Nomor 3GPP Newsletter – 2007#08

Overview LTE PHY: Part 2 – LTE PHY Signals/Channels

Authors: Eiko Seidel, Volker Pauli

Overview

We will continue to introduce the latest decisions on LTE and familiarize you with the LTE terminology. This month's newsletter will explain the different existing LTE physical layer signals and control channels. Physical layer data channels are not yet presented in detail.

Downlink Physical Signals and Channels

- **Physical Signals**
  - Reference Signal, RS
  - Synchronisation Signal, SCH
- **Control Channel**
  - Physical Control Format Indicator Channel, PCFICH
  - Physical Downlink Control Channel, PDCCH
- **Data Channel**
  - Physical Downlink Shared Channel, PDSCH
  - Physical Multicast Channel, PMCH
  - Physical Broadcast Channel, PBCH

Uplink Physical Signals and Channels

- **Physical Signals**
  - Reference signal
    - Reference signals for coherent detection
    - Reference signals for channel sounding
  - Random Access Preamble
    - Separate presentation
- **Control Channel**
  - Physical Uplink Control Channel, PUCCH
- **Data Channels**
  - Physical Uplink Shared Channel, PUSCH
  - Physical Random Access Channel, PRACH

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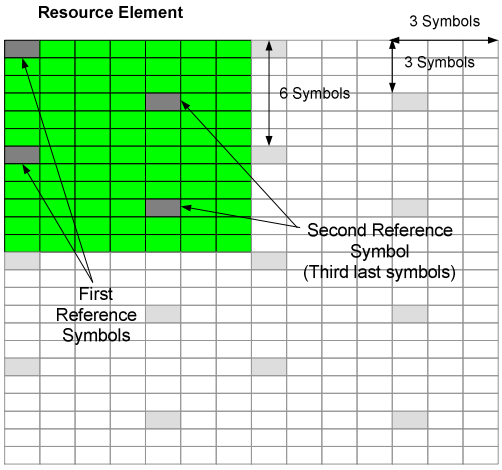
LTE DL Physical Signals

DL Reference Symbols (Pilots)

- Used for:
  - Cell search and initial acquisition
  - Channel estimation
  - Coherent detection
  - Channel-quality estimation



- First and second reference symbol shifted (frequency domain staggering)
- Interpolation and averaging across sub-frames optional
- Reference signals have different complex values of a sequence
- Different patterns per antenna for multi stream MIMO!
- Power Boosting
  - Power of the reference signal can be increased
  - Increase of coverage and reception quality
  - Signaling of RS Tx Power in P-BCH with 1 … 4 bits (for further study)

Reference Symbols in MIMO case

- Channel estimation per antenna required
- Reference signal needed per antenna
- Orthogonal reference signals between cells and fixed beams of the same Node B (corresponding REs of other antennas must be kept vacant)

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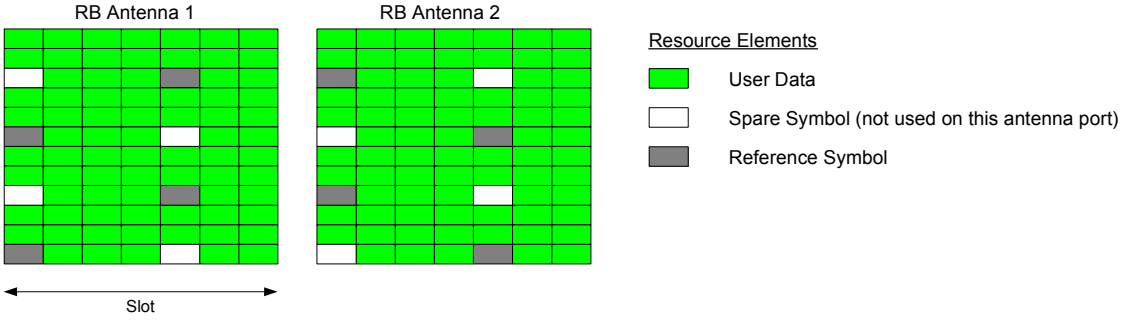
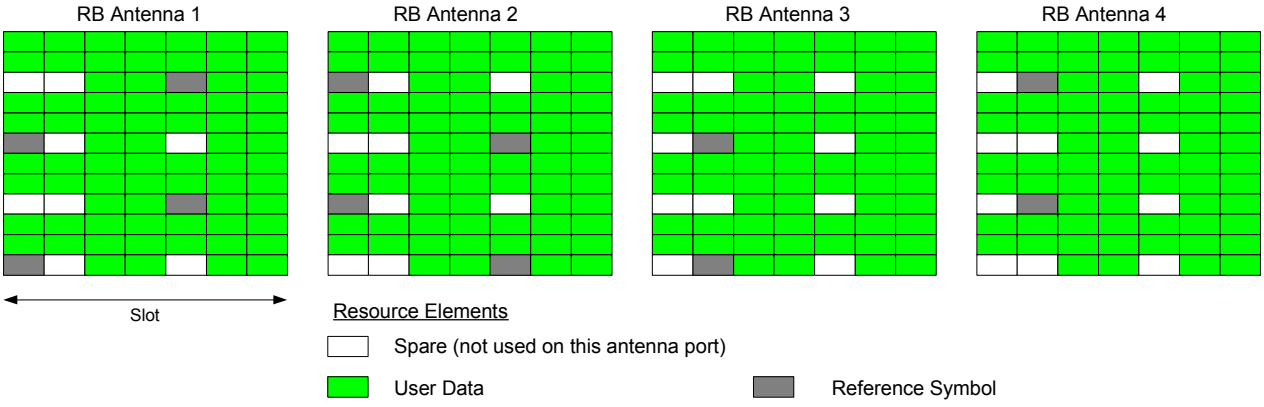
- **Two Antenna** reference signal structure:



- **Four Antenna** reference signal structure



- Overhead increases with number of antennas (1 = 5.5%; 2 = 11%; 3 = 16.7%).
- Less pilots are used on antenna 3 and 4 to reduce the overhead, therefore it is more difficult to track fast channel variations. However, 4 antennas are used for low-mobility terminals only, anyway.

Synchronization Signal (SCH)

- The SCH is located in the center band to be found by the UE independent of the bandwidth.
- It is used by the UE to find the carrier and the cell and to synchronize to it, to allow for reading the broadcast channel later on.
- SCH is sent twice per frame in subframe #0 and subframe #5.
- The SCH size is 6 resource blocks to get full frequency diversity in the smallest bandwidth allocation supported by LTE (1.25 MHz).

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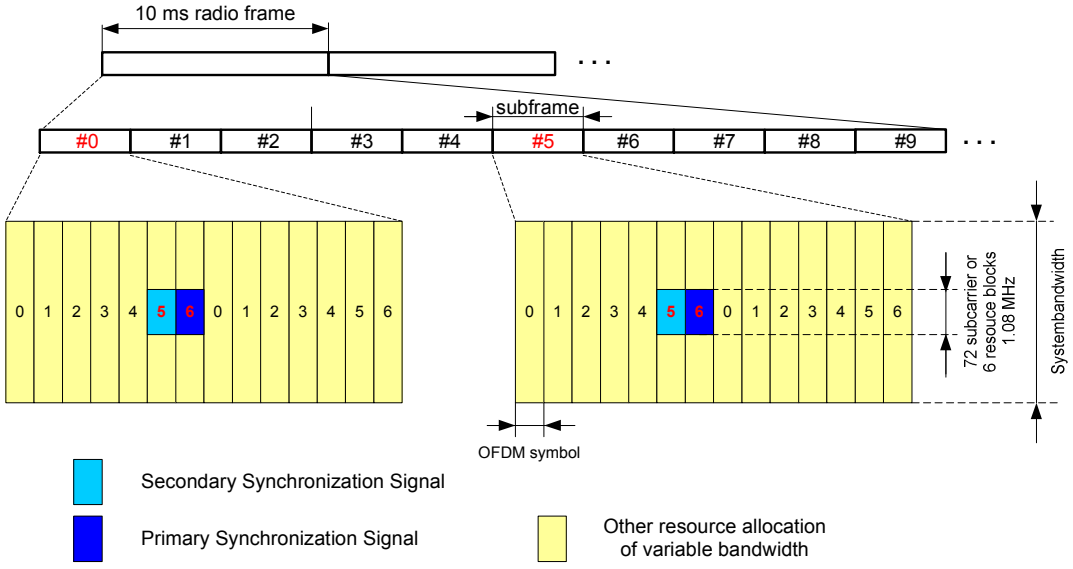
- There is a primary and a secondary Synchronization Channel (P-SCH, S-SCH) which are detected in sequence
- P-SCH, once detected, can be used for coherent detection of S-SCH.



Cell Search Procedure

- **Step 1: Find Primary SCH sequence**
- Obtain 5ms timing
- Three sequences specified to get cell identity
- **Step 2: Find Secondary SCH sequence**
- Sequence pair to obtain exact frame timing
- Obtain cell identity group
- Know also the reference signal sequence
- **Step 3: Read BCH**
- Obtain basic data as bandwidth, RACH parameter etc.

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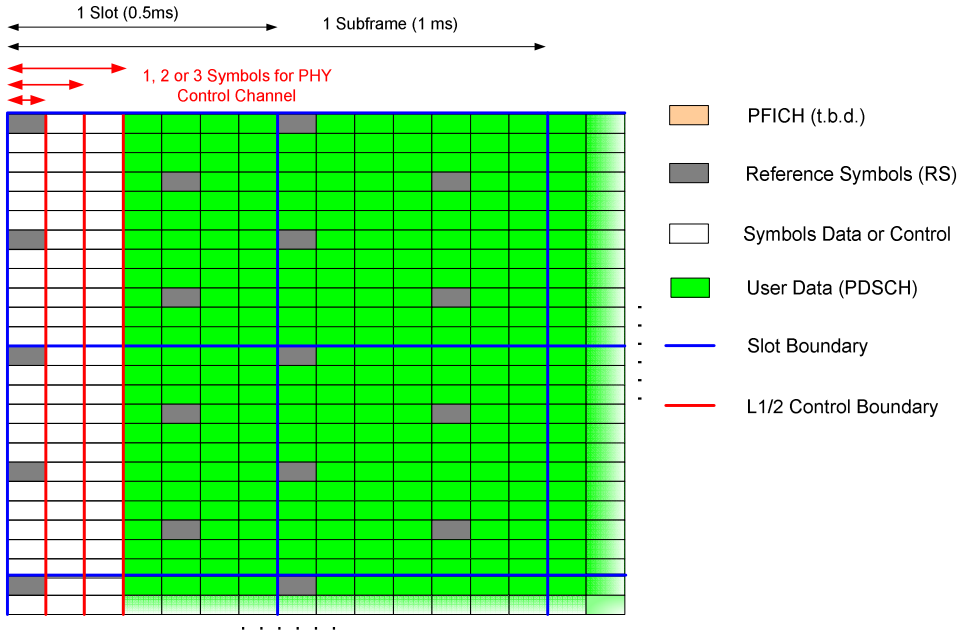
LTE Downlink Physical Control Channel

- Downlink physical control channels (PDCCHs) are transmitted in the first symbols of each sub-frame. The size is quite dynamic and mainly depends on the number of users being scheduled, the traffic behaviour (QoS, UL/DL asymmetry etc) and the system bandwidth. There is a PCFICH that signals the size and the format of the Control Channels, which has to be decoded before the Control Channels can be read.

Physical Control Format Indicator Channel, PCFICH

- Informs the UE about the number of OFDM symbols used for the PDCCHs (1, 2 or 3)
- Transmitted in every subframe
- Always in the first symbol
- No mix of PDCCH and PDSCH possible
- PCFICH mapped to 16 REs
    - Exact location is still to be decided, probably scattered over the frequency



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Physical HARQ Indicator Channel

- Existence just decided last meeting
- Format and location is still to be decided. Most likely some form of code division multiplex

Physical Downlink Control Channel, PDCCH

- The PCCCH contains all the information for the UE to decode the downlink transmission in the same sub-frame (Resource indicaton, Transport format (modulation scheme, TB size, etc), Downlink Hybrid ARQ information) and to know where and how to transmit in the uplink at the next time instance.
- Carries DL-CCH (Downlink Control Channel) also called “L1/2 Control Signalling”
- Located within first 3 OFDM symbol
- Number of PDCCHs is configurable
- Interleaving over the frequency band
- Allocate PCFICH and PHICH then allocate PDCCH
- Modulation QPSK, but different code rates possible

Working assumption for the **DL Scheduling Assignment and Resource Information**:

Field		Bits	Comment
General	RB assignment	?	Number of bits depends on the resource indication scheme selected (if necessary, includes any explicit info to handle distributed transmission)
	CRC	16-20	MAC ID implicitly encoded in the CRC. The MAC ID is 16 bits.
	TPC	2-4	Power control of PUCCH
First trans	Transport format	4-7	• Approach 1: signal MCS, compute transport block size from resource block assignment • Approach 2: signal transport block size index and modulation scheme, compute code rate and actual transport block size from resource block assignment (similar to HSDPA)

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port block	Hybrid ARQ process number	3-4 (FDD) max 4 (TDD)	Depends on the number of HARQ processes used, TDD may need a larger/smaller number than FDD for certain allocations different PDCCH sizes for FDD and TDD
	Retransmission sequence number (RSN)	2-3	• Approach 1: RSN (2bits) doubles as new data indicator (=0 indicates new data, >0 indicates retransmission) and redundancy version. • Approach 2: Separate new data indicator (1 bit) and redundancy version (2 bits)
Information needed for spatial multiplexing SU-MIMO support Information needed for MU-MIMO is FFS			
Second transport block (MIMO support)	Number of layers	0-2	1, 2, 3 or 4 layers (4 Tx eNodeB) or 1, 2 layers (2 Tx eNodeB) The need depends on the rank adaptation scheme adopted.
	Transport format	3-7	• Approach 1: signal MCS, compute transport block size from resource block assignment • Approach 2: signal transport block size index and modulation scheme, compute code rate and actual transport block size from resource block assignment (similar to HSDPA) • Approach 3: obtained relative to the transport format for the first code word
	Hybrid ARQ process number	0 - 4 (FDD) 0 or max 5 (TDD)	According to minutes from RAN1#47bis, there is full flexibility in mapping between HARQ process and codewords. The understanding of “full flexibility” was different between companies. To be considered if the process number could be derived from first transport block e.g. as in Rel-7.
	Retransmission sequence number (RSN)	0-3	• Approach 1: RSN (2bits) doubles as new data indicator (=0 indicates new data, >0 indicates retransmission) and redundancy version. • Approach 2: Separate new data indicator (1 bit) and redundancy version (2 bits)

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Working assumption for the **UL Scheduling Grant**:

Field	Bits	Comment
Format	0-1	Indicates UL or DL information. FFS if implicitly indicated.
RB assignment	$\lceil \log_2 (N_{RB}^{UL}(N_{RB}^{UL}+1)/2 \rceil$	Indicates the resource blocks the UE shall transmit upon.
CRC	16-20	MAC ID implicitly encoded in the CRC. The MAC ID is 16 bits.
Transport format	4-7	• Approach 1: signal MCS, compute transport block size from resource block assignment • Approach 2: signal transport block size index and modulation scheme, compute code rate and actual transport block size from resource block assignment (similar to HSDPA)
Retransmission sequence number (RSN)	1-3	• Approach 1: RSN (2bits) doubles as new data indicator (=0 indicates new data, >0 indicates retransmission) and redundancy version. • Approach 2: Separate retransmission indicator (1 bit) and possibly complemented by a redundancy version (2 bits)
TPC	Tentative range: 2-4	Power control of PUSCH
Cyclic shift for DMRS	0 or 3	The cyclic shift to used for generation of the demodulation reference signal (needed at least in case of spatial multiplexing). FFS if the field is always present or semi-static configuration is used to indicate presence/absence of this field.
UL index (TDD)		Used to indicate which uplink subframe(s) the grant is valid for. Necessary for TDD. The size may depend on the UL/DL allocation.

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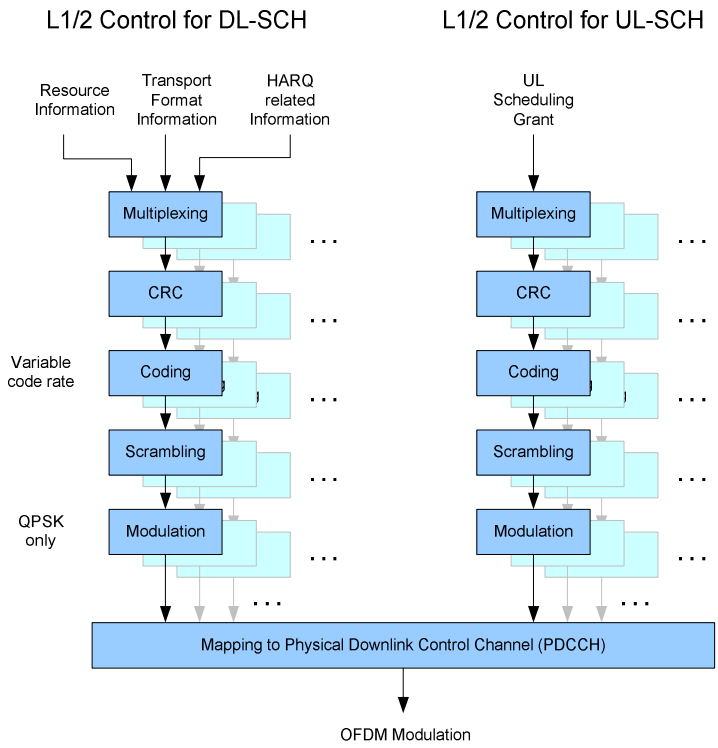
- DL Scheduling Assignment and Resource Information can be multiplexed unto the PDCCH in the following manner.



LTE UL Physical Signals

UL Reference Symbols (pilots)

- Transmission of pilots time multiplexed every 4th symbol
- Transmission over the entire Tx bandwidth
  - Frequency multiplexing not possible due to SC and PAR
- Specific *Cazac* (Constant Amplitude Zero-Auto-Correlation) sequences used, that are called *Zadoff-Chu* sequences
- Neighbor cells should use different sequences
- Sectors should use time shifted sequences
- No support of spatial multiplexing in UL

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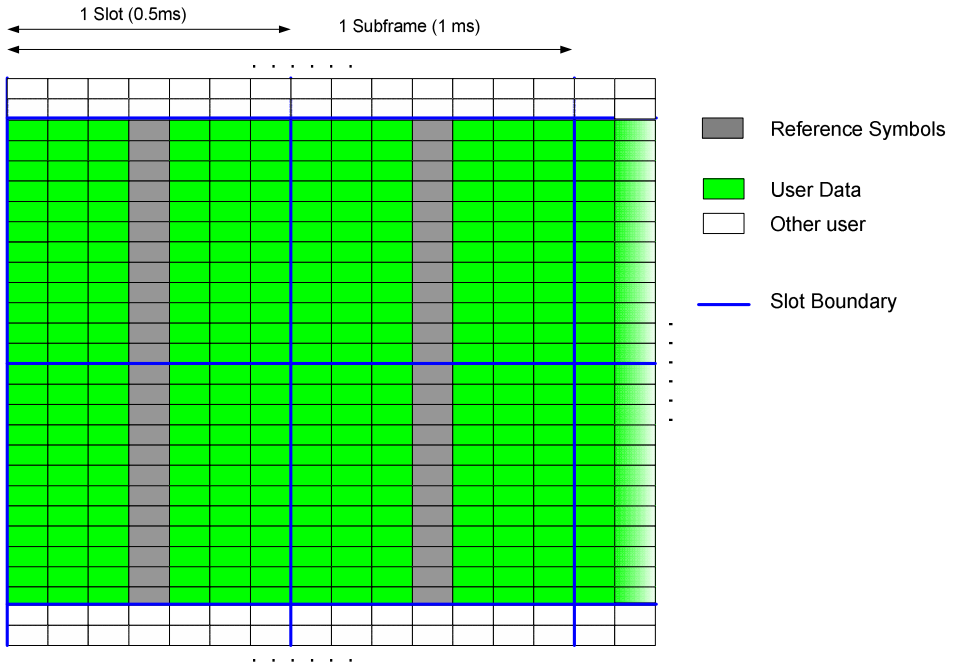

UL Sounding Reference Signal (SRS)

- Uplink channel estimation (as needed by the scheduler to assign uplink resources) is only possible at positions where the UE transmits in the time-frequency grid. To get knowledge about the missing parts or to stay synchronized in the UL the UE can transmit Sounding Reference Signals.
- Support of UL channel dependent scheduling
    - Reference signals only available in own tx band
- Also used by UEs having no UL transmission
    - Can also be used to stay UL sync
- Transmitted less frequently (e.g. once every subframe)
- Network explicitly assigns reserved blocks
- Multiplexing of channel sounding from multiple UEs
    - Time domain
    - Frequency domain
    - Cyclic shift of Zadoff-Chu sequences

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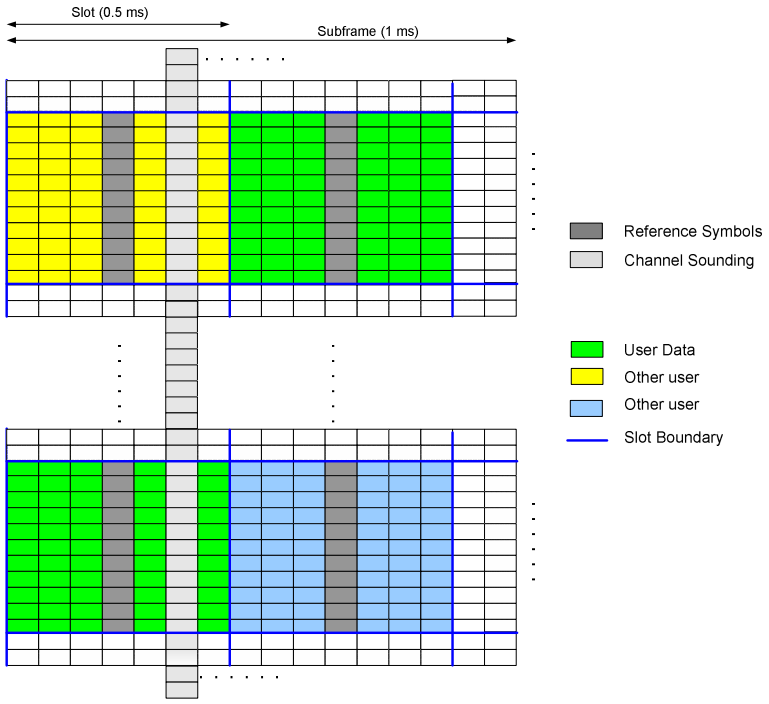

LTE UL Physical Control Channel

- Uplink control information mainly consists of uplink channel quality reporting and ACK/NACK indication for the related downlink transmission.
- The uplink transport format does not need to be signalled since everything has already been decided by the base station.
- No related HARQ information needs to be signalled in the uplink since synchronous HARQ is being used.

Control Channel Information multiplexed onto PUSCH

- Due to the single carrier constraint the user and control data must be transmitted jointly. So if there is uplink data transmission, the control information is multiplexed to the PUSCH, whereas the PUCCH does not existi.
- Control data will benefit from adaptive coding and modulation and there will be no resource fragmentation.
- Separate decoding should allow for independent processing to simplify processing.
- Same power must be used for control and data, but different coding might be applied.

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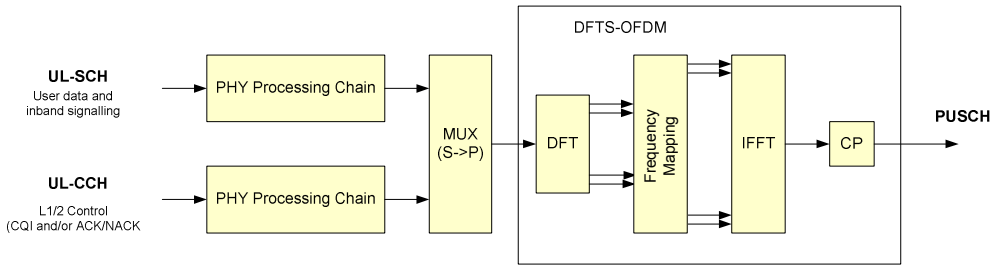
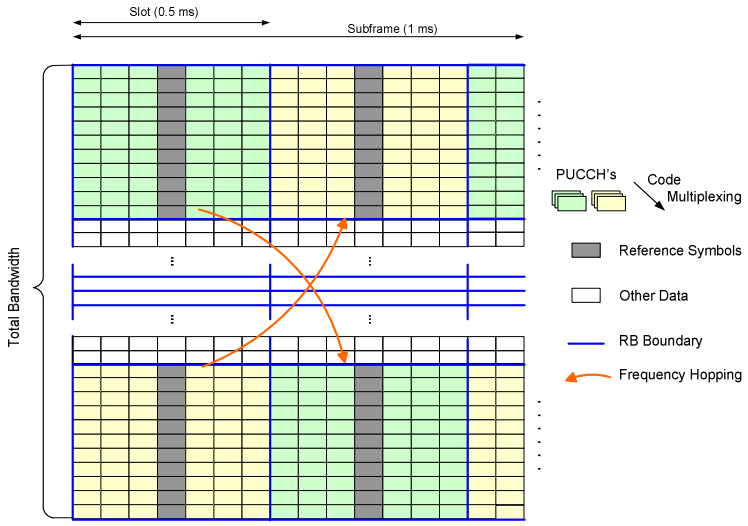
- Multiplexing of user and control data in the uplink:



Physical Uplink Control Channel (PUCCH)

- PUCCHs are specified in the following manner:



- PUCCH is defined by a code and two consecutive RBs
  - Code multiplexing by using orthogonal sequences
- Located at the edge of the total bandwidth
  - Prevent resource fragmentation
- Frequency hopping at slot boundary
  - Obtain maximum diversity
- PUCCH carries the following information
  - **HARQ ACK/NACK**

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- BPSK for 1 bit ACK/NACK
- QPSK for 2 bit ACK/NACK in case of 2 streams
- Repetition might be applied (FFS)

- **Channel Quality Indicator**
  - Needed per MIMO stream
  - 5 bits would allow an SINR range from -5dB to 25dB with 1dB granularity
- **Rank Index (RI) and Precoding Matrix Indication (PMI)**
  - RI and PMI also needed in case of MIMO. Size depends on the number of antennas and the scheme used. Example table by Qualcomm:

Bit Field	**Antenna Configuration (No.Tx x No. Rx)**	**Description**	**Bit Width**
RI	2x2	Rank 1 or 2	1
	4x2	Rank 1 or 2	1
	4x4	Rank 1 or 2 or 3 or 4	2
PMI (per rank)	2x2	3 precoders for rank 2 6 precoders for rank 1	2 for rank 2 3 for rank 1
	4x2	16 precoders per rank	4
	4x4	16 precoders per rank	4

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