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1. Introduction

This paper discusses some aspects of the services provided by the LTE physical layer to higher layers, primarily Layer 2. Concluding on such “*physical-layer models*”, which correspond to the release 6 physical-layer models described in [1], is important in order to allow for work on LTE to progress at least partly independently between the different RAN working groups.

2. Physical layer model – *Downlink*

2.1. Downlink Shared Channel (DL-SCH) – *Single-layer transmission*

In [2], RAN1 has defined *Localized Virtual Resource Blocks* and *Distributed Virtual Resource Blocks* that can be seen as the basic downlink resource accessible to Layer 2 for transfer of transport blocks over the radio interface. The fundamental difference between localized and distributed virtual resource blocks is that localized resource blocks are mapped locally to the physical resource, i.e. to consecutive OFDM sub-carriers within one sub-frame, while the distributed resource blocks are mapped to distributed sub-carriers within one sub-frame. Localized resource blocks are typically targeting information transfers for which channel-dependent scheduling in the frequency domain is to be applied. On the other hand, distributed resource blocks are typically targeting information-transfer scenarios for which frequency diversity is desirable.

Each virtual resource block is assumed to be associated with a *Channel-Quality Indicator* (CQI) provided by Layer 1 to Layer 2 at the transmitter (Node B) side¹. The CQI can be used by Layer 2 e.g. for (channel-dependent) scheduling and transport-format decisions. For a given sub-frame, the CQI is typically different for different localized resource blocks (due to frequency-selective fading) but more or less the same for all distributed resource blocks (due to distribution in the frequency domain and the corresponding frequency diversity).

For each TTI, the scheduler selects a set of virtual resource blocks for transmission of a *single* transport block of *dynamic size* to a UE. Given the set of selected resource blocks, the size of the overall time/frequency resource available for transmission is given. Together with the transport-block size this gives the downlink *Transport Format* (modulation scheme and channel-coding rate including possible rate matching) used for the transmission of the transport block. Information about the resource allocation (the set of resource blocks selected) and the transport format, in essence the transport-block size, can be signaled out-band by means of a *Transport Format and Resource Indicator* (TFRI) together with Hybrid-ARQ-related information.

This leads to the UE physical-layer model of DL-SCH single-layer transmission outlined in [Figure 1](#). As mentioned below (Section 2.3), the physical-layer models for BCH and PCH, assuming specific BCH and PCH transport-channel types are defined, would be identical except that Hybrid-ARQ information would not be relevant in these cases. Alternatively, as also discussed in Section 2.3, no specific BCH and PCH transport-channel types are defined but the corresponding information is instead transmitted DL-SCH.

¹ It should be understood that this does not necessarily imply that one CQI per resource block is reported over the radio interface (from the UE to the Node). However it is assumed that, what-ever is being reported and how, Layer 1 at the Node B transforms this into a CQI per resource block which is then provided to Layer 2.

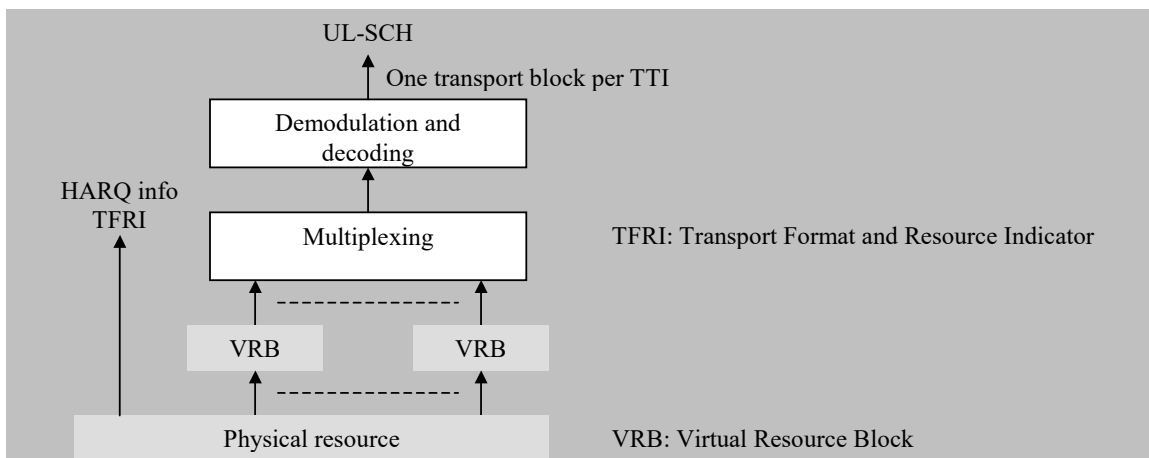


Figure 1 UE physical-layer model for *DL-SCH – Single-layer transmission*.
Physical-layer model for *BCH* and *PCH* is identical except that HARQ information is not used.

2.2. DL-SCH – Multi-layer transmission

DL-SCH multi-layer transmission implies that the same set of resource blocks are scheduled to the same UE on multiple layers. The same resource blocks cannot be scheduled to different users on different layers

Regarding mapping of transport blocks, two alternatives are currently under consideration in RAN1:

- A single transport block is transmitted over all layers. In this case, the physical-layer model will be identical to that of [Figure 1](#). The only difference to the single-layer case is that the available physical resource is expanded due to the presence of multiple layers.
- One transport block is transmitted per layer. Different transport formats (transport-block sizes) can be used for each layer. In this case, the physical-layer model of [Figure 1](#) needs so be expanded to cover also the multi-layer case. Furthermore, at least in this case it is assumed that there is one CQI available per layer.

2.3. Transport channels for paging messages and system information

From a Layer 1 point-of-view, paging messages ("PCCH") and system information ("BCCH") can be transmitted in the same way as data being transmitted using the DL-SCH or, more exactly, the physical-layer characteristics of transfer of paging messages and system information can be assumed to be a sub-set of the possible physical-layer characteristics of DL-SCH transmission. Thus one may question if there really is a need to define specific transport-channel types (PCH and BCH) for transmission of paging messages and system information or if these should be transmitted using the DL-SCH. Not having to define specific BCH and PCH transport-channel types would obviously lead to a simplified transport-channel structure.

2.4. Multi-cell transmission

Multi-cell transmission, including simultaneous transmission from multiple Node B, should be supported by E-UTRA, at least for broadcast/multicast user data. As this implies additional functionality compared to what is otherwise needed for DL-SCH transmission, one may consider if multi-cell transmission is better supported by means of a separate transport-channel type, rather than DL-SCH. Special characteristics of such a transport-channel type could then include:

- *Support for multi-cell transmission*
- *Scheduling decision made by a higher node than the Node B.*
- *No fast HARQ*
- *Potentially special reference-signal structure*
- *Potentially special scrambling (content-specific scrambling)?*

3. Physical layer model – Uplink

3.1. Uplink Shared² Channel (UL-SCH) – Single-layer transmission

The basic uplink resource made available to a UE for scheduled transfer of transport blocks over the radio interface is a certain frequency resource of a certain size during one sub-frame. For each TTI, the UE is scheduled (assigned) such an uplink resource to use for UL-SCH transmission. For each TTI, a *single* transport block of *dynamic size* is then transferred over the radio interface using the UL-SCH. The size in available modulation symbols of the scheduled uplink resource together with the size of the transport block determines the uplink *Transport Format* (modulation scheme and coding rate including possible rate matching) to be used for the transmission of the transport block.

As the Node B fully determines the UL-SCH physical resource, no uplink resource indication is needed in case of UL-SCH transmission. It remains to be decided if an explicit uplink transport-format indicator is necessary in case of UL-SCH transmission or if the uplink UL-SCH transport format should be fully determined by the Node B scheduling. If an uplink transport-format indicator is required, it can be signaled out-band together with Hybrid-ARQ-related information.

This leads to the physical-layer model of UL-SCH single-layer transmission outlined in Figure 2.

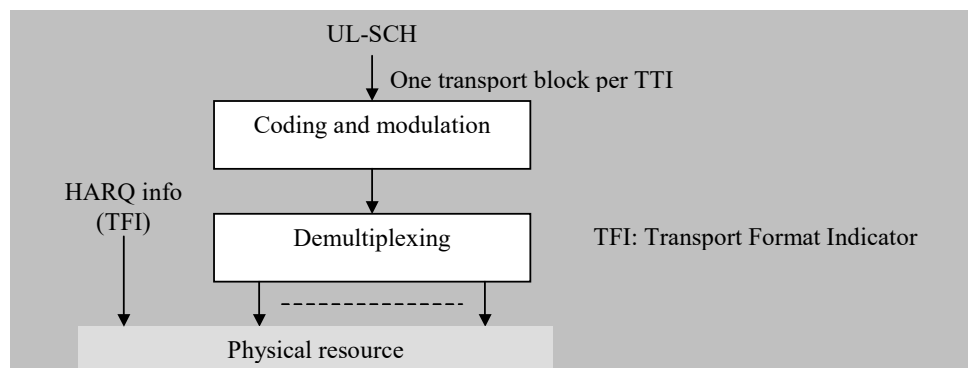


Figure 2 UE physical-layer model for UL-SCH – Single-layer transmission

3.2. UL-SCH – Multi-layer transmission

UL-SCH multi-layer transmission implies that the same uplink resource is scheduled to the same UE on multiple layers. Regarding mapping of transport blocks two alternatives are currently under consideration:

- A single transport block is transmitted over all layers. The physical-layer model of Figure 2 is then valid also for the multi-layer case.
- One transport block is transmitted per layer. Different transport formats (transport-block sizes) can be used for each layer. The physical-layer model of Figure 2 then needs to be expanded to cover also the multi-layer case.

Note that different UEs can be scheduled the same uplink resource on different layers, sometimes referred to as “Virtual MIMO”. However, also note that this would be invisible to the UE.

3.3. Non-scheduled uplink transmission and random access

Scheduled transmission should be the main mode-of-transmission for the E-UTRA uplink. However, non-scheduled (contention-based) transmission must also be supported. As a minimum, non-scheduled uplink transmission is needed for uplink scheduling requests, i.e. UE requests for uplink resource allocation. However, it is not yet clear if non-scheduled transmission of *transport blocks* should also be possible, i.e. if there is a need to define a non-scheduled uplink *transport channel* (a “*random-access transport channel*”). If a non-scheduled uplink transport channel is to be defined, the physical-layer model of Figure 2 should basically be applicable also in this case with the main difference being that a collision may occur for a non-scheduled transport channel. For non-scheduled transmission, a Transport Format Indicator would definitely be needed.

² It should be considered if Uplink *Shared* Channel is an appropriate name for this channel. What is “*Shared*” with it? Is e.g. Uplink *Scheduled* Channel a more appropriate name?

It should be noted that scheduled vs. non-scheduled transmission is not the same thing as synchronous vs. non-synchronous transmission. Uplink synchronization is required for uplink orthogonality, regardless if uplink transmission is scheduled or non-scheduled. Thus, in case the UE has lost uplink synchronization, uplink transport-channel transmission should be preceded by a random-access procedure that ensures uplink synchronization. Layer 2 should trigger a random-access procedure in this case. However, it is assumed that the random-access procedure itself does not imply any transport-block transfer over the radio interface. Instead any transport block is transmitted in a second step, either by means of scheduled or non-scheduled (transport) channel, see e.g. [2].

4. Summary

We have outlined proposals for the physical-layer models of E-UTRA DL-SCH and UL-SCH.

We have also suggested that no specific transport-channel types may be needed for PCCH and BCCH. Instead the BCCH and PCCH could be mapped to the DL-SCH, leading to a more simple E-UTRA transport-channel structure.

Furthermore we have suggested that a specific transport-channel type may be needed to support multi-cell downlink transmission, e.g. for multi-cell broadcast/multicast transmission.

Finally we have discussed some aspects of the physical-layer model for uplink non-scheduled transmission including the question if non-scheduled uplink transmission should only be applicable to L1/L2 control signaling such as scheduling requests or if non-scheduled transmission could also be used for transmission of transport blocks (need for a contention-based transport channel).

5. References

- [1] TS25.302 v6.5.0, "Services provided by the physical layer (Release 6)"
- [2] R1-060263, "TP for 25.814 on physical resource block size and allocation for DL"
- [3] R1-060584, "E-UTRA Random Access"