



MEDIUM ACCESS CONTROL

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The Problem of Medium Access

- ❑ **Multiple nodes may need to share a channel**
 - **Simultaneous communication not possible (?)**
- ❑ **MAC Protocols schedule communication among multiple senders**
 - **Aim to maximize number of communications**
 - **Aim to achieve fairness among all transfers**
- ❑ **Objectives:**
 - **Efficiency:**
 - **If single sender, it gets full capacity R**
 - **Fairness:**
 - **If N senders, each gets R/N**
 - **Simple**
 - **Decentralized**

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Outline

- ❑ **Coordinated Access Protocols:**
 - SDMA, TDMA, FDMA, CDMA

- ❑ **Random Access Protocols:**
 - Slotted ALOHA
 - CSMA/CD
 - MACAW

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COORDINATED ACCESS PROTOCOLS

SDMA, FDMA, TDMA, CDMA

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Coordinated Access Protocols

- ❑ Each host is “scheduled” to transmit
 - Goal: avoid excessive interference between simultaneous transmissions
- ❑ How to schedule?
 - SDMA (Space Division Multiple Access)
 - FDMA (Frequency Division Multiple Access)
 - TDMA (Time Division Multiple Access)
 - CDMA (Code Division Multiple Access)

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Space Division Multiple Access

- ❑ SDMA used for allocating a separated space to users
- ❑ Typical application:
 - Assigning an optimal base station to mobile phone
 - Almost never used in isolation
 - But in conjunction with FDM, TDM, or CDM
 - MAC algorithm could decide which base station is best, depending on available frequencies, slots, or codes.
- ❑ Infrastructure/Basis:
 - Cells and sectorized antennas
 - New: beam-forming antenna arrays
 - Can improve overall capacity of a cell
 - Optimal SDMA:
 - Infinitesimal beam-width, infinitely fast tracking ability
 - Unique channel, free from interference from all other users

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Frequency Division Multiple Access

- ❑ Assign a certain sub-frequency to a sender-receiver pair
 - Fixed or dynamic allocation
- ❑ Pure FDMA – permanent (radio broadcast)
- ❑ Combine with TDMA – frequency hopping
 - Sender and receiver agree on sequence of frequencies
 - ☺: Helps circumvent narrowband interference
 - Types:
 - Slow hopping – hopping slower than symbol rate (GSM)
 - Fast hopping (FHSS)

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Time Division Multiple Access

- ❑ TDMA – any scheme that controls TDM
 - Assign the sending frequency to a sender-receiver pair for a certain amount of time
- ❑ TDMA systems transmit in a “buffer-and-burst” manner
 - Transmission is non-continuous
 - Digital data and digital modulation must be used
 - FDMA systems can accommodate analog FM
 - Results in low battery consumption
 - Transmitter can be turned off when not in use (which is most of the time)
- ❑ Synchronization has to be achieved in the time domain
 - High synchronization and guard space overheads
- ❑ Fixed or dynamic allocation possible
- ❑ e.g., DECT

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Code Division Multiple Access

- ❑ **Main issues in CDMA:**
 - How to find good codes
 - How to separate signals from noise from other signals and environment
- ❑ **Good codes:**
 - Have good autocorrelation
 - Helps synchronize receiver with incoming data stream
 - But poor correlation with shifted chips
 - Helps tune out multi-path signals
 - Are orthogonal to other codes
 - Helps minimize interference
 - Provides protection against eaves-dropping

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CDMA: Power Control

- ❑ **Power Control:**
 - Each mobile within coverage area provides same signal level to base station receiver
 - To prevent stronger signals from raising the noise floor for weaker signals
- ❑ **Done by:**
 - Rapidly sampling the radio signal strength indicator (RSSI) levels of each mobile
 - Sending a power change command to the mobile
 - e.g., UMTS adapts power 1500 times per second!
- ❑ **Out-of-cell mobiles can still cause interference though**

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RANDOM ACCESS PROTOCOLS

ALOHA

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Random Access Protocols

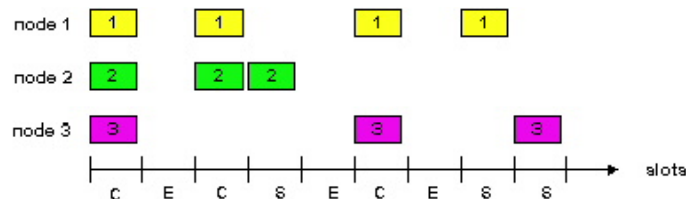
- ❑ **Characteristics:**
 - Each host randomly decides when to transmit
 - If two or more nodes transmit, collisions occur
 - Collisions detected by comparing signal with channel content
- ❑ **Random Access MAC protocol specifies:**
 - How to schedule communications
 - How to recover from collisions
- ❑ **Examples:**
 - ALOHA, Slotted ALOHA
 - CSMA, CSMA/CD, CSMA/CA

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Slotted ALOHA

- Time is divided into equal-sized slots
 - Nodes start to transmit frames only at beginning of slots
 - All frames are of same size; nodes are synchronized
- Operation:
 - Nodes transmit fresh frames in next slot
 - If no collision, nodes can send a new frame in next slot
 - If collision, node retransmits frame in subsequent slots with probability p (until success)



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Slotted ALOHA

- Pros:
 - Single active node can continuously transmit at full rate
 - Highly decentralized and simple
- Cons:
 - Collisions, wasting slots
 - Nodes must be able to detect collision in less than time to transmit packet
 - Clock synchronization needed
- Efficiency:
 - Suppose N nodes, each transmits in slot with prob p
 - prob that node 1 has success in a slot $= p(1-p)^{N-1}$
 - prob that any node has a success $= Np(1-p)^{N-1}$
 - For max efficiency with N nodes, find p that maximizes $Np(1-p)^{N-1}$
 - For large N , take limit of $Np(1-p)^{N-1}$ as $N \rightarrow \infty$, gives $1/e = .37$

At best: channel used for useful transmissions 37% of time!

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CARRIER SENSE MULTIPLE ACCESS

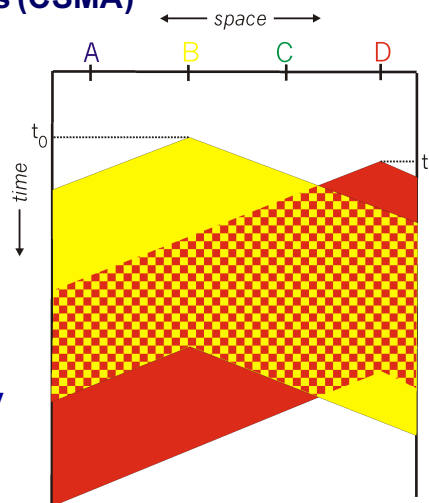
CSMA, CSMA/CD

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The Simple Fix: CSMA

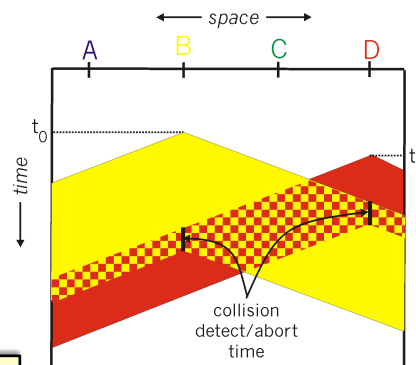
- ❑ Uninhibited first transmission in ALOHA
 - Plenty of collisions → poor throughput at high load
- ❑ Carrier Sense Multiple Access (CSMA)
 - Defer transmission when signal on channel
 - Listen before you talk
- ❑ Collisions can still occur
 - Non-zero propagation delay between transmitters
 - Entire packet transmission time wasted on collision
 - Distance (propagation delay) influence collision probability





CSMA/CD (Collision Detection)

- Keep listening to channel while transmitting
 - If (transmitted signal $\neq$ sensed signal)
 - ➔ sender knows collision has occurred
 - ➔ ABORT !
- Assumptions:
 - Transmitter can send/listen concurrently
 - The signal is identical at Tx and Rx
 - Non-dispersive



The TRANSMITTER can detect if and when collision occurs !

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**UNFORTUNATELY,
BOTH OBSERVATIONS DO NOT HOLD
FOR WIRELESS NETWORKS !**

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Energy Detection

- ❑ CSMA: listen-before-you-talk
 - Requires device to detect if media is *idle* or not
- ❑ Energy detection strategies:
 - Signal present, if square of periodically-sampled signal exceeds threshold
 - Carrier-sense approximation:
 - If received power < P_{CS} , channel idle
 - else, channel busy
 - Detect transition from idle-busy and vice-versa
 - Instead of detecting presence of signal
- ❑ Feature detection:
 - Detect a “well-known” waveform to know if transmission is taking place
 - Preamble

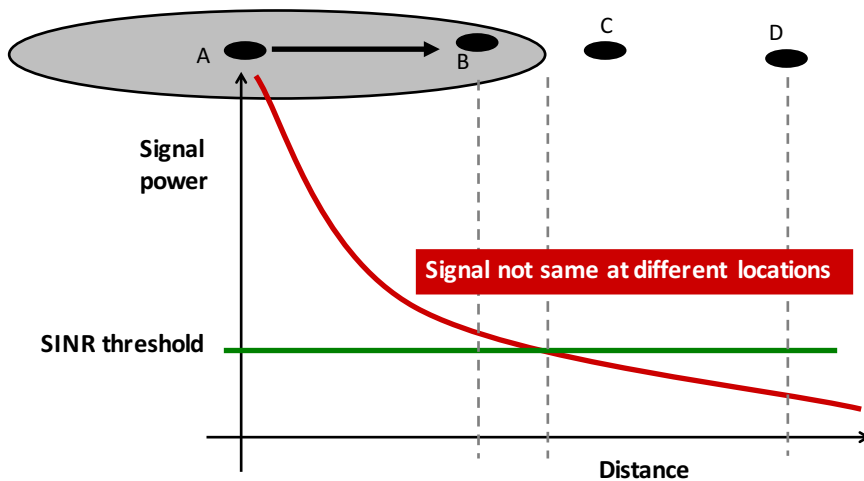
Energy vs. Feature detection: simplicity vs. accuracy

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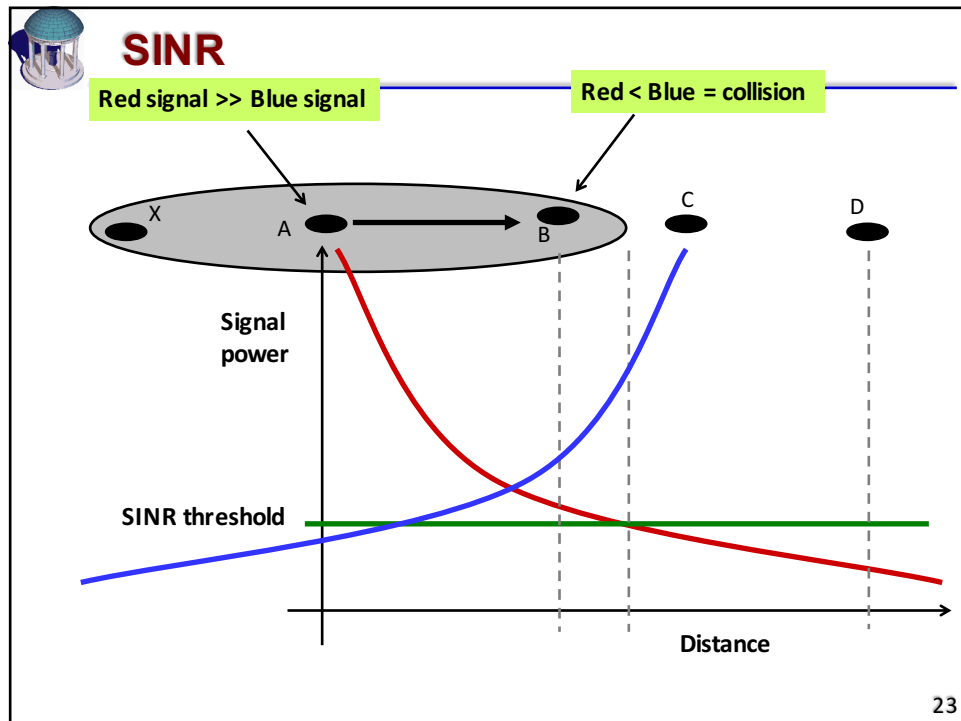


Wireless Media Disperse Energy

A cannot send and listen in parallel



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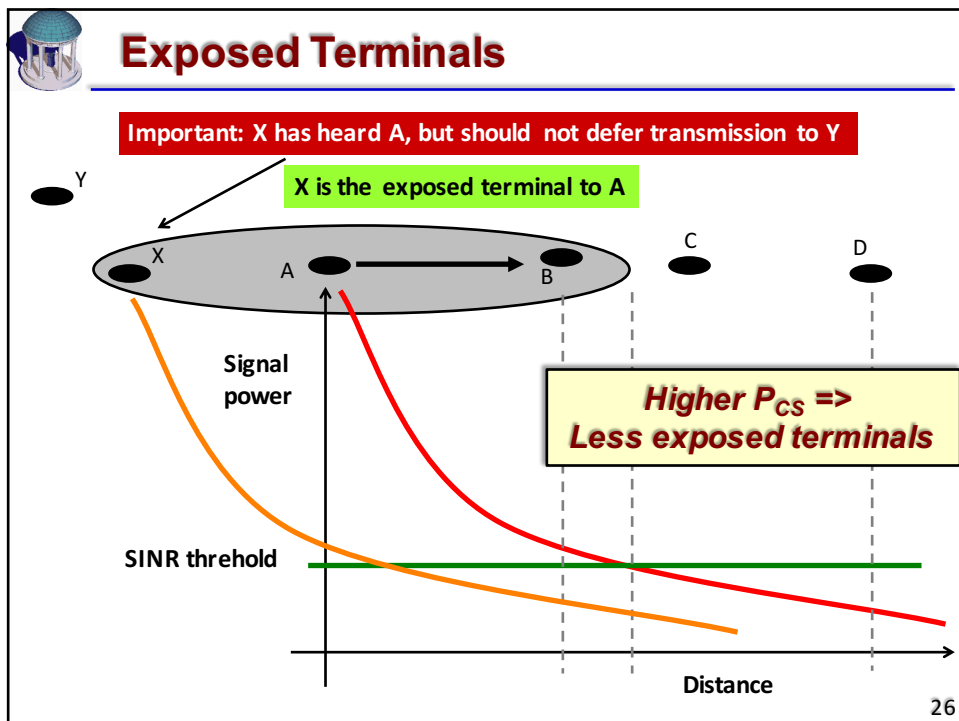
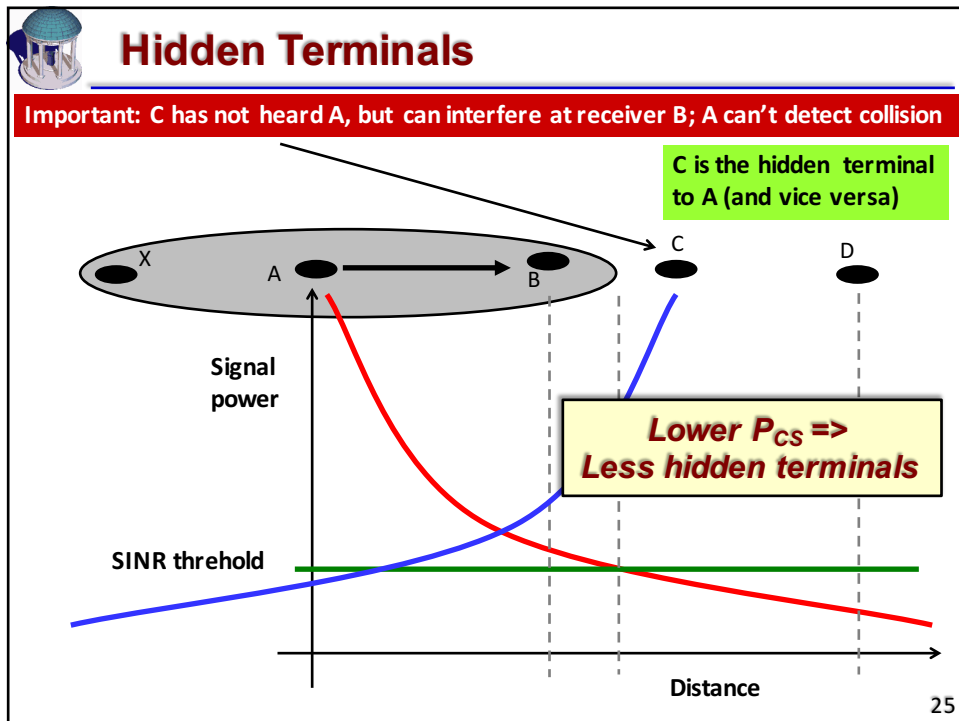


Collision Detection Difficult

- ❑ Signal reception based on SINR
- ❑ Receiving while transmitting:
 - Received signal dominated by transmitted signal
- ❑ Collision occurs at receiver, not the transmitter
 - Sender can not determine signal quality at receiver

Collision detection difficult at transmitter without feedback from receiver

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Hidden and Exposed Terminals

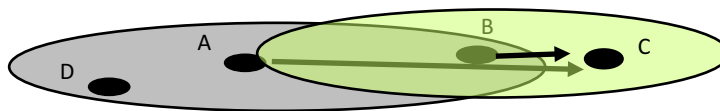
- ❑ Cannot eliminate all collisions using carrier sensing
- ❑ Trade-off between hidden and exposed terminals
 - Controlled by carrier sensing threshold, P_{CS}
- ❑ Optimal carrier sense threshold:
 - Function of network “topology” and traffic characteristics

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Near and Far Terminals

- ❑ Terminals A and B send, C receives
 - The signal of terminal B drowns out A's signal
 - C cannot receive A



- ❑ If C was an arbiter for sending rights, terminal B would drown out terminal A already on the physical layer
- ❑ Also severe problem for CDMA-networks – precise power control needed!

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