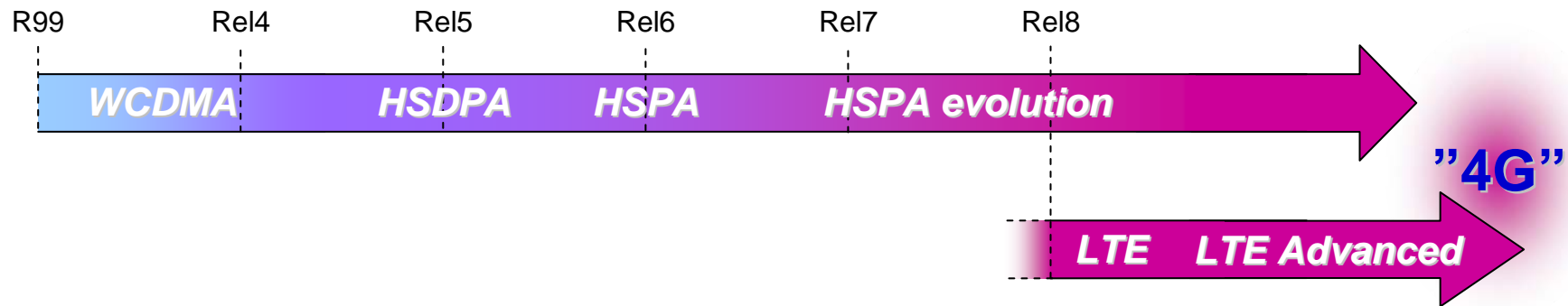


LTE – Long-Term Evolution

Stefan Parkvall

3G Evolution



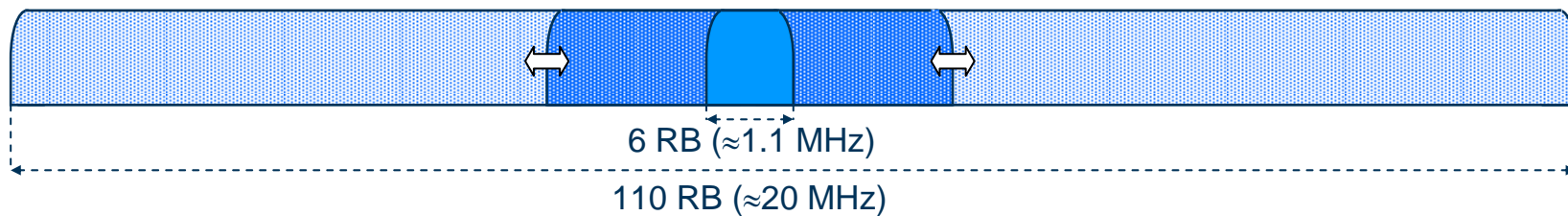
- HSPA evolution
 - gradually improved performance at a low additional cost *in 5MHz spectrum allocation*
- LTE
 - significantly improved performance *in a wide range of spectrum allocations*
 - further evolved into *IMT-Advanced*

LTE Key Features

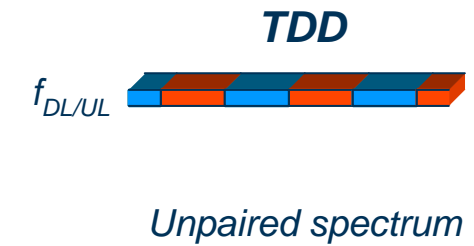
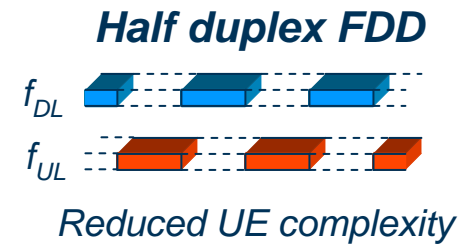
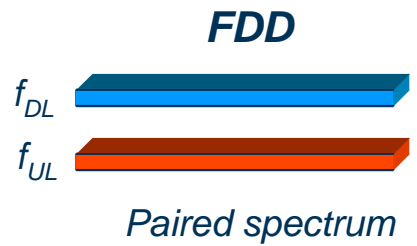
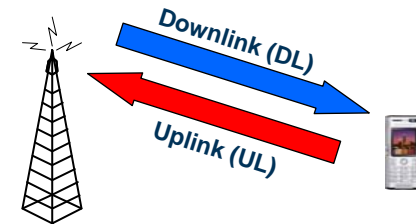


Bandwidth flexibility

- LTE physical-layer specification supports any bandwidth in the range 6 RBs to 110 RBs in steps of one RB (1 RB=12×15 kHz)



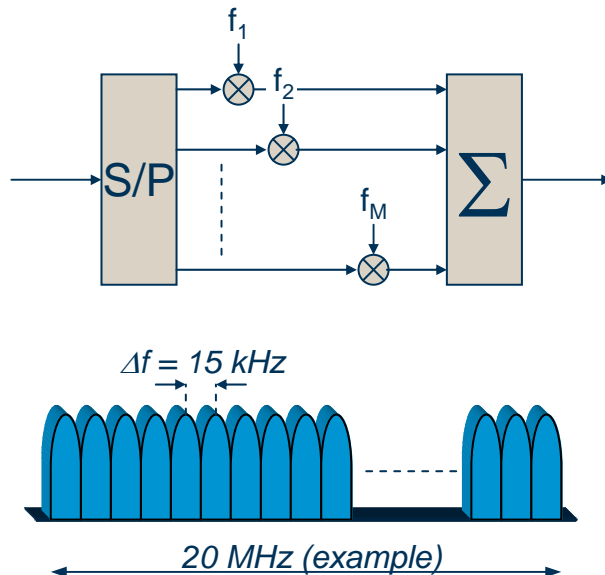
- Support for paired *and* unpaired spectrum allocations



Transmission Schemes

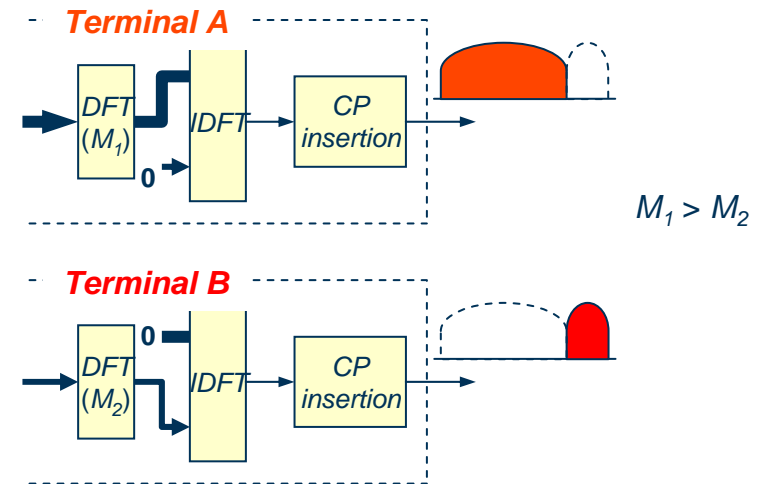
- Downlink – OFDM

- Broadcast, MIMO, ...
- Robustness, especially at high bandwidths
- Access to frequency domain



- Uplink – SC-FDMA

- Single-carrier
 - ➔ small PA back-off
 - ➔ improved coverage
- Scheduled TDMA/FDMA uplink
 - ➔ intra-cell orthogonality

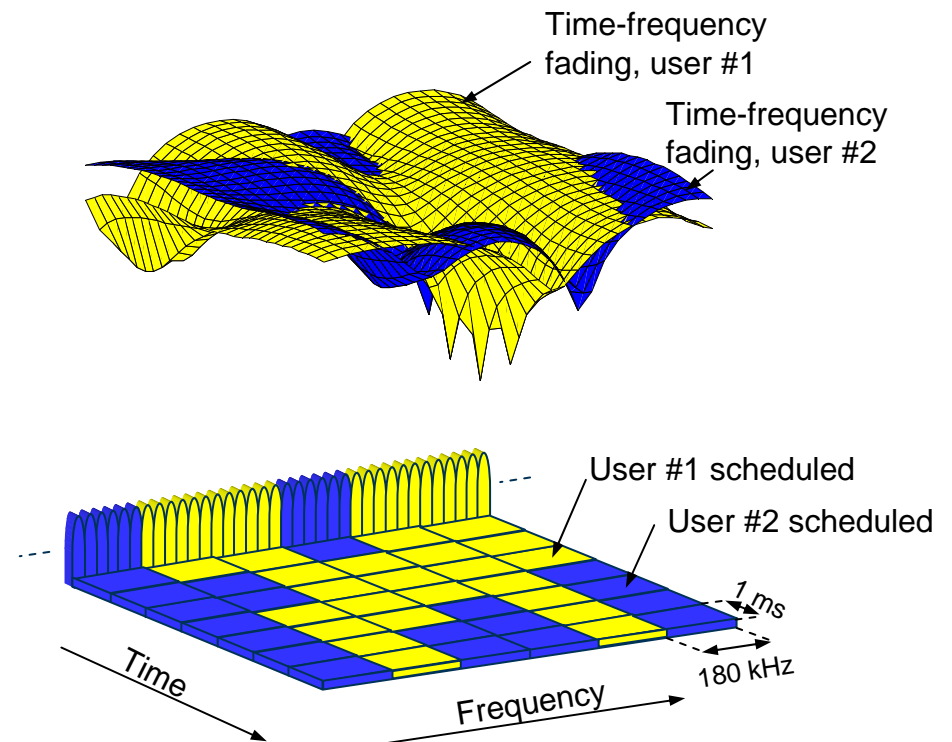


Channel-Dependent Scheduling

- Shared channel transmission
- Select user and data rate based on *instantaneous* channel quality
 - Time-domain adaptation used already in HSPA



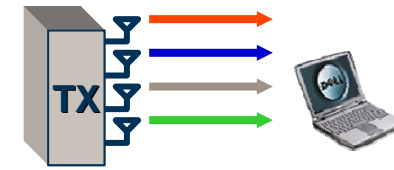
- Scheduling in time **and** frequency domain
 - Link adaptation in time domain only



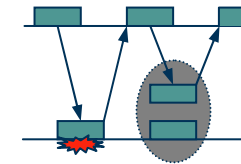
MIMO, HARQ, and MBSFN

Who said you were tired of abbreviations?

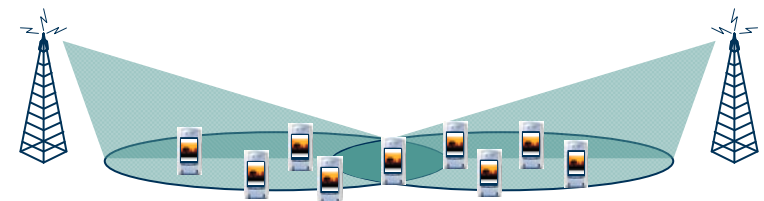
- Multi-antenna support
 - Integral part of LTE
 - All terminals support 2 Rx antennas
- Hybrid ARQ
 - Rapid retransmission, soft combining
 - 8 ms HARQ RTT
- MBSFN
 - Multicast-Broadcast Single-Frequency Network



Multi-layer transmission
("MIMO")

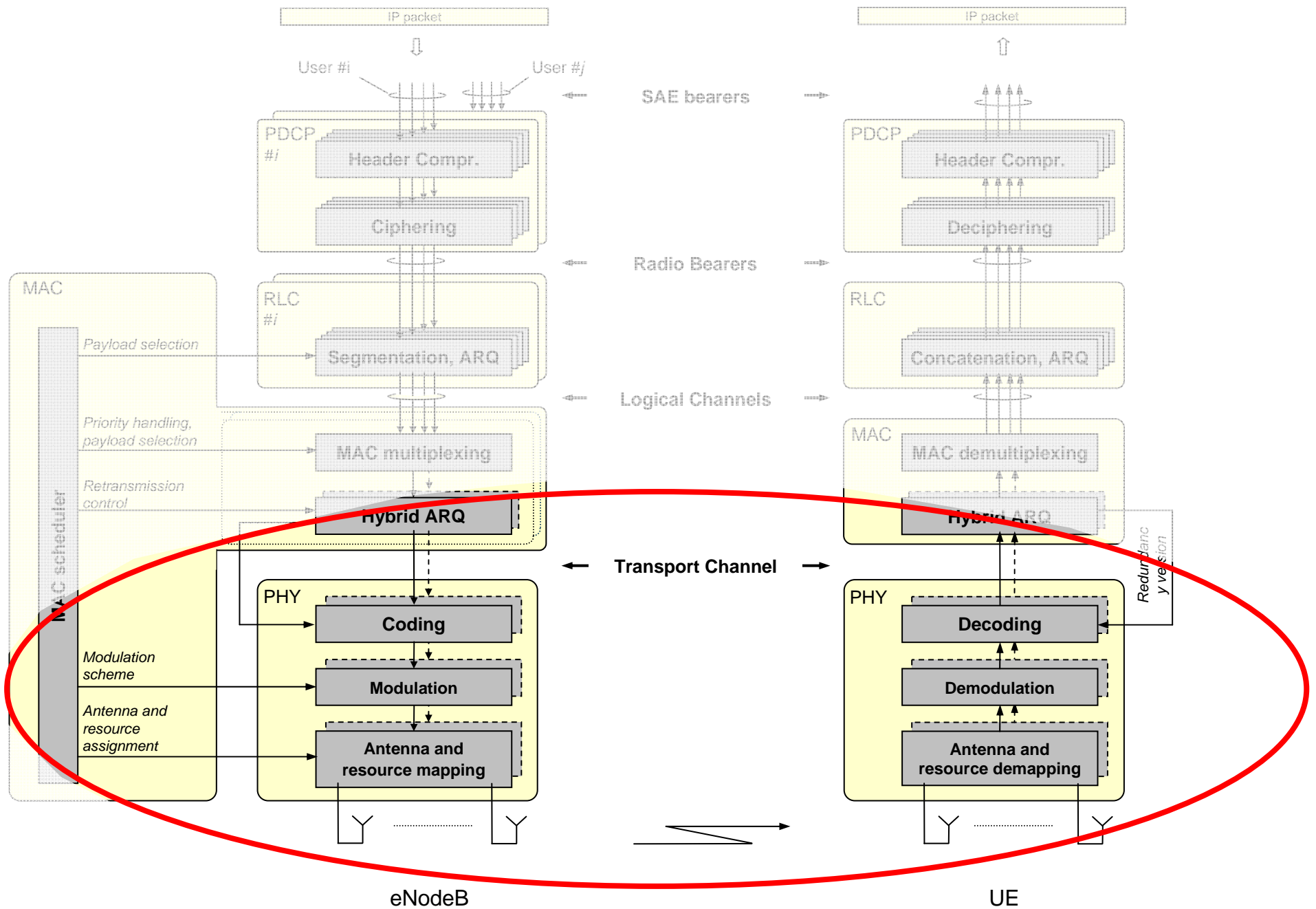


Fast Retransmissions
with Soft Combining



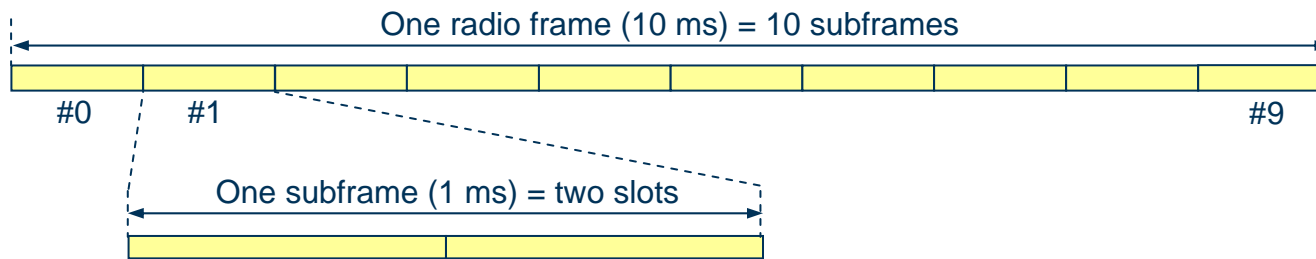
L1 Overview



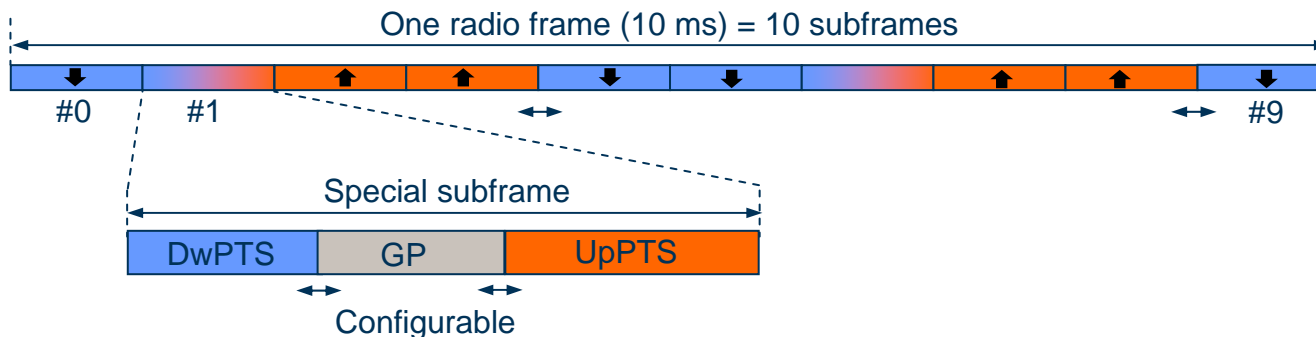


Time-domain Structure

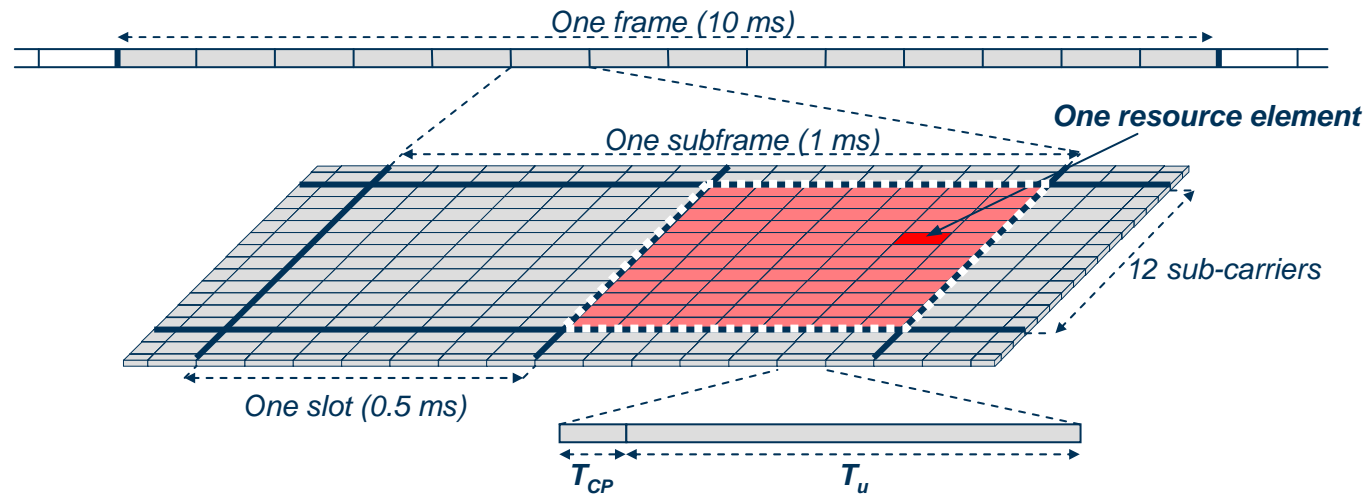
- Frame structure type 1 for FDD (full and half duplex)



- Frame structure type 2 for TDD
 - Similar to FS1...but with a special subframe for DL-to-UL switch



Physical Resources



- Time domain structure:
 - 10 ms frame consisting of 10 Subframes of length 1 ms
 - Each subframe consisting of 2 Slots of length 0.5 ms
 - Each slot consisting of 7 OFDM symbols (6 symbols in case of extended CP)

Downlink Processing

CRC insertion (16 bit for BCH, 24 bit for DL-SCH)

DL-SCH: Turbo w. QPP, extra CRC per code block
 BCH: tail-biting conv. code

Rate matching, redundancy version generation per code block, circular buffer

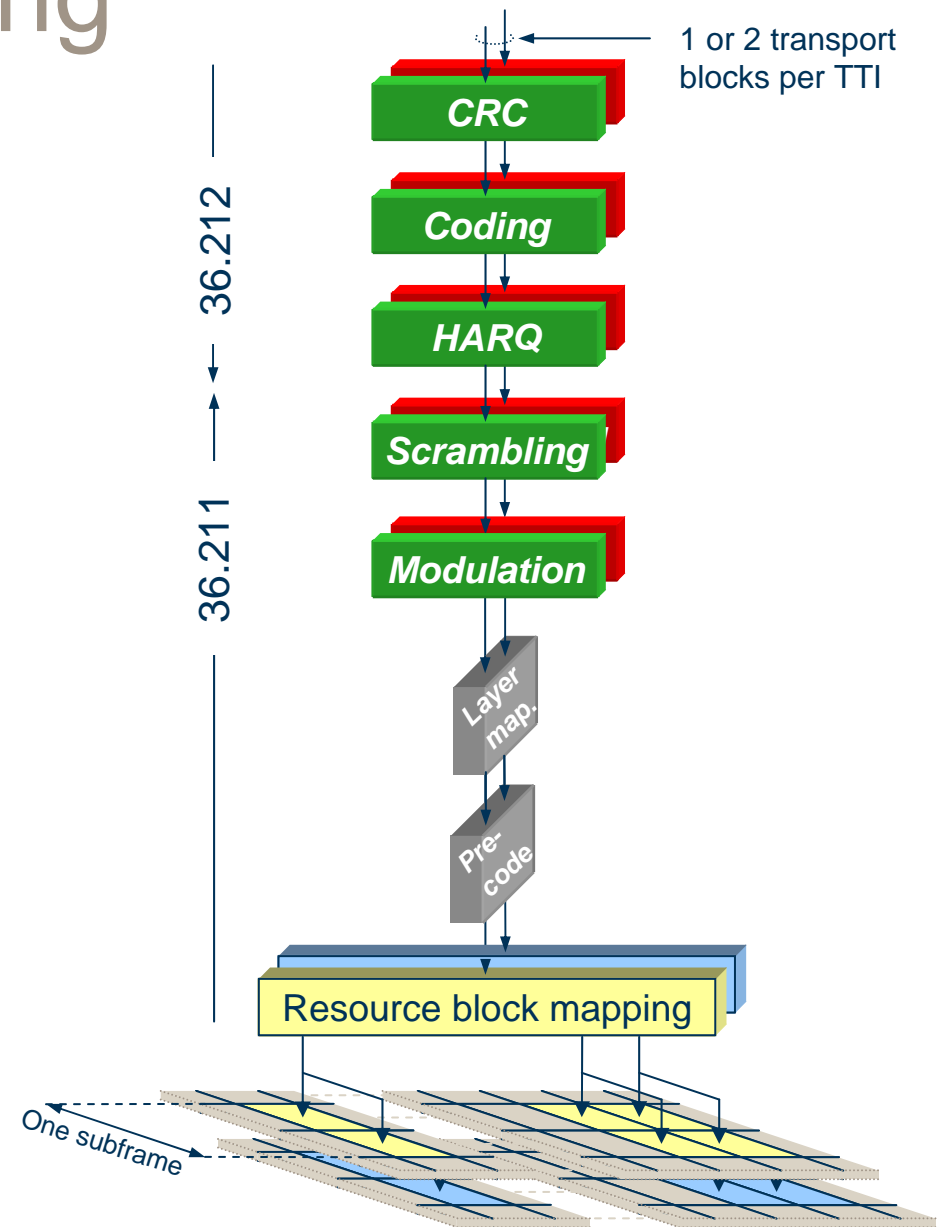
Transport-channel-specific scrambling using length-33 Gold sequences

Modulation (QPSK, 16QAM, 64QAM)

Mapping to transmission layers (for multi-layer transmission)

Precoding (for multi-rank transmission)

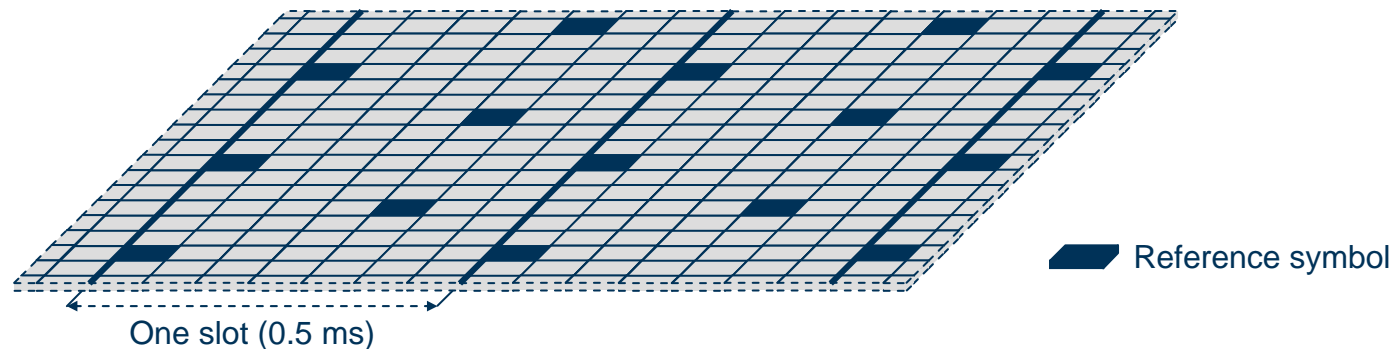
Resource block mapping



Cell-specific reference signals

Single-antenna transmission

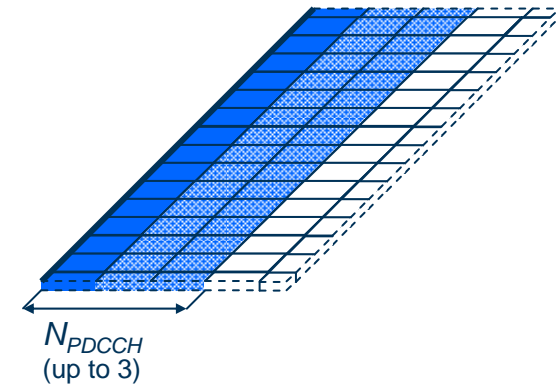
- Time-domain position: In OFDM symbol #0 and #4 of each slots
 - Symbol #0 and #3 in case of extended CP
- Frequency-domain position: Every 6th subcarriers
 - 3 subcarriers staggering between symbols



- 504 different *Reference Signal Sequences*
 - *Normal CP*: 168 Pseudo-random sequences × 3 Orthogonal Sequences
 - *Extended CP*: 504 Pseudo-random sequences
- PDSCH-to-RS EPRE different (but known) in RS and non-RS OFDM symbols

Downlink L1/L2 control signaling

- To support DL-SCH and UL-SCH transmission
- Mapped to first N_{PDCCH} OFDM symbols of each subframe
 - $N_{PDCCH}=1, 2, 3$ OFDM symbols
 - TDM of data and control → micro-sleep possible



- PCFICH – Physical Control Format Indicator Channel
 - Value of N_{PDCCH}
- PHICH – Physical Hybrid ARQ Indicator Channel
 - ACK/NAK of uplink transmission
- PDCCH – Physical Downlink Control Channel
 - Scheduling assignments, scheduling grants, ...

UL-SCH Processing

- UL-SCH processing similar to DL-SCH

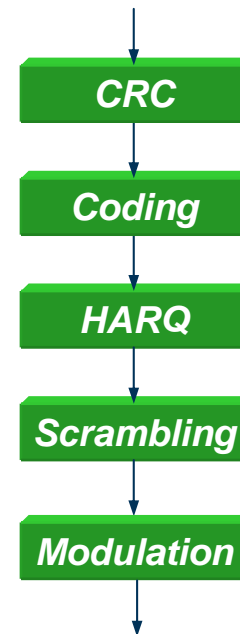
CRC insertion (24 bits)

Rel 6 Turbo coding (with QPP interleaver)

Rate matching, redundancy version generation

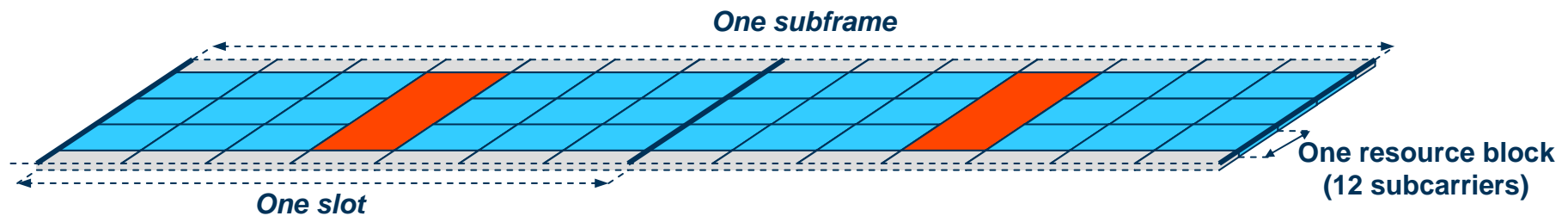
UE-specific scrambling for interference randomization

Modulation (QPSK, 16QAM, 64QAM)



To DFTS-OFDM modulation,
including mapping to assigned
frequency resource

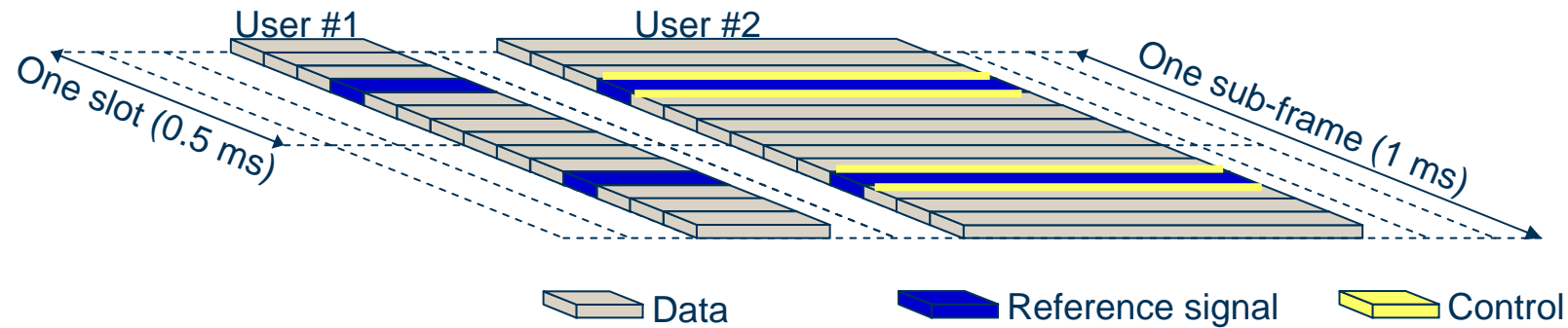
PUSCH DM RS



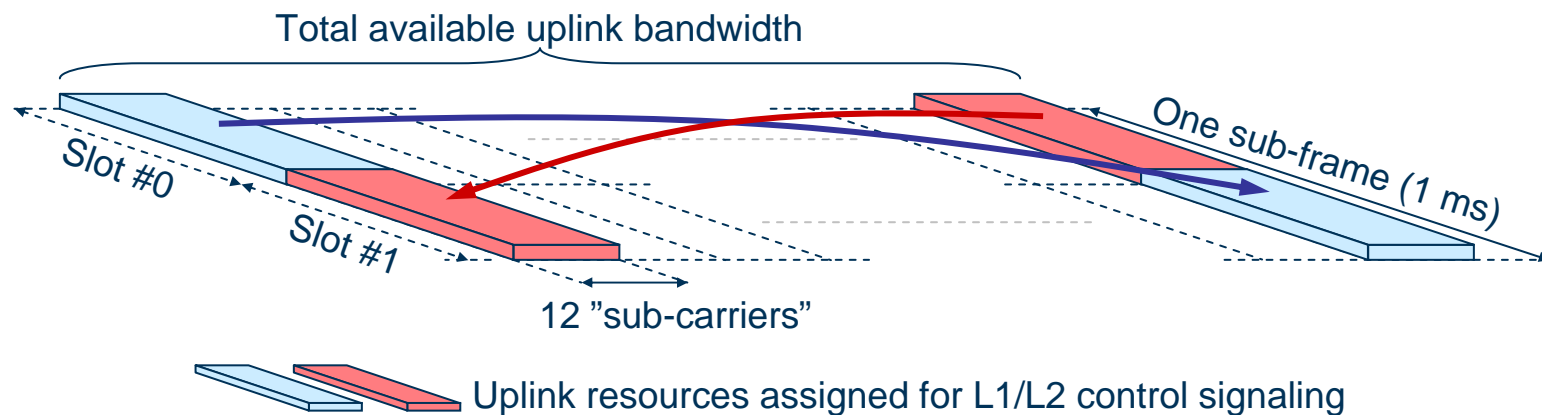
- One reference-signal symbol per slot (*two per subframe*)
 - In DFTS-OFDM symbol #3
- RS bandwidth equals uplink resource-allocation size
 - $N_{RB} = 3$ in example above

Uplink Control Signaling

- Control on PUSCH (simultaneous data and control)

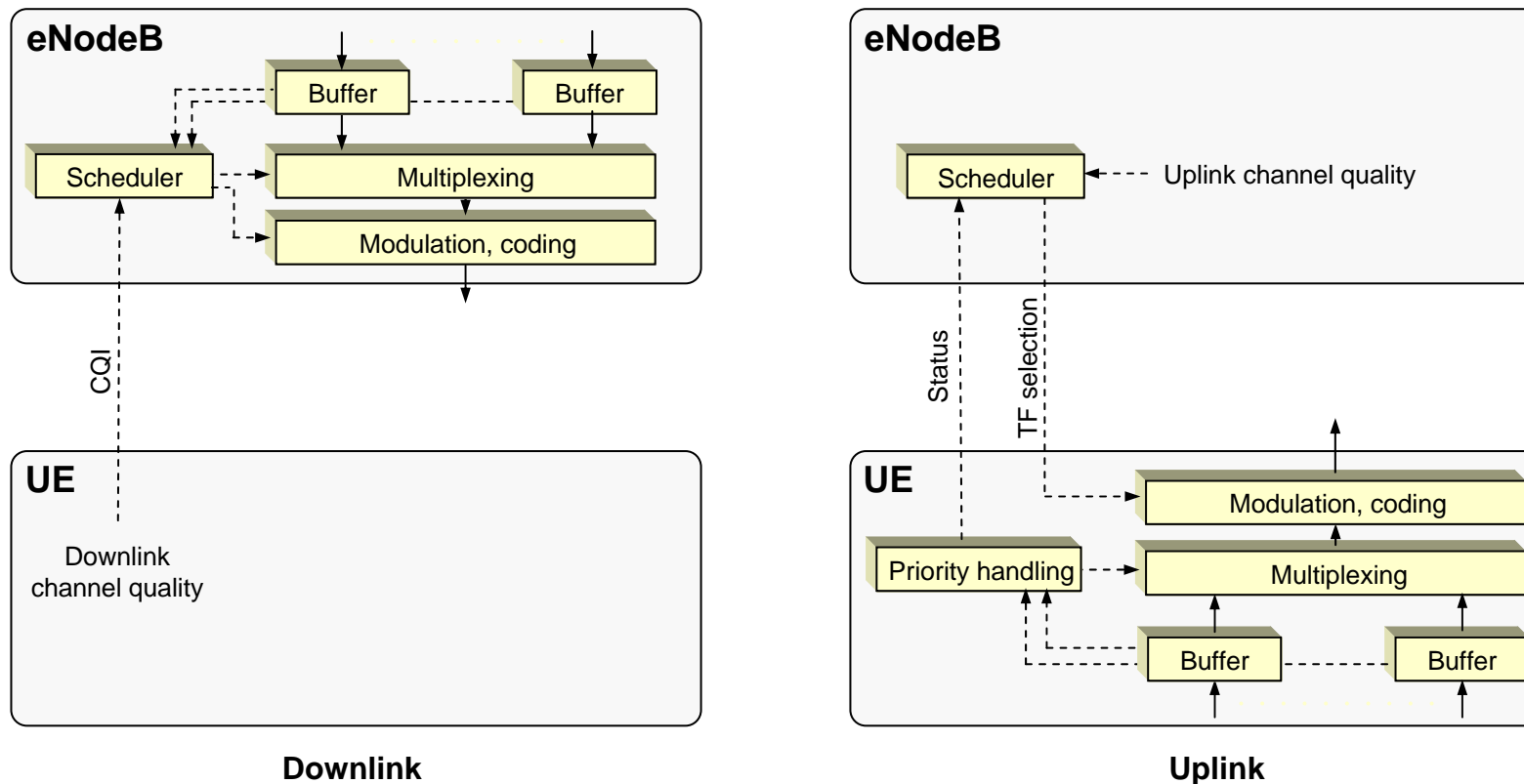


- Control on PUCCH (control only)



Uplink Scheduling

- Uplink transport format *controlled by eNodeB*
 - No TFC selection in the UE



UE Categories

Category	1	2	3	4	5
DL peak rate	10	50	100	150	300
UL peak rate	5	25	50	50	75
Max DL mod	64QAM				
Max UL mod	16QAM	?	?	?	64QAM
Layers for spatial mux.	1	2		?	4

- All UEs support 4 Tx antennas at eNodeB
- Soft buffer sizes under discussion
- MBMS is a separate capability
- FDD, HD-FDD and TDD are independent capabilities

Work in 3GPP

Standardization

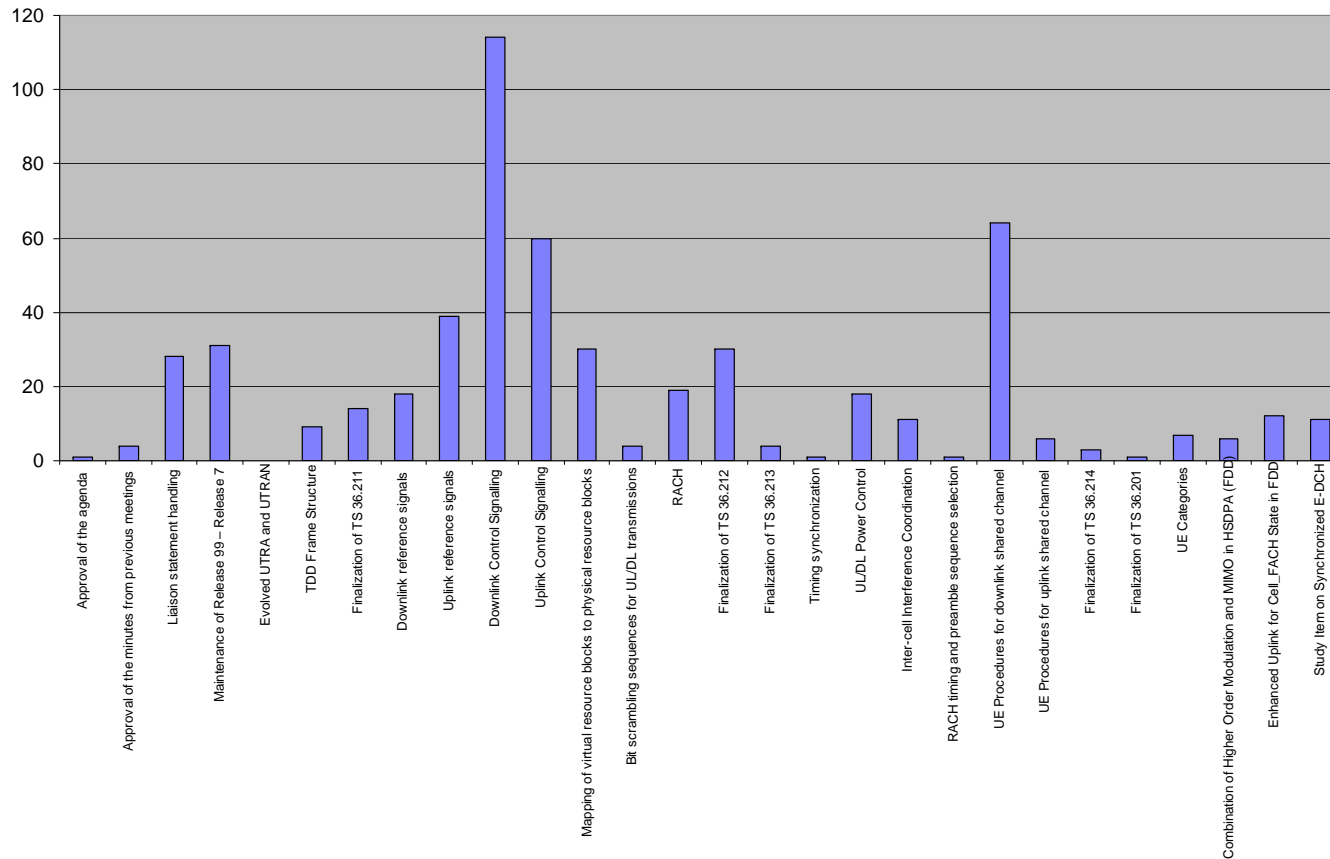
- RAN1 meetings held ~8 times a year
 - Meetings run from Monday to Friday
 - Held in various countries in Europe, North America, and Asia

- Meeting schedule 2007
 - January 15-19, Sorrento, Italy
 - February 12-16, St Louis, USA
 - March 26-30, St Juliens, Malta
 - April 17-20, Beijing, China
 - May 7-11, Kobe, Japan
 - June 25-29, Orlando, USA
 - August 20-24, Athens, Greece
 - October 8-12, Shanghai, China
 - November 5-9, Seoul, Korea

Typical RAN1 Meeting

- Approx 200 delegates attending and ~550 documents submitted...

Number of Contributions per Agenda Item



3GPP Status

- LTE (Rel-8) almost completed
- L1 specifications frozen and under change control
 - Only "bug fixes" possible
- Higher layers will mostly be frozen in March 2008
- Around 3 years in 3GPP to complete LTE Core Specifications
 - Study item approved late 2004
 - Study item completed September 2006
 - Detailed specifications (work item) ready late 2007/early 2008

Taking You Forward...

