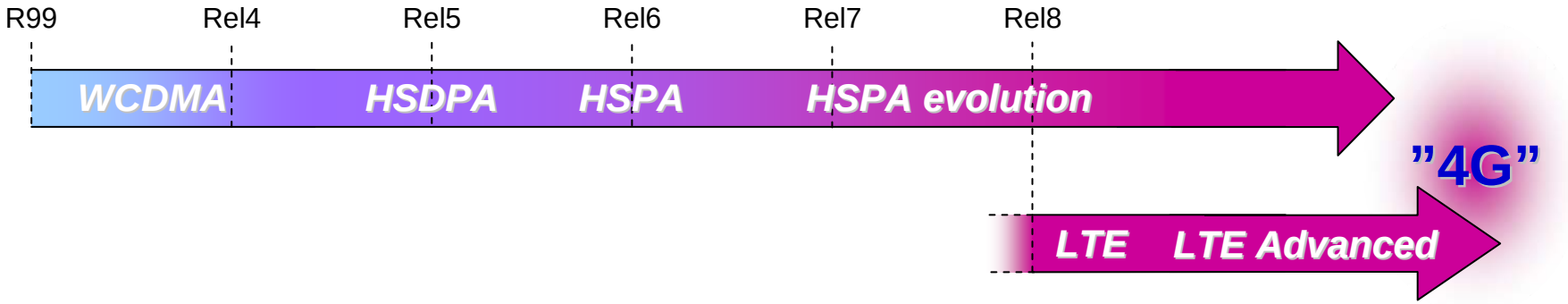
LTE – Long-Term Evolution

Stefan Parkvall

ERICSSON

TAKING YOU FORWARD

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*

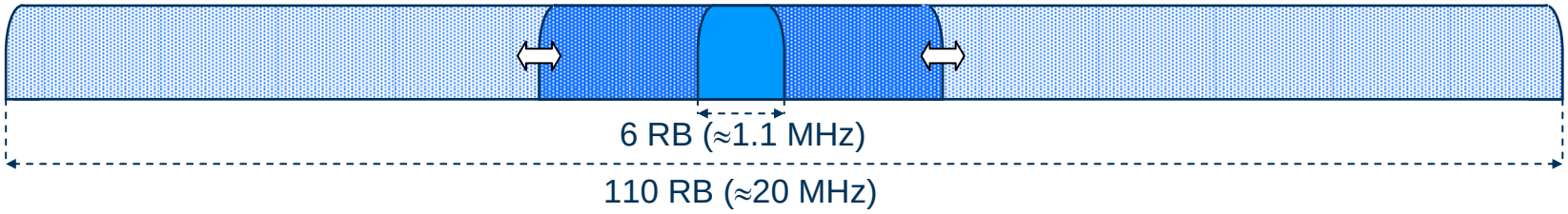
LTE Key Features

ERICSSON

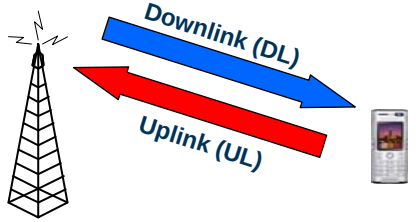
TAKING YOU FORWARD

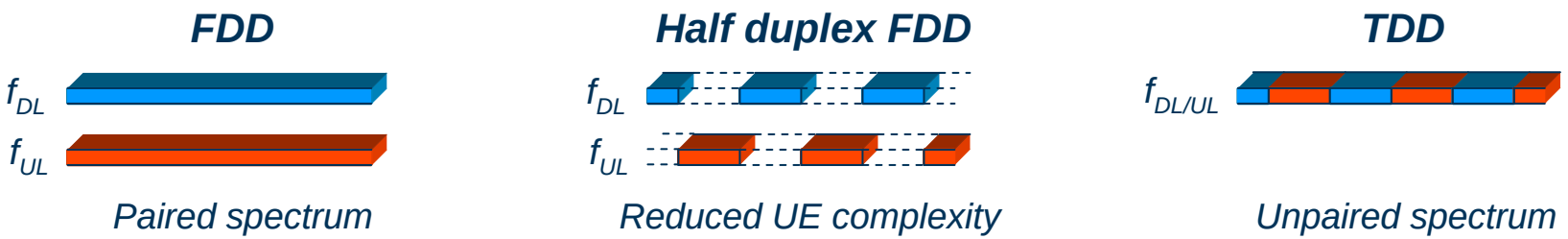
Bandwidth flexibility

- 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)



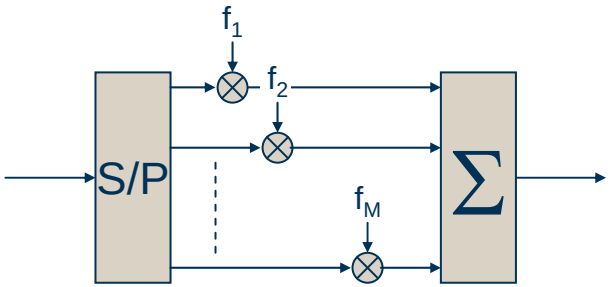
- Support for paired *and* unpaired spectrum allocations

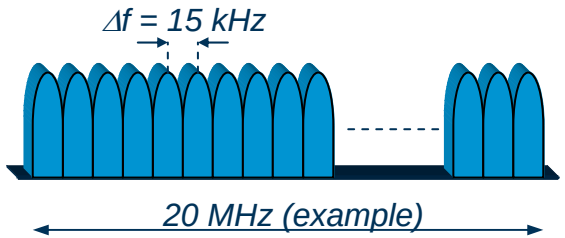




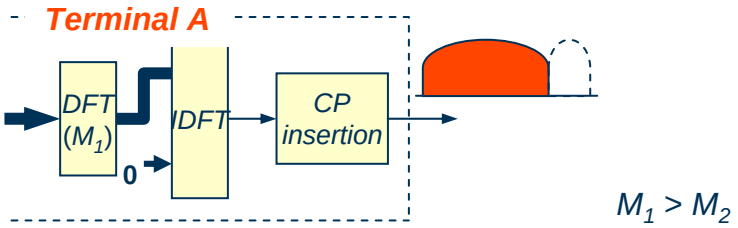
Transmission Schemes

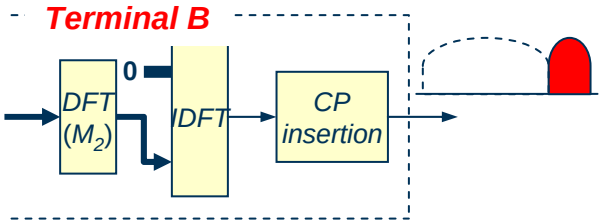
- Downlink – OFDM
  - Broadcast, MIMO, ...
  - Robustness, especially at high bandwidths
  - Access to frequency domain





- Uplink – SC-FDMA
  - Single-carrier
    - ➡ small PA back-off
    - ➡ improved coverage
  - Scheduled TDMA/FDMA uplink
    - ➡ intra-cell orthogonality

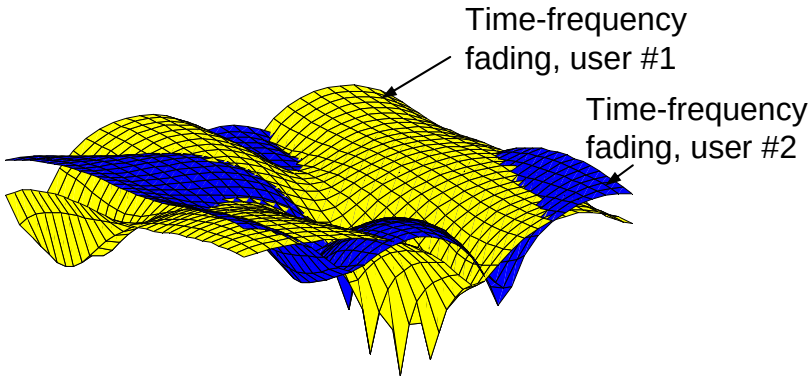


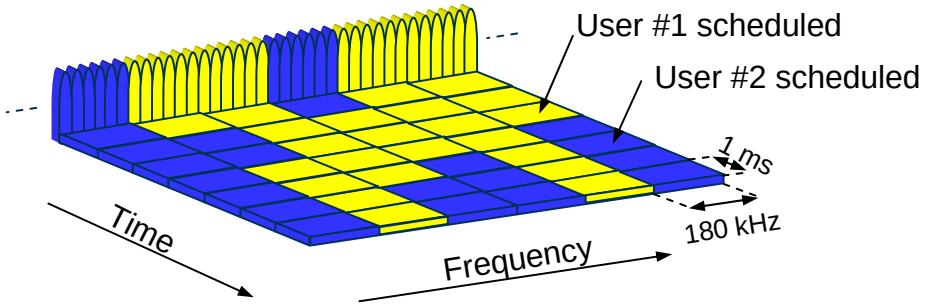


Channel-Dependent Scheduling

- 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

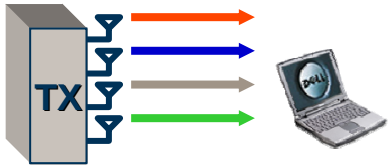




MIMO, HARQ, and MBSFN

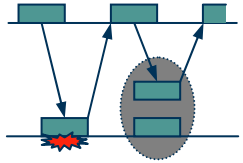
Who said you were tired of abbreviations?

- Multi-antenna support
  - Integral part of LTE
  - All terminals support 2 Rx antennas



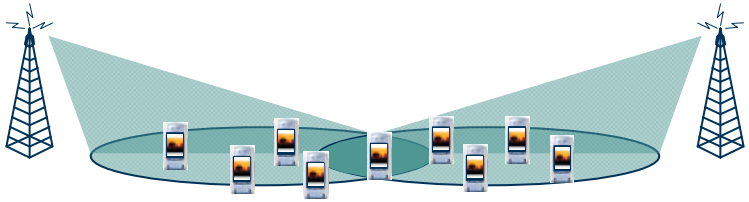
Multi-layer transmission ("MIMO")

- Hybrid ARQ
  - Rapid retransmission, soft combining
  - 8 ms HARQ RTT

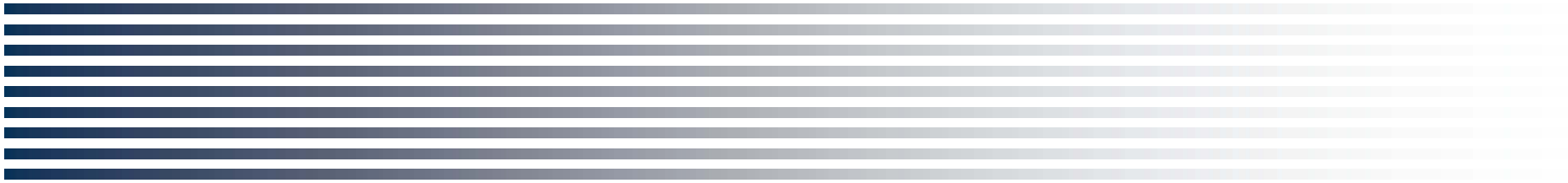


Fast Retransmissions with Soft Combining

- MBSFN
  - Multicast-Broadcast Single-Frequency Network

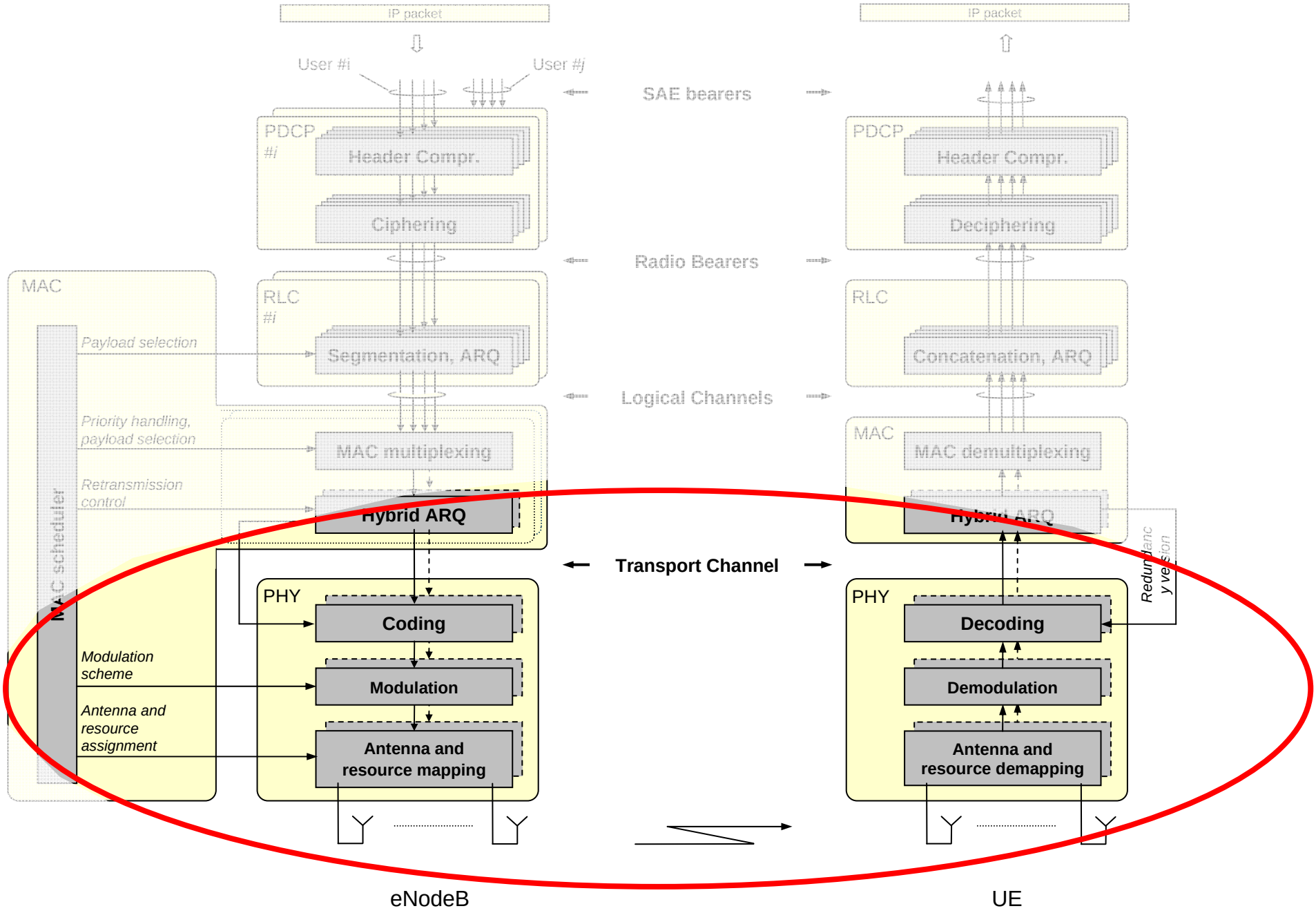


L1 Overview



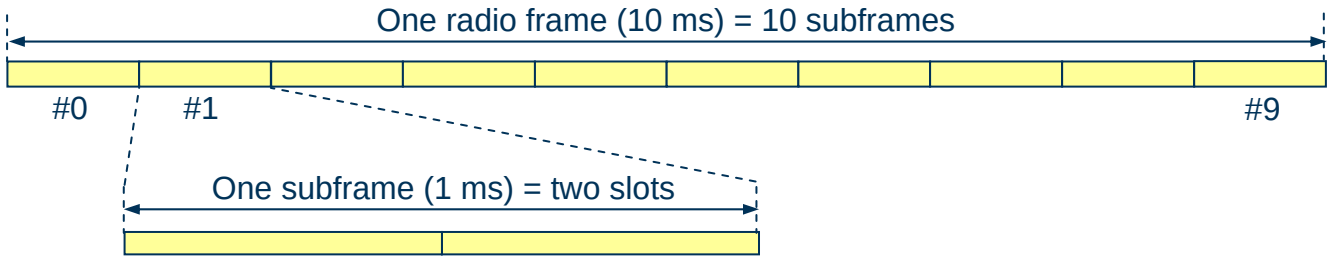
ERICSSON

TAKING YOU FORWARD

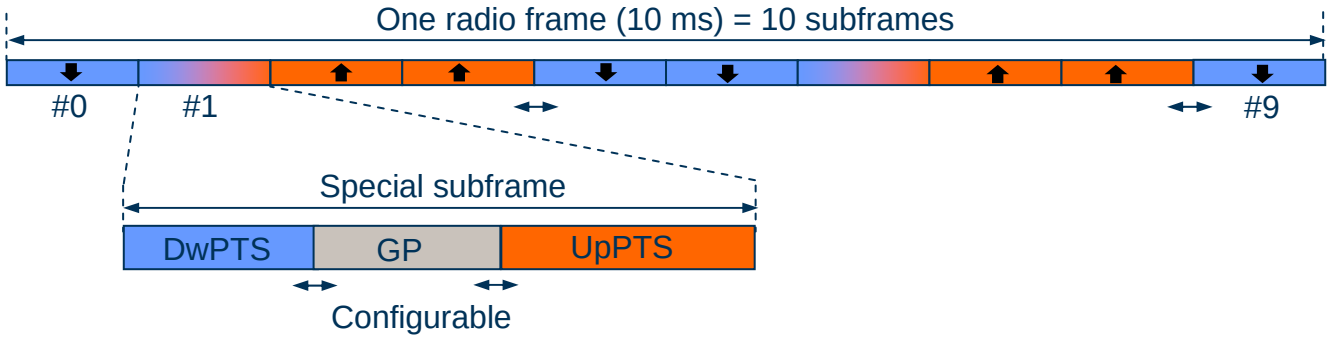

IP packet
IP packet
User #i
User #j
SAE bearers
PDCP
#i
Header Compr.
Ciphering
PDCP
Header Compr.
Deciphering
Radio Bearers
MAC
RLC
#i
Segmentation, ARQ
RLC
Concatenation, ARQ
Logical Channels
Payload selection
Priority handling, payload selection
MAC multiplexing
MAC
MAC demultiplexing
Retransmission control
Hybrid ARQ
Hybrid ARQ
MAC scheduler
Transport Channel
PHY
Coding
PHY
Decoding
Modulation scheme
Modulation
Demodulation
Antenna and resource assignment
Antenna and resource mapping
Antenna and resource demapping
eNodeB
UE

Time-domain Structure

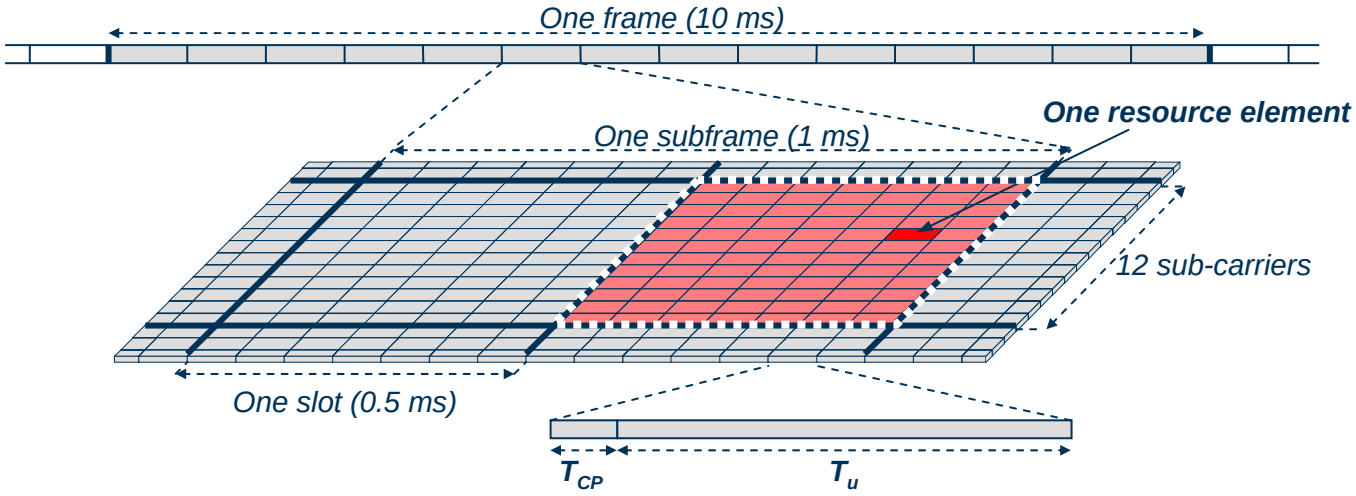
- Frame structure type 1 for FDD (full and half duplex)



- 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

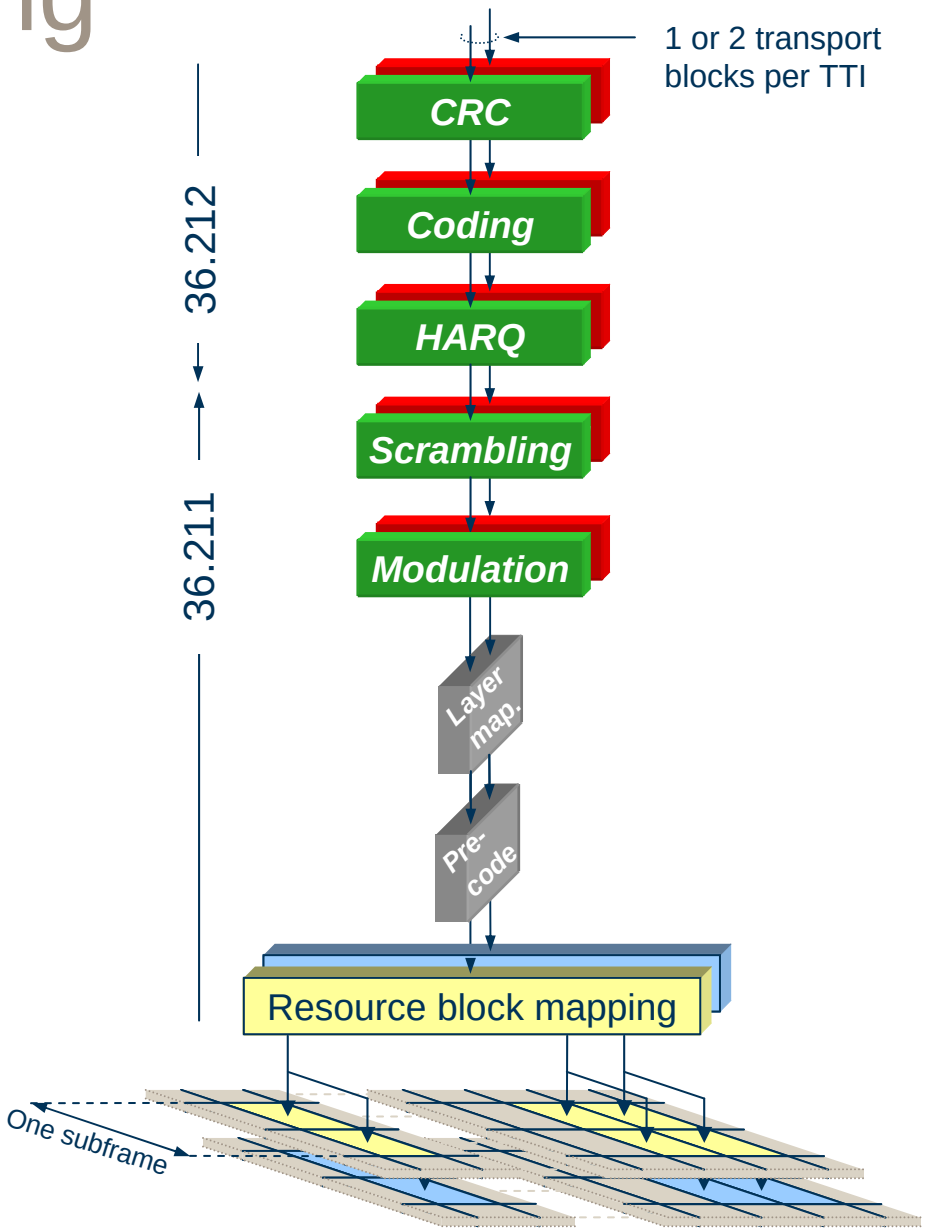
Transport-channel-specific scrambling using length-33 Gold sequences

Modulation (QPSK, 16QAM, 64QAM)

Mapping to transmission layers (for multi-layer transmission)

Precoding (for multi-rank transmission)

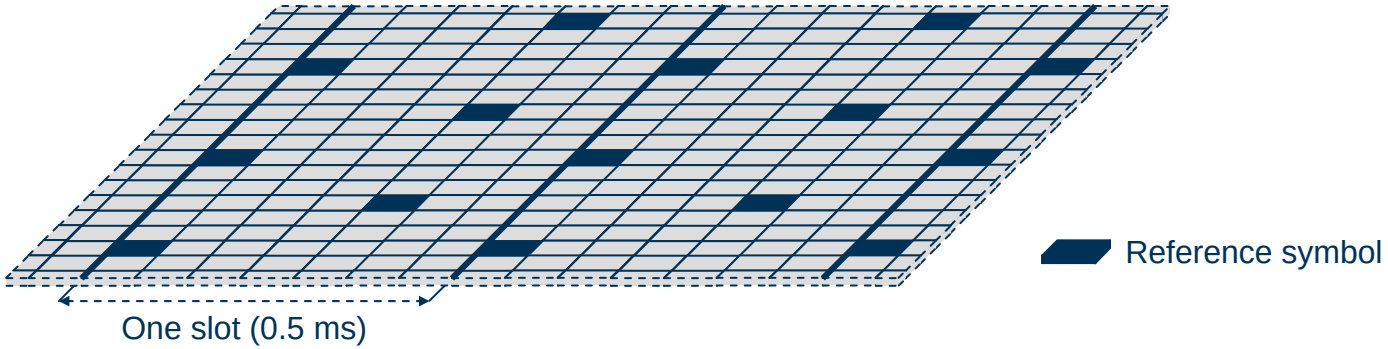
Resource block mapping



Cell-specific reference signals

Single-antenna transmission

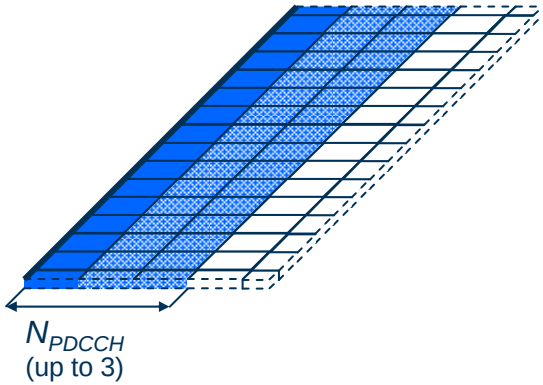
- Time-domain position: In OFDM symbol #0 and #4 of each slots
  - Symbol #0 and #3 in case of extended CP
- Frequency-domain position: Every 6th subcarriers
  - 3 subcarriers staggering between symbols



- 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

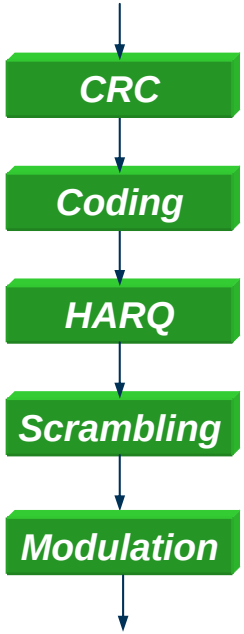
CRC insertion (24 bits)

Rel 6 Turbo coding (with QPP interleaver)

Rate matching, redundancy version generation

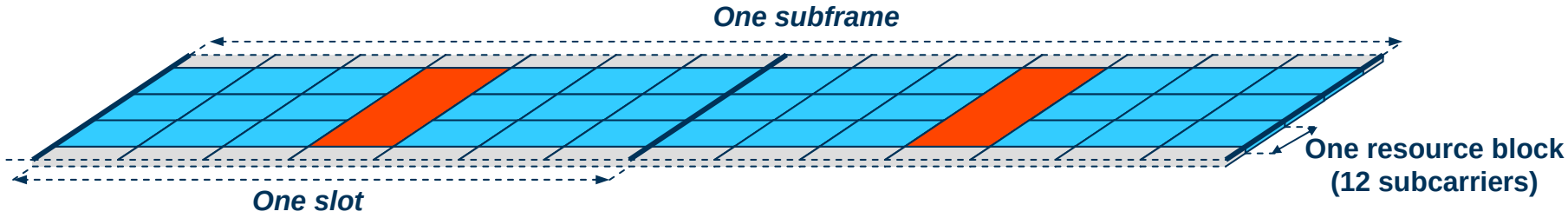
UE-specific scrambling for interference randomization

Modulation (QPSK, 16QAM, 64QAM)



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

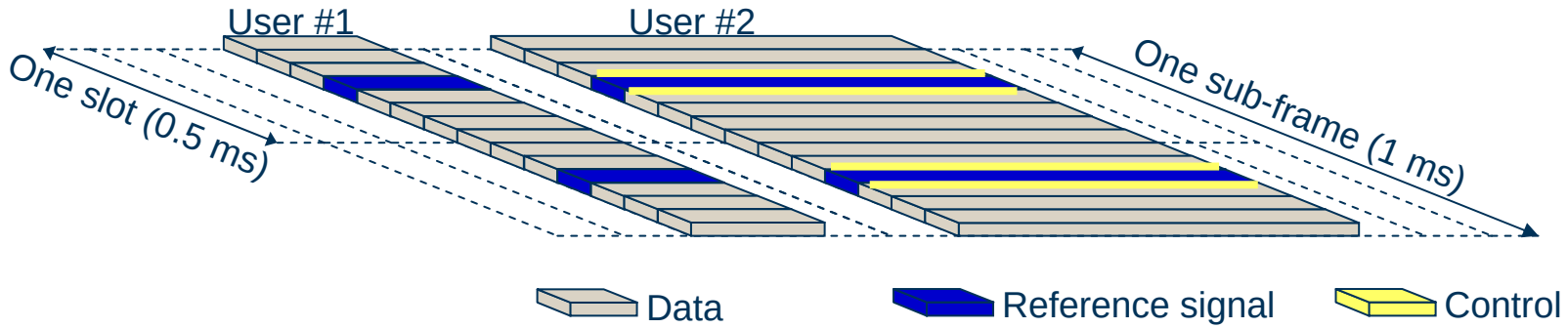
PUSCH DM RS



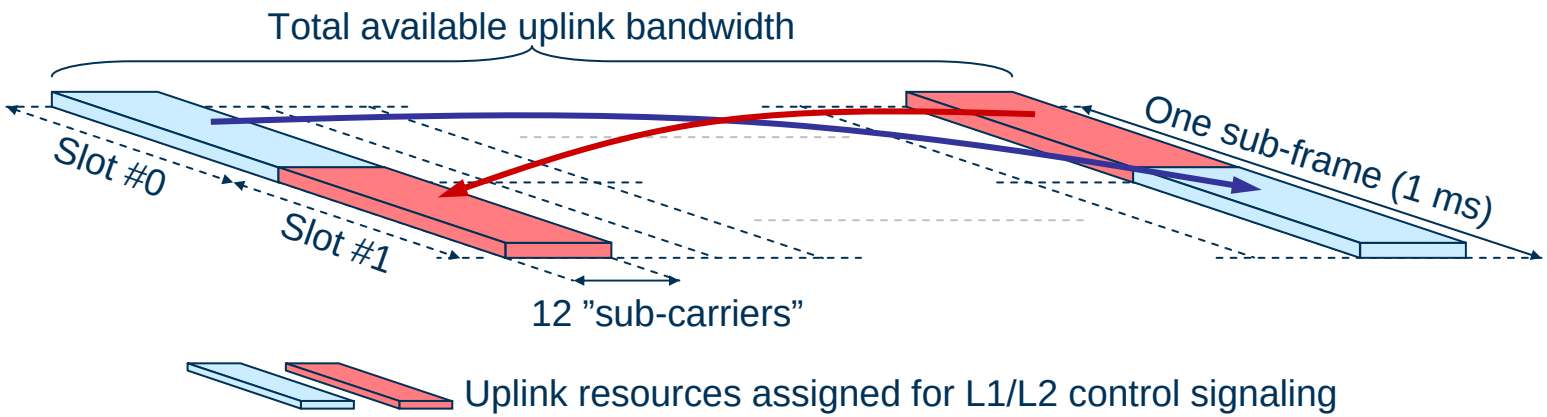
- One reference-signal symbol per slot (*two per subframe*)
  - In DFTS-OFDM symbol #3
- RS bandwidth equals uplink resource-allocation size
  - N_{RB} = 3 in example above

Uplink Control Signaling

- Control on PUSCH (simultaneous data and control)

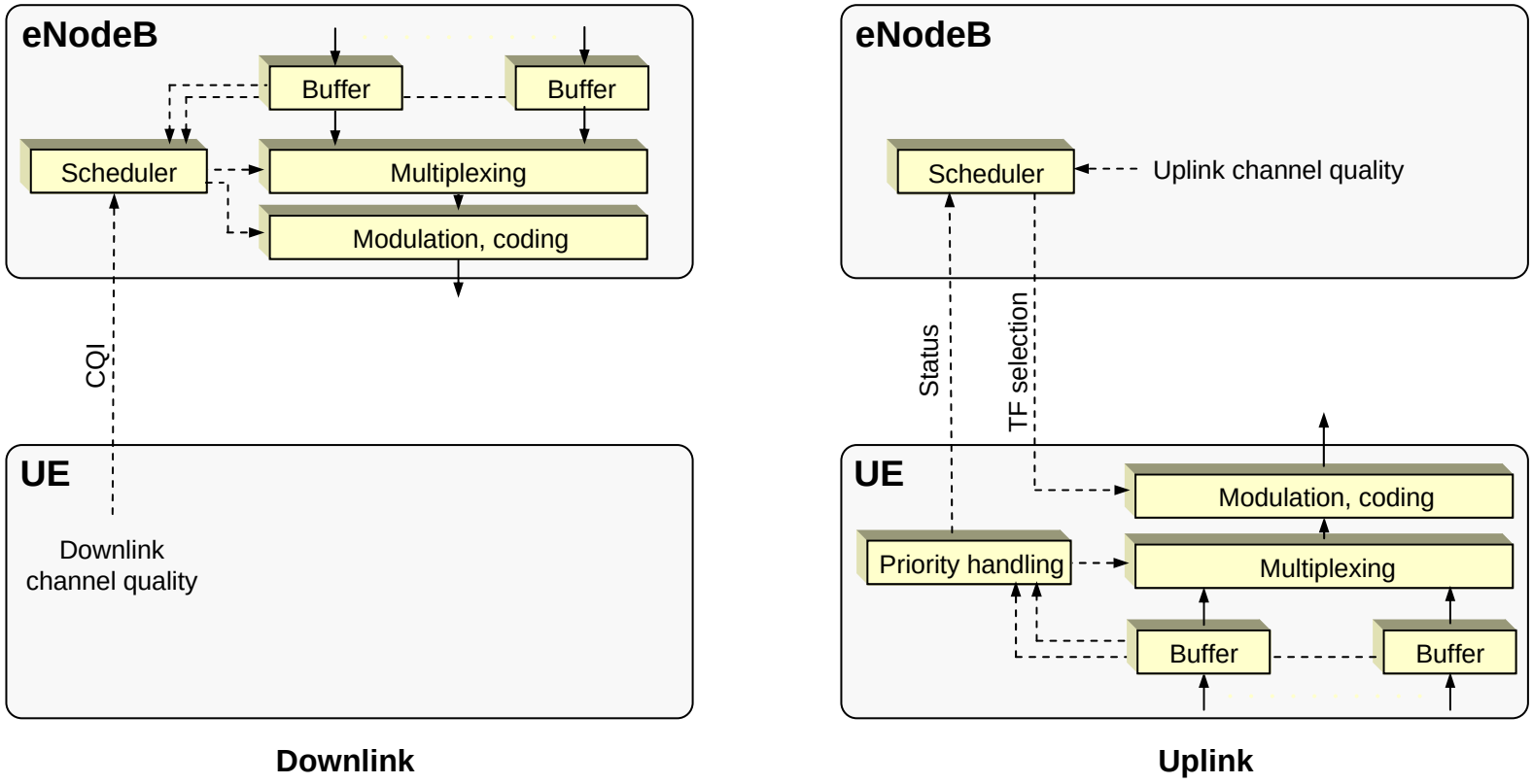


- Control on PUCCH (control only)



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

ERICSSON

TAKING YOU FORWARD

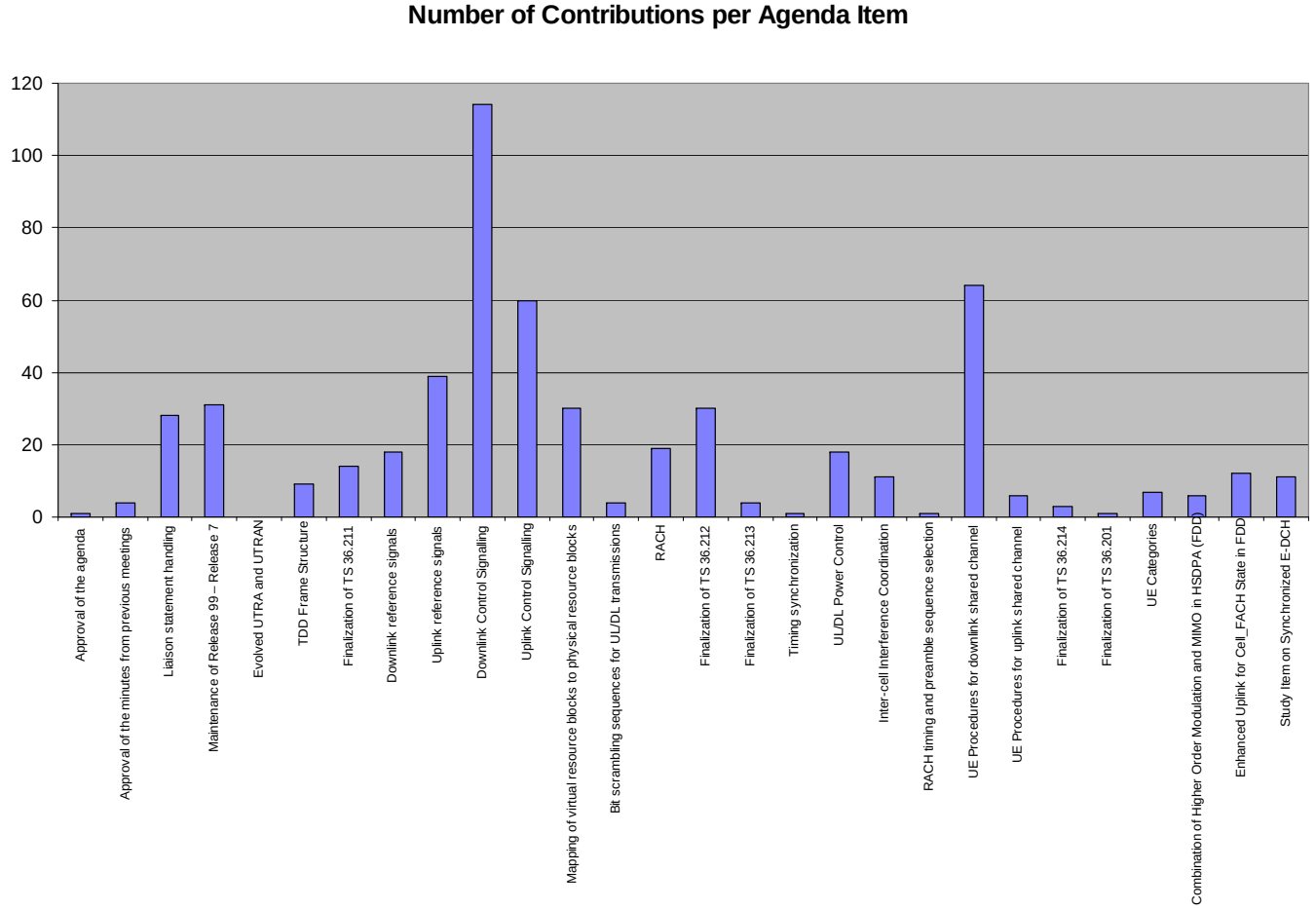
Standardization

- 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...



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 specifcations (work item) ready late 2007/early 2008

Taking You Forward...