LTE – A Technical Overview

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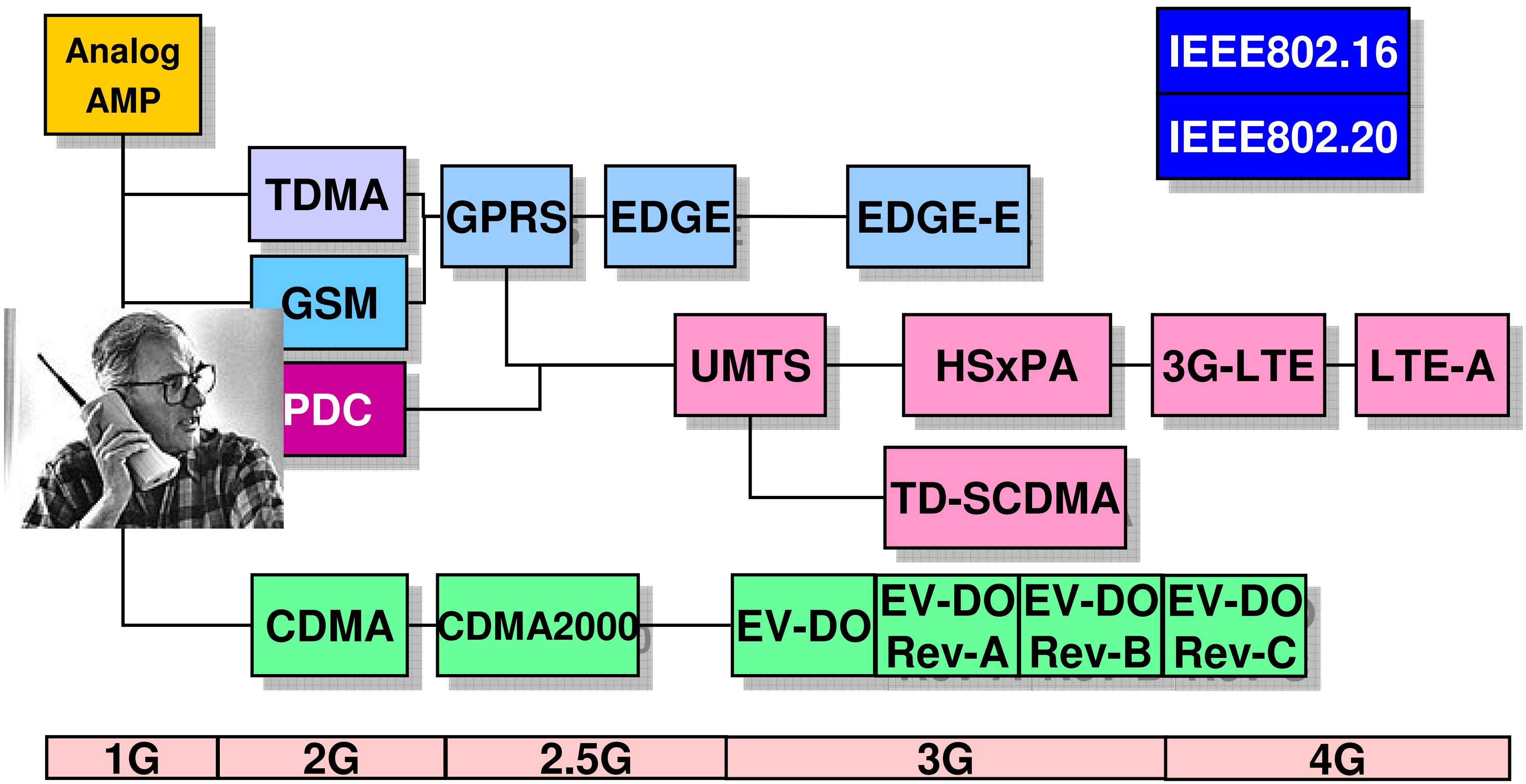
Scope of Presentation

- Cellular wireless systems
- LTE system & architecture
- Key Technologies

Cellular Wireless Systems

Wireless Standard Evolution



IEEE802

- IEEE802.16
  - **IEEE standard that defines a wireless network on a metropolitan area (WMAN)**
  - **Original goal to support fixed and nomadic users (16a~d)**
  - **Evolved to mobility (vehicular speeds) and increased data rates (16e)**
  - **16m under development**
- IEEE802.20
  - **Span off from 802.16 to support high mobility applications**
  - **For whatever reasons, it lost momentum**
  - **Its survival is in doubt**

3GPP2 Evolution

- CDMA2000 1X (1999)
- CDMA2000 1xEV-DO (2000)
- EV-DO Rev. A (2004): VoIP
- EV-DO Rev. B (2006): Multi-carrier
- Ultra Mobile Broadband (UMB) (a.k.a. EV-DO Rev. C)
  - Based on EV-DO, IEEE 802.20, and FLASH-OFDM
  - Commercially available in 2009
- UMB's fate?

3GPP Evolution

- Release 99 (Mar. 2000): UTRA in FDD and TDD (3.84 Mcps) modes
- Rel-4 (Mar. 2001): TD-SCDMA
- Rel-5 (Mar. 2002): HSDPA with IMS (IP Multimedia Services)
- Rel-6 (Mar. 2005): HSUPA with MBMS
- Rel-7 (2007): DL MIMO, optimized real-time services (VoIP, gaming, push-to-talk)
- Rel-8 (Dec. 2008) Long Term Evolution (LTE)

System & Architecture

LTE

- Standardization effort started in late 2004
  - With HSPA (downlink and uplink), UTRA will remain highly competitive for several years
  - IEEE is standardizing mobile WiMAX => Threat for loosing competitive edge
- LTE focus:
  - Enhancement of the UTRA
  - Optimisation of the UTRAN architecture
  - To ensure the continued competitiveness of the 3GPP technologies for the future
- LTE was the first and only technology recognized by the Next Generation Mobile Network alliance to meet its broad requirements
- Target deployment in 2010

Service Capabilities

- Reduced cost per bit
  - Improve spectrum efficiency (e.g. 2-4 x Rel6)
  - Reduce cost of backhaul (transmission in UTRAN)
- Increased service provisioning – more services at lower cost with better user experience
- Focus on delivery of services utilising ”IP”
- Reduced latency, to 10 msec round-trip time between user equipment and the base station, and to less than 100 msec transition time from inactive to active
- Increase the support of QoS for the various types of services (e.g. VoIP)
- Increase “cell edge bit rate” whilst maintaining same site locations as deployed today
- Reasonable terminal power consumption
- Flexibility of use of existing and new frequency bands

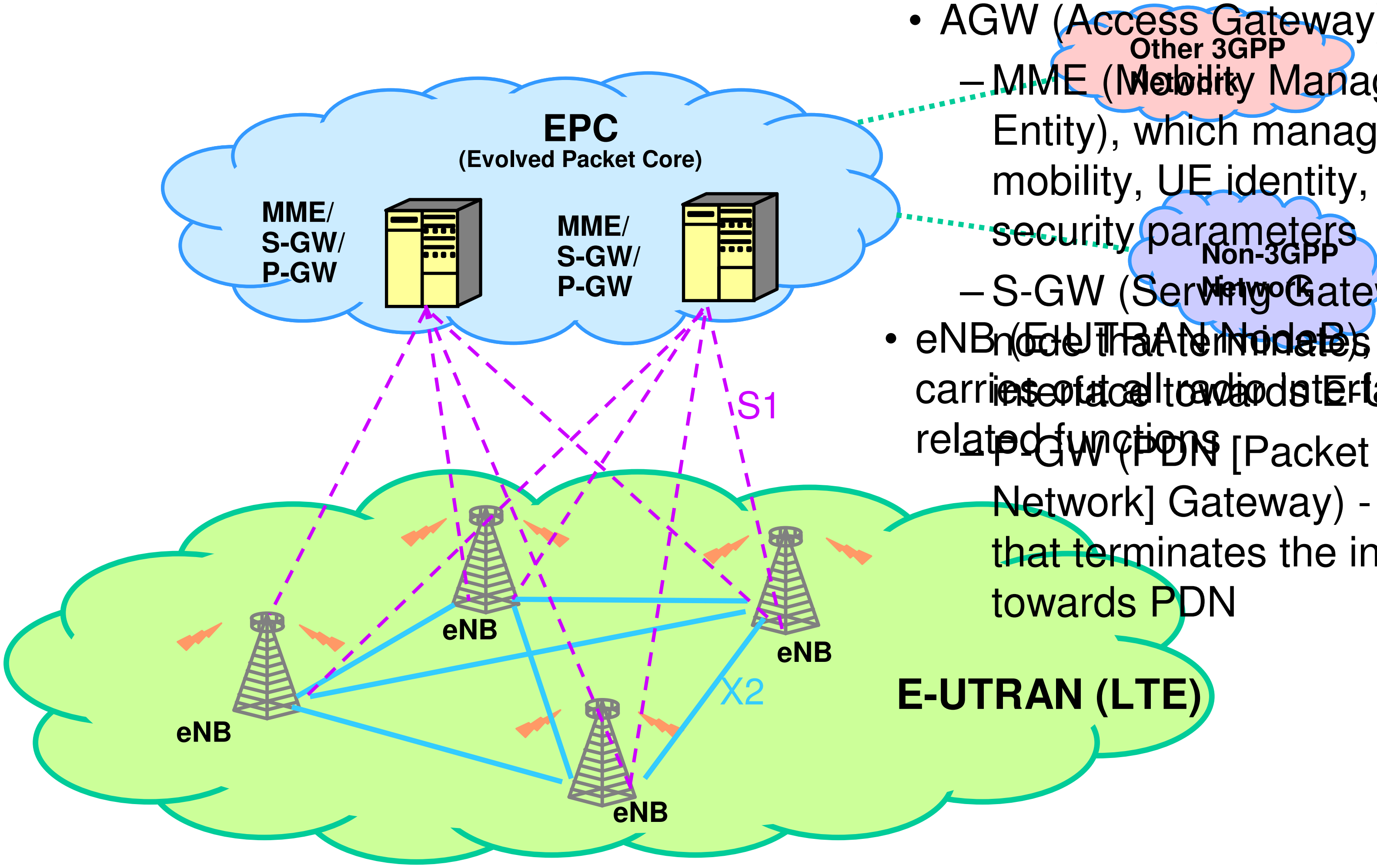
System Capabilities

- Downlink peak data rates up to 326 Mbps with 20 MHz bandwidth
- Uplink peak data rates up to 86.4 Mbps with 20 MHz bandwidth
- Operation in both TDD and FDD modes.
- Variable duplex technology within bands as well as between bands
- Scalable bandwidth up to 20 MHz, covering 1.4, 2.5, 5, 10, 15, and 20 MHz
- Increased spectral efficiency over Release 6 HSPA by a factor of two to four
- Enhance the bit rate for MBMS (e.g. 1-3 Mbps)

Architecture & Mobility Capabilities

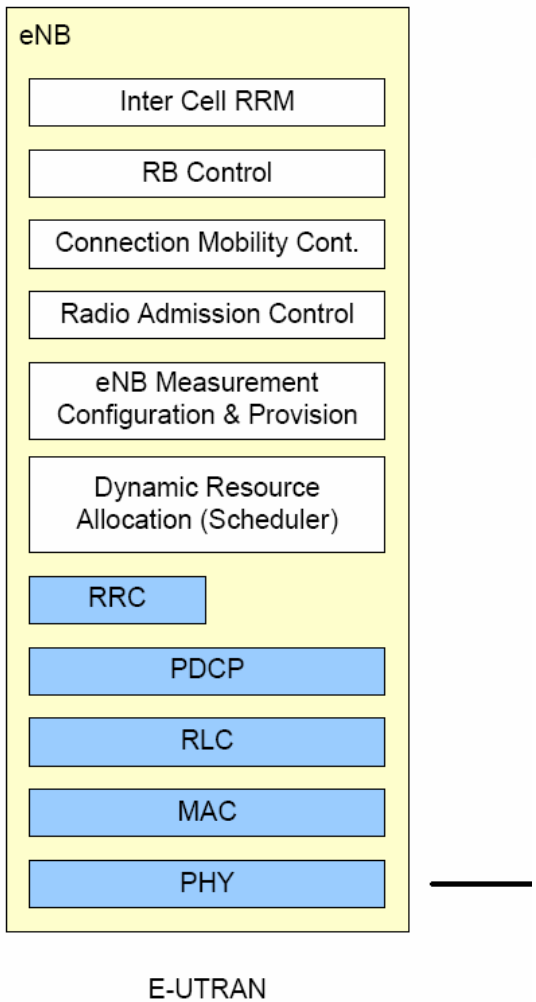
- UTRAN Evolution and UTRA Evolution with simplified architecture
- Open interfaces to support Multi-vendor deployments
- Robustness – no single point of failure
- Support of multi-RAT with resources controlled from the network
- Support of seamless mobility to legacy systems as well as to other emerging systems including
  - Inter-RAT Handovers
  - Service based RAT Selection
- Maintain appropriate level of security

Evolved Packet System (EPS)



- AGW (Access Gateway)
  - MME (Mobility Management Entity), which manages mobility, UE identity, and security parameters
  - S-GW (Serving Gateway) - node that terminates the interface towards E-UTRAN
  - P-GW (PDN [Packet Data Network] Gateway) - Node that terminates the interface towards PDN
- eNB (E-UTRAN NodeB), which carries out all radio interface-related functions

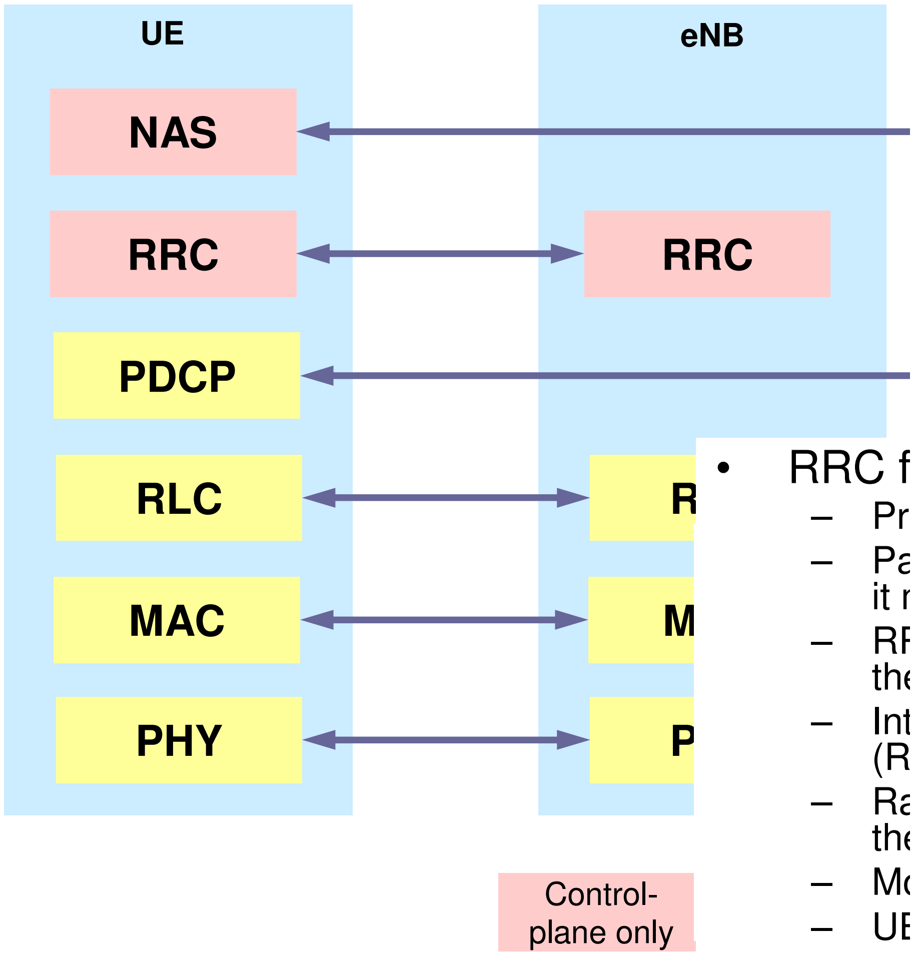
Functional Split between eNB & AGW



- eNB functions
  - Selection of aGW
  - Routing towards activation;
  - Scheduling and t paging messages;
  - Scheduling and transmission of BCCH information;
  - Dynamic allocation of resources to UEs in both uplink and downlink;
  - The configuration and provision of eNB measurements;
  - Radio Bearer Control;
  - Radio Admission Control;

- AGW functions
  - Paging origination
  - Ciphering of the user plane
  - PDCP
  - SAE Bearer Control
  - Ciphering and integrity protection of NAS signaling

Protocol Stack



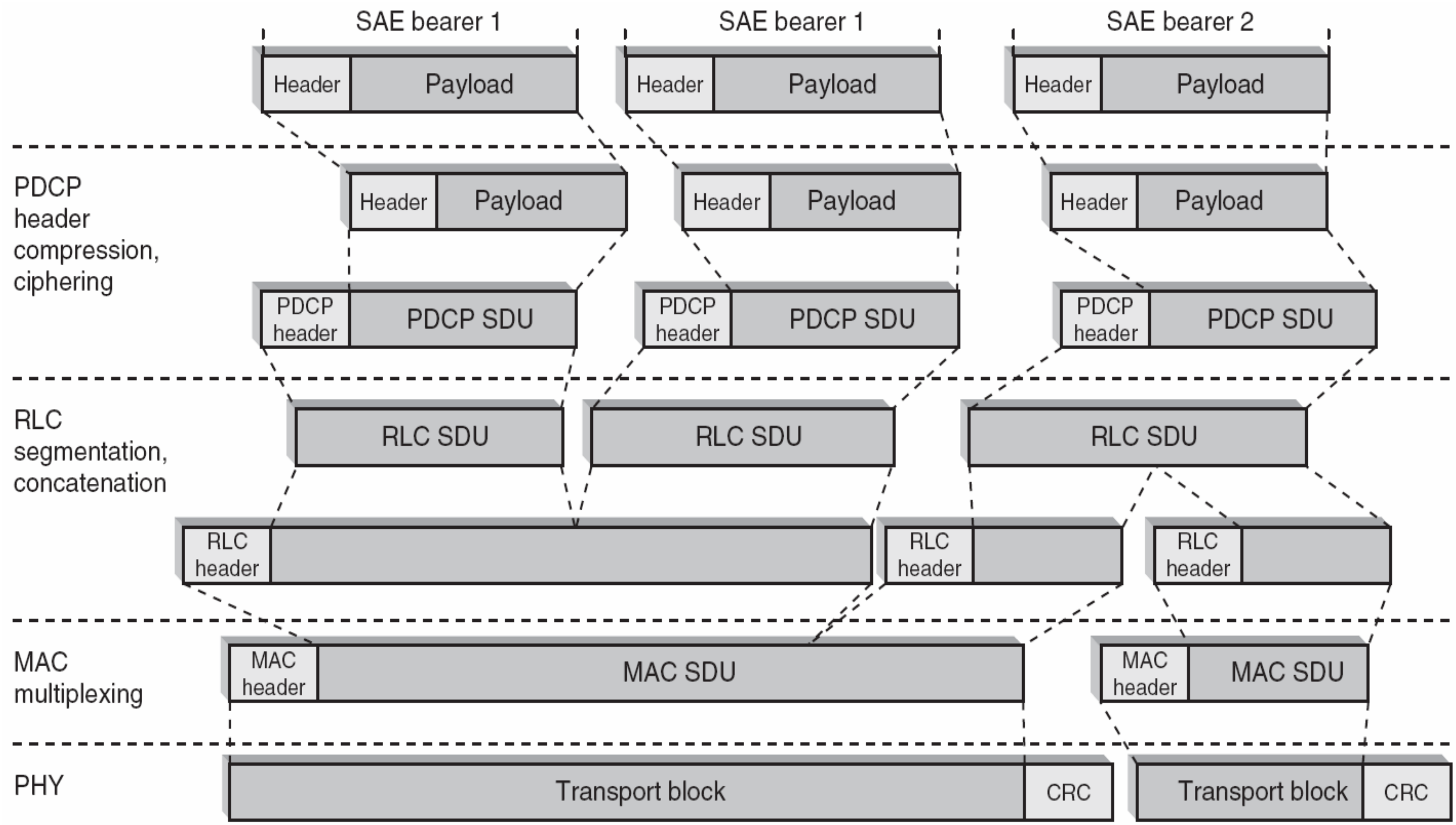
- RRC f
  - Pr
  - Pa
    it r
  - RF
    the
  - Int
    (R
  - Ra
    the
  - Mo
  - UE
    qu

- RLC Functions
  - Transferring upper layer PDUs
  - Error correction through ARQ
  - Concatenation, segmentation and reassembly of RLC SDUs
  - Re-segmentation of RLC data PDUs
- MAC Functions
  - Mapping between logical channels and transport channels
  - Scheduling information reporting
  - Managing HARQ
  - Logical channel prioritization;
  - Transport format selection.

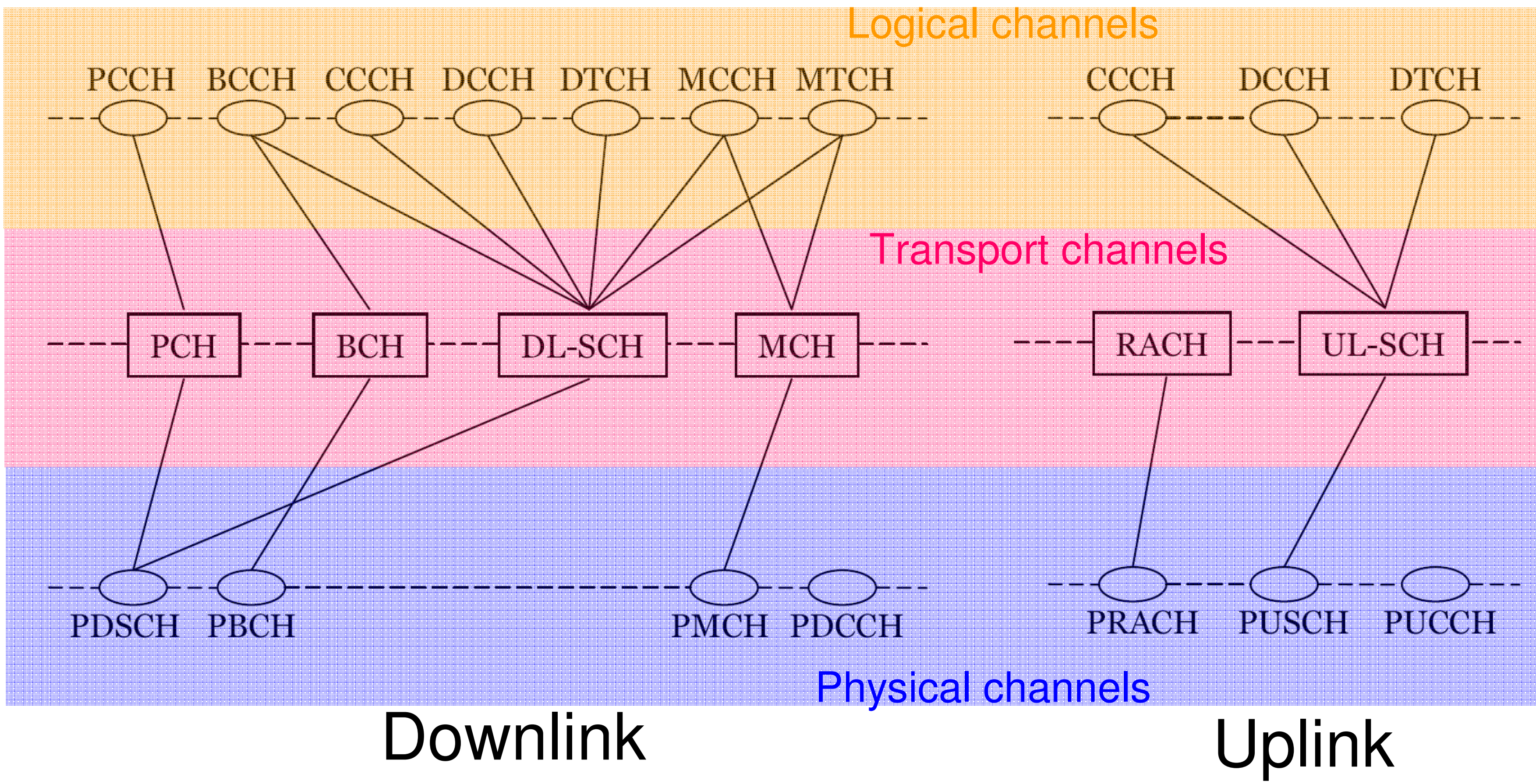
protocol stack between Core Network CN and User Equipment UE

- Supporting signaling and traffic between these two elements

Data Flow


SAE bearer 1
SAE bearer 1
SAE bearer 2
Header
Payload
PDCP
header
compression,
ciphering
PDCP
header
PDCP SDU
RLC
segmentation,
concatenation
RLC SDU
RLC
header
MAC
multiplexing
MAC
header
MAC SDU
PHY
Transport block
CRC

Channel Mapping



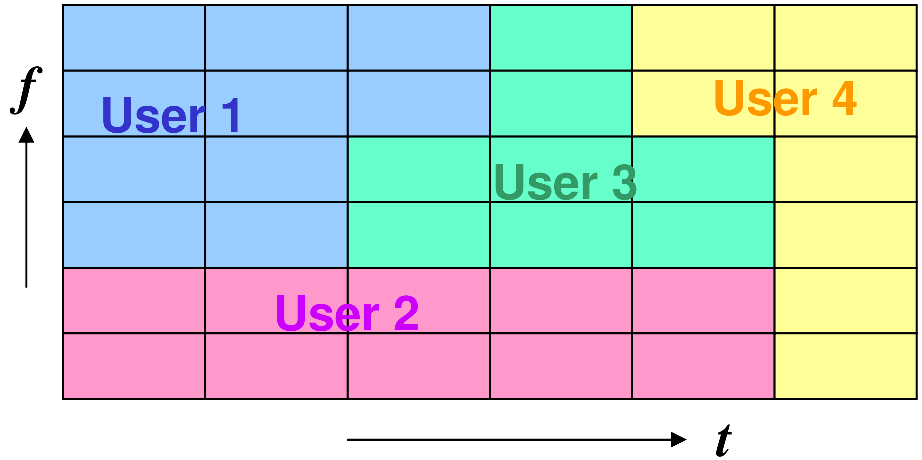
Key Technologies

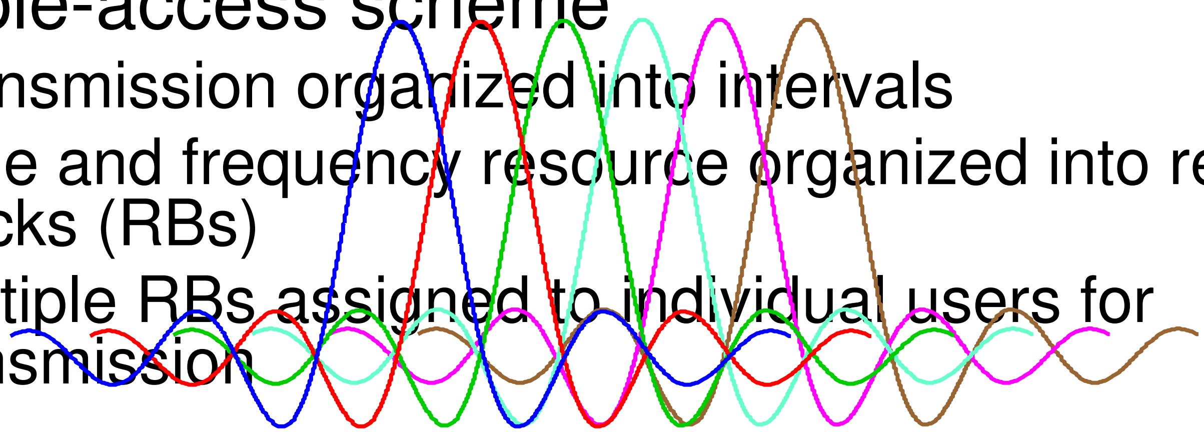
Key Technologies

- OFDMA for DL
- SC-FDMA (Single Carrier FDMA) for UL
- Bandwidth Flexibility
- Advanced antenna technology
- Link adaptation
- Inter-cell-interference coordination (ICIC)
- Two-layered retransmission (ARQ/HARQ)
- Multicarrier channel-dependent resource scheduling
- Discontinuous Rx and Tx
- MBMS

OFDMA

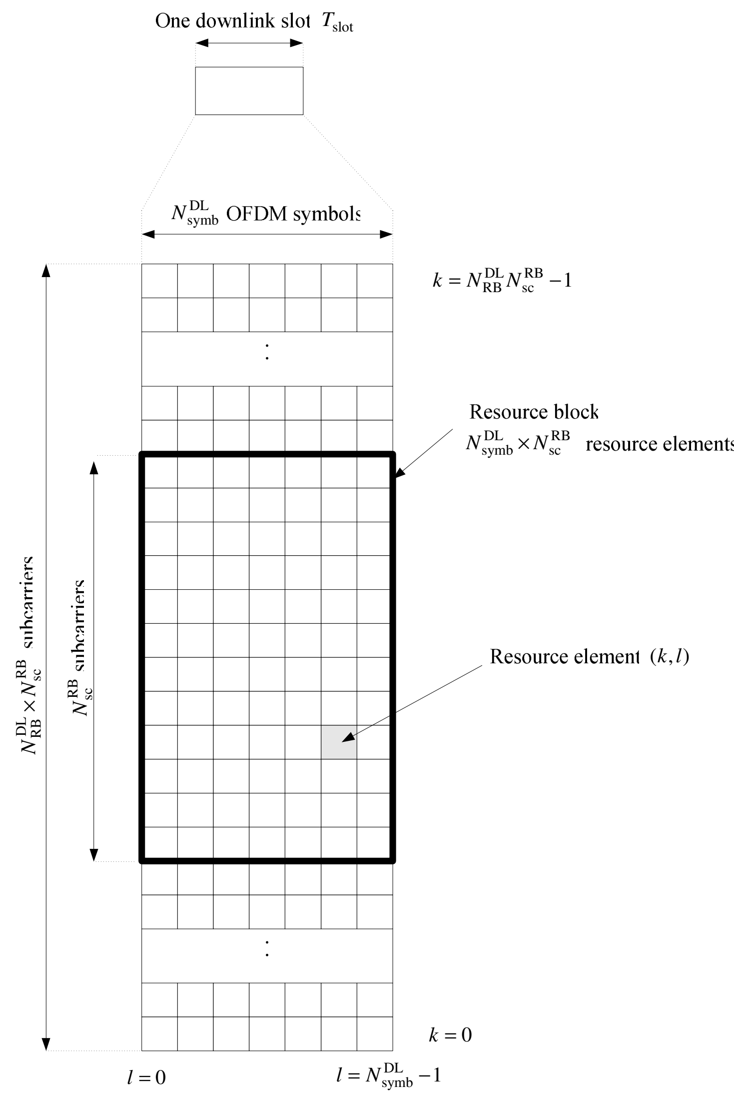
- Modulation - OF
  - An OFDM symb
    certain time dur
  - Transmitting dat
    subcarriers
  - Each subcarrier
    (e.g., QPSK)
- Multiple-access scheme
  - Transmission organized into intervals
  - Time and frequency resource organized into resource blocks (RBs)
  - Multiple RBs assigned to individual users for transmission





Time and Frequency Resource

- Resource element: subcarrier in an OFDM symbol
  - uniquely identified by the index pair (k,l) in a slot
- Resource block consisting of multiple RE Physical RB
  - Normal CP: 12x7
  - Extended CP: 12x6 (for 15KHz) and 24x3 (for 7.5KHz)



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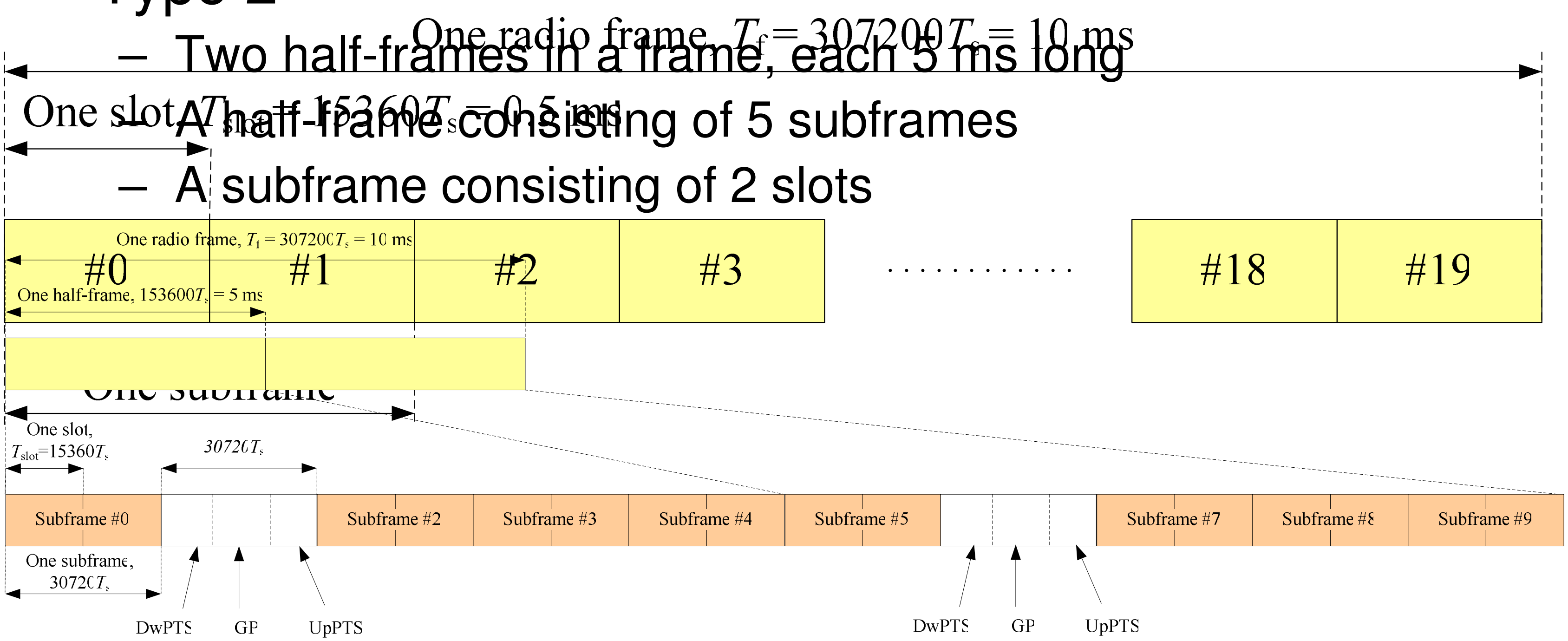
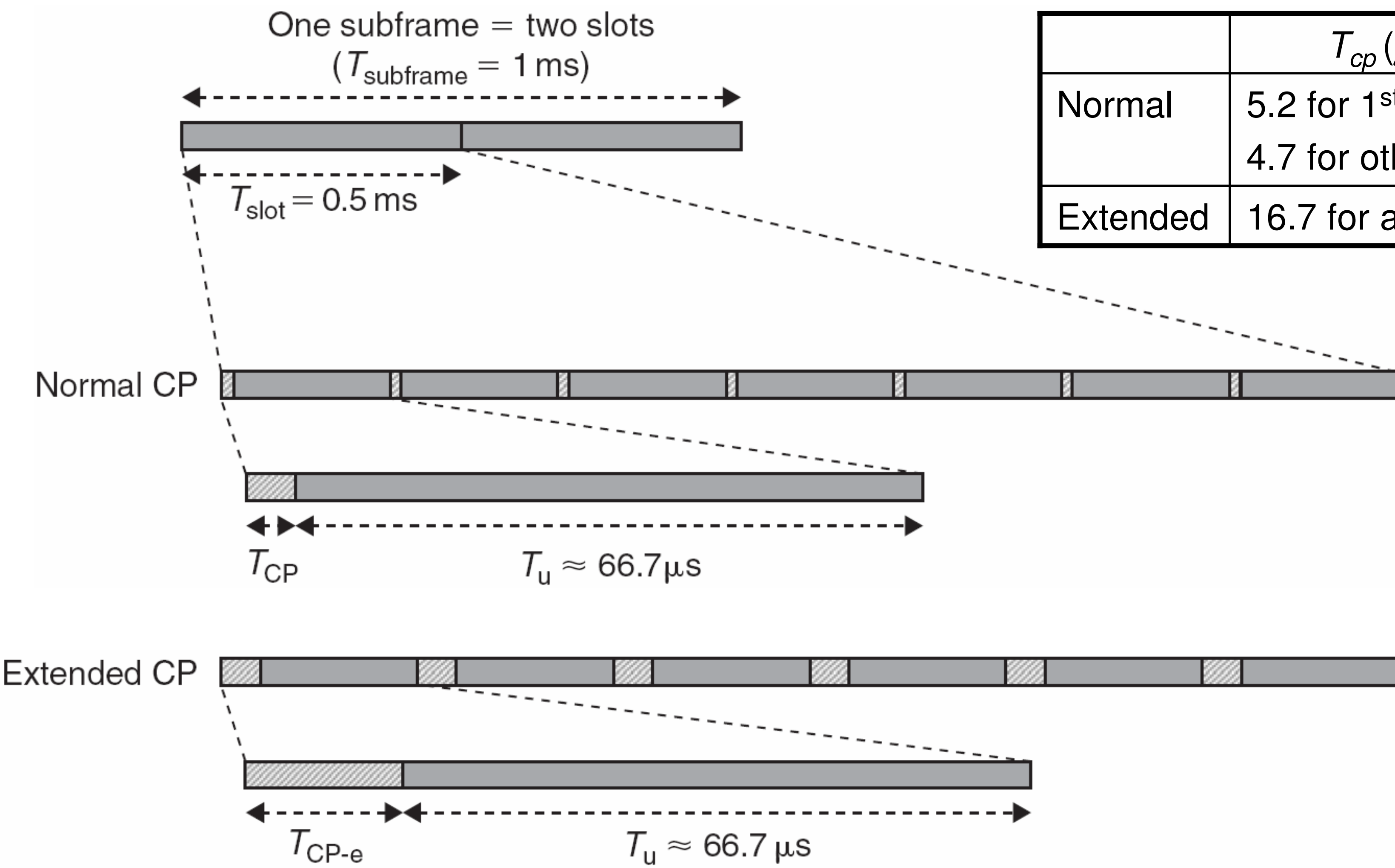
Frame Structure

- Type 1
  - Twenty time slots in a frame, each 0.5 ms long
  - A subframe consisting of two slots
  - Ten subframes for DL and 10 for UL
- Type 2
  - Two half-frames in a frame, each 5 ms long
  - A half-frame consisting of 5 subframes
  - A subframe consisting of 2 slots

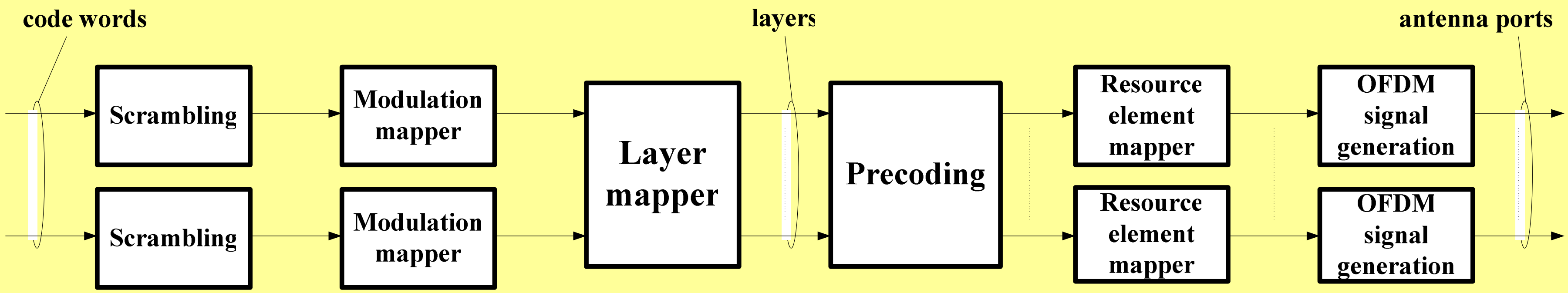


Subframe



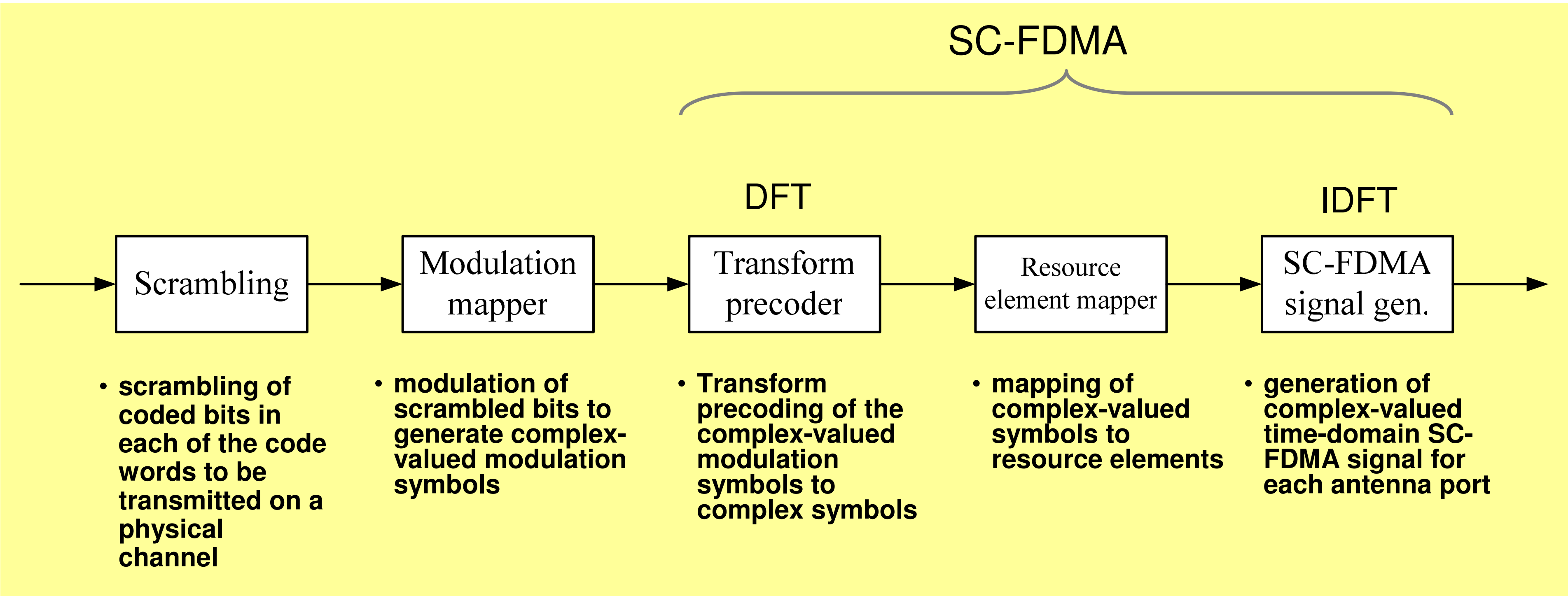
	T_{cp} (μs)
Normal	5.2 for 1st symbol 4.7 for others
Extended	16.7 for all

DL Physical Channel Processing



- scrambling of coded bits in each of the code words to be transmitted on a physical channel
- modulation of scrambled bits to generate complex-valued modulation symbols
- mapping of the complex-valued modulation symbols onto one or several transmission layers
- precoding of the complex-valued modulation symbols on each layer for transmission on the antenna ports
- mapping of complex-valued modulation symbols for each antenna port to resource elements
- generation of complex-valued time-domain OFDM signal for each antenna port

UL Physical Channel Processing



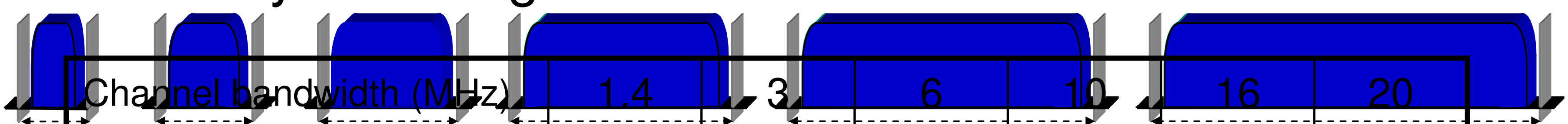
- Utilizes single carrier modulation and frequency domain equalization
- SC-FDMA can be regarded as DFT-precoded or DFT-spread OFDMA

SC-FDMA

- Two types of SC transmission
  - Localized transmission
    - Multi-user scheduling gain in frequency domain
    - Need to feedback channel state information
    - Mainly for low-to-medium mobility users
  - Distributed transmission
    - Robust transmission for control channels and high mobility UE
    - Mainly for high mobility users

Bandwidth Flexibility

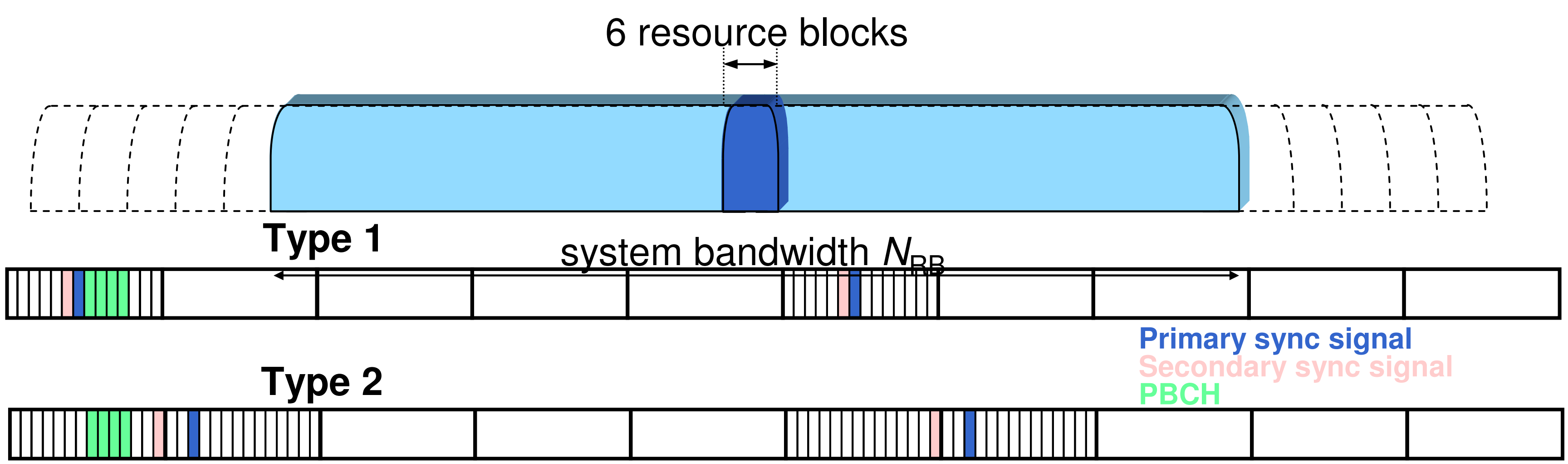
- Supported bandwidths: 1.4, 3.0, 5, 10, 15, 20 MHz
- All UE support bandwidth of 110 RBs (110x180 kHz≈20 MHz)
- Fixed subcarrier spacing
- Modular sampling rates for different BWs
- Adjusting the numbers of RB for different BWs
- Fixed symbol length for all BWs



Channel bandwidth (MHz)	1.4	3	6	10	16	20
Subcarrier spacing (KHz)	15	15	15	15	15	15
Number of occupied subcarriers	72	180	300	600	900	1200
Number of RB per slot	6	15	25	50	75	100
IDFT/DFT size	128	256	512	1024	1536	2048
Sampling rate (MHz)	1.92	3.84	7.68	15.36	23.04	30.72

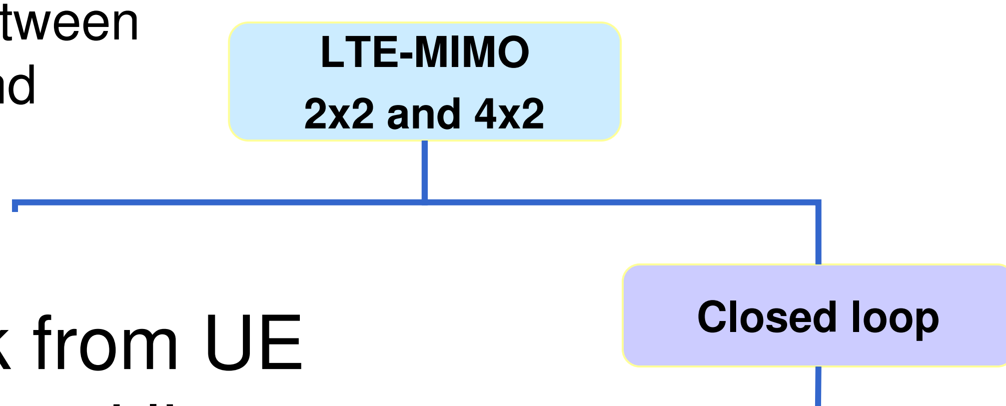
DL Synchronization Signals

- Transmitted on the 72 centre sub-carriers (around DC sub-carrier)
- Primary sync signal
  - carrying 3 unique identities of a cell group
  - Tx at 1st and 5th subframes (Type1) or at 2nd and 6th subframes (Type 2)
- Secondary sync signal
  - carrying 168 cell identity groups
  - Tx at 1st and 5th subframes
- Generated from Zadoff-Chu sequences



DL MIMO Modes

- Dynamic switching between spatial multiplexing and SFBC

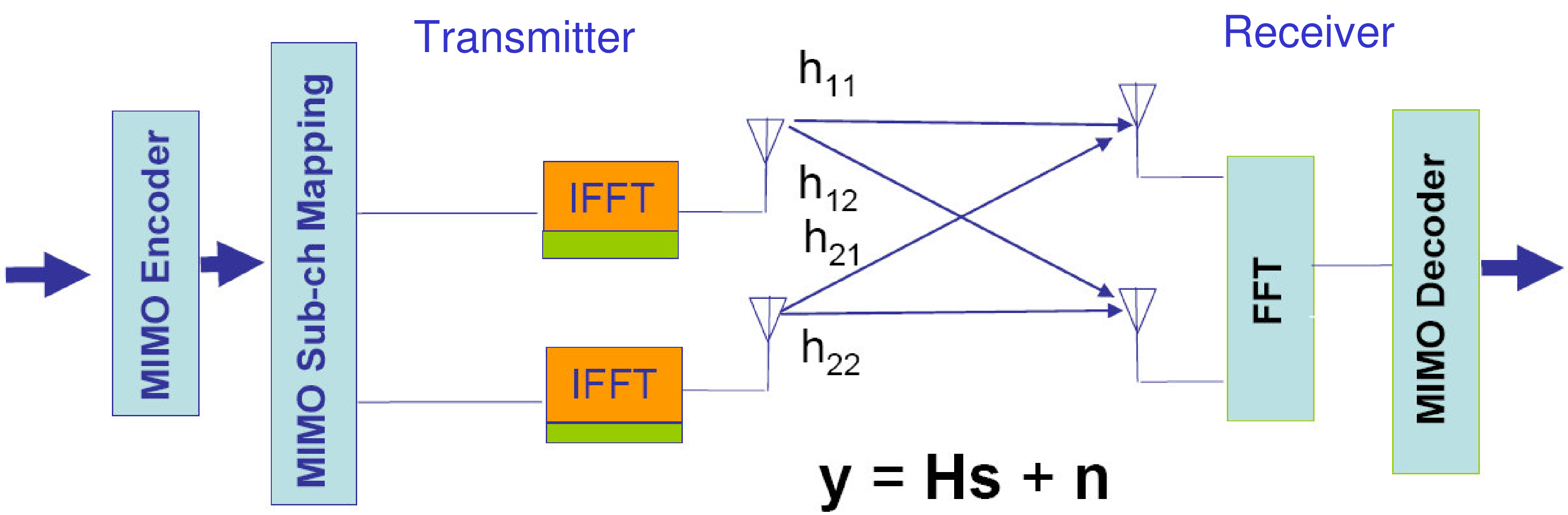


- CL
  - PMI feedback from UE
  - Codebook-based linear precoding
  - PSRC
    - Uses diversity to transmit multiple data streams over multiple transmit antennas
  - MU-MIMO/SDMA
    - To improve capacity

- OL single stream
  - SFBC
- OL multiple streams
  - PARC
    - Uses diversity to transmit multiple data streams over multiple transmit antennas
  - Beamforming
    - To improve coverage

DL MIMO

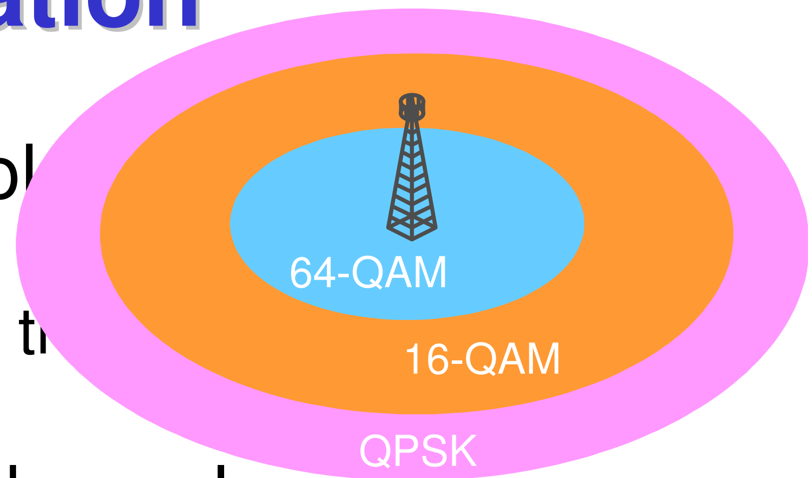
- MIMO operation in the frequency domain



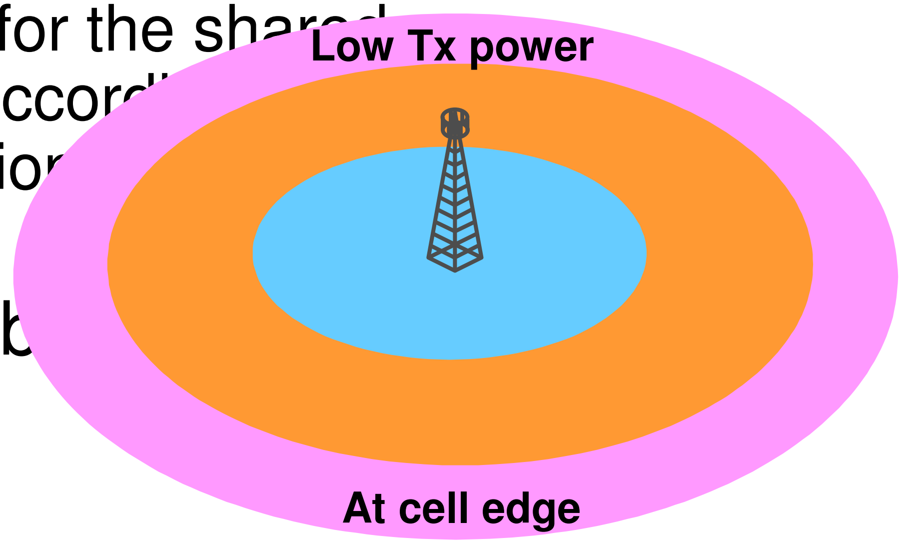
$$y = Hs + n$$

Link adaptation

- Transmission power control
  - Support fractional path-loss compensation: UEs close to t border use less tx power



- Adaptive modulation and channel coding rate
  - Modulation and coding for the shar data channel adapted accord Channel Quality Indicatio reported by UE
- Adaptive transmission b
  - RB allocation



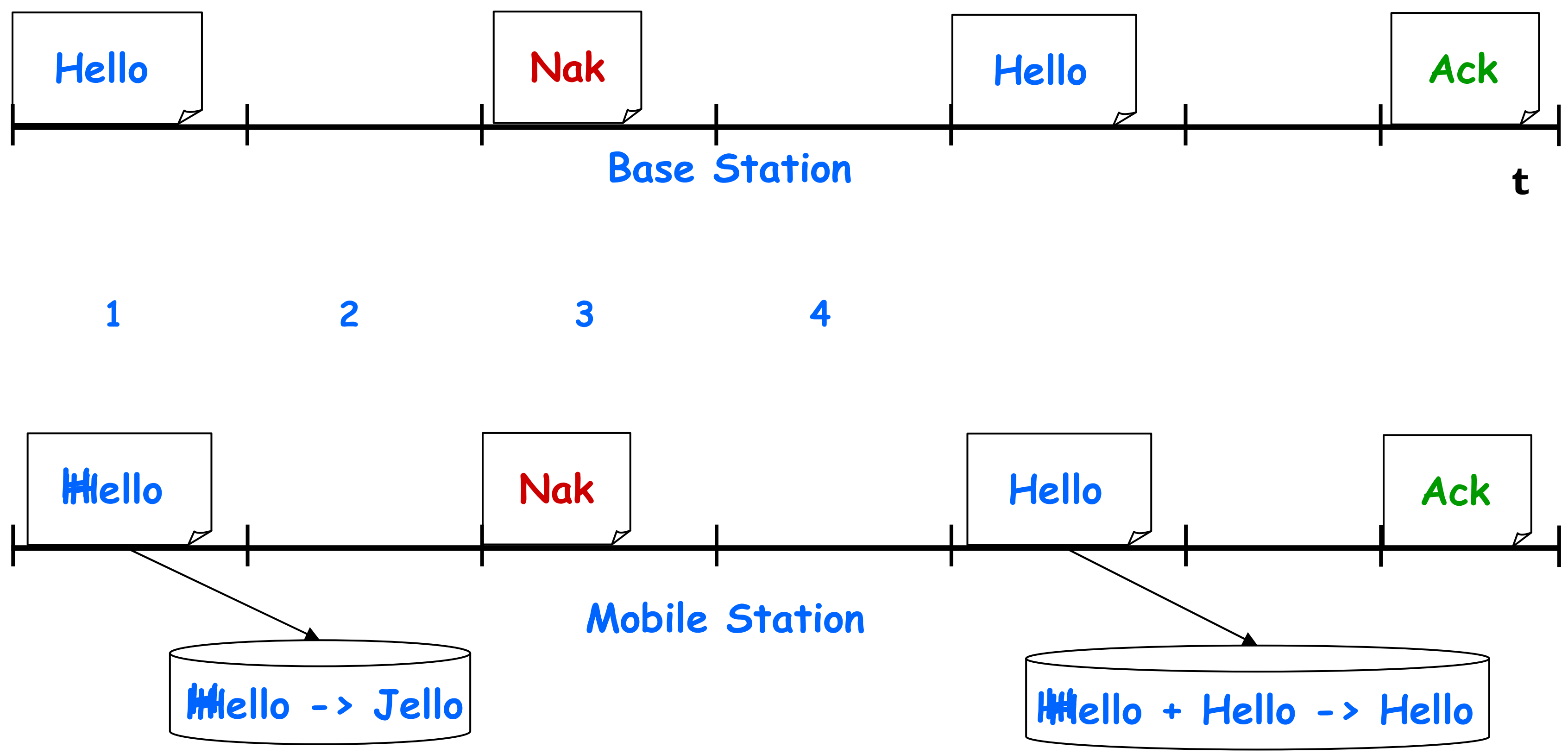
Inter-Cell-Interference Coordination

- Allowing frequency reuse >1 at cell edge
- UL ICIC
  - Supported through High-Interference and Overload Indicators, sent to neighboring cells
  - Avoiding scheduling UL use at the cell edge in some parts of the bandwidth
- DL ICIC
  - Restriction of tx power in some parts of the bandwidth
  - Coordination supported through RNTP indicator, sent to neighboring cells

ARQ/HARQ

- eNB or UE can to request retransmissions of incorrectly received data packets
- Use two-layered mechanism to achieve low latency and low overhead without sacrificing reliability
- Most errors captured by HARQ protocol

HARQ Protocol

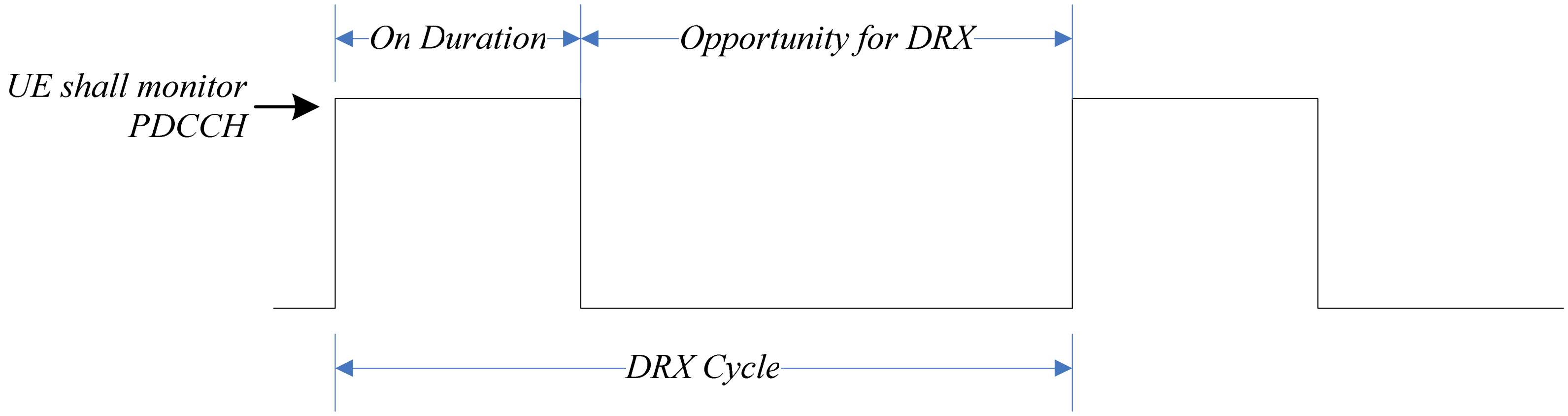


Scheduling

- eNB scheduler
  - Taking into account of different types of information
    - QoS parameters and measurements from the UE
    - UE capabilities and buffer status
  - Each subframe (1ms), determining
    - which users are allowed to transmit
    - on what frequency resource,
    - at what data rate
  - Examlple – channel dependent scheduling – taking advantage of channel quality variation for more efficient use of BW
- Types of scheduling
  - Dynamic scheduling
  - Semi-persistent scheduling
  - With HARQ

Power Saving: DRX and DTX

- LTE power save protocols
  - Discontinuous Reception (DRX)
  - Discontinuous Transmission (DTX)
  - Both reducing transceiver duty cycle while in active operation
  - DRX also applies to the RRC_Idle state with a longer cycle time than active mode



Long and Short DRX

- DRX may have long or short “off” durations, configured by the RRC
- Transition between long DRX and short DRX
  - Determined by the eNB (MAC commands) or by the UE based on an activity timer
- A lower duty cycle could be used during a pause in speaking during a voice over IP call
- When speaking resumes, this results in lower latency
- For packets arriving at a lower rate, the UE can be off for a longer period of time
- For packets arriving more often, the DRX interval is reduced during this period

MBMS

- MBMS is an essential requirement for LTE - an integral part of LTE.
- Cells may be configured to be part of an SFN for transmission of an MBMS service
  – the cells and content are synchronized to enable for the UE to soft-combine the energy from multiple transmissions
- The MBMS traffic can share the same carrier with the unicast traffic or be sent on a separate carrier
- Suppoeted by MBSFN reference signals

LTE -Advanced

- Advanced version of LTE (3GPP Rel. 10) designed to meet IMT-Advanced requirements

- Evolution of current OFDMA approaches
- High-order MIMO (e.g., 4X4)
- Wider radio channels (e.g., 50 to 100 MHz).
- Optimization in narrower bands (e.g., less than 20 MHz) due to spectrum constraints in some deployments
- Multi-channel operation in either same or different frequency bands
- Ability to share bands with other services.

About Neocific

- A wireless technology company
  - Consulting
  - Prototyping and product development
  - Reference designs on HW/SW platforms
- Technical strength
  - OFDM/OFDMA broadband wireless system
  - IP networking software development
  - Embedded software development
- Current focus
  - Broadband wireless technologies : WiMAX, LTE, and others
  - Sensor networks

Thank you!