3) EPC).

- 4.1.2** After publication, the **European patent specification** can be downloaded free of charge from the EPO publication server <https://data.epo.org/publication-server> or ordered from the Vienna sub-office upon payment of a fee (OJ EPO 2005, 126).

Upon request in writing each proprietor will receive the certificate for the European patent together with a copy of the patent specification, provided that the request is filed within the time limit of Rule 71(3) EPC. If such a request has been previously filed, it has to be confirmed within the time limit of Rule 71(3) EPC. The requested copy is free of charge. If the request is filed after expiry of the Rule 71(3) time limit, the certificate will be delivered without a copy of the patent specification (R. 74 EPC, Decision of the President of the EPO, Special edition No. 3, OJ EPO 2007, D.2.).

4.1.3 Filing of translations in the Contracting States

As regards translation requirements prescribed by the Contracting States under Article 65(1) EPC, please consult the website of the European Patent Office

www.epo.org → Law & practice → Legal texts, National law relating to the EPC

www.epo.org → Law & practice → All Legal texts → London Agreement

In the case of a valid extension

As regards translation requirements prescribed by the Extension States, please consult the website of the European Patent Office

www.epo.org → Law & practice → Legal texts, National law relating to the EPC

Failure to supply a prescribed translation in a Contracting State or an Extension State may result in the patent being deemed to be void *ab initio* in the State concerned (Art. 65(3) EPC).

4.2 In case of 2.2 above

If the present communication under Rule 71(3) EPC is based on upon an auxiliary request and, within the time limit, you maintain the main request or a higher ranking request which is not allowable, the application will be refused (Art. 97(2) EPC).

If the Examining Division gives its consent to the requested amendments or corrections, it will issue a new communication under Rule 71(3) EPC; otherwise, it shall resume the examination proceedings (R. 71(6) EPC).

5. Filing of a divisional application

Any divisional application relating to this European patent application must be filed directly with the European Patent Office in Munich, The Hague or Berlin and will be in the language of the proceedings for the present application, or if the latter was not in an official language of the EPO, the divisional application may be filed in the language of the present application as filed (see Article 76(1) and Rule 36(2) EPC). Any such divisional application must be filed while the present application is still pending and the time limit for filing divisional applications must be observed (R. 36(1) EPC; Guidelines A-IV, 1.1.1).

6. Important notes concerning fee payments

6.1 For all payments, please refer to the relevant **fee code(s)**.

6.2 Automatic debiting procedure

The fee for grant, including the fee for printing (Art. 2(2) RFees), and any additional claims fees due under Rule 71(4) EPC will be debited automatically on the date of filing of the translations of the claims, or on the last day of the period of this communication. However, if the designation fee(s) become(s) due as set out in Rule 71a(3) EPC and/or a renewal fee becomes due as set out in Rule 71a(4) EPC, these should be paid separately by another permitted way of payment in order not to delay the publication of the mention of the grant. The same applies in these circumstances to the payment of extension fees. For further details see the Arrangements for the automatic debiting procedure (AAD) and accompanying information from the EPO concerning the automatic debiting procedure (Annexes A.1 and A.2 to the Arrangements for deposit accounts (ADA) in Supplement to OJ EPO 3/2009).

6.3 Fee amounts

Following any amendment to the Rules relating to Fees, the amount(s) mentioned in this communication may be different from the amount(s) **actually due on the date of payment**. The latest version of the Schedule of fees and expenses, published as a Supplement to the Official Journal of the EPO, is also available on the EPO website (www.epo.org) and can be found under www.epo.org/schedule-of-fees, which allows you to view, download and search for individual fee amounts, both current and previous.

- 6.4 Payments by cheque** delivered or sent direct to the EPO are no longer accepted as from 1 April 2008 (see OJ EPO 2007, 626).

Examining Division:

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2nd Examiner:	Volpato, Andrea
1st Examiner:	Lastoria, Gianluca



Hingel, Wolfgang
For the Examining Division
Tel. No.: +49 89 2399 - 8717

Enclosure(s): Text intended for grant(38 pages)

 EPO Form 2056
 EPO Form 2906



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Annex to EPO Form 2004, Communication pursuant to Rule 71(3) EPC

Bibliographical data of European patent application No. 04 773 142.7

For the intended grant of the European patent, the bibliographical data are set out below, for information:

Title of invention:

- FUNKPAKETKOMMUNIKATIONSVERFAHREN UND FUNKPAKETKOMMUNIKATIONSVORRICHTUNG
- RADIO PACKET COMMUNICATION METHOD AND RADIO PACKET COMMUNICATION APPARATUS
- PROCEDE DE COMMUNICATION DE PAQUETS RADIO ET APPAREIL DE COMMUNICATION DE PAQUETS RADIO

Classification: INV. H04W74/08 ADD. H04W72/02

Date of filing: 09.09.2004

Priority claimed: JP / 09.09.2003 / JPA2003317100

Contracting States*
for which fees have
been paid: DE FR GB

Extension States*
for which fees have
been paid:

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- *) If the time limit for the payment of designation fees according to Rule 39(1) EPC has not yet expired and the applicant has not withdrawn any designation, **all Contracting States/Extension States** are currently still deemed to be designated. See also Rule 71(8) EPC and, if applicable, the above Note to users of the automatic debiting procedure.
- **) If two or more applicants have designated different Contracting States, this is indicated here.

1 The independent claims of the main request do not comply with the requirements of Article 84 EPC for the following reasons:

1.1 According to the description, page 4 and 5, the current application aims to overcome the problem incurring in the prior art when a station, which has been assigned a channel (CH#3) which happen to be idle, starts transmitting data packets in concomitance with the transmission of second station, which has been assigned a plurality of channels (CH#1, CH#2). Leakage from CH#3, when using MIMO at the receiver, could comprise transmission over CH#1 and CH#2. The invention, therefore, lies in preventing the further station, which is allowed to transmit on CH#3, to transmit data when CH#3 is idle in case a mandatory channel, e.g. CH#1, which has the highest priority among the channels, is busy.

While **claim 1** of the main request claims that transmission of data can happen only when the mandatory channel is idle, it **does not** claim that a further station refrains from transmitting data on a channel allocated to said station when said channel is idle in case the mandatory channel is busy.

This feature, disclosed i.a. on page 10, lines 14 and 15 of the description as published, is considered to be **essential** to the definition of the invention.

Since independent **claim 1** does **not** contain this feature, it does not meet the requirements of Article 84 EPC taken in combination with Rules 43(1) and (3) EPC that any independent claim must contain **all** the technical features essential to the definition of the invention.

Similar considerations apply to the remaining **independent claims**.

1.2 The sentence "...*determined to be idle by carrier sense and MIMO*" used in **claim 1** is **not** clear, Article 84 EPC. In particular, it is not clear how a channel could be determined to be MIMO, as no steps are given in this regard.

Furthermore, MIMO is understood as a technology for transmitting/receiving data over a multitude of antennas and therefore channels. MIMO is not understood as being a channel.

Similar considerations apply to the remaining **independent claims**.

- 1.3 Finally, even if **claims 2 and 6** have been cast as independent claims, they actually depend, respectively, on **claims 1 and 5**, as they only add the feature of distinguishing between two stations to the feature combination of **claims 1 and 5**. The claims, therefore, do not comply with the requirements of Rule 43 (2) EPC.

HOFFMANN · EITLE

MÜNCHEN LONDON DÜSSELDORF

HOFFMANN · EITLE · Postfach 81 04 20 · D-81904 München

European Patent Office

80298 Munich

EPO - Munich
27

14. Feb. 2014

Munich, February 14, 2014

Our Ref.: 110 895 q4/q21
European Patent Application No. 04 773 142.7
NIPPON TELEGRAPH AND TELEPHONE CORPORATION

In response to the communication pursuant to Rule 71(3) EPC
dated October 31, 2013

1. We herewith submit new claims 1-8 for the further procedure.
The new claims are identical to the claims appended to the
above mentioned communication except that reference to a
“system” has been corrected to an “apparatus” in claims 5-8.

2. It is requested to replace the title of the text enclosed in the
communication according to Rule 71(3) by the following
amended title:

“WIRELESS PACKET COMMUNICATION METHOD
AND WIRELESS PACKET COMMUNICATION
APPARATUS”

Encl.



- new claims 1-8, fair and mark-up

copy

Dr. Lorenz von Kurowski
European Patent Attorney
Association No. 151

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Claims

1. A wireless packet communication method for transmitting a plurality of wireless packets having equal packet time lengths simultaneously by using multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense and by using MIMO, the method characterized by comprising:

setting a mandatory channel among multiple wireless channels that is always used for transmission and has the highest priority among wireless channels that have a plurality of priorities;

transmitting the wireless packets by using wireless channels (Ch#1, Ch#2) that include the mandatory channel, only when the mandatory channel is idle; and

refraining from transmitting wireless packets by another station on a channel (Ch#3) determined to be idle, when the mandatory channel is busy.

2. Wireless packet communication method according to claim 1, comprising:

distinguishing a STA A from a STA B, the STA A for which the mandatory channel is set, the STA B for which no mandatory channel is set; and

when wireless packets are addressed to said STA A, transmitting the wireless packets to said STA A by using wireless channels (Ch#1, Ch#2) that include the mandatory channel, only when the mandatory channel is idle; and

when wireless packets are addressed to said STA B, transmitting the wireless packets to said STA B by using idle wireless channel or channels (Ch#1, Ch#2).

3. The wireless packet communication method according to claim 1 or 2, characterized in that

the packet time length corresponds to a packet size or a transmission time.

4. The wireless packet communication method according to claim 1 or 2, characterized by further comprising

simultaneously transmitting wireless packets selectively using the multiple wireless channels (Ch#1, Ch#2) or the MIMO in accordance with a number of pieces of data or a number of MIMOs that depends on a channel condition.

5. A wireless packet communication system for transmitting a plurality of wireless packets having equal packet time lengths simultaneously by using multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense and by using MIMO, the system characterized by comprising

a unit (23) setting a mandatory channel among multiple wireless channels that is always used for transmission and has the highest priority among wireless channels that have a plurality of priorities, and transmitting the wireless packets only when the mandatory channel is idle by using wireless channels (Ch#1, Ch#2) that include the mandatory channel; and

a station refraining from transmitting wireless packets on a channel (Ch#3) determined to be idle, when the mandatory channel is busy.

6. Wireless packet communication system according to claim 5, comprising

a unit (23) distinguishing a STA A from a STA B and determining destinations of the wireless packets so as to transmit wireless packets addressed to said STA A only when the mandatory channel is idle by using wireless channels (Ch#1, Ch#2) that include a mandatory channel, and to transmit wireless packets addressed to said STA B by using idle wireless channel or channels(Ch#1, Ch#2), the STA A for which the mandatory channel is set, the STA B for which no mandatory channel is set.

7. The wireless packet communication system according to claim 5 or 6, characterized in that

the packet time length corresponds to a packet size or a transmission time.

8. The wireless packet communication system according to claim 5 or 6, characterized by further comprising:

a unit simultaneously transmitting wireless packets selectively using the multiple wireless channels (Ch#1, Ch#2) or the MIMO in accordance with a number of pieces of data or a number of MIMOs that depends on a channel condition.

Claims

1. A wireless packet communication method for transmitting a plurality of wireless packets having equal packet time lengths simultaneously by using multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense and by using MIMO, the method characterized by comprising:

setting a mandatory channel among multiple wireless channels that is always used for transmission and has the highest priority among wireless channels that have a plurality of priorities;

transmitting the wireless packets by using wireless channels (Ch#1, Ch#2) that include the mandatory channel, only when the mandatory channel is idle; and

refraining from transmitting wireless packets by another station on a channel (Ch#3) determined to be idle, when the mandatory channel is busy.

2. Wireless packet communication method according to claim 1, comprising:

distinguishing a STA A from a STA B, the STA A for which the mandatory channel is set, the STA B for which no mandatory channel is set; and

when wireless packets are addressed to said STA A, transmitting the wireless packets to said STA A by using wireless channels (Ch#1, Ch#2) that include the mandatory channel, only when the mandatory channel is idle; and

when wireless packets are addressed to said STA B,
transmitting the wireless packets to said STA B by using
idle wireless channel or channels (Ch#1, Ch#2).

3. The wireless packet communication method according to
claim 1 or 2, characterized in that

the packet time length corresponds to a packet size or a
transmission time.

4. The wireless packet communication method according to
claim 1 or 2, characterized by further comprising

simultaneously transmitting wireless packets selectively
using the multiple wireless channels (Ch#1, Ch#2) or the
MIMO in accordance with a number of pieces of data or a
number of MIMOs that depends on a channel condition.

5. A wireless packet communication system for transmitting
a plurality of wireless packets having equal packet time
lengths simultaneously by using multiple wireless
channels (Ch#1, Ch#2) determined to be idle by carrier
sense and by using MIMO, the ~~apparatus~~system
characterized by comprising

a unit (23) setting a mandatory channel among multiple
wireless channels that is always used for transmission
and has the highest priority among wireless channels
that have a plurality of priorities, and transmitting
the wireless packets only when the mandatory channel is
idle by using wireless channels (Ch#1, Ch#2) that
include the mandatory channel; and

a station refraining from transmitting wireless packets
on a channel (Ch#3) determined to be idle, when the
mandatory channel is busy.

6. Wireless packet communication ~~apparatus~~system according to claim 5, comprising

a unit (23) distinguishing a STA A from a STA B and determining destinations of the wireless packets so as to transmit wireless packets addressed to said STA A only when the mandatory channel is idle by using wireless channels (Ch#1, Ch#2) that include a mandatory channel, and to transmit wireless packets addressed to said STA B by using idle wireless channel or channels(Ch#1, Ch#2), the STA A for which the mandatory channel is set, the STA B for which no mandatory channel is set.

7. The wireless packet communication ~~apparatus~~system according to claim 5 or 6, characterized in that

the packet time length corresponds to a packet size or a transmission time.

8. The wireless packet communication ~~apparatus~~system according to claim 5 or 6, characterized by further comprising:

a unit simultaneously transmitting wireless packets selectively using the multiple wireless channels (Ch#1, Ch#2) or the MIMO in accordance with a number of pieces of data or a number of MIMOs that depends on a channel condition.

European patent application No. 04773142.7

After communication under Rule 71(3) EPC (IGRA) but before decision to grant (EPO Form 2006A)

☒ **Request for amendments/corrections of documents (IGRE coded) dated 14.02.2014**

Note 1: If the request is treated when the decision to grant (EPO Form 2006A) has already been handed over to the EPO postal service, it is to be submitted to the examining division with EPO Form 2051.

Note 2: If the request concerns only the title(s) and/or classification, it is to be submitted to the examining division as described in Fil d'Ariane.

☐ **Third-party observations under Article 115 EPC (TIPA coded) dated Continue with point 2.**

Note: If the observations are treated when the decision to grant (EPO Form 2006A) has already been handed over to the EPO postal service, they must no longer be submitted to the examining division.

1. Finding

- ☒ The request was received **within** the IGRA period.
- ☐ The request was received **after** expiry of the IGRA period. The applicant failed to reply in time (ADWI situation) but further processing has been requested.
- ☐ The request was received **after having already paid fees and submitted translations of claims** in due time. The decision to grant (EPO Form 2006A) has not yet been handed over to the EPO postal service.

2. To the examining division

Please decide below whether the requested amendments/corrections are allowable or whether the third-party observations are relevant.

Date: 17-02-2014 Formalities Officer: Toscano, Lucia

3. To the formalities officer

- 3.1 ☐ **Consent** is given to the amendments/corrections requested. A new communication under Rule 71(3) EPC (IGRA) is to be issued.
- 3.2 ☐ Following a telephone conversation **agreement** has been reached. A new communication under Rule 71(3) EPC (IGRA) is to be issued. Attached EPO Form 2036 (telephone consultation) is to be enclosed with it.
- 3.3 ☐ **Not all or none** of the amendments/corrections can be allowed. Examination proceedings are to be resumed.
- ☐ Attached **communication** is to be despatched with EPO Form 2001 (EXRE) / 2909 (INBA).
 - ☐ Attached EPO Form 2036 (**telephone consultation**) is to be despatched with EPO Form 2049 (EXRE).
 - ☐ Attached **summons to oral proceedings** is to be despatched with EPO Form 2008 (ORAL).
(Note for examiner: At least one communication under Rule 71(1)(2) EPC must have been sent before summons to oral proceedings can be sent.)
 - ☐ Attached reasoned **refusal** is to be despatched with EPO Form 2007 (REFU).
(Note for examiner: At least one communication under Rule 71(1)(2) EPC must have been sent and the applicant's rights according to Articles 113(1) and 116 EPC must have been met before a refusal can be sent.)
- ☐ The communication under Rule 71(3) EPC was based upon an auxiliary request. Since the applicant maintains the main or higher ranking request which is not allowable, the application is to be refused (Art. 97(2) EPC).

- ☐ The applicant has expressed disapproval. Since there is no text on which to base a decision, the application is to be refused (Art. 113(2) EPC; see T 237/96 and Guidelines C-V, 4.9).
(Note for examiner: Standard clause N17C will be used.)

3.4 ☐ **Observations by a third party (Art. 115 EPC)**

- ☐ The observations under Article 115 EPC give no cause for amendment of the documents.
Note: TIPA04 is to be coded (to release RPUB).
- ☐ Examination proceedings are to be resumed. Attached communication is to be dispatched.

Date: _____ Examining Division

Chairman

Second Examiner

Primary Examiner

Legal Member



European patent application No. 04773142.7

After communication under Rule 71(3) EPC (IGRA) but before decision to grant (EPO Form 2006A)

☒ **Request for amendments/corrections of documents (IGRE coded) dated 14.02.2014**

Note 1: If the request is treated when the decision to grant (EPO Form 2006A) has already been handed over to the EPO postal service, it is to be submitted to the examining division with EPO Form 2051.

Note 2: If the request concerns only the title(s) and/or classification, it is to be submitted to the examining division as described in Fil d'Ariane.

☐ **Third-party observations under Article 115 EPC (TIPA coded) dated Continue with point 2.**

Note: If the observations are treated when the decision to grant (EPO Form 2006A) has already been handed over to the EPO postal service, they must no longer be submitted to the examining division.

Finding

- ☒ The request was received **within** the IGRA period.
- ☐ The request was received **after** expiry of the IGRA period. The applicant failed to reply in time (ADWI situation) but further processing has been requested.
- ☐ The request was received **after having already paid fees and submitted translations of claims** in due time. The decision to grant (EPO Form 2006A) has not yet been handed over to the EPO postal service.

2. To the examining division

Please decide below whether the requested amendments/corrections are allowable or whether the third-party observations are relevant.

Date: 17-02-2014 Formalities Officer: Toscano, Lucia

3. To the formalities officer

☒ **Consent** is given to the amendments/corrections requested. A new communication under Rule 71(3) EPC (IGRA) is to be issued.

3.2 ☐ Following a telephone conversation **agreement** has been reached. A new communication under Rule 71(3) EPC (IGRA) is to be issued. Attached EPO Form 2036 (telephone consultation) is to be enclosed with it.

3.3 ☐ **Not all or none** of the amendments/corrections can be allowed. Examination proceedings are to be resumed.

- ☐ Attached **communication** is to be despatched with EPO Form 2001 (EXRE) / 2909 (INBA).
- ☐ Attached EPO Form 2036 (**telephone consultation**) is to be despatched with EPO Form 2049 (EXRE).
- ☐ Attached **summons to oral proceedings** is to be despatched with EPO Form 2008 (ORAL).
(Note for examiner: At least one communication under Rule 71(1)(2) EPC must have been sent before summons to oral proceedings can be sent.)
- ☐ Attached reasoned **refusal** is to be despatched with EPO Form 2007 (REFU).
(Note for examiner: At least one communication under Rule 71(1)(2) EPC must have been sent and the applicant's rights according to Articles 113(1) and 116 EPC must have been met before a refusal can be sent.)
- ☐ The communication under Rule 71(3) EPC was based upon an auxiliary request. Since the applicant maintains the main or higher ranking request which is not allowable, the application is to be refused (Art. 97(2) EPC).

- ☐ The applicant has expressed disapproval. Since there is no text on which to base a decision, the application is to be refused (Art. 113(2) EPC; see T 237/96 and Guidelines C-V, 4.9).
(Note for examiner: Standard clause N17C will be used.)

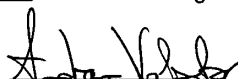
3.4 ☐ **Observations by a third party (Art. 115 EPC)**

- ☐ The observations under Article 115 EPC give no cause for amendment of the documents.
Note: TIPA04 is to be coded (to release RPUB).
☐ Examination proceedings are to be resumed. Attached communication is to be dispatched.

Date: 21.02.2014

Examining Division


Chairman


Second Examiner


Primary Examiner


Legal Member

~~Amendments pursuant to Rule 86(2) to (4) EPC~~

~~WIRELESS PACKET COMMUNICATION METHOD AND
WIRELESS PACKET COMMUNICATION APPARATUS~~

TECHNICAL FIELD

The present invention relates to a wireless packet communication method and a wireless packet communication apparatus for simultaneously transmitting a plurality of wireless packets by using multiple wireless channels or Multiple Input Multiple Output (hereinafter, MIMO).

BACKGROUND ART

In a conventional wireless packet communication apparatus, a wireless channel to be used is determined in advance. Prior to transmission of a data packet, the wireless packet communication apparatus performs carrier sense to detect whether or not that wireless channel is idle. Only when that wireless channel is idle, the wireless packet communication apparatus transmits one data packet. This management allows a plurality of stations (hereinafter, STA) to share one wireless channel in a staggered manner ((1) "International Standard ISO/IEC 8802-11 ANSI/IEEE Std 802.11, 1999 edition, Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications", (2) "Low-powered Data Communication System/Broadband Mobile Access Communication System (CSMA) Standard", ARIB STD-T71 version 1.0, Association of Radio Industries and Businesses, settled in 2000).

On the other hand, a wireless packet communication method is known in which, when multiple wireless channels are found idle by carrier sense, a plurality of wireless packets are transmitted simultaneously by using the wireless channels. This method is generally described with reference to Figs. 13 and 14.

Fig. 13(1) shows a case where two wireless channels are idle for three wireless

packets. Two of the three wireless packets are transmitted simultaneously by using the two wireless channels. Fig. 13(2) shows a case where three wireless channels are idle for two wireless packets. All (two) wireless packets are transmitted simultaneously by using the two wireless channels.

- 5 Fig. 14 shows a case where a known MIMO technique (Kurosaki et al., "100Mbit/s SDM-COFDM over MIMO Channel for Broadband Mobile Communications", Technical Reports of the Institute of Electronics, Information and Communication Engineers, A · P 2001-96, RCS2001-135(2001-10)) is used together. In MIMO, different wireless packets are transmitted from a plurality of antennas at the same time on the same wireless channel.
- 10 Those wireless packets transmitted at the same time on the same wireless channel are separated from each other by digital signal processing that can deal with a difference between propagation coefficients of the wireless packets received by a plurality of antennas in an opposed STA. The number of MIMOs is determined in accordance with the propagation coefficients and the like.

- 15 Fig. 14(1) shows a case where three wireless channels are idle for seven wireless packets when the number of MIMOs of each wireless channel is two. When MIMO is applied to each of the three wireless channels, up to six wireless packets can be transmitted simultaneously. Therefore, six of the above seven wireless packets are transmitted simultaneously by using the three wireless channels.

- 20 Figs. 14(2) and (3) show cases where three wireless channels are idle for four wireless packets when the Number of MIMOs of each wireless channel is two. When MIMO is applied to each of the three wireless channels, up to six wireless packets can be transmitted simultaneously. However, the number of transmission-standby wireless packets is four. Therefore, MIMO is applied to a part of the three wireless channels. For
- 25 example, one of the wireless channels transmits two wireless packets by using MIMO, while

each of the remaining two wireless channels transmits one wireless packet without using MIMO, as shown in Fig. 14(2). Thus, four wireless packets are transmitted simultaneously by using the three wireless channels in total. Alternatively, four wireless packets are transmitted simultaneously on two wireless channels each using MIMO, as show in Fig.

5 14(3).

In the case where center frequencies of multiple wireless channels used at the same time are close to each other, an effect of leakage power from one wireless channel to a frequency region used by another wireless channel becomes large. In general, in case of transferring a wireless packet, a transmit-side STA transmits the wireless packet and
10 thereafter a receive-side STA transmits an acknowledgment packet (Ack) for the received wireless packet to the transmit-side STA. When the transmit-side STA tries to receive this acknowledgment packet (hereinafter, ACK packet), the effect of leakage power from another wireless channel used for simultaneous transmission becomes a problem.

For example, a case is considered where center frequencies of wireless channels #1
15 and #2 are close to each other and transmission times of wireless packets transmitted simultaneously from the respective wireless channels are different from each other, as shown in Fig. 15. In this case, the wireless packet transmitted on the wireless channel #1 is shorter. Thus, when an ACK packet (Ack1) for that wireless packet is received, the wireless channel #2 is performing transmission. Therefore, the wireless channel #1 may not receive
20 that ACK packet (Ack1) because of leakage power from the wireless channel #2. In this situation, throughput cannot be improved even if simultaneous transmission is performed using multiple wireless channels at the same time.

In a wireless LAN system, for example, data sizes of data frames input from a network are not constant. Thus, in case of sequentially converting the input data frames
25 into wireless packets for transmission, packet time lengths of the wireless packets are also

different. Therefore, even when a plurality of wireless packets are transmitted simultaneously at the same time, as shown in Fig. 15, the transmission time of each wireless packet is different. This increases a possibility of unsuccessful receiving of the ACK packet.

5 In order to overcome the above problem, there is a known method in which transmission of a plurality of wireless packets is terminated at the same time or substantially at the same time by making equal or equivalent packet time lengths (time required to transmit the wireless packets) of the wireless packets transmitted simultaneously. In this case, a transmit-side STA is not performing transmission at a
10 timing at which ACK packets for the respective wireless packets reach the transmit-side STA. Thus, the transmit-side STA can receive all the ACK packets without being affected by leakage power between wireless channels or the like. Therefore, the throughput can be improved.

However, even if the packet time lengths of the wireless packets transmitted
15 simultaneously are made the same, the effect of leakage power may become a problem. This case is now described with reference to Fig. 16.

At timing t1, wireless channels #1 and #2 of a transmit-side STA are idle, while a wireless channel #3 is busy. Thus, the transmit-side STA transmits wireless packets having the same packet time length by using the idle wireless channels #1 and #2. Therefore, the
20 effect of leakage power can be avoided between the wireless channels #1 and #2. When the wireless channel #3 becomes idle during transmission of those wireless packets (at timing t2), another STA may determine that the wireless channel #3 is idle and may transmit a wireless packet to the above transmit-side STA by using the wireless channel #3. However, the transmit-side STA is transmitting the wireless packets by using the wireless
25 channels #1 and #2 and therefore cannot receive the wireless packet on the wireless

channel #3 because of leakage power from the wireless channels #1 and #2. In other words, the STA in transmission cannot receive a wireless packet transmitted on a wireless channel that is adjacent to the wireless channel being in transmission. This problem occurs not only in case of simultaneous transmission using multiple wireless channels but also in a conventional case where wireless packets are transmitted by using one wireless channel and an adjacent wireless channel that is affected by leakage power receives the wireless packets.

WO 2004/114561 A1 relates to a radio packet communication method and radio packet communication apparatus. Data packets are transmitted between two stations capable of using plural radio channels and MIMO together, by using idle channels and MIMO. When at least one idle channel has been detected, plural data packets are generated in the same number as the sum of MIMO numbers of the respective idle channels, in which the data packets are generated from one or plural data frames, and plural data packets having the same packet time length are transmitted simultaneously between the two stations by using the idle channels and MIMO. < page 5b >

It is an object of the present invention to avoid leakage power from affecting an adjacent channel so as to improve throughput by simultaneous transmission.

[->] This object is accomplished by the independent claims. Advantageous embodiments are described in the dependent claims.

<DISCLOSURE OF THE INVENTION>

A first ^{example} aspect of the invention provides a wireless packet communication method for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, or the multiple wireless channels and the MIMO. The wireless packet communication method includes setting a mandatory channel that is always used for

[-> sa]
8.10.12 v. Amos

< please insert the text in
 page 5 between lines 21
 and 22, as indicated
 on page 5 >

EP 1 263 168 42

~~Newly cited prior-art document D2~~ relates to a wireless communication apparatus in a wireless communication system employing CSMA (carrier sense multiple access). In CSMA an access point senses a carrier for transmitting the packet prior to transmitting the packet to a wireless station. The wireless communication apparatus comprises an adaptive array antenna generating a plurality of radio waves with comparatively narrow directivities to a plurality of stations. The number of antenna beams and the number of stations carrying out simultaneous communication may be arbitrarily two or more. By means of the antenna beams, the access point can communicate with the plurality of stations via the substantially same channel or adjacent channel while reducing interference between stations. The transmission data is transmitted as data packets each having the same packet length.

8-10.13 v. Lundh.

transmission and transmitting the wireless packets by using a wireless channel or wireless channels that includes/include the mandatory channel, only when the mandatory channel is idle.

In other words, for transmitting a plurality of wireless packets simultaneously, transmission is performed by using the wireless channel(s) including the mandatory channel. Transmission is not performed when the mandatory channel is not idle. Moreover, wireless packets are always transmitted via wireless channels including the mandatory channel, and when the mandatory channel is busy, transmission is not performed even if there is another wireless channel. In other words, the mandatory channel can be regarded as a wireless

[continue on page 6]

[-b6]

5a

8.10.13 v. *Amend.*

channel having the highest priority among wireless channels that have a plurality of priorities.

A second ~~aspect of the invention~~ ^{example} provides a wireless packet communication method for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, or the multiple wireless channels and the MIMO. The wireless packet communication method includes distinguishing an STA A, for which a mandatory channel always used for transmission is set, from an STA B for which no mandatory channel is set. Wireless packets addressed to the STA A are transmitted by using the wireless channel(s) including the mandatory channel, only when the mandatory channel is idle. Wireless packets addressed to the STA B are transmitted by using the idle wireless channel(s).

The STA A has a similar function as that of the invention of claim 1. The STA B for which no mandatory channel is set, is made transmittable even when the mandatory channel is busy.

Another ~~aspect of the invention~~ ^{example} is such that the plurality of wireless packets transmitted simultaneously are set to have the same or equivalent packet time length that corresponds to a packet size or a transmission time.

Another ~~aspect of the invention~~ ^{example} is such that wireless packets are simultaneously transmitted selectively using the multiple wireless channels or MIMO in accordance with the number of pieces of data or the number of MIMOs that depends on a channel condition.

Another ~~aspect of the invention~~ ^{example} provides a wireless packet communication apparatus for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels determined to be idle by carrier sense, a wireless channel determined to be idle and MIMO, or the multiple wireless channels and the MIMO. The wireless packet

communication apparatus includes a unit setting a mandatory channel that is always used for transmission and transmitting the wireless packets by using the multiple wireless channels or the wireless channel that include/includes the mandatory channel, only when the mandatory channel is idle.

Another ^{example} ~~aspect of the invention~~ provides a wireless packet communication apparatus for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels determined to be idle by carrier sense, a single wireless channel determined to be idle and MIMO, or the multiple wireless channels and the MIMO. The wireless packet communication apparatus includes a unit distinguishing an STA A, for which a mandatory channel that is always used for transmission is set, from an STA B for which no mandatory channel is set, and determining destinations of the wireless packets. In case of wireless packets addressed to the STA A, the unit transmits the wireless packets by using the multiple wireless channels or the wireless channel that include/includes the mandatory channel, only when the mandatory channel is idle. In case of wireless packets addressed to the STA B, the unit transmits the wireless packets by using idle wireless channel or channels.

Another ^{example} ~~aspect of the invention~~ is such that the plurality of wireless packets transmitted simultaneously are set to have the same or equivalent packet time length that corresponds to a packet size or a transmission time.

Another ^{example} ~~aspect of the invention~~ is such that wireless packets are simultaneously transmitted selectively using the multiple wireless channels or MIMO in accordance with the number of pieces of data or the number of MIMOs that depends on a channel condition.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a flowchart according to a first embodiment of the present invention.

Fig. 2 is a time chart of an exemplary operation in the first embodiment of the present invention.

Fig. 3 explains methods for reconstructing a data packet.

Fig. 4 is a flowchart according to a second embodiment of the present invention.

5 Fig. 5 is a time chart of an exemplary operation in the second embodiment of the present invention.

Fig. 6 is a flowchart according to a third embodiment of the present invention.

Fig. 7 is a flowchart according to a fourth embodiment of the present invention.

Fig. 8 is a flowchart according to a fifth embodiment of the present invention.

10 Fig. 9 is a flowchart according to a sixth embodiment of the present invention.

Fig. 10 is a flowchart according to a seventh embodiment of the present invention.

Fig. 11 is a flowchart according to an eighth embodiment of the present invention.

Fig. 12 is a block diagram of an exemplary wireless packet communication apparatus according to the present invention.

15 Fig. 13 explains exemplary methods for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels.

Fig. 14 explains exemplary methods for transmitting a plurality of wireless packets simultaneously by using multiple wireless channels (and MIMO).

Fig. 15 explains an effect of leakage power of a wireless channel.

20 Fig. 16 explains a case where the effect of leakage power becomes a problem even if packet time lengths of wireless packets transmitted simultaneously are made the same.

Fig. 17 shows a structure of a wireless packet used in the wireless packet communication apparatus of the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

[First Embodiment]

Fig. 1 is a flowchart of a wireless packet communication method according to the first embodiment of the present invention. Fig. 2 is a time chart of the wireless communication method according to the first embodiment of the present invention. In this embodiment, wireless channels #1, #2, and #3 are provided, and the wireless channel #1 is set as a mandatory channel for every STA. Each STA is regularly notified of the mandatory channel. When the mandatory channel is busy, each STA does not perform transmission even if there is other idle wireless channel. That is, no transmission is performed. It is assumed that the wireless channels #1, #2, and #3 affect each other due to a leakage and that when one of the wireless channels is in transmission, the other channels cannot receive data.

When data is stored in a transmission buffer, an idle wireless channel is searched by carrier sense (S1 and S2). In this example, it is found that the wireless channel #3 is busy at a timing data is generated (I), and the wireless channels #1 and #2 are idle. Then, it is determined whether or not the mandatory channel is idle (S3). When the mandatory channel is busy, a procedure goes back to the search of an idle wireless channel. On the other hand, when the mandatory channel is idle, data packets are reconstructed to data packets having the same packet time length for every wireless channel in accordance with the number of idle channels and the number of transmission stand-by data packets. The reconstructed data packets are transmitted (simultaneously) (S4). In this example, since the wireless channel #1 as the mandatory channel is idle, the wireless packets is simultaneously transmitted by using two wireless channels as the wireless channels #1 and #2.

The following three methods are known data packet reconstruction methods. In

the case where there is one data packet and two idle channels, for example, two data packets having the same packet time length are generated by fragmenting the data packet, as shown in Fig. 3(1). In the case where there are three data packets and two idle channels, a data packet 2 is divided into two portions and the two portions are connected to data packets 1 and 3, respectively, for example, as shown in Fig. 3(2). In this manner, two data packets having the same packet time length are generated. Alternatively, the two data packets having the same packet time length can be generated by connecting the three data packets into one block and then dividing the block into two. Alternatively, the data packets 1 and 2 may be aggregated to each other and dummy data is added to the data packet 3, as shown in Fig. 3(3), thereby obtaining two data packets having the same packet time length. Moreover, in the case where multiple wireless channels having different transmission rates are used, the packet time lengths of data packets are adjusted to be the same by associating a size ratio of each data packet with a ratio of the transmission rates.

Even when the wireless channel #3 becomes idle, another STA does not perform transmission because the wireless channel #1 set as the mandatory channel is busy. On the other hand, at a timing data is generated (2), all the wireless channels including the wireless channel #1 set as the mandatory channel are idle. Therefore, each STA becomes transmittable. For example, in the case where an STA transmits the wireless packets at the timing data is generated (1), another STA transmits a wireless packet to the STA having transmitted at the timing data is generated (2).

[Second Embodiment]

Fig. 4 is a flowchart of a wireless packet communication method according to the second embodiment of the present invention. Fig. 5 is a time chart of that wireless packet communication method. In this embodiment, there are an STA A for which a mandatory channel is set and an STA B for which no mandatory channel is set. There is no specific

limitation to transmission to the STA B, while transmission to the STA A is allowed only when the mandatory channel is idle, and is not performed when the mandatory channel is busy even if another wireless channel is idle. Please note that in the first embodiment a mandatory channel is set for every STA so that packet transmission is always performed via
5 wireless channels including the mandatory channel without an address of a wireless packet being considered.

First, when data is stored in a transmission buffer, an idle wireless channel is searched by carrier sense (S1 and S2). In this example, it is found that at a timing data is generated (I), a wireless channel #3 is busy and wireless channels #1 and #2 are idle.
10 Then, an address of one data packet stored in the transmission buffer is decoded (S11), and it is determined whether or not any mandatory channel is set for an STA that is the decoded address (S12). When a mandatory channel is set for the receive-side STA, it is determined whether or not that mandatory channel is idle (S13). When that mandatory channel is idle, transmission stand-by data packets are reconstructed to have the same packet time length
15 for every wireless channel in accordance with the number of idle channels and the number of the transmission stand-by data packets. The reconstructed data packets are transmitted (simultaneously) (S4). In this example, for wireless packets addressed to the STA A, simultaneous transmission is performed using two wireless channels as the wireless channels #1 and #2 because the wireless channel #1 set as the mandatory channel is idle.

20 On the other hand, when no mandatory channel is set for the receive-side STA in S12, the state of the mandatory channel need not be considered so that the transmission stand-by data packets are reconstructed to have the same packet time length for every wireless channel in accordance with the number of idle channels and the number of the transmission stand-by data packets. The reconstructed data packets are transmitted
25 (simultaneously) (S4). Moreover, when the mandatory channel is not idle in S13, the

wireless packet cannot be transmitted to the STA A for which the mandatory channel is set. Therefore, it is then determined whether or not there is another data packet in the transmission buffer (S14). With a presence of a data packet therein, a procedure returns to decoding of an address of the data packet in S11. With no data packet, an idle channel is
5 searched in S2.

In this example, when the wireless channel #3 becomes idle, transmission of a wireless packet to the STA B in which no mandatory channel is set using the wireless channel #3 becomes possible. On the other hand, transmission of a wireless packet to the STA A using the wireless channel #3 is not performed because the wireless channel #1 is
10 busy, and has to wait until the wireless channel #1 becomes idle.

At a timing data is generated (2), the wireless channels #1 and #2 are idle. Therefore, wireless packets addressed to the STA A for which the mandatory channel is set and to the STA B for which no mandatory channel is set can be transmitted by using the wireless channels #1 and #2.

15 [Third Embodiment]

Fig. 6 is a flowchart of a wireless packet communication method according to the third embodiment of the present invention. This embodiment has a feature in using MIMO additionally for simultaneous transmission of wireless packets in the first embodiment as well as in reconstructing wireless packets in S4 in the first embodiment such that
20 reconstructed wireless packets have the same packet time length for the number of simultaneous transmissions that corresponds to a total number of MIMOs of idle channels (S5). Except for the above, this embodiment is the same as the first embodiment.

[Fourth Embodiment]

Fig. 7 is a flowchart of a wireless packet communication method according to the
25 fourth embodiment of the present invention. This embodiment has the following feature.

In case of applying MIMO to simultaneous transmission of wireless packets, antenna correlation is obtained from propagation coefficients prior to reconstruction of wireless packets to wireless packets having the same packet time length for the number of simultaneous transmissions that corresponds to a total number of MIMOs of idle channels
5 in S5 in the third embodiment. Then, the number of MIMOs that that can be multiplexed in one channel is obtained by using a predetermined threshold value (S6). Except for the above, this embodiment is the same as the third embodiment.

[Fifth Embodiment]

Fig. 8 is a flowchart of a wireless packet communication method according to the
10 fifth embodiment of the present invention. This embodiment has a feature that simultaneous transmission using multiple wireless channels as described in the first embodiment or simultaneous transmission using MIMO as described in the third embodiment is selected in accordance with the number of pieces of data stored in the transmission buffer or the number of MIMOs as described in the fourth embodiment that
15 depends on a channel condition (S7). In accordance with this selection, wireless packets are reconstructed to have the same packet time length for the number of idle channels or the Number of MIMOs. The reconstructed packets are transmitted simultaneously (S4 and S8). Except for the above, this embodiment is the same as the first embodiment.

[Sixth Embodiment]

20 Fig. 9 is a flowchart of a wireless packet communication method according to the sixth embodiment of the present invention. This embodiment has a feature that MIMO is applied to simultaneous transmission of wireless packets in the second embodiment. More specifically, wireless packets in S4 in the second embodiment is reconstructed in such a manner that reconstructed wireless packets have the same packet time length for the
25 number of simultaneous transmissions that corresponds to a total number of MIMOs of idle

channels (S5). Except for the above, this embodiment is the same as the second embodiment.

[Seventh Embodiment]

Fig. 10 is a flowchart of a wireless packet communication method according to the seventh embodiment of the present invention. This embodiment has the following feature. In case of applying MIMO to simultaneous transmission of wireless packets, antenna correlation is obtained from propagation coefficients prior to reconstruction of wireless packets to wireless packets having the same packet time length for the number of simultaneous transmissions that corresponds to a total number of MIMOs of idle channels in S5 in the sixth embodiment. Then, the number of MIMOs that can be multiplexed in one channel is obtained by using a predetermined threshold value (S6). Except for the above, this embodiment is the same as the sixth embodiment.

[Eighth Embodiment]

Fig. 11 is a flowchart of a wireless packet communication method according to the eighth embodiment of the present invention. This embodiment has a feature that simultaneous transmission using multiple wireless channels as described in the second embodiment or simultaneous transmission using MIMO as described in the sixth embodiment is selected in accordance with the number of pieces of data stored in the transmission buffer or the number of MIMOs described in the seventh embodiment that depends on a channel condition (S7). In accordance with this selection, reconstruction of wireless packets is performed in such a manner that reconstructed wireless packets have the same packet time length for the number of idle channels or the Number of MIMOs. The reconstructed wireless packets are transmitted simultaneously (S4 and S8). Except for the above, this embodiment is the same as the second embodiment.

[Exemplary structure of a wireless packet communication apparatus]

Fig. 12 shows an exemplary structure of a wireless packet communication apparatus of the present invention. Although the following description will be directed to the structure of the wireless packet communication apparatus capable of transmitting and receiving three wireless packets simultaneously by using three wireless channels #1, #2, and #3, the number of simultaneously transmittable/receivable wireless packets may be set arbitrarily. Where MIMO is used for each wireless channel, wireless packets can be transmitted and received simultaneously in the number of simultaneous transmissions that is equal to the sum of MIMO numbers of multiple wireless channels. However, the MIMO will not be taken into consideration in the following description as well as a case where multiple wireless channels are independently used.

In Fig. 12, the wireless packet communication apparatus includes a transmission/reception block 10-1, 10-2, and 10-3, a transmission buffer 21, a data packet generating block 22, a data frame management block 23, an analyzer of channels' occupation status 24, a packet switching block 25, a packet order management block 26, and a data frame extraction block 27.

The transmission/reception blocks 10-1, 10-2, and 10-3 perform wireless communication via different wireless channels #1, #2, and #3, respectively. These wireless channels are independent of each other because they have different wireless frequencies from each other, therefore, the blocks can perform wireless communication using multiple wireless channels at the same time. Each transmission/reception block 10 includes a modulator 11, a transmitter 12, an antenna 13, a receiver 14, a demodulator 15, a frame selection block 16, and a carrier sense block 17.

Radio frequency signals transmitted from another wireless packet communication apparatus via different wireless channels #1, #2, and #3 are input to the receivers 14 through the antennas 13 of the transmission/reception block 10-1, 10-2, and 10-3,

respectively. Each receiver 14 corresponding to each wireless channel performs a reception processing on the input radio frequency signal. The reception processing contains frequency conversion, filtering, quadrature detection, and AD conversion. A radio frequency signal on a wireless propagation path of each wireless channel is always input to the corresponding receiver 14 except during periods the antenna 13 connected to the receiver 14 is used for transmission. The receiver 14 outputs, to the carrier sense block 17, an RSSI signal indicating a received electric field strength of each wireless channel. When receiving a radio frequency signal on the corresponding wireless channel, the receiver 14 outputs to the demodulator 15 a baseband signal for which the reception processing is performed.

The demodulator 15 performs a demodulation processing on the baseband signal input from the receiver 14, and outputs a resulting data packet to the frame selection block 16. The frame selection block 16 performs CRC check on the input data packet. In the case where the data packet has been received correctly, the frame selection block 16 determines whether or not the data packet is directed to an own STA. More specifically, the frame selection block 16 determines whether or not a receive-side STA ID of the data packet is coincident with ID of the own STA. Then, the frame selection block 16 outputs the data packet addressed to the own STA to the packet order management block 26 while transmitting to the modulator 11 an ACK packet generated in an ACK packet generating block (not shown) and performs a reply processing. In transmission of the ACK packet, a transmission mode may be set in such a manner that a transmission rate is set or MIMO is not applied. On the other hand, when the data packet is not directed to the own STA, the frame selection block 16 discards the data packet.

The packet order management block 26 checks sequence numbers added to received data packets and rearranges the received data packets in an appropriate order, i.e.,

in order of sequence numbers. The rearranged data packets are output to the data frame extraction block 27 as received data packets. The data frame extraction block 27 removes a packet header from each of the data packets contained in the received data packets, and outputs the resulting data packets as received data frames.

5 When receiving an RSSI signal, the carrier sense block 17 compares a value of a received electric field strength represented by the RSSI signal with a preset threshold value. When a state where the received electric field strength is smaller than the threshold value continues for a predetermined period, the carrier sense block 17 determines that the assigned wireless channel is idle. Otherwise, the carrier sense block 17 determines that the
10 assigned wireless channel is busy. The carrier sense blocks 17 corresponding to the respective wireless channels output the determination results as carrier sense results CS1 to CS3. Please note that in each transmission/reception block 10, no RSSI signal is input to the carrier sense block 17 while the antenna 13 is in transmission. Moreover, in the case where the antenna 13 has already been in a transmission state, it is not possible to
15 simultaneously transmit another data packet as a radio frequency signal by means of the same antenna 13. Therefore, when receiving the RSSI signal, each carrier sense block 17 outputs the carrier sense result indicating that the wireless channel assigned thereto is busy.

The carrier sense results CS1 to CS3 that are output from the carrier sense blocks 17 corresponding to the respective wireless channels are input to the analyzer of channels' occupation status 24. The analyzer of channels' occupation status 24 manages an idle
20 status of each wireless channel based on the corresponding carrier sense result and notifies the data frame management block 23 of information on an idle wireless channel, the number of idle channels, and the like (Fig. 12, a).

On the other hand, sent data frames to be transmitted are input to and buffered in
25 the transmission buffer 21. The sent data frames consists one or more data frames. The

transmission buffer 21 successively notifies the data frame management block 23 of the number of data frames the transmission buffer 21 currently stores, ID information of a receive-side wireless packet communication apparatus, a data size, address information indicating a position in the buffer, and other information (b).

5 The data frame management block 23 determines how to generate data packets from which data frame and on which wireless channel to transmit, according to information about data frames for each receive-side STA ID from the transmission buffer 21 and information about the wireless channels from the analyzer of channels' occupation status 24. The data frame management block 23 then notifies the transmission buffer 21, the
10 data packet generating block 22, and the data packet switching block 25 of the determined data frame, generation manner, and wireless channel, respectively (c, d, and e). For example, in the case where the number N of idle wireless channels including the mandatory channel is smaller than the number K of transmission stand-by data frames in the transmission buffer 21, the number N of idle wireless channels including the mandatory
15 channel is determined as the number of data packets transmitted simultaneously. The transmission buffer 21 is notified of address information to designate N data frames from the K data frames (c). The data packet generating block 22 is notified of information necessary for generating N data packets from data frames input from the transmission buffer 21 (d). The packet switching block 25 is instructed to associate the N data packets
20 generated by the data packet generating block 22 with the idle wireless channels (e).

 According to an output instruction, the transmission buffer 21 outputs the data frames to the data packet generating block 22 (f). The data packet generating block 22 extracts data fields from the respective data frames to generate a plurality of data blocks having the same packet time length, and adds a packet header and a CRC code (FCS region)
25 to each of the data blocks to generate data packets shown in Fig. 17. The packet header

contains ID information on a receive-side STA as a destination of the corresponding data packet, control information such as a sequence number indicating an order of the data frame, and other information. The control information also contains information required for a receive-side STA to convert a data packet into the original data frame when it receives
5 the data packet. The packet switching block 25 associates the data packets input from the data packet generating block 22 with the respective wireless channels.

As a result, the data packet associated with the wireless channel #1 is input to the modulator 11 in the transmission/reception block 10-1; the data packet associated with the wireless channel #2 is input to the modulator 11 in the transmission/reception block 10-2;
10 and the data packet associated with the wireless channel #3 is input to the modulator 11 in the transmission/reception block 10-3. When receiving a data packet from the packet switching block 25, each modulator 11 performs a predetermined modulation processing on the data packet and outputs the processed data packet to the transmitter 12. Each transmitter 12 performs a transmission processing on the modulated data packet input
15 from the modulator 11. The transmission processing contains DA conversion, frequency conversion, filtering, and power amplification. After the transmission processing, each transmitter 12 transmits the processed data packet as a wireless packet on the corresponding wireless channel via the corresponding antenna 13.

The processings described in the first to eight embodiments are performed under a
20 control of the data frame management block 23 with the mandatory channel taken into consideration. This can prevent a situation that a wireless packet cannot be received by use of multiple wireless channels because of leakage of power from one channel to an adjacent channel.

25

INDUSTRIAL AVAILABILITY

According to the present invention, while a transmit-side STA is in transmission using one or more wireless channels including a mandatory channel, the other STAs do not perform transmission to the transmit-side STA. Thus, it is possible to avoid a situation
5 that the transmit-side STA cannot receive a wireless packet addressed to an own STA. On the other hand, the other STAs can surely transfer a wireless packet to the transmit-side STA by transmitting the wireless packet after the mandatory channel becomes idle. Thus, throughput can be improved.

Moreover, in the case where there is an STA for which no mandatory channel is set,
10 transmission is enabled between STAs including the STA even when the mandatory channel is busy. Thus, reduction of the throughput can be suppressed.

EP 04 773 142 7-2414

NIPPON TELEGRAPH AND TELEPHONE CORPORATION

110 895 q4/q21/sim

February 14, 2014

Claims

1. A wireless packet communication method for transmitting a plurality of wireless packets having equal packet time lengths simultaneously by using multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense and by using MIMO, the method characterized by comprising:

setting a mandatory channel among multiple wireless channels that is always used for transmission and has the highest priority among wireless channels that have a plurality of priorities;

transmitting the wireless packets by using wireless channels (Ch#1, Ch#2) that include the mandatory channel, only when the mandatory channel is idle; and

refraining from transmitting wireless packets by another station on a channel (Ch#3) determined to be idle, when the mandatory channel is busy.

2. Wireless packet communication method according to claim 1, comprising:

distinguishing a STA A from a STA B, the STA A for which the mandatory channel is set, the STA B for which no mandatory channel is set; and

when wireless packets are addressed to said STA A, transmitting the wireless packets to said STA A by using wireless channels (Ch#1, Ch#2) that include the mandatory channel, only when the mandatory channel is idle; and

when wireless packets are addressed to said STA B, transmitting the wireless packets to said STA B by using idle wireless channel or channels (Ch#1, Ch#2).

3. The wireless packet communication method according to claim 1 or 2, characterized in that

the packet time length corresponds to a packet size or a transmission time.

4. The wireless packet communication method according to claim 1 or 2, characterized by further comprising

simultaneously transmitting wireless packets selectively using the multiple wireless channels (Ch#1, Ch#2) or the MIMO in accordance with a number of pieces of data or a number of MIMOs that depends on a channel condition.

5. A wireless packet communication system for transmitting a plurality of wireless packets having equal packet time lengths simultaneously by using multiple wireless channels (Ch#1, Ch#2) determined to be idle by carrier sense and by using MIMO, the system characterized by comprising

a unit (23) setting a mandatory channel among multiple wireless channels that is always used for transmission and has the highest priority among wireless channels that have a plurality of priorities, and transmitting the wireless packets only when the mandatory channel is idle by using wireless channels (Ch#1, Ch#2) that include the mandatory channel; and

a station refraining from transmitting wireless packets on a channel (Ch#3) determined to be idle, when the mandatory channel is busy.

6. Wireless packet communication system according to claim 5, comprising

a unit (23) distinguishing a STA A from a STA B and determining destinations of the wireless packets so as to transmit wireless packets addressed to said STA A only when the mandatory channel is idle by using wireless channels (Ch#1, Ch#2) that include a mandatory channel, and to transmit wireless packets addressed to said STA B by using idle wireless channel or channels (Ch#1, Ch#2), the STA A for which the mandatory channel is set, the STA B for which no mandatory channel is set.

7. The wireless packet communication system according to claim 5 or 6, characterized in that

the packet time length corresponds to a packet size or a transmission time.

8. The wireless packet communication system according to claim 5 or 6, characterized by further comprising:

a unit simultaneously transmitting wireless packets selectively using the multiple wireless channels (Ch#1, Ch#2) or the MIMO in accordance with a number of pieces of data or a number of MIMOs that depends on a channel condition.

1 / 12

FIG. 1

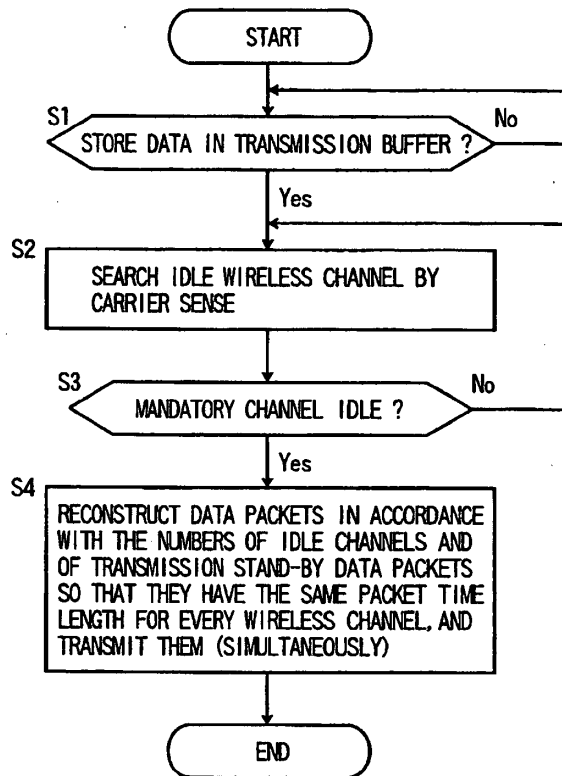
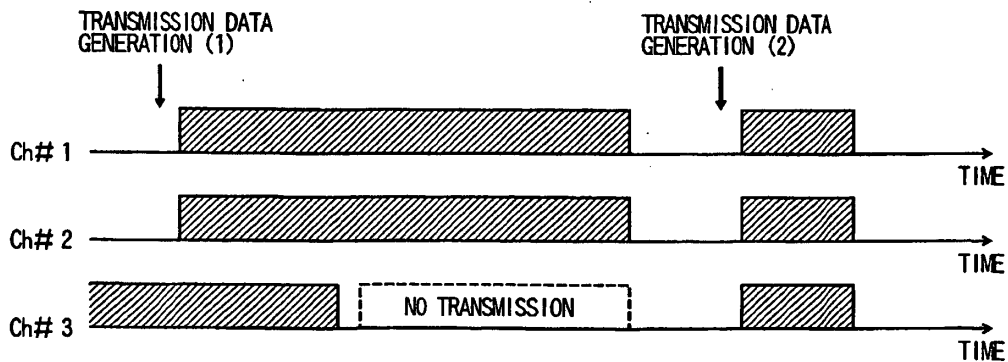


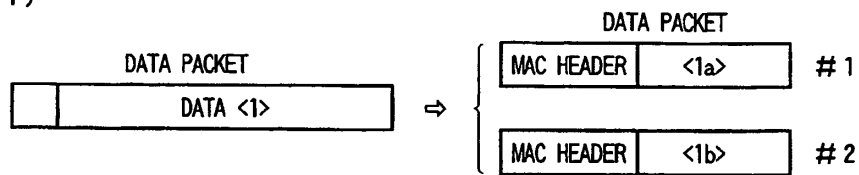
FIG. 2



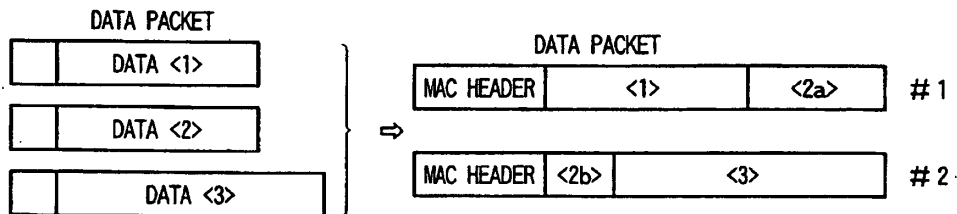
2 / 12

FIG. 3

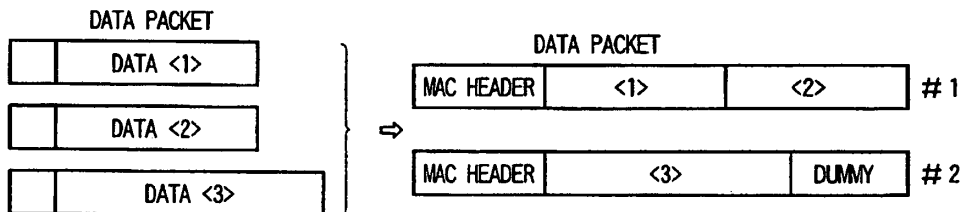
(1)



(2)



(3)



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FIG. 4

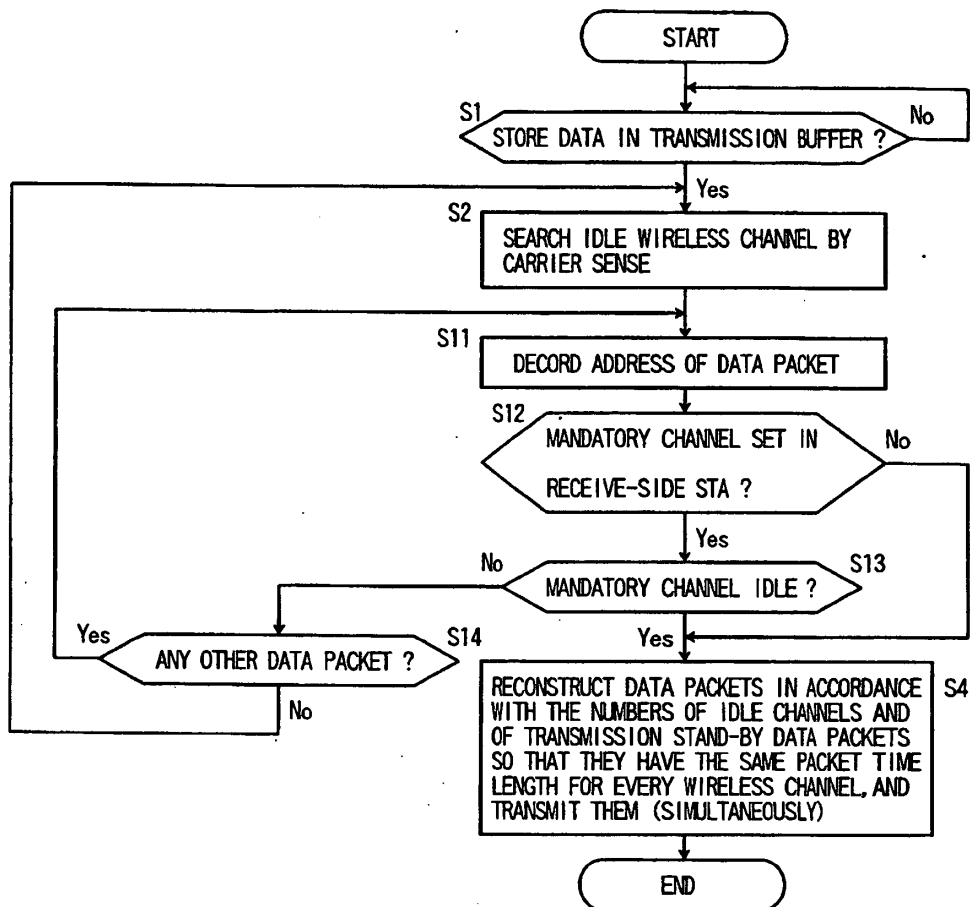
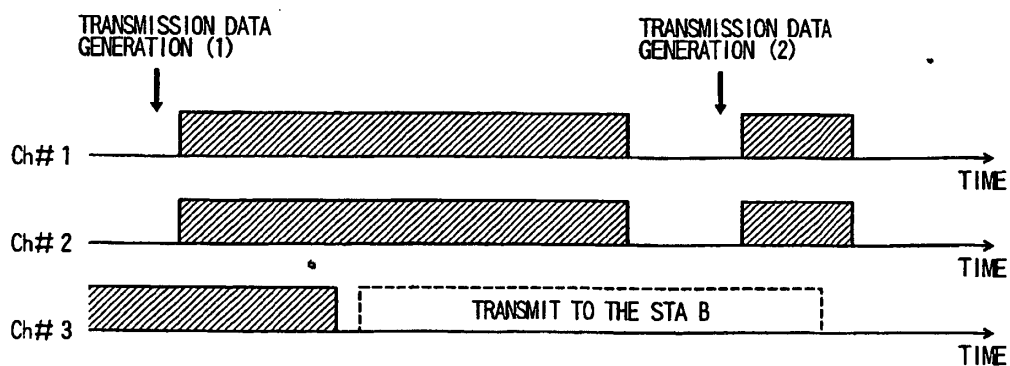
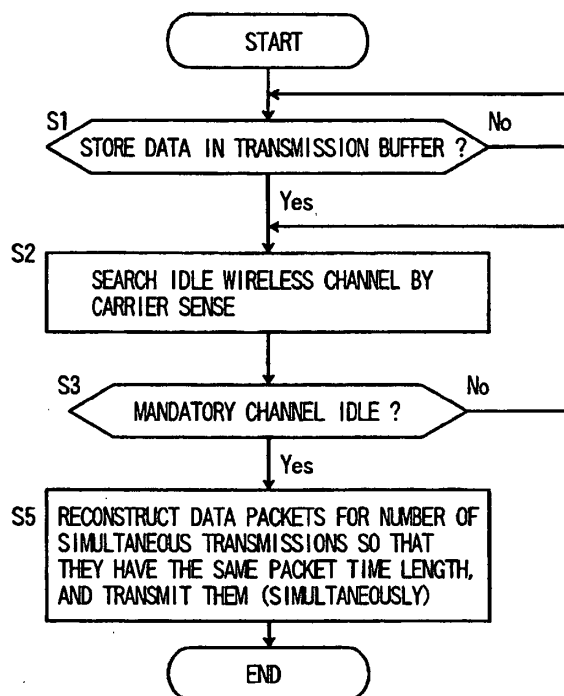


FIG. 5



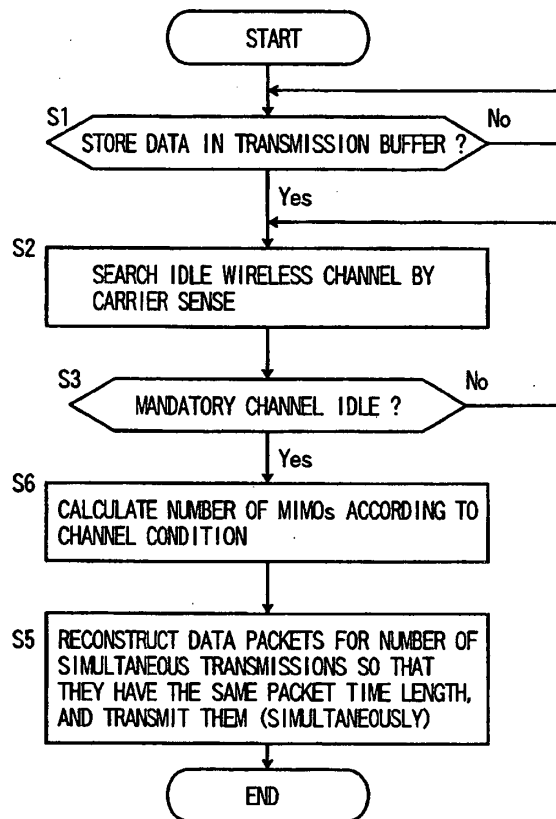
4 / 1 2

FIG. 6



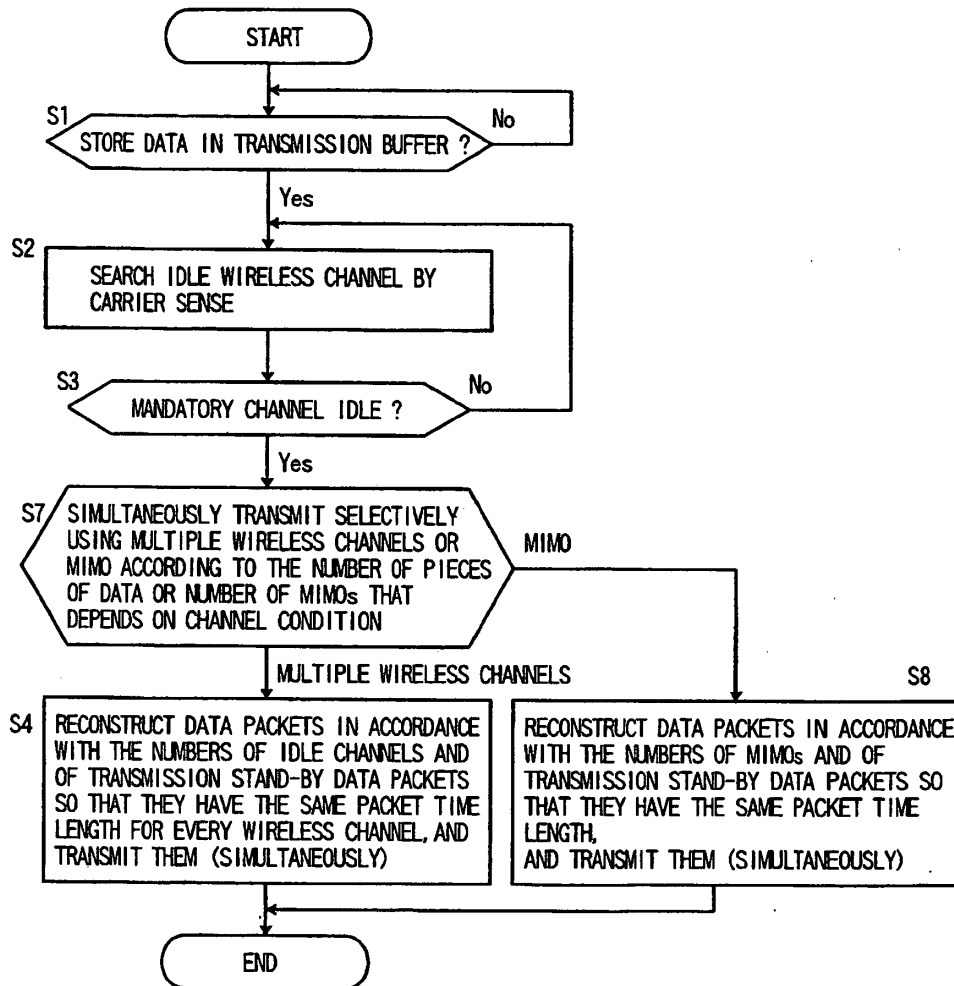
5 / 1 2

FIG. 7



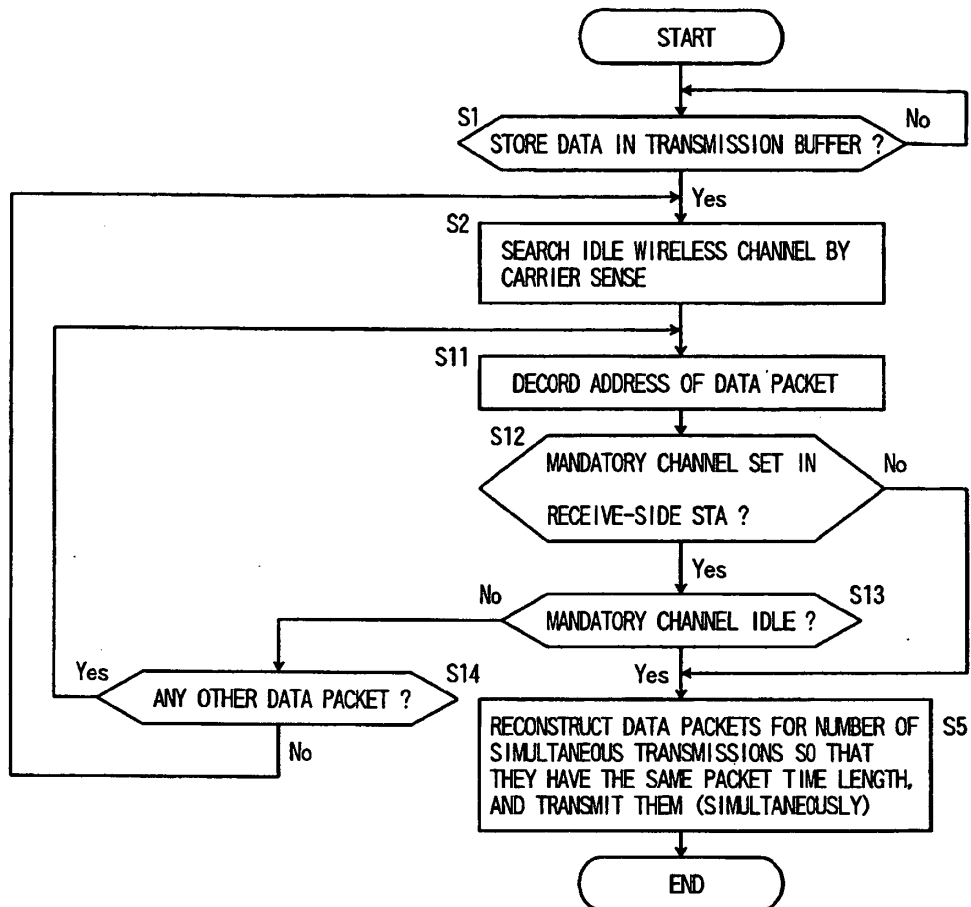
6 / 12

FIG. 8



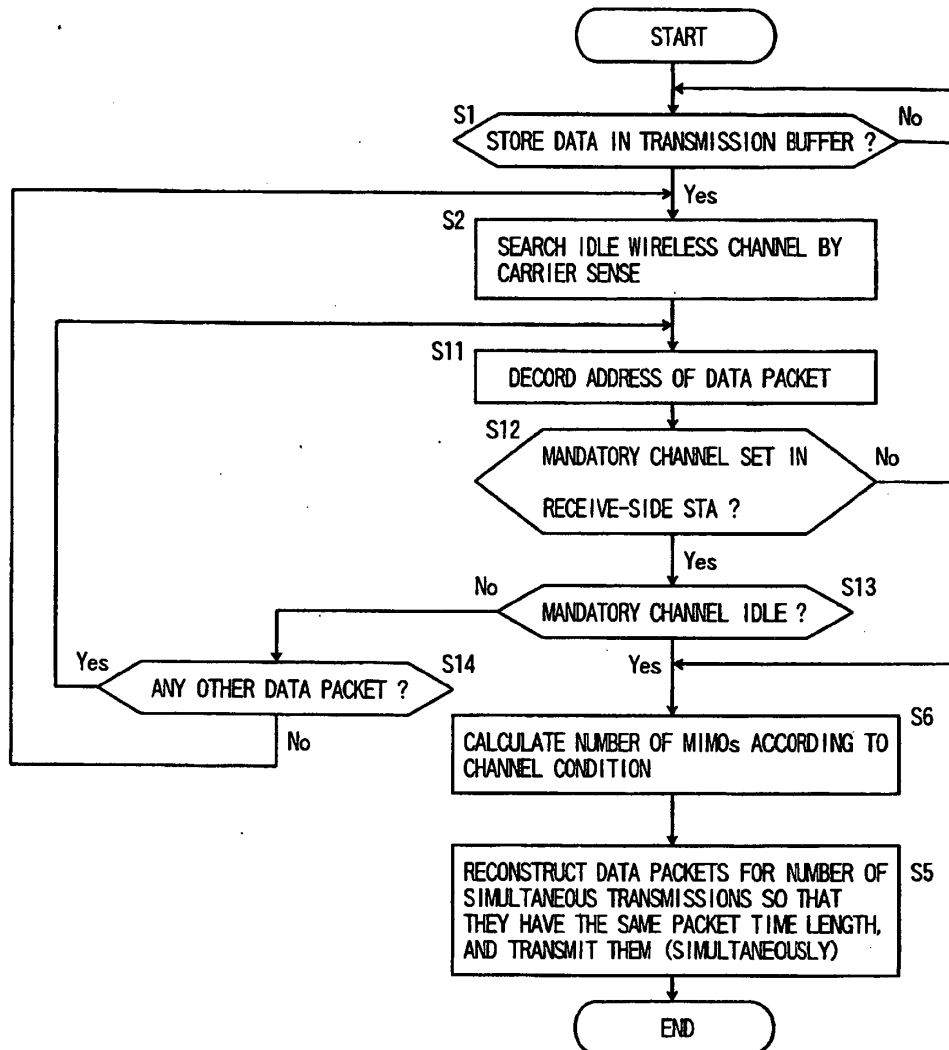
7/12

FIG. 9



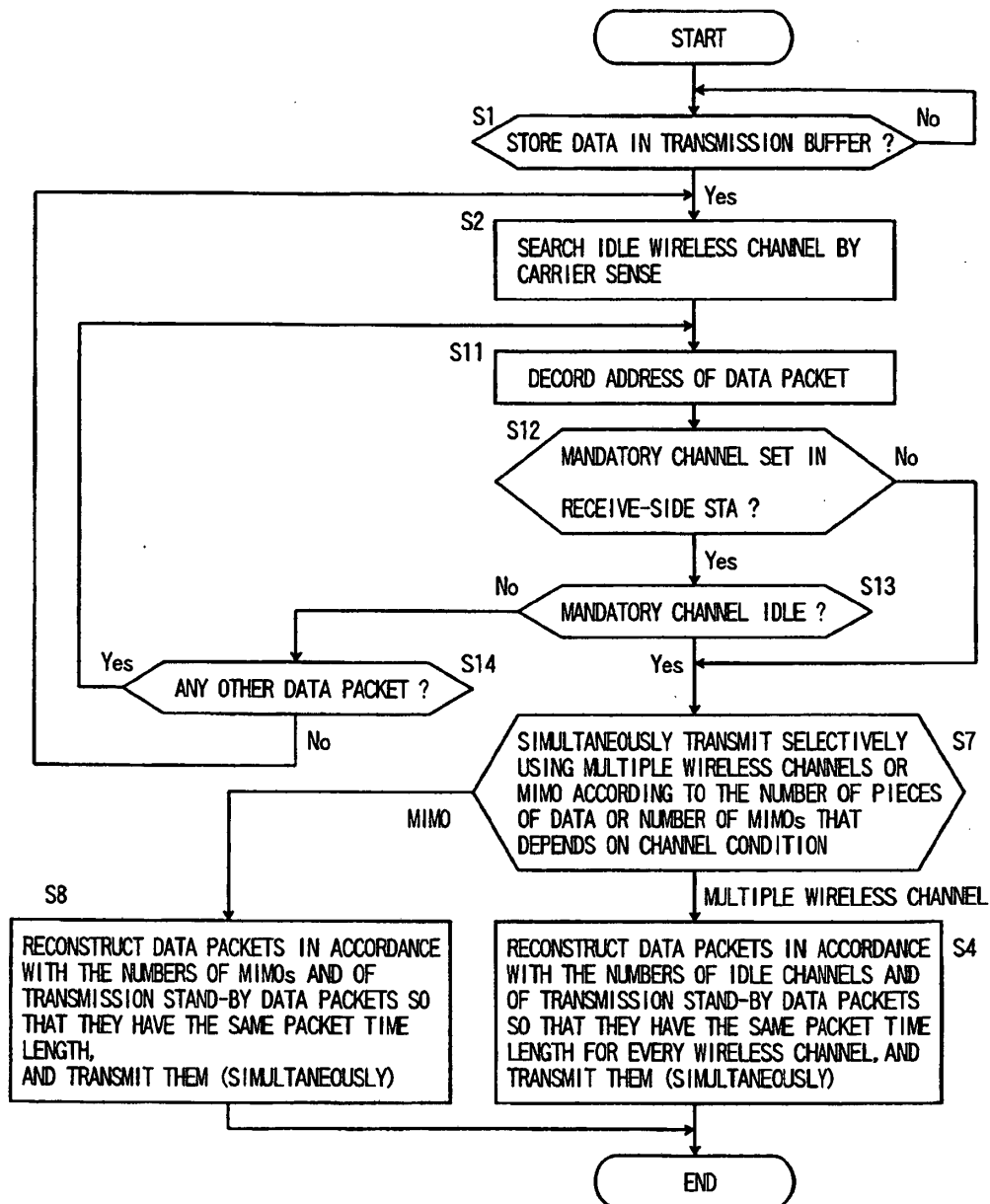
8/12

FIG. 10

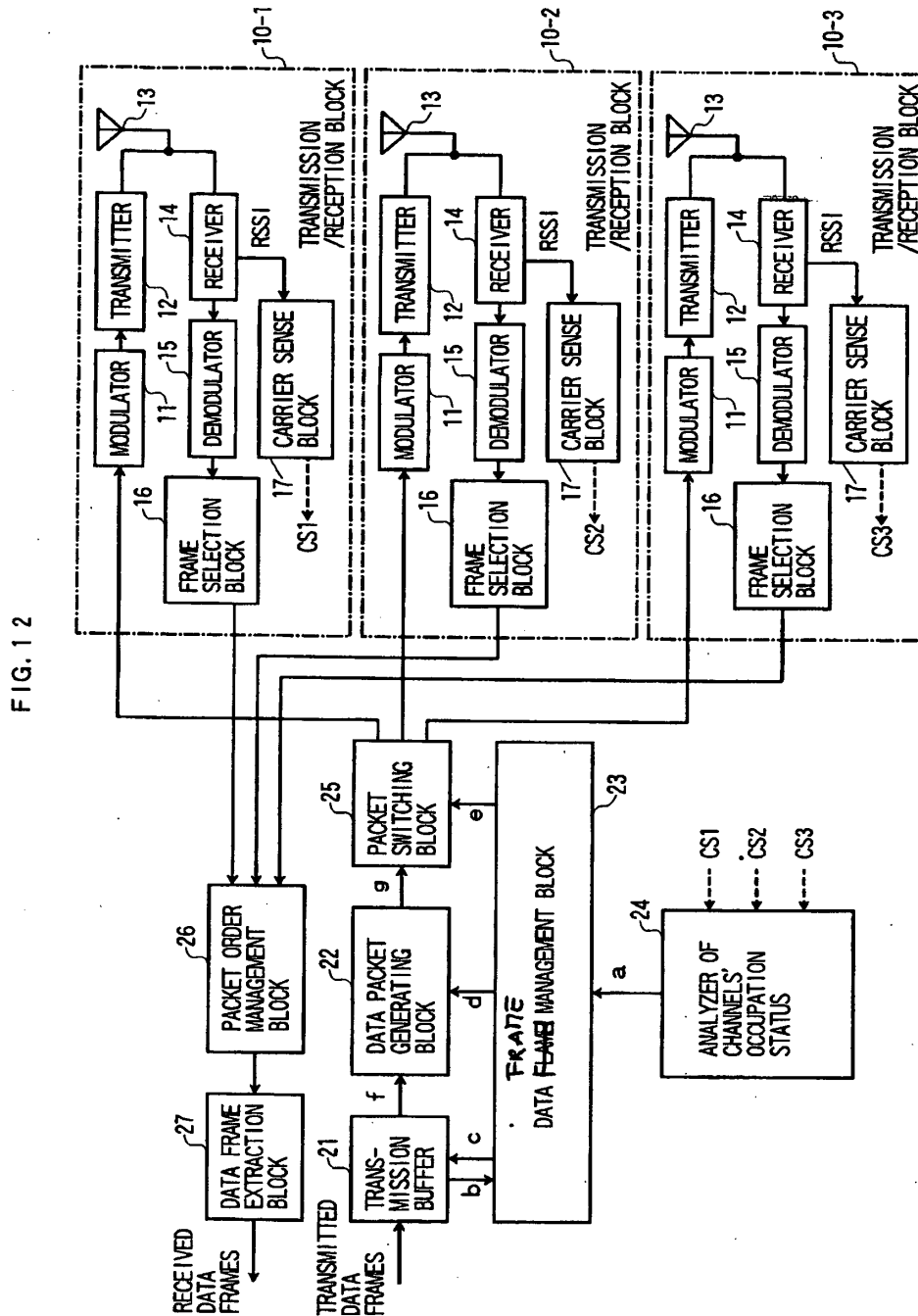


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FIG. 11



10/12



11/12

FIG. 13

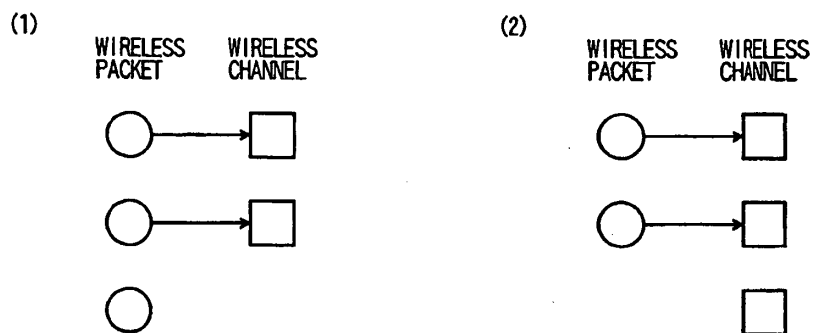
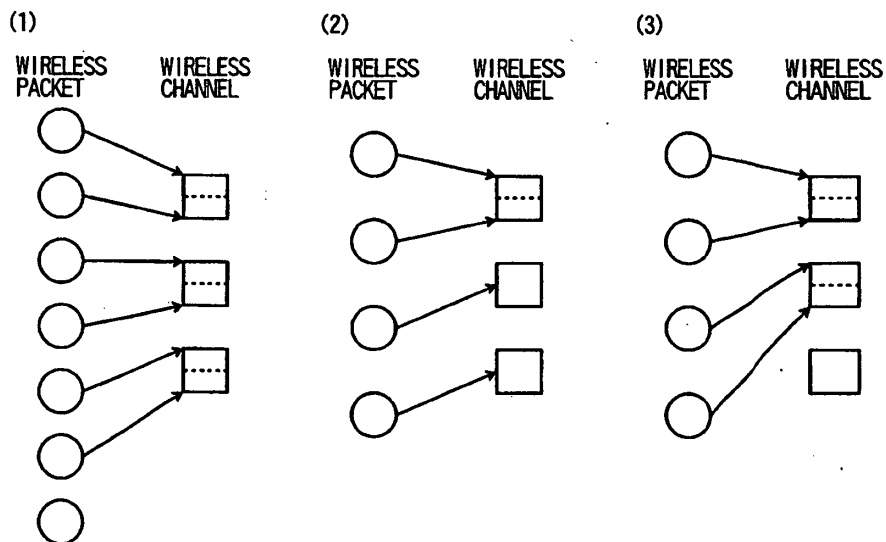


FIG. 14



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FIG. 15

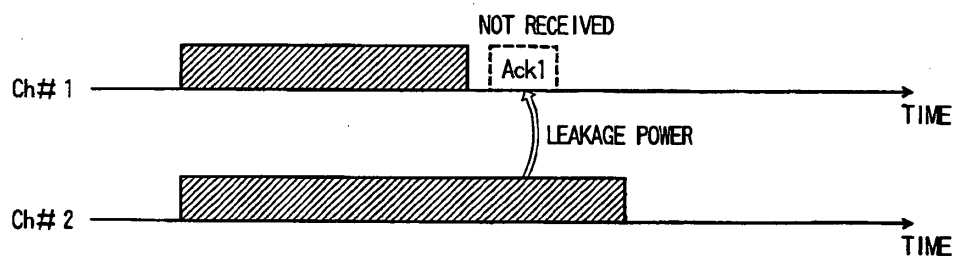


FIG. 16

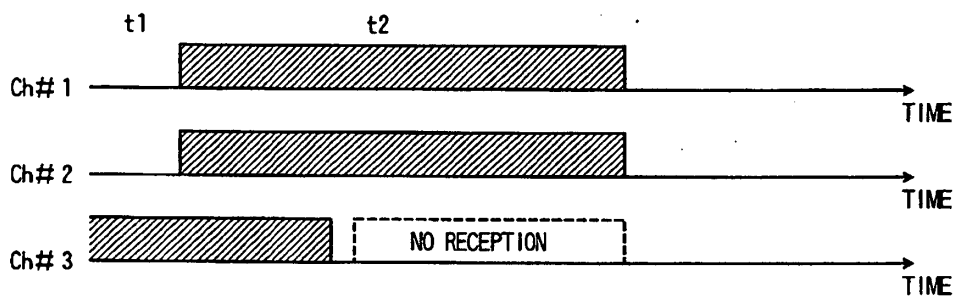
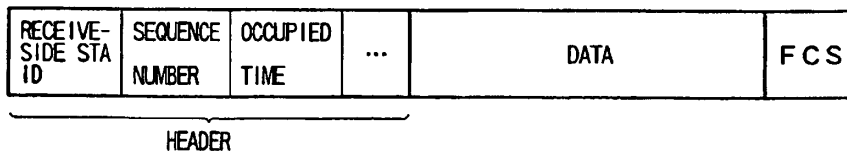


FIG. 17



Application No.:

04 773 142.7

IV.2. Patent classification

The classification has been changed. It now is as follows:

INV. H04W74/08 ADD. H04W72/02

IV.3. Title of the invention

The title indicated on the published patent application remains unchanged. It reads as follows:

FUNKPAKETKOMMUNIKATIONSVERFAHREN UND
FUNKPAKETKOMMUNIKATIONSVORRICHTUNG

RADIO PACKET COMMUNICATION METHOD AND RADIO PACKET
COMMUNICATION APPARATUS

PROCEDE DE COMMUNICATION DE PAQUETS RADIO ET APPAREIL DE
COMMUNICATION DE PAQUETS RADIO

IV.4. Documentation

CDOC The following documents not mentioned in the Search Report were cited during the Examination Procedure:

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28 November 2002 (2002-11-28)

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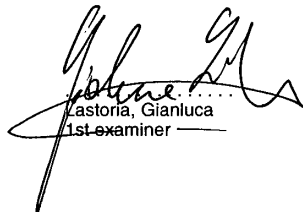
04 773 142.7

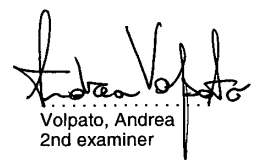
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DOI: 10.1109/INFCOM.2002.1019388
ISBN: 978-0-7803-7476-8

27.02.14...
Date


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Volpato, Andrea
2nd examiner

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Form 2906



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Application No. 04 773 142.7 - 1858	Ref. 110 895 a/me	Date 03.03.2014
Applicant NIPPON TELEGRAPH AND TELEPHONE CORPORATION		

Communication under Rule 71(3) EPC

1. Intention to grant

You are informed that the Examining Division intends to grant a European patent on the basis of the above application with the text and drawings and the related bibliographic data as indicated below.

A copy of the relevant documents is enclosed.

1.1 Auxiliary Request 1

In the text for the Contracting States:
DE FR GB

Description, Pages

1-4, 8-20	filed with entry into the regional phase before the EPO	
5, 5a, 5b, 6, 7	filed during Oral proceedings on	08-10-2013

Claims, Numbers

1-8	received on	14-02-2014	with letter of	14-02-2014

Drawings, Sheets

1/12-12/12	filed with entry into the regional phase before the EPO

With the following amendments to the above-mentioned documents proposed by the division

Drawings, Sheets	10/12

Comments

Clerical mistake in figure 12 has been corrected

See also comments on the enclosed EPO Form 2906.

1.2 Bibliographic data

The title of the invention in the three official languages of the European Patent Office, the international patent classification, the designated Contracting States, the registered name(s) of the applicant(s) and the other bibliographic data are shown on the **enclosed EPO Form 2056**.

2. Invitation

You are invited, **within a non-extendable period of four months** of notification of this communication,

2.1 to EITHER approve the text communicated above and verify the bibliographic data (R. 71(5) EPC)

(1) by filing a translation of the claim(s) in the other two official languages of the EPO

	Fee code	EUR
(2a) by paying the fee for grant including the fee for printing (Art. 2(2) RFees):	007	875.00
minus any amount already paid (R. 71a(5) EPC):		0.00
(2b) by paying the printing fee (Art. 2(2) RFees) for the 36th and each subsequent page; number of pages payable: 2	008	28.00
minus any amount already paid (R. 71a(5) EPC):		0.00
Total amount:		903.00
(3) by paying additional claims fees under Rule 71(4) EPC; number of claims fees payable: 0	016	0.00
minus any amount already paid (R. 71a(5) EPC):		0.00
Total amount:		0.00

Important: If the translations of the claims and fees have already been filed and paid respectively in reply to a previous communication under Rule 71(3) EPC, e.g. in the case of resumption of examination after approval (see Guidelines C-V, 6), **agreement as to the text to be granted** (R. 71a(1) EPC) must be expressed within the same time limit (e.g. by approving the text and verifying the bibliographic data, by confirming that grant proceedings can go ahead with the documents on file and/or by stating which translations of the claims already on file are to be used).

Note 1: See "Important notes concerning fee payments" below.

Note 2: Any overpaid "minus" amounts will be refunded when the decision to grant (EPO Form 2006A) has been issued.

2.2 OR, in the case of disapproval, to request reasoned amendments or corrections to the text communicated above or keep to the latest text submitted by you (R. 71(6) EPC).

In this case the translations of the claims and fee payments mentioned under point 2.1 above are NOT due.

The terms "amendment(s)" and "correction(s)" refer only to amendments or corrections of the application documents and not of other documents (e.g. bibliographic data, the designation of the inventor, etc.).

If filing amendments, you must identify them and indicate the basis for them in the application as filed. Failure to meet either requirement may lead to a communication from the Examining Division requesting that you correct this deficiency (R. 137(4) EPC).

2.3 Bibliographic data

Where you request a change or correction of bibliographic data in response to the Rule 71(3) communication, this will **not** cause the sending of a second communication under Rule 71(3) EPC. You will still have to pay the fees and file translations in reply to the Rule 71(3) communication in the case of 2.1 above, unless you also file a reasoned request for amendments or corrections in response to the Rule 71(3) communication (see case 2.2 above).

3. Loss of rights

If neither of the two possible actions above (see points 2.1 or 2.2) is performed in due time, the European patent application will be deemed to be withdrawn (R. 71(7) EPC).

4. Further procedure

4.1 In the case of point 2.1 above

- 4.1.1 The decision to grant the European patent will be issued, and the **mention of the grant** of the patent will be published in the European Patent Bulletin, if the requirements concerning the translation of the claims and the payment of all fees are fulfilled and there is agreement as to the text to be granted (R. 71a(1) EPC).

Note on payment of the renewal fee:

If a renewal fee becomes due before the next possible date for publication of the mention of the grant of the European patent, publication will be effected only after the renewal fee and any additional fee have been paid (R. 71a(4) EPC).

Under Article 86(2) EPC, the obligation to pay renewal fees to the European Patent Office terminates with the payment of the renewal fee due in respect of the year in which the mention of the grant of the European patent is published.

Note on payment of the designation fee(s):

If the designation fee(s) become(s) due after the communication under Rule 71(3) EPC, the mention of the grant of the European patent will not be published until the designation fee(s) has/have been paid (R. 71a(3) EPC).

- 4.1.2 After publication, the **European patent specification** can be downloaded free of charge from the EPO publication server <https://data.epo.org/publication-server> or ordered from the Vienna sub-office upon payment of a fee (OJ EPO 2005, 126).

Until 31 December 2013, each proprietor may request in writing to receive the certificate for the European patent together with one copy of the new patent specification only if the request is filed within three-month or the additional two-month period (R. 95(3) and (4) EPC). If such request has been previously filed, it has to be confirmed within the same period. The requested copy is free of charge. Any request or confirmation of a request filed after 31 December 2013 or after expiry of these periods will not be dealt with and the certificate will be delivered without a copy of the new European patent specification (cf. Notice from the European Patent Office dated 16 July 2013 concerning communication of the certificate for a European patent, OJ 2013, 418).

4.1.3 Filing of translations in the Contracting States

As regards translation requirements prescribed by the Contracting States under Article 65(1) EPC, please consult the website of the European Patent Office

www.epo.org → Law & practice → Legal texts, National law relating to the EPC

www.epo.org → Law & practice → All Legal texts → London Agreement

In the case of a valid extension

As regards translation requirements prescribed by the Extension States, please consult the website of the European Patent Office

www.epo.org → Law & practice → Legal texts, National law relating to the EPC

Failure to supply a prescribed translation in a Contracting State or an Extension State may result in the patent being deemed to be void *ab initio* in the State concerned (Art. 65(3) EPC).

4.2 In case of 2.2 above

If the present communication under Rule 71(3) EPC is based on an auxiliary request and, within the time limit, you maintain the main request or a higher ranking request which is not allowable, the application will be refused (Art. 97(2) EPC).

If the Examining Division gives its consent to the requested amendments or corrections, it will issue a new communication under Rule 71(3) EPC; otherwise, it shall resume the examination proceedings (R. 71(6) EPC).

5. Filing of a divisional application

Any divisional application relating to this European patent application must be filed directly with the European Patent Office in Munich, The Hague or Berlin and will be in the language of the proceedings for the present application, or if the latter was not in an official language of the EPO, the divisional application may be filed in the language of the present application as filed (see Article 76(1) and Rule 36(2) EPC). Any such divisional application must be filed while the present application is still pending and the time limit for filing divisional applications must be observed (R. 36(1) EPC; Guidelines A-IV, 1.1.1).

6. Important notes concerning fee payments

6.1 For all payments, please refer to the relevant **fee code(s)**.

6.2 Automatic debiting procedure

The fee for grant, including the fee for printing (Art. 2(2) RFees), and any additional claims fees due under Rule 71(4) EPC will be debited automatically on the date of filing of the translations of the claims, or on the last day of the period of this communication. However, if the designation fee(s) become(s) due as set out in Rule 71a(3) EPC and/or a renewal fee becomes due as set out in Rule 71a(4) EPC, these should be paid separately by another permitted way of payment in order not to delay the publication of the mention of the grant. The same applies in these circumstances to the payment of extension fees. For further details see the Arrangements for the automatic debiting procedure (AAD) and accompanying information from the EPO concerning the automatic debiting procedure (Annexes A.1 and A.2 to the Arrangements for deposit accounts (ADA) in Supplement to OJ EPO 3/2009).

6.3 Important information relating to fee amounts

Following any amendment to the Rules relating to Fees, the amount(s) mentioned in this communication may be different from the amount(s) **actually due on the date of payment**. The latest version of the Schedule of fees and expenses, published as a Supplement to the Official Journal of the EPO, is also available on the EPO website (www.epo.org) and can be found under www.epo.org/schedule-of-fees, which allows the viewing, downloading and searching for individual fee amounts, both current and previous.

Please note that procedural fees are usually adjusted every two years, on even years, with effect from 1 April.

- 6.4 Payments by cheque** delivered or sent direct to the EPO are no longer accepted as from 1 April 2008 (see OJ EPO 2007, 626).

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EPO Form 2056
EPO Form 2906



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Annex to EPO Form 2004, Communication pursuant to Rule 71(3) EPC

Bibliographical data of European patent application No. 04 773 142.7

For the intended grant of the European patent, the bibliographical data are set out below, for information:

Title of invention:

- FUNKPAKETKOMMUNIKATIONSVERFAHREN UND FUNKPAKETKOMMUNIKATIONSVORRICHTUNG
- RADIO PACKET COMMUNICATION METHOD AND RADIO PACKET COMMUNICATION APPARATUS
- PROCEDE DE COMMUNICATION DE PAQUETS RADIO ET APPAREIL DE COMMUNICATION DE PAQUETS RADIO

Classification: INV. H04W74/08 ADD. H04W72/02

Date of filing: 09.09.2004

Priority claimed: JP / 09.09.2003 / JPA2003317100

Contracting States*
for which fees have
been paid: DE FR GB

Extension States*
for which fees have
been paid:

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*) If the time limit for the payment of designation fees according to Rule 39(1) EPC has not yet expired and the applicant has not withdrawn any designation, **all Contracting States/Extension States** are currently still deemed to be designated. See also Rule 71(8) EPC and, if applicable, the above Note to users of the automatic debiting procedure.

**) If two or more applicants have designated different Contracting States, this is indicated here.

1 The independent claims of the main request do not comply with the requirements of Article 84 EPC for the following reasons:

1.1 According to the description, page 4 and 5, the current application aims to overcome the problem incurring in the prior art when a station, which has been assigned a channel (CH#3) which happen to be idle, starts transmitting data packets in concomitance with the transmission of second station, which has been assigned a plurality of channels (CH#1, CH#2). Leakage from CH#3, when using MIMO at the receiver, could comprise transmission over CH#1 and CH#2. The invention, therefore, lies in preventing the further station, which is allowed to transmit on CH#3, to transmit data when CH#3 is idle in case a mandatory channel, e.g. CH#1, which has the highest priority among the channels, is busy.

While **claim 1** of the main request claims that transmission of data can happen only when the mandatory channel is idle, it **does not** claim that a further station refrains from transmitting data on a channel allocated to said station when said channel is idle in case the mandatory channel is busy.

This feature, disclosed i.a. on page 10, lines 14 and 15 of the description as published, is considered to be **essential** to the definition of the invention.

Since independent **claim 1** does **not** contain this feature, it does not meet the requirements of Article 84 EPC taken in combination with Rules 43(1) and (3) EPC that any independent claim must contain **all** the technical features essential to the definition of the invention.

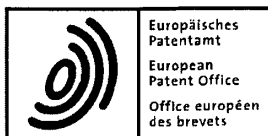
Similar considerations apply to the remaining **independent claims**.

1.2 The sentence "...*determined to be idle by carrier sense and MIMO*" used in **claim 1** is **not** clear, Article 84 EPC. In particular, it is not clear how a channel could be determined to be MIMO, as no steps are given in this regard.

Furthermore, MIMO is understood as a technology for transmitting/receiving data over a multitude of antennas and therefore channels. MIMO is not understood as being a channel.

Similar considerations apply to the remaining **independent claims**.

- 1.3 Finally, even if **claims 2 and 6** have been cast as independent claims, they actually depend, respectively, on **claims 1 and 5**, as they only add the feature of distinguishing between two stations to the feature combination of **claims 1 and 5**. The claims, therefore, do not comply with the requirements of Rule 43 (2) EPC.



Zahlung von Gebühren und Auslagen

EPO - München
81
01. Juli 2014

Europäisches Patentamt
Kassen- und Rechnungs-
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Deutschland
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Bitte nur Maschinenschrift verwenden

Name des Einzahlers

01 **HOFFMANN · EITLE**

Patent- und Rechtsanwälte

Zeichen des Einzahlers/Auftraggebers

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Anschrift

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D-81925 München

02

Zahlungsort

☐ Einzahlung/Überweisung¹

Bankinstitut des EPA

☒ Abbuchung vom beim
EPA geführten laufenden
Konto wird beantragt²

Nummer des laufenden Kontos

2800.0363

Anmeldenummer/Nr. des Patents (für jede Akte ein Formblatt)

03 **EP 04 773 142.7** **PCT** 03

	Kennziffer		Währung	Betrag
04	001	Anmeldegebühr – EP-Direktanmeldung ³	EUR	
05	002	Recherchegebühr	EUR	
06	005	Benennungsgebühr(en) ⁴	EUR	
07	015	Anspruchsgebühr(en) (Regeln 45(1), 162(1) EPÜ) ⁵	EUR	
08	055	Zusätzliche Kopie	EUR	
09	006	Prüfungsgebühr	EUR	
10	1	007 Erteilungsgebühr ⁶	EUR	915,00
11	2	008 Zusätzliche Druckkostengebühr für die Patentschrift (mehr als 35 Seiten) ⁷	EUR	30,00
12	033	Jahresgebühr für das 3. Jahr	EUR	
13	034	Jahresgebühr für das 4. Jahr	EUR	
14	035	Jahresgebühr für das 5. Jahr	EUR	
15	020	Anmeldegebühr – Eintritt in die EP-Phase ³	EUR	
16		Erstreckungsgebühr(en) für ⁸ :	EUR	
17			EUR	
18			EUR	
19			EUR	
20			EUR	
21			EUR	
22		Gesamtbetrag	EUR	945,00

Unterschrift **Dr. Matthias Kindler**

Ort, Datum **München, 01.07.2014**

Erläuterungen 1 - 8 siehe Rückseite.

ANSPRÜCHE

1. Funkpaketkommunikationsverfahren zum Übertragen von mehreren Funkpaketen aufweisend gleiche Paketzeidlängen gleichzeitig durch Anwenden mehrfacher Funkkanäle (Ch#1, Ch#2), die durch Carrier Sense und durch Anwenden von MIMO als leerlaufend befunden werden, wobei das Verfahren dadurch gekennzeichnet ist, dass es Folgendes aufweist:

Festlegen eines vorgeschriebenen Kanals unter mehreren Funkkanälen, der immer für eine Übertragung benutzt wird und unter den Funkkanälen, die mehrere Prioritäten aufweisen, die höchste Priorität hat;

Übertragen der Funkpakete durch Anwenden von Funkkanälen (CH#1, CH#2), die den vorgeschriebenen Kanal einschließen, nur wenn sich der vorgeschriebene Kanal im Leerlauf befindet; und

Unterlassen eines Übertragens von Funkpaketen durch eine andere Station auf einem Kanal (CH#3), der als leerlaufend bestimmt wird, wenn der vorgeschriebene Kanal besetzt ist.

2. Funkpaketkommunikationsverfahren nach Anspruch 1, aufweisend:

Unterscheiden einer STA A von einer STA A, die STA A ist für den vorgeschriebenen Kanal, die STA B für den nicht vorgeschriebenen Kanal festgelegt; und

wenn Funkpakete an die STA A adressiert sind, Übertragen der Funkpakete an die STA A durch Anwenden von Funkkanälen (Ch#1, Ch#2), die den vorgeschriebenen Kanal einschließen, nur wenn sich der vorgeschriebene Kanal im Leerlauf befindet; und

wenn Funkpakete an die STA B adressiert sind,
Übertragen der Funkpakete an die STA B durch Anwenden
von des leerlaufenden Kanals oder der leerlaufenden
Kanäle (Ch#1, Ch#2).

3. Funkpaketkommunikationsverfahren nach Anspruch 1 oder
2, dadurch gekennzeichnet, dass

die Paketzeitlänge einer Paketgröße oder einer
Übertragungszeit entspricht.

4. Funkpaketkommunikationsverfahren nach Anspruch 1 oder
2, dadurch gekennzeichnet, dass das Verfahren ferner
Folgendes aufweist:

gleichzeitiges Übertragen von Funkpaketen durch
selektives Anwenden der mehrfachen Funkkanäle (Ch#1,
Ch#2) oder von MIMO in Übereinstimmung mit einer
Anzahl von Datenteilen oder einer Anzahl von MIMO, die
von einem Kanalzustand abhängig ist.

5. Funkpaketkommunikationssystem zum Übertragen von
mehreren Funkpaketen aufweisend gleiche
Paketzeitlängen gleichzeitig durch Anwenden mehrfacher
Funkkanäle (Ch#1, Ch#2), die durch Carrier Sense und
durch Anwenden von MIMO als leerlaufend befunden
werden, wobei das System dadurch gekennzeichnet ist,
dass es Folgendes aufweist:

eine Einheit (23), die einen vorgeschriebenen Kanal
unter mehreren Kanälen festlegt, der immer für
Übertragung benutzt wird und die höchste Priorität
unter Funkkanälen hat, die mehrere Prioritäten haben,
und Übertragen der Funkpakete nur, wenn sich der
vorgeschriebene Kanal im Leerlauf befindet unter
Anwenden von Funkkanälen (Ch#1, Ch#2), die den
vorgeschriebenen Kanal aufweisen; und

eine Station, die ein Übertragen von Funkpaketen auf einem Kanal (Ch#3), der als leerlaufend befunden wird, nur wenn der vorgeschriebene Kanal besetzt ist.

6. Funkpaketkommunikationssystem nach Anspruch 5, aufweisend:

eine Einheit (23), die zwischen einer STA A und einer STA B unterscheidet und die Ziele der Funkpakete bestimmt, um an die STA A adressierte Funkpakete nur zu übertragen, wenn sich der vorgeschriebene Kanal im Leerlauf befindet, durch ein Anwenden von Funkkanälen (Ch#1, Ch#2), die einen vorgeschriebenen Kanal aufweisen, und zum Übertragen von an die STA B adressierten Funkpaketen durch Anwenden von einem leerlaufenden Funkkanal oder leerlaufenden Funkkanälen (Ch#1, Ch#2), wobei für die STA A der vorgeschriebene Kanal und für die STA B kein vorgeschriebener Kanal festgelegt ist.

7. Funkpaketkommunikationssystem nach Anspruch 5 oder 6, dadurch gekennzeichnet, dass

die Paketzeitlänge einer Paketgröße oder einer Übertragungszeit entspricht.

8. Funkpaketkommunikationssystem nach Anspruch 5 oder 6, dadurch gekennzeichnet, dass das Gerät ferner Folgendes aufweist:

eine Einheit, die gleichzeitig Funkpakete unter selektivem Anwenden der mehreren Funkkanäle (Ch#1, Ch#2) oder von MIMO in Übereinstimmung mit einer Anzahl von Datenteilen oder einer Anzahl von MIMO, die von einem Kanalzustand abhängig ist.

REVENDECATIONS

1. Procédé de communication de paquets sans fil permettant de transmettre une pluralité de paquets sans fil ayant des durées de paquet égales simultanément en
5 utilisant plusieurs canaux sans fil (Ch#1, Ch#2) déterminés comme étant inactifs par écoute de porteuse et en utilisant une technique MIMO, le procédé étant caractérisé en ce qu'il comprend le fait :

d'établir un canal obligatoire parmi plusieurs canaux
10 sans fil qui est toujours utilisé pour la transmission et présente la priorité la plus élevée parmi des canaux sans fil qui présentent une pluralité de priorités ;

de transmettre les paquets sans fil en utilisant des canaux sans fil (Ch#1, Ch#2) qui comportent le canal
15 obligatoire, uniquement lorsque le canal obligatoire est inactif ; et

d'empêcher la transmission des paquets sans fil par une autre station sur un canal (Ch#3) déterminé comme étant inactif, lorsque le canal obligatoire est occupé.

20 2. Procédé de communication de paquets sans fil selon la revendication 1, comprenant le fait :

de distinguer une STA A d'une STA B, la STA A pour laquelle le canal obligatoire est établi, la STA B pour laquelle aucun canal obligatoire n'est établi ; et

25 de transmettre, lorsque des paquets sans fil sont adressés à ladite STA A, les paquets sans fil à ladite STA A en utilisant des canaux sans fil (Ch#1, Ch#2) qui comportent le canal obligatoire, uniquement lorsque le canal obligatoire est inactif ; et

30 de transmettre, lorsque des paquets sans fil sont adressés à ladite STA B, les paquets sans fil à ladite STA B en utilisant un canal ou des canaux sans fil inactif(s) (Ch#1, Ch#2).

3. Procédé de communication de paquets sans fil selon
35 la revendication 1 ou 2, caractérisé en ce que

la durée de paquet correspond à une taille de paquet ou à un temps de transmission.

4. Procédé de communication de paquets sans fil selon la revendication 1 ou 2, caractérisé en ce qu'il comprend
5 en outre le fait

de transmettre simultanément des paquets sans fil de manière sélective en utilisant les plusieurs canaux sans fil (Ch#1, Ch#2) ou la technique MIMO en fonction d'un certain nombre d'éléments de données ou d'un certain nombre
10 de techniques MIMO qui dépend d'une condition de canal.

5. Système de communication de paquets sans fil destiné à transmettre une pluralité de paquets sans fil ayant des durées de paquet égales simultanément en utilisant plusieurs canaux sans fil (Ch#1, Ch#2) déterminés
15 comme étant inactifs par écoute de porteuse et en utilisant une technique MIMO, l'système étant caractérisé en ce qu'il comprend

une unité (23) établissant un canal obligatoire parmi plusieurs canaux sans fil qui est toujours utilisé pour la
20 transmission et présente la priorité la plus élevée parmi des canaux sans fil qui présentent une pluralité de priorités, et transmettant les paquets sans fil uniquement lorsque le canal obligatoire est inactif en utilisant des canaux sans fil (Ch#1, Ch#2) qui comportent le canal
25 obligatoire ; et

une station empêchant la transmission des paquets sans fil sur un canal (Ch#3) déterminé comme étant inactif, lorsque le canal obligatoire est occupé.

6. Système de communication de paquets sans fil selon
30 la revendication 5, comprenant

une unité (23) distinguant une STA A d'une STA B et déterminant des destinations des paquets sans fil de manière à transmettre des paquets sans fil adressés à ladite STA A uniquement lorsque le canal obligatoire est
35 inactif en utilisant des canaux sans fil (Ch#1, Ch#2) qui comportent un canal obligatoire, et à transmettre des

paquets sans fil adressés à ladite STA B en utilisant un canal ou des canaux sans fil inactif(s) (Ch#1, Ch#2), la STA A pour laquelle le canal obligatoire est établi, la STA B pour laquelle aucun canal obligatoire n'est établi.

- 5 7. Système de communication de paquets sans fil selon la revendication 5 ou 6, caractérisé en ce que

la durée de paquet correspond à une taille de paquet ou à un temps de transmission.

- 10 8. Système de communication de paquets sans fil selon la revendication 5 ou 6, caractérisé en ce qu'il comprend en outre :

- 15 une unité transmettant simultanément des paquets sans fil de manière sélective en utilisant les plusieurs canaux sans fil (Ch#1, Ch#2) ou la technique MIMO en fonction d'un certain nombre d'éléments de données ou d'un certain nombre de techniques MIMO qui dépend d'une condition de canal.

HOFFMANN · EITLE

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HOFFMANN · EITLE · Postfach 81 04 20 · D-81904 München

European Patent Office

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EPO - Munich
81

01. Juli 2014

Munich, July 1, 2014

Our Ref.: 110 895 b/mst

European Patent Application No. 04 773 142.7 - 1858

NIPPON TELEGRAPH AND TELEPHONE CORPORATION

This is in reference to the communication under Rule 71(3) EPC dated March 3, 2014:

1. We approve the text as enclosed to the Communication under Rule 71(3) EPC and request the grant of the patent on the basis of said text.
2. We herewith enclose the German and French translations of patent claims.
3. A deposit account debit order for the official fee is also enclosed.

Zur Kasse

945. €

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Please let us have a written confirmation indicating the requested correction.



Dr. M. Kindler
European Patent Attorney
(Association No. 151)

Encl.
deposit account debit order
translation of claims in German
translation of claims in French



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ALLEMAGNE

Date

17.07.14

Reference 110 895 a/jme	Application No./Patent No. 04773142.7 - 1854 / 1667480
Applicant/Proprietor NIPPON TELEGRAPH AND TELEPHONE CORPORATION	

Decision to grant a European patent pursuant to Article 97(1) EPC

Following examination of European patent application No. 04773142.7 a European patent with the title and the supporting documents indicated in the communication pursuant to Rule 71(3) EPC dated 03.03.14 is hereby granted in respect of the designated Contracting States.

Patent No. : 1667480
Date of filing : 09.09.04
Priority claimed : 09.09.03/JPA 2003317100

Designated Contracting States
and Proprietor(s) : DE FR GB
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This decision will take effect on the date on which the European Patent Bulletin mentions the grant (Art. 97(3) EPC).

The mention of the grant will be published in European Patent Bulletin 14/33 of 13.08.14.

Examining Division

Lastoria G

Volpato A

Pinilla-Ariza D



Registered letter
EPO Form 2006A 12.07 (10/07/14)

to EPO postal service: 11.07.14

ANMERKUNG ZUR ENTSCHEIDUNG ÜBER DIE ERTEILUNG
EINES EUROPÄISCHEN PATENTS (EPA Form 2006)

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NOTE RELATING TO THE DECISION TO GRANT A
EUROPEAN PATENT (EPO Form 2006)

1. **EPO Information Brochure "National law relating to the EPC"**
This brochure provides useful information regarding formal requirements and the steps to be taken before the patent authorities of the Contracting States in order to acquire rights in those states. Since the necessary steps are subject to change the latest edition of the brochure should always be used. Subsequent information is published in the Official Journal.
2. **Translation of the European patent application under Article 65(1) of the European Patent Convention**
Your attention is again drawn to the requirements regarding translation of the European patent specification laid down by a number of Contracting States under Article 65(1) EPC, to which reference is made in the communication under Rule 71(5) EPC. Failure to supply such translation(s) may result in the patent being deemed to be void "ab initio" in the State(s) in question. For further details you are recommended to consult the above-mentioned brochure.
3. **Payment of renewal fees for European patents**
Under Article 141 EPC "national" renewal fees in respect of a European patent may be imposed for the years which follow that in which the mention of the grant of the European patent is published in the "European Patent Bulletin". For further details you are recommended to consult the above-mentioned brochure.

REMARQUE RELATIVE A LA DECISION DE DELIVRANCE
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Cette brochure fournit d'utiles renseignements sur les conditions de forme requises et sur les actes à accomplir auprès des offices de brevet des Etats contractants aux fins d'obtenir des droits dans les Etats contractants. Etant donné que les actes indispensables sont susceptibles de modifications, il serait bon de toujours consulter la dernière édition de la brochure. Toute information ultérieure est publiée au Journal Officiel.
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Votre attention est de nouveau attirée sur l'obligation faite par certains Etats contractants, en vertu de l'article 65(1) CBE, de fournir une traduction du fascicule du brevet européen, à laquelle il est fait référence dans la notification établie conformément à la règle 71(5) CBE. Si la(les) traduction(s) n'est(ne sont) pas fournie(s), le brevet européen peut, dès l'origine, être réputé sans effet dans oet(ces) Etat(s). Pour plus de détails, nous vous renvoyons à la brochure susmentionnée.
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Reference 110 895 a/jme	Application No./Patent No. 04773142.7 - 1854 / 1667480
Applicant/Proprietor NIPPON TELEGRAPH AND TELEPHONE CORPORATION	

Transmission of the certificate for a European patent pursuant to Rule 74 EPC

The certificate for a European patent is herewith transmitted.

The European patent specification can be downloaded from the EPO publication server
<https://data.epo.org/publication-server/> (see OJ EPO 2005, 126).

Note:

A corrected title page of the European patent specification will be published, if the bibliographic data have been changed after completion of the technical preparations.

For the Examining Division





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Reference 110 895 a/jme	Application No./Patent No. 04773142.7 - 1854 / 1667480
Applicant/Proprietor NIPPON TELEGRAPH AND TELEPHONE CORPORATION	

Communication regarding the expiry of the time limit within which notice of opposition may be filed

You are hereby informed that on expiry of the nine-month time limit from the publication of the mention of the grant of European patent No. 1667480 no notice of opposition had reached the files.

The entry in the Register of European Patents will be automatically generated by the electronic data processing system.

For the Examining Division



EPPU 02: 13.08.14 1854