

# 3GPP Long Term Evolution eUTRAN

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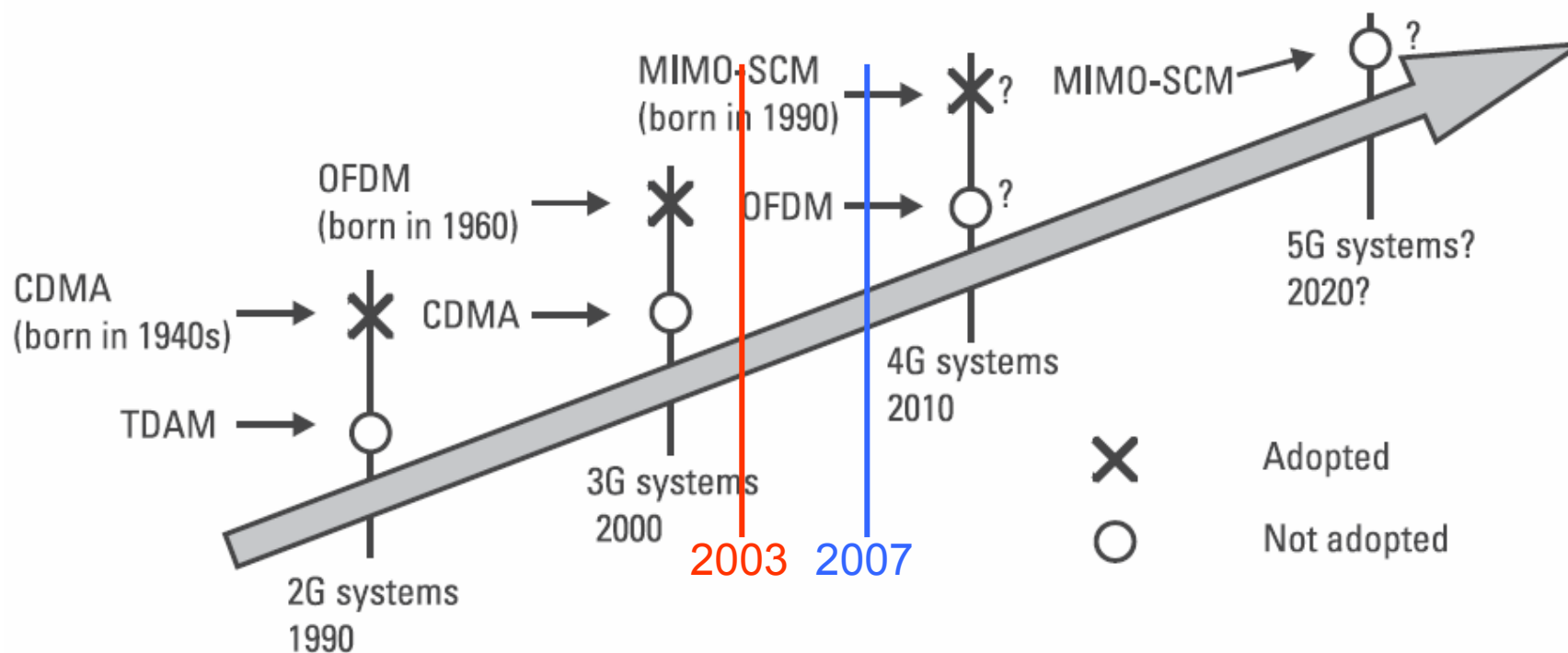
KTL FEI STU  
2007



# Agenda

- OFDM vs. CDMA
- LTE candidates
- Details of LTE design
- SAE/EPC

# CDMA vs. OFDM



CDMA: code divisions multiple access

TDAM: time divisions multiple access

OFDM: orthognal frequency division multiplexing

MIMO-SCM: multiple input multiple output-single carrier modulation

# 3GPP Feasibility Study

“The studies carried out within the study item indicates that the basic OFDM scheme offers the possibility for improved performance, compared to HSDPA release 5 with a Rake receiver, for channels with significant time dispersion. This performance advantage decreases for channels with less time dispersion. However, by the introduction of more advanced receiver structure, there is **no significant performance** difference between **HSDPA** release 5 and the performance of the **OFDM**.”

# Texas Instruments

“With larger channel bandwidths, **OFDM** offers **advantage** over **CDMA** because of simplified receiver processing: 10 MHz, 20 MHz.”

# Not so easy...

- OFDMA
- MC-CDMA
- SC modulation (spread / not spread)

# OFDM/OFDMA

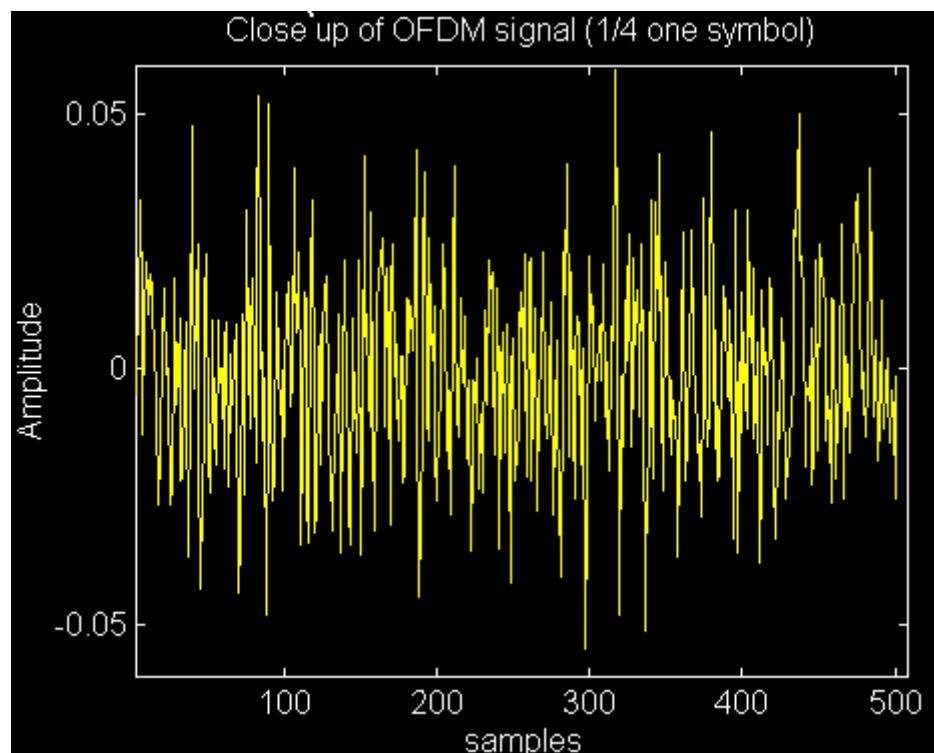
## PROS

- Resistance in frequency selective channels
- ISI & ICI reduction
- Simple equalization
- Less sensitive to timing offsets
- Resistance to NB interference
- Spectrum efficiency
- Spectrum flexibility

## CONS

- Sensitive to frequency offsets & phase noise
- Large PAPR

# OFDM signal – time view



Peak power =  $N$  \* average power (for  $N$  subcarriers)



# MC-CDMA

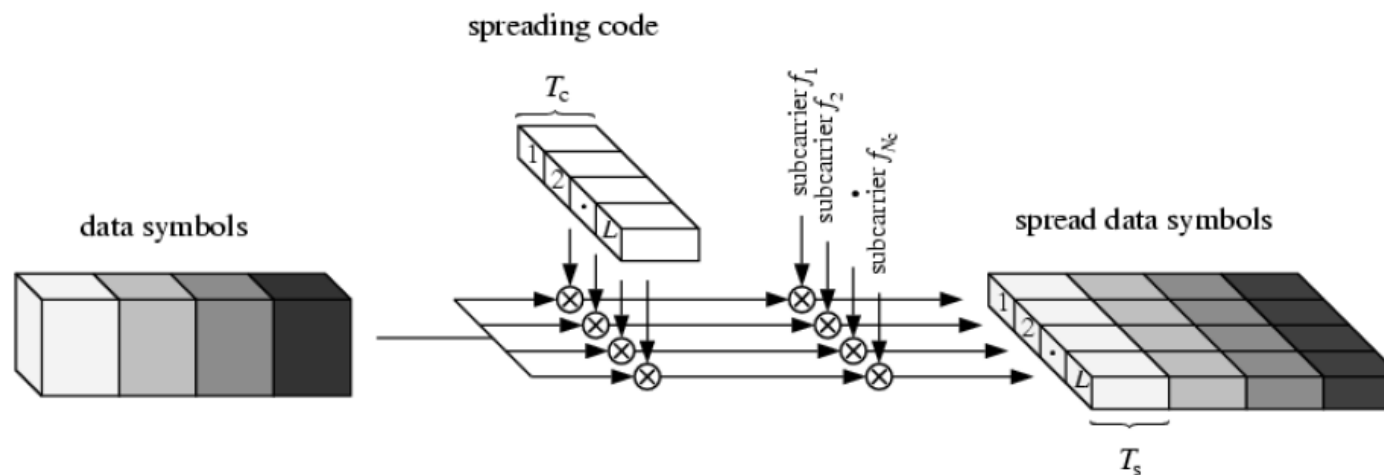
## PROS

- Similar to OFDM
  - Multipath resistance
  - Flexible
  - Simple timing synchronization
  - Frequency diversity
- PAPR can be reduced by code allocation

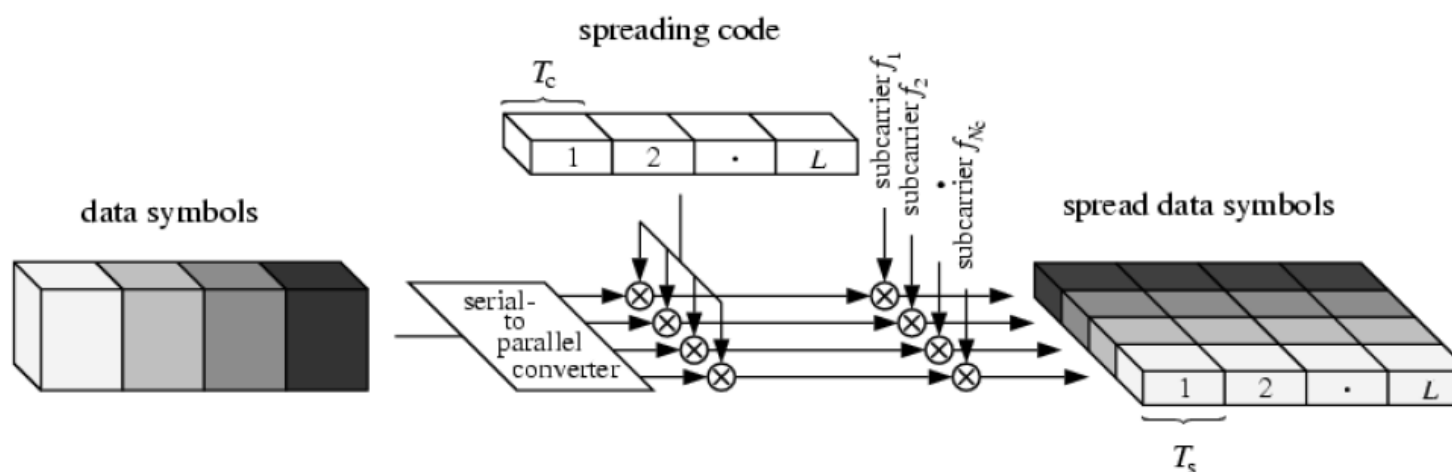
## CONS

- Sensitive to frequency offsets & phase noise
- $PAPR > \text{Single carrier modulation}$

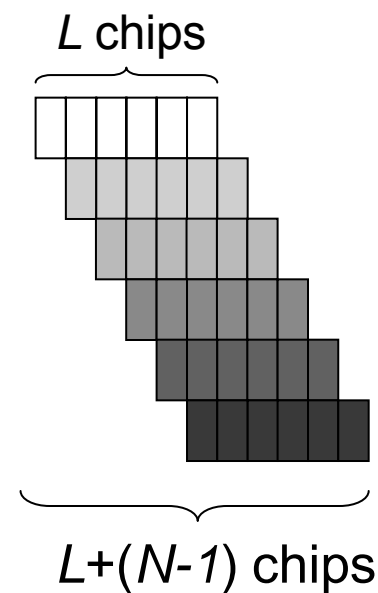
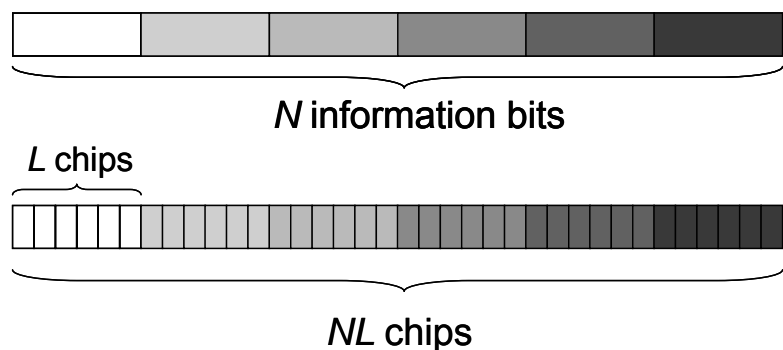
# MC-CDMA



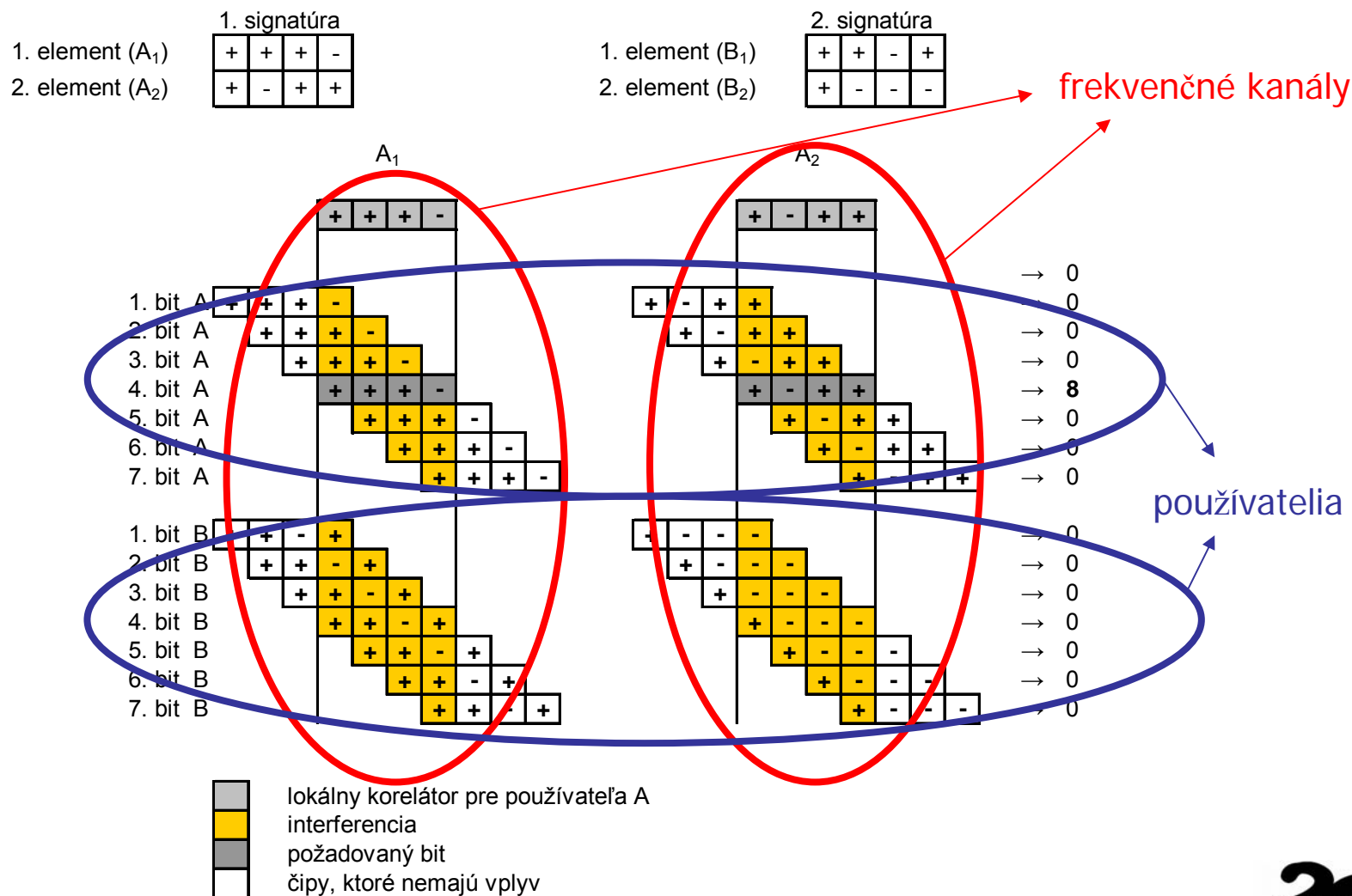
# MC-DS-CDMA



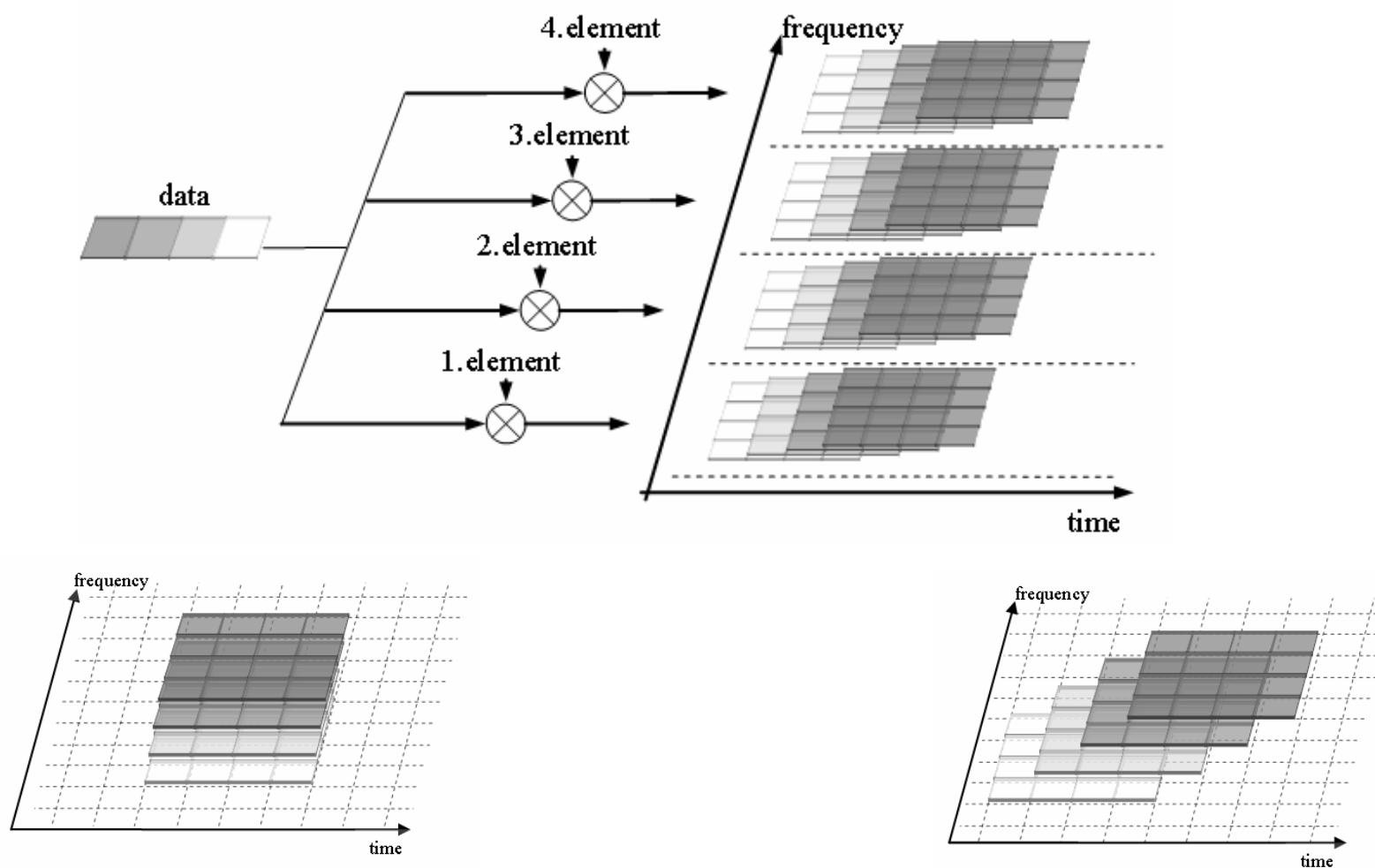
# Complementary code CDMA



# Complementary codes

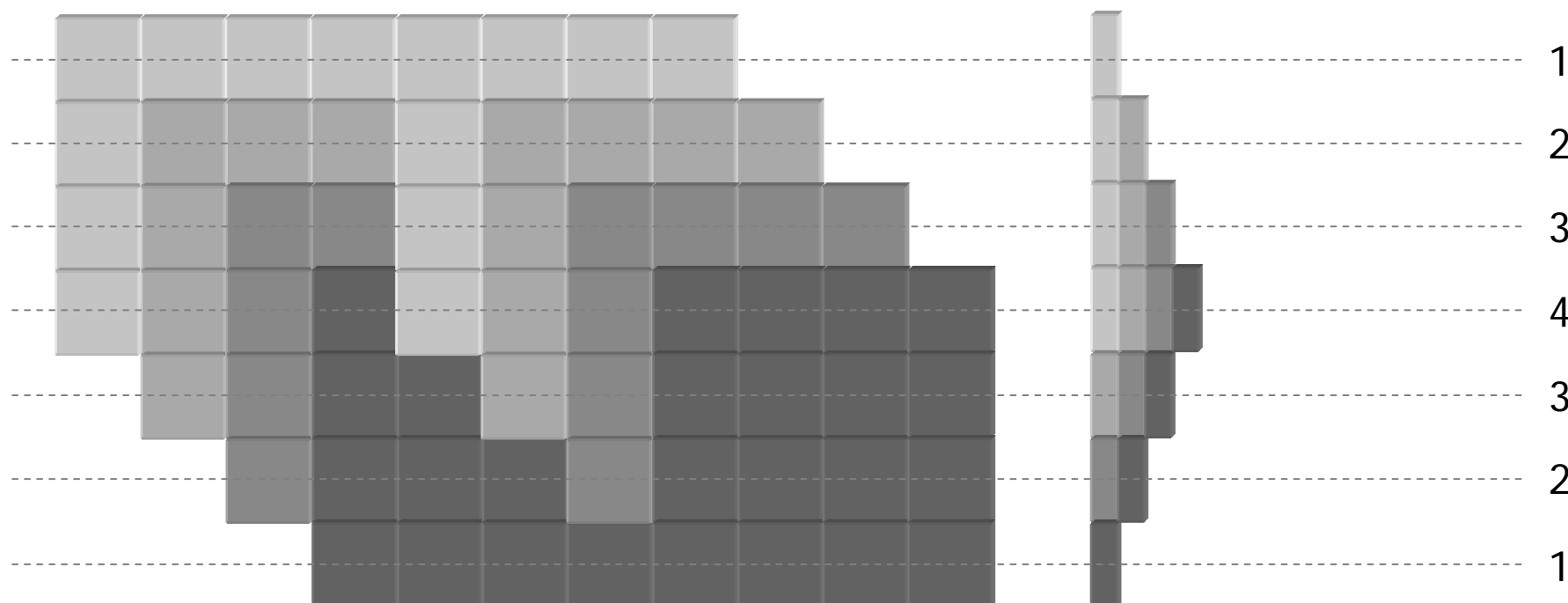


# 2D Complementary codes



# Transmission strategies

↓ diagonal – 1 user



# Single carrier modulation

## Spread (SC-DS-CDMA)

- Pros
  - Low PAPR
  - Multipath fading resistance
  - NB, WB interference rejection
- Cons
  - Advanced receivers
  - MAI if not synchronized

## TDMA/(O)FDMA

- Pros
  - Spectrum flexibility
  - Low PAPR
  - Intra cell orthogonality in time & frequency
- Cons
  - Advanced receivers
  - Tight frequency synchronization

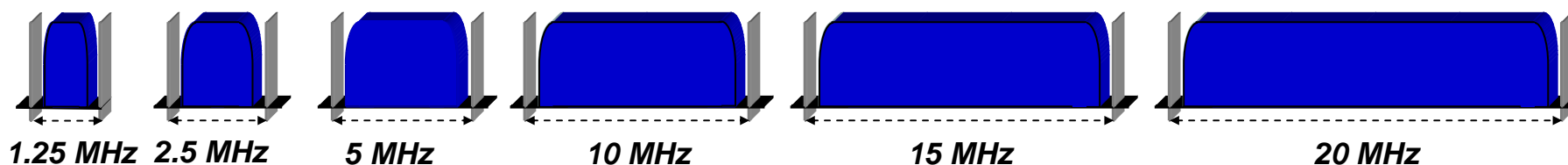


# 3GPP LTE – *Requirements/targets*

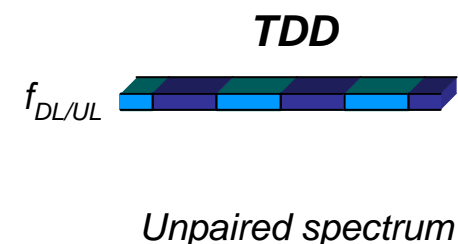
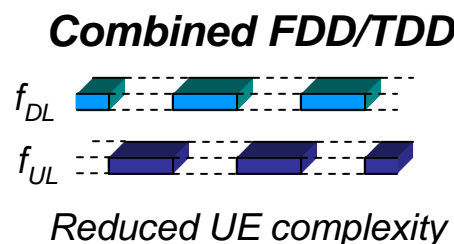
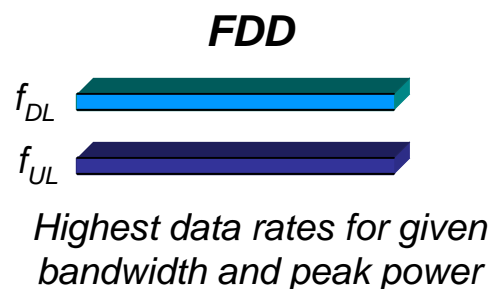
- **Focus on PS-domain services**
- **High data rates**
  - *Peak data rates:* Beyond 100 Mbps (DL) / Beyond 50 Mbps (UL)
  - *Average user throughput:* 3-4 times HSPA Release 6
  - *Cell-edge user throughput:* 2-3 times HSPA Release 6
- **Low latency**
  - *User plane:* Less than 10 ms (RAN RTT)
  - *Control plane:* Less than 50 ms (dormant → active)
- **High spectral efficiency**
  - 3-4 times HSPA Release 6
  - Improved performance for broadcast services
- **Spectrum flexibility**
  - Deployable in a wide-range of different spectrum allocations of different sizes
  - Unpaired and paired spectrum

# Spectrum Flexibility

- Spectrum flexibility to enable operation in differently-sized spectrum allocations



- Duplex flexibility to enable operation in paired and unpaired spectrum



# Concepts

- **Downlink**

- OFDMA [FDD/TDD]
- MC-WCDMA [FDD]
- MC-TD-SCDMA [TDD]

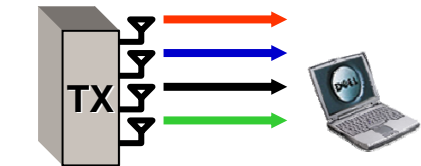
$$960kchip / s = \frac{3,84Mchip / s}{5MHz} \cdot 1,25MHz$$

- **Uplink**

- SC-FDMA [FDD/TDD]
- OFDMA [FDD/TDD]
- MC-WCDMA [FDD]
- MC-TD-SCDMA [TDD]

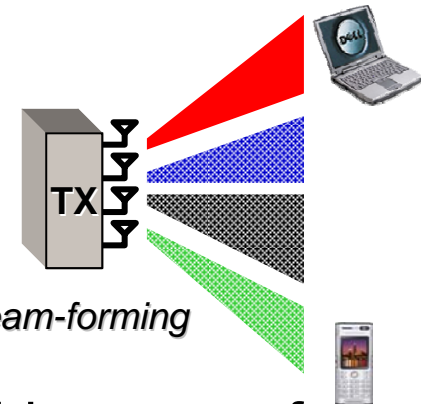
# 3GPP LTE – *Advanced antenna solutions*

- Advanced multi-antenna solutions is **the** key component to achieve these targets



Multi-layer transmission  
("MIMO")

- Different antenna solutions needed for different scenarios/targets
  - High peak data rates ➡ Multi-layer transmission
  - Good coverage ➡ Beam-forming
  - High capacity ➡ Beam forming+multi-layer transmission



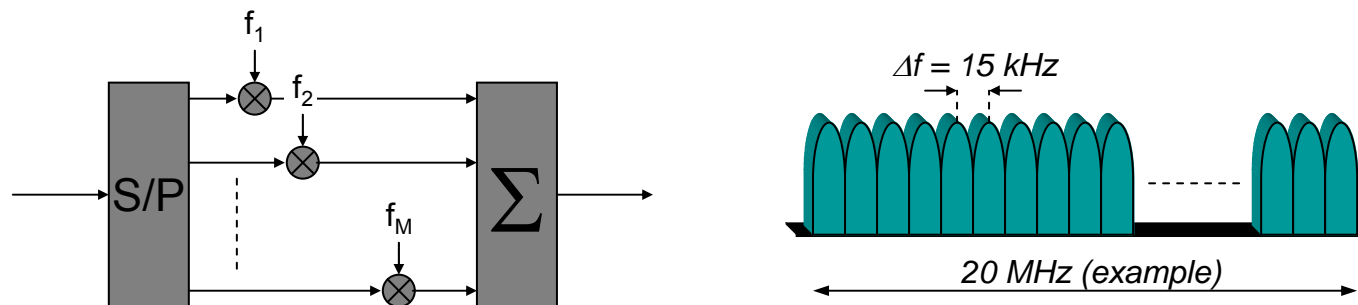
Beam-forming

- ➡ A “generic” LTE antenna concept adaptable to a wide range of scenarios  
(large vs. small cells, high peak data rates vs. good coverage, ...)

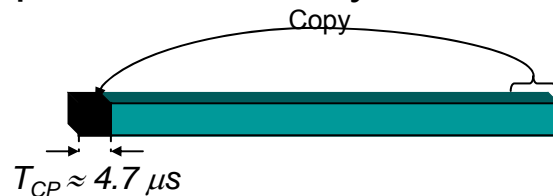
- Multi-antenna terminals will be mandatory for LTE

# Downlink – OFDM with Cyclic Prefix

- Parallel transmission using a large number of narrowband “sub-carriers”
- “Multi-carrier” transmission
  - Typically implemented with FFT

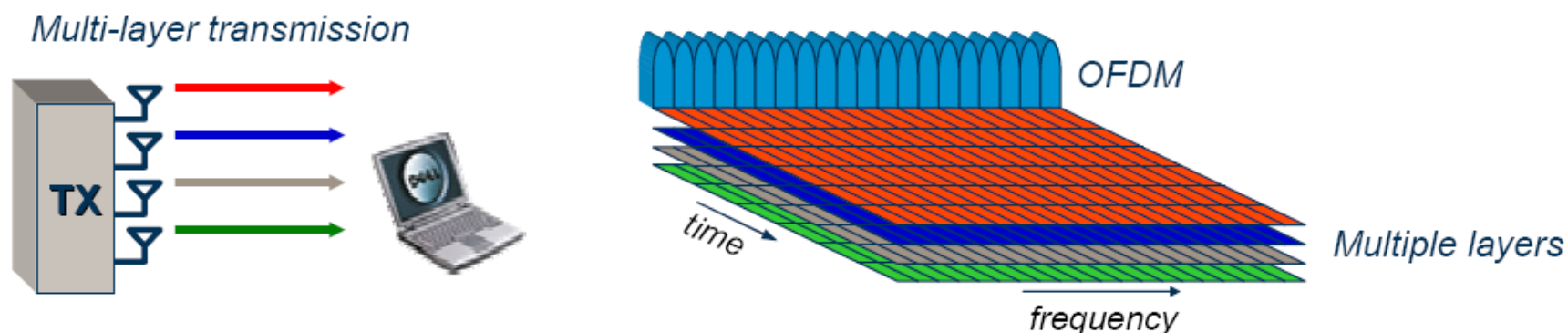


- Insertion of cyclic prefix prior to transmission
  - Improved robustness in time-dispersive channels – *requires  $CP > \text{delay spread}$*
  - Spectral efficiency loss



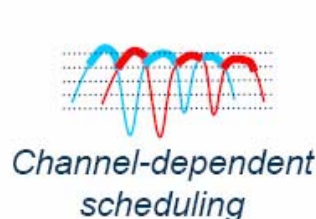
# 3G LTE – *Downlink radio access*

- **Addaptive Multi-Layer OFDM**
- **Adaptive** to channel conditions and spectrum scenarios
  - Time and frequency-domain channel adaptation
  - Multiple frequency bands, flexible bandwidth, duplex flexibility, ...
- **Multi-layer transmission** to provide *very high data rates* and *high spectrum efficiency*
- **OFDM** for robust broadband transmission, for lower-complexity multi-layer transmission, and to enable frequency-domain channel adaptation



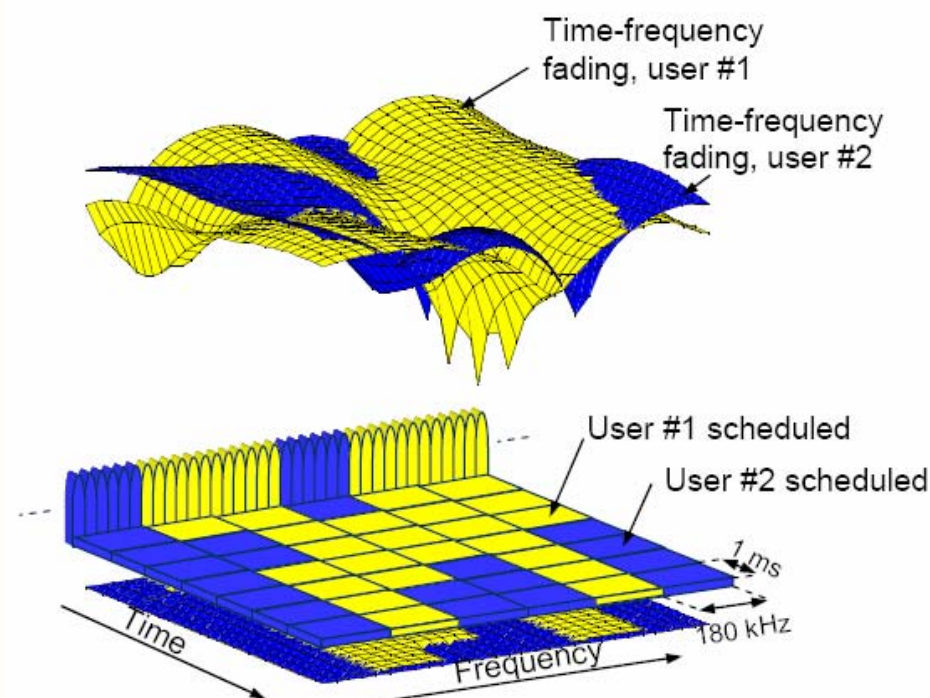
# Frequency-domain channel adaptation

- Select user and data rate based on *instantaneous* channel quality
- Scheduling/adaptation in time-domain already for HSPA



**LTE scheduling/adaptation on a  $1 \text{ ms} \times 180 \text{ kHz}$  basis**  
(one "Resource Block")

**LTE:** Additional scheduling/adaptation in the **frequency** domain



*Both for downlink and uplink*



# Downlink Coding Chain

*Segmentation for per-stream channel coding/decoding and error detection*

*24 bit CRC addition*

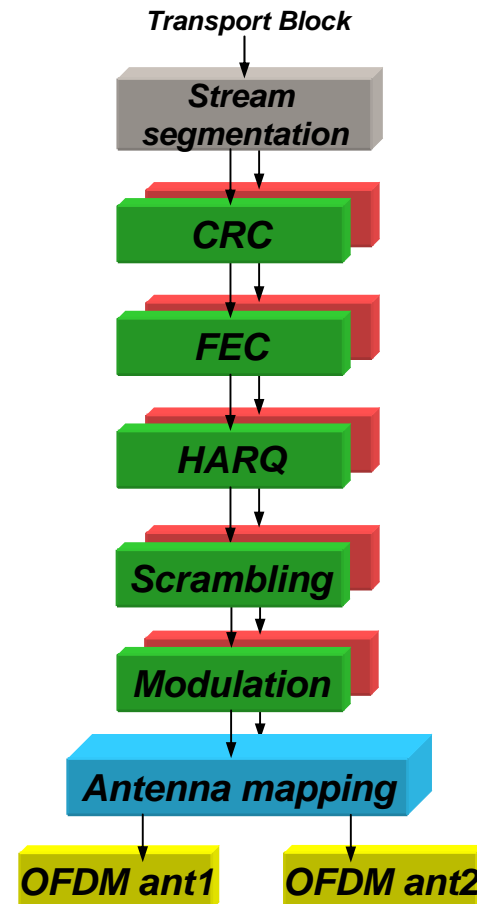
*Rel6 Turbo coding*

*Select sub-set of coded bits as determined by scheduler and HARQ status*

*Scrambling for inter-cell interference randomization*

*Modulation as determined by scheduler (QPSK, 16QAM, 64QAM)*

*OFDM modulation (per antenna)*

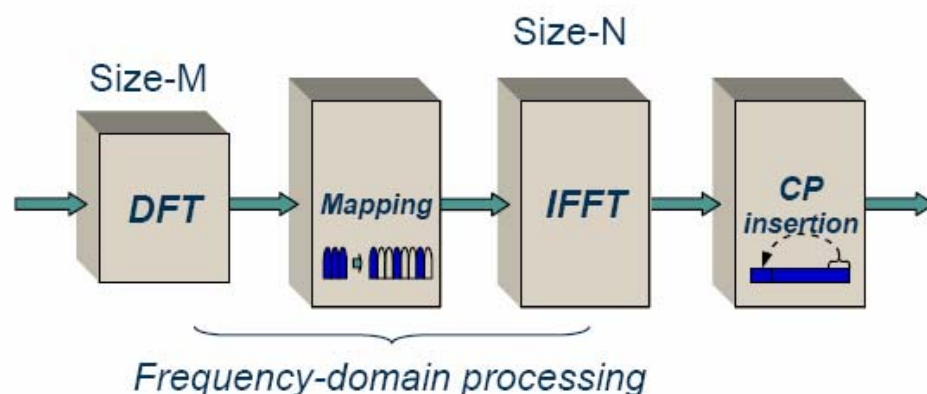




# Downlink phy channels

- Physical Downlink Shared Channel, PDSCH
- Physical Broadcast Channel, PBCH
- Physical Multicast Channel, PMCH
- Physical Control Format Indicator Channel, PCFICH
- Physical Downlink Control Channel, PDCCH
- Physical Hybrid ARQ Indicator Channel, PHICH

# LTE SC-FDMA – *DFT-spread OFDM*



- Mapping to consecutive IFFT inputs ➔ *“Localized” transmission*
- Mapping to distributed IFFT inputs ➔ *“Distributed” transmission*



*Localized transmission*



*Distributed transmission*

- Low-PAPR “single-carrier” transmission  $\Rightarrow$  *High power-amplifier efficiency*
- ... but can also be seen as ***pre-coded OFDM***

# Uplink Coding Chain

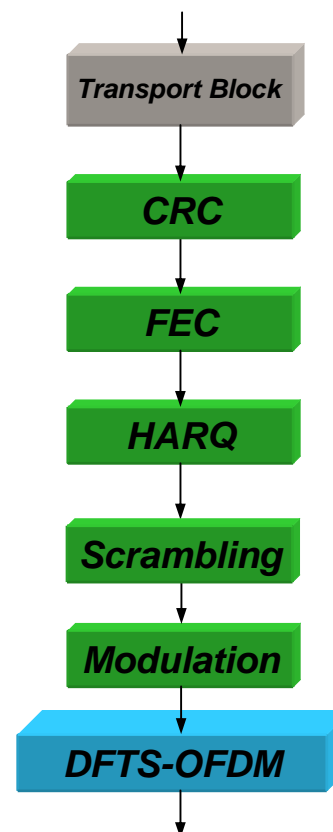
*24 bit CRC addition*

*Rel6 Turbo coding*

*Select sub-set of coded bits as determined by scheduler and HARQ status*

*Scrambling for interference randomization*

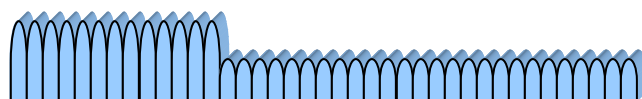
*Modulation as determined by scheduler  
(QPSK, 16QAM, 64QAM)*



# Uplink phy channels

- Physical Uplink Shared Channel, PUSCH
- Physical Uplink Control Channel, PUCCH
- Physical Random Access Channel, PRACH

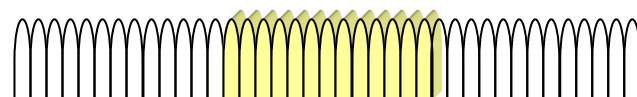
# Cell/user separation



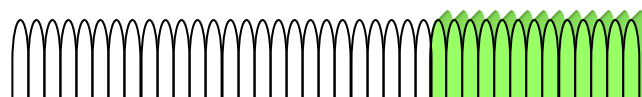
Cell center terminals



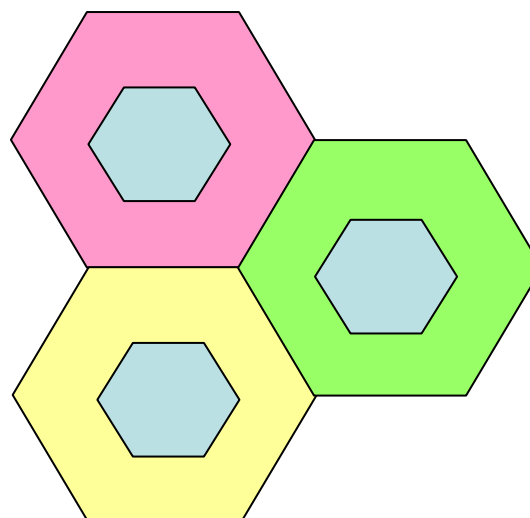
Cell edge terminals



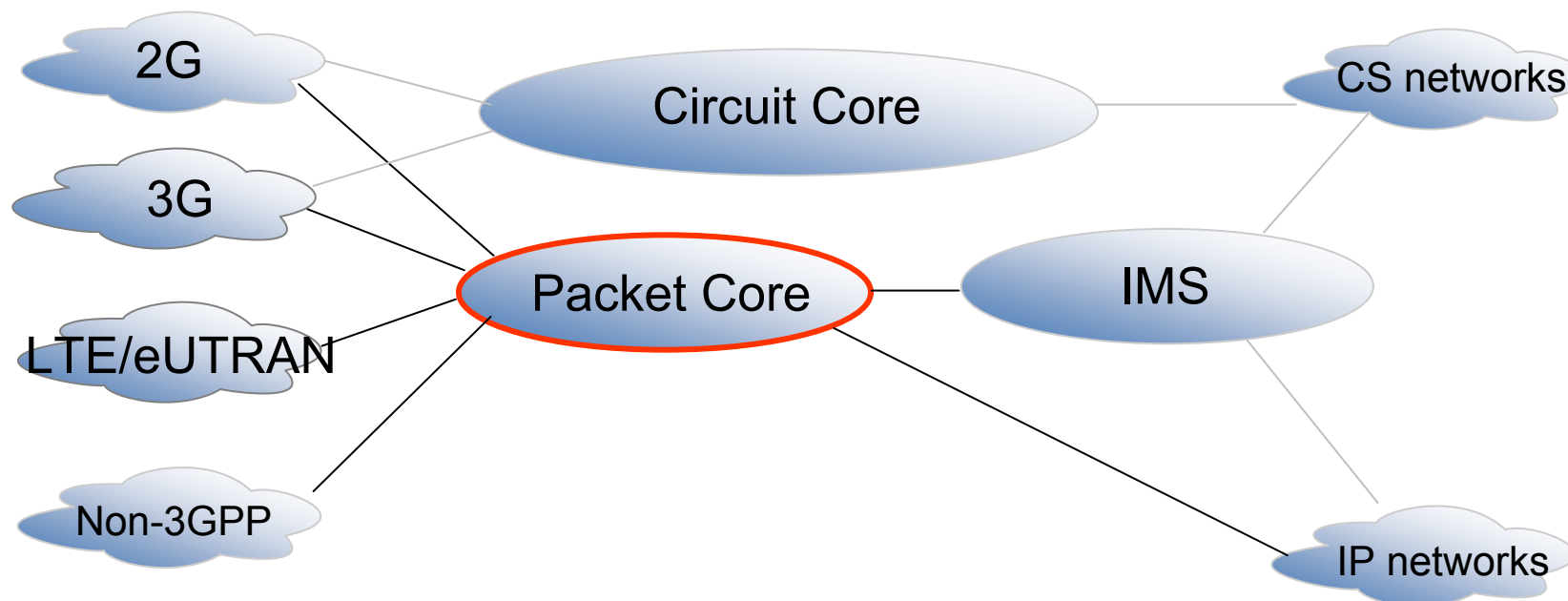
Neighbor cell 1 edge terminals



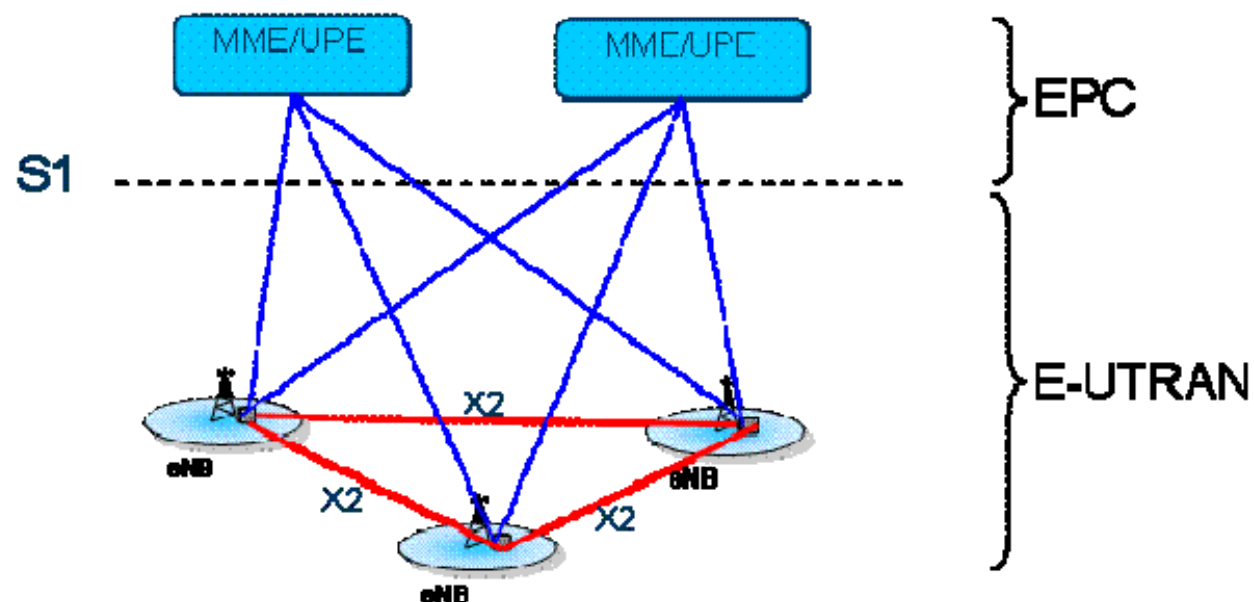
Neighbor cell 2 edge terminals



# Where is SAE?



# SAE/EPC



# Detailed EPC view

