Comba 京信通信

LTE Principle and Service Flow

2018.10.xx

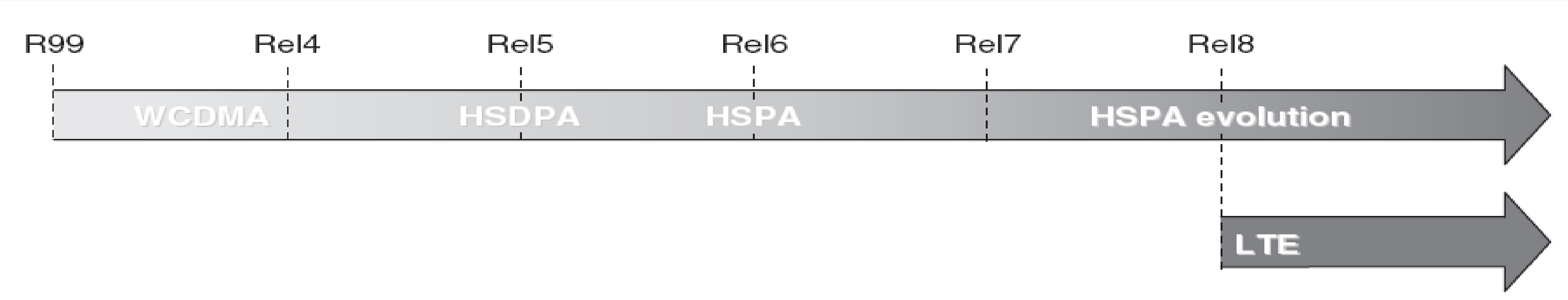
Ms./Mr. xxxx

Solution Dept.

Catalog

Background

- 3GPP is working on two approaches for 3G evolution: the LTE and the HSPA Evolution
  - HSPA Evolution is aimed to be backward compatible while LTE do not need to be backward compatible with WCDMA and HSPA
  - By the end of 2007, 3GPP R8 is released as the first specs of LTE



LTE requirements and targets

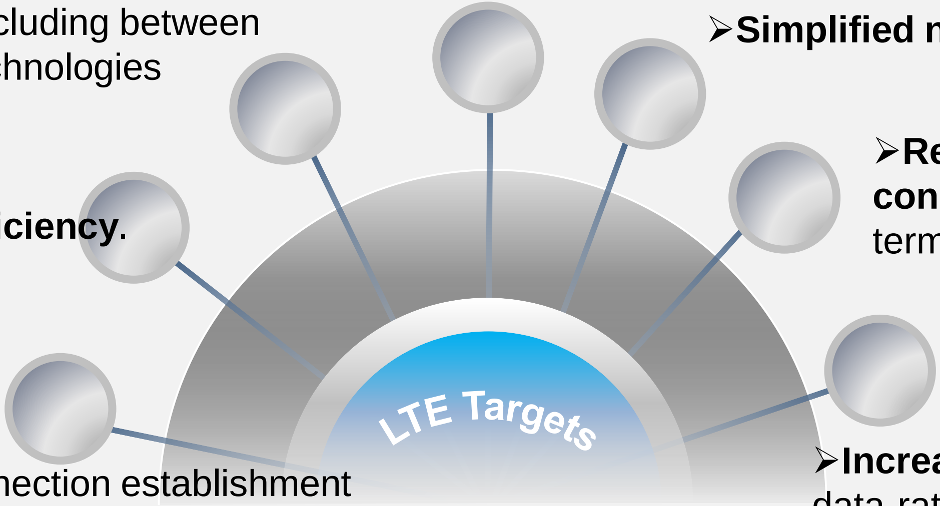
➢Supporting **flexible spectrum allocation** (1.4, 3, 5, 10, 15 and 20 MHz) to meet the complicated spectrum situation requirement

➢**Seamless mobility**, including between different radio-access technologies

➢**Simplified network architecture**.

➢**Reasonable power consumption** for the mobile terminal.

➢**Improved spectral efficiency**.



➢**Reduced delays:** Connection establishment (<100ms) and transmission latency (< 10ms)

➢**Increased user data rates**: (Peak data-rate DL100 Mbit/s and UL 50 Mbit/s in 20MHz spectrum allocation)

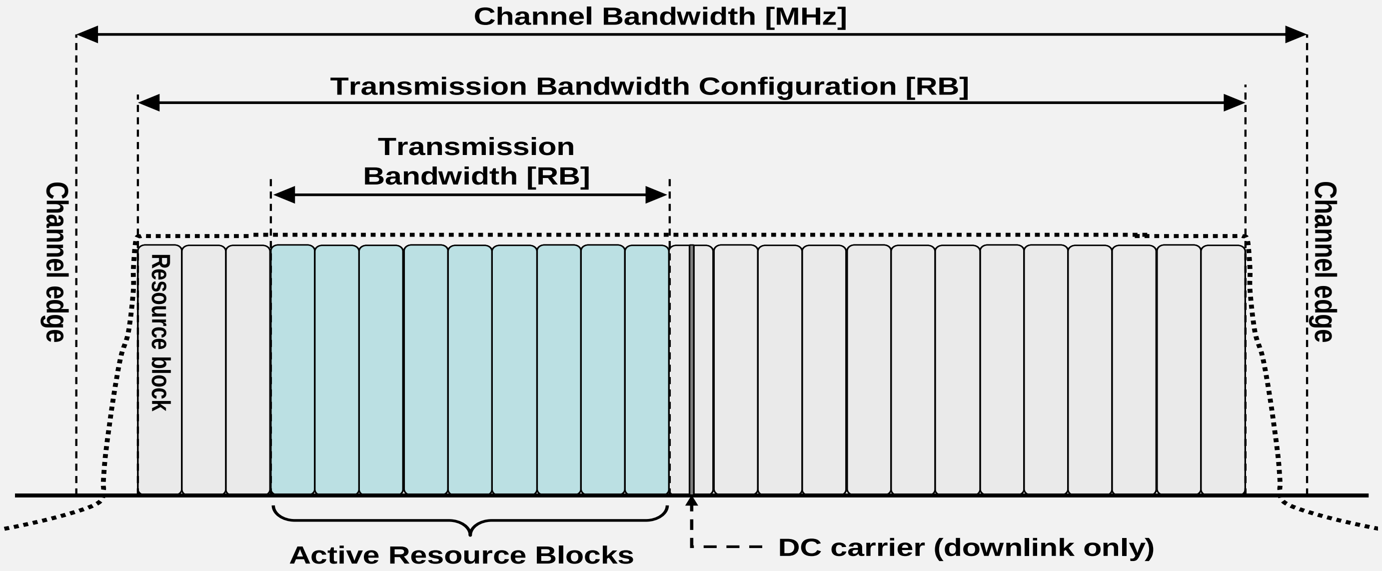
LTE technical features

DL OFDMA UL SC-FDMA	The LTE downlink transmission scheme is based on **downlink OFDMA** and **uplink SC-FDMA**
Shared-channel Transmission	the time-frequency resource is dynamically shared between users. This is similar to the approach taken in HSDPA
HARQ	with soft combining is used in LTE
MIMO	MIMO is supported by LTE, basically this is Spatial multiplexing can increase data rate prominently
ICIC	Inter-Cell Interference Coordination(ICIC)

LTE frequency bands

- LTE is designed to operate in these frequency bands：
  - 2.1GHz, 1.9GHz, 1.7GHz, 2.6GHz, 900 MHz, 800 MHz, 450 MHz, etc , refer to 36.101 for details.
- Transmission bandwidth could be:

Channel bandwidth $BW_{Channel}$ [MHz]	1.4	3	5	10	15	20
Transmission bandwidth configuration N_{RB}	**6**	**15**	**25**	**50**	**75**	**100**



LTE standardization and specifications

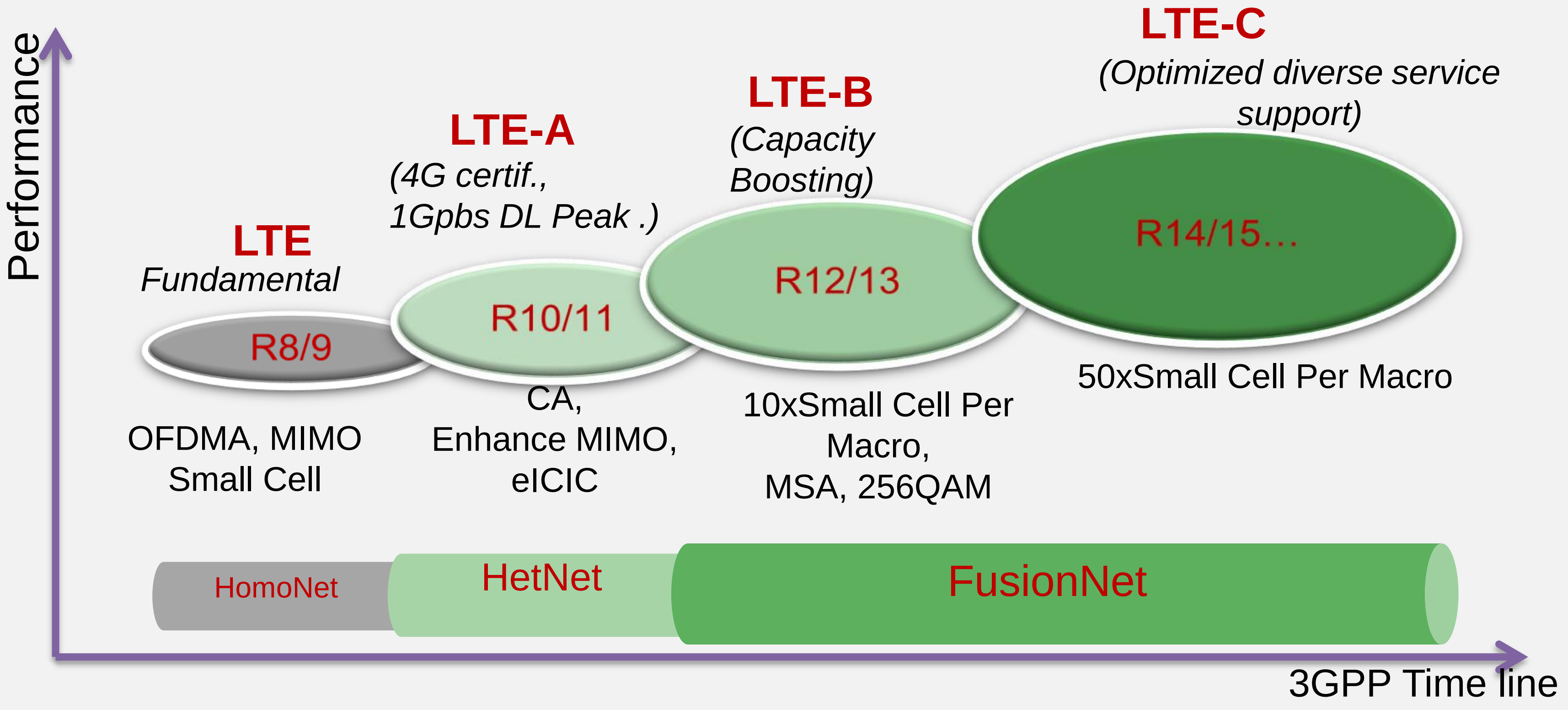
Docs for 3GPP specifications.

http://www.3gpp.org/specifications

The specification document for LTE is 36 series, inherits the structure of UTRAN 25 series:

- 36.1xx series is about the physical layer general aspect
- 36.2xx series is about radio interface physical layer
- 36.3xx series is about the radio interface layer 2 and 3
- 36.4xx series is about the terrestrial interfaces (S1, X2)

LTE Release 9 FDD/TDD



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PART-1 LTE system principle

PART-2 LTE system services flows

Basic principles –why OFDM

Why OFDM

In order to **transmit high data rates**, short symbol periods must be used, In a multi-path environment, a shorter symbol period leads to a greater chance for Inter-Symbol Interference (ISI).

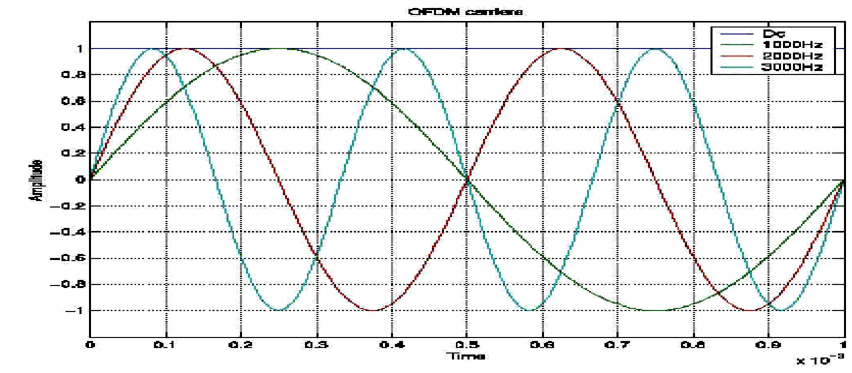
Efficient use of radio spectrum includes placing modulated carriers as close as possible without causing Inter-Carrier Interference (ICI)

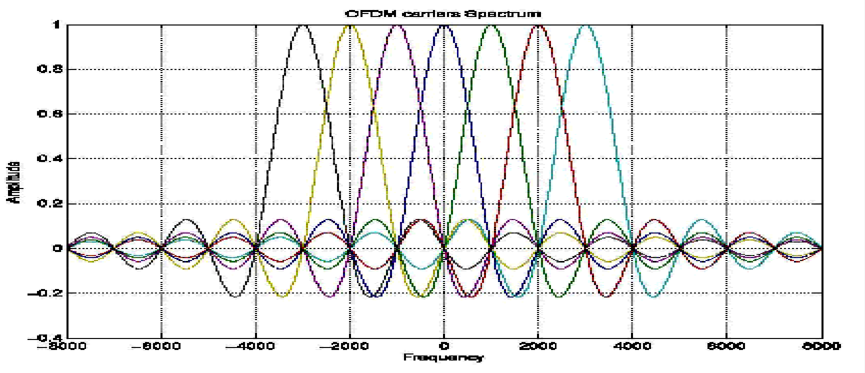
Orthogonal Frequency Division Multiplexing (OFDM) addresses both of these problems:

- OFDM provides a technique allowing the bandwidths of modulated carriers to overlap without interference (no ICI).
- It also provides a high date rate with a long symbol duration, thus helping to eliminate ISI.

Basic principles – signaling transporting

- Transmission by means of OFDM can be seen as a kind of multi-carrier transmission.
- Due to the fact that two modulated OFDM subcarriers are mutually orthogonal, multiple signals could be transmitted in parallel over the same radio link, the overall data rate can be increased up to M times.





Advantage of OFDM

cyclic prefix

- inter-symbol interference could be minimized

long symbol duration

- OFDMA is more tolerant to multi-path environment and better entitled to eliminate ISI (inter symbol interference)

Flexible

- OFDM is flexible in allocating power and rate optimally among narrowband sub-carriers (scheduling)

High spectrum efficiency

- the bandwidth of each subcarrier would be adjacent to its neighbors, so there would be no wasted spectrum

Frequency diversity

- Frequency diversity could be enabled due to the wide spectrum

Questions

- **Which is LTE bandwidth as follows?**

    a. 1.4MHz.
    b. 3MHz.
    c. 5MHz.
    d. 10MHz.
    e. 15MHz.
    f. 20MHz.
    g. 40MHz

Questions

- **Which is the LTE downlink and uplink technical?**

  a. OFDMA, SC-FMDA.

  b. SC-FDMA, OFDMA

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PART-1 LTE system principle

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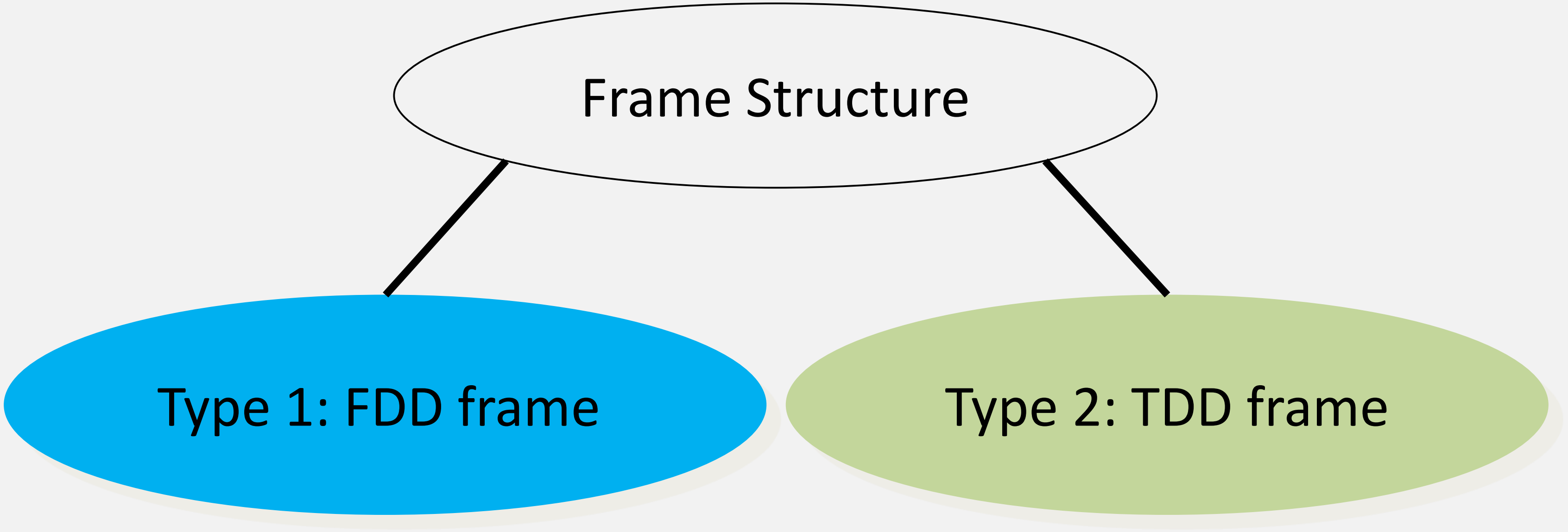
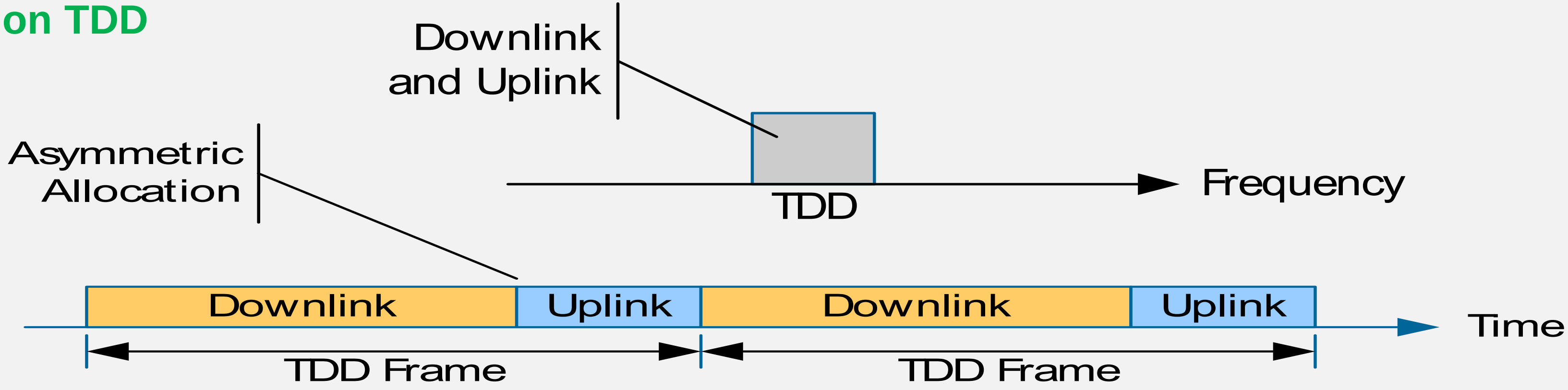
Frame Structure overview



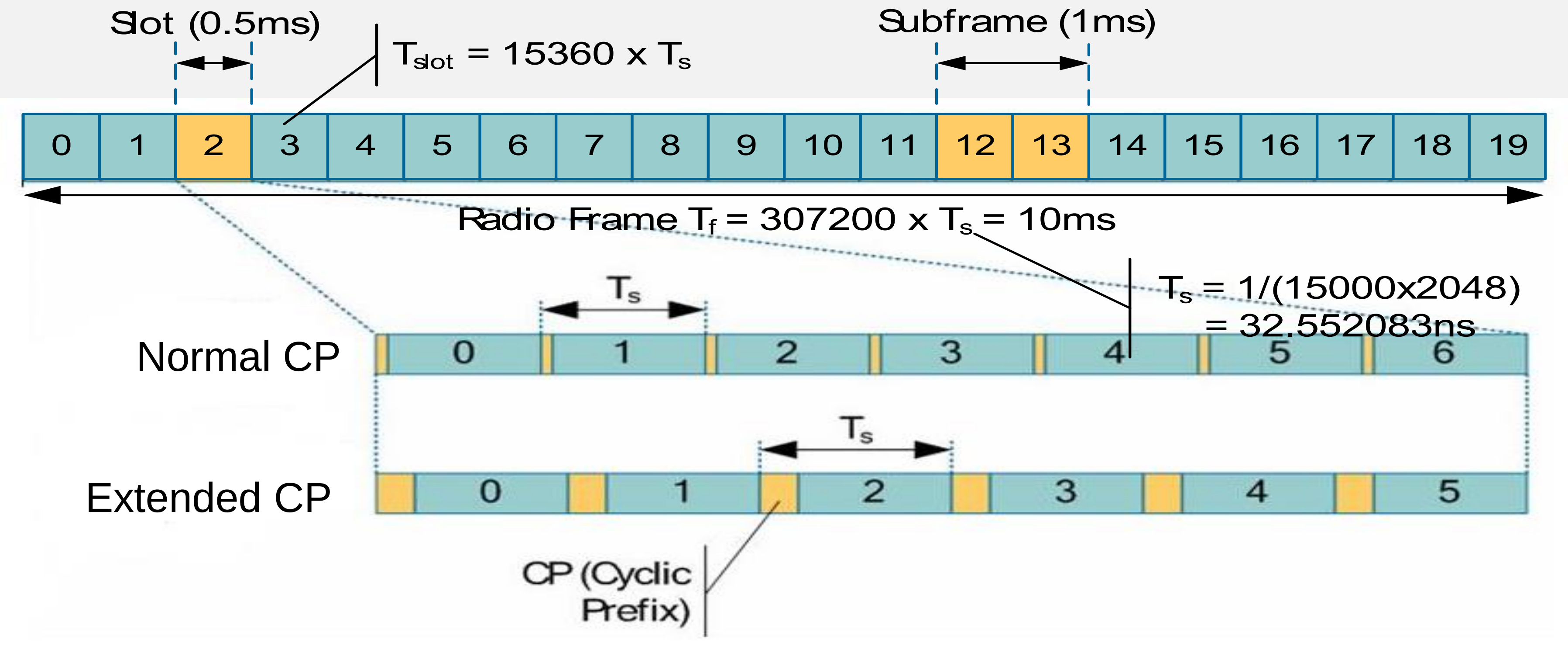
Transmission Modes TDD & FDD summary

Transmission FDD

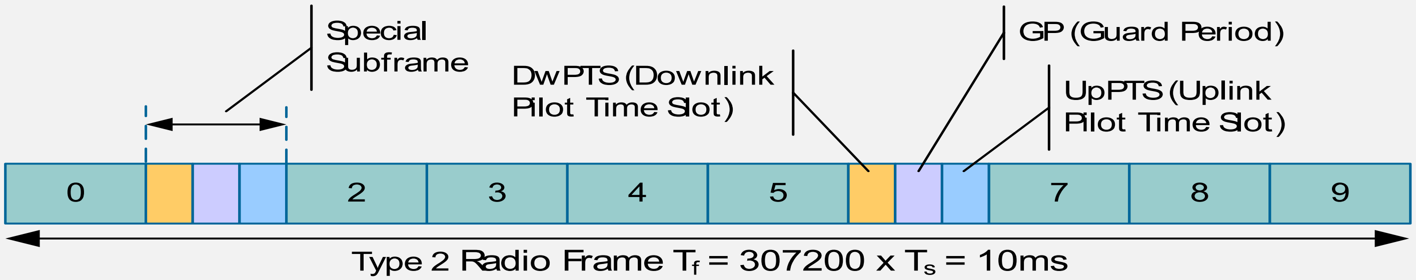
Transmission TDD



FDD Frame details

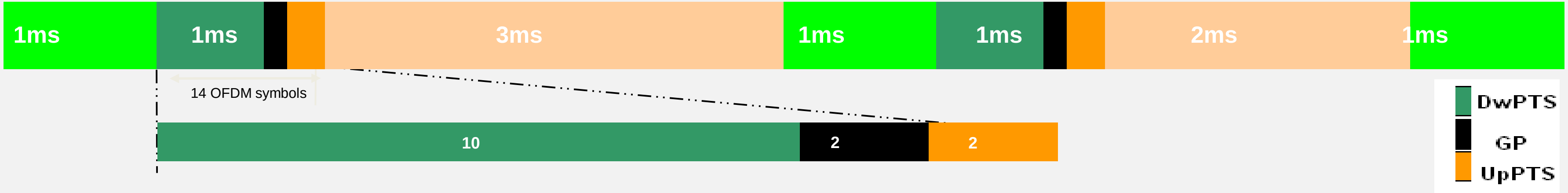


TDD Frame details



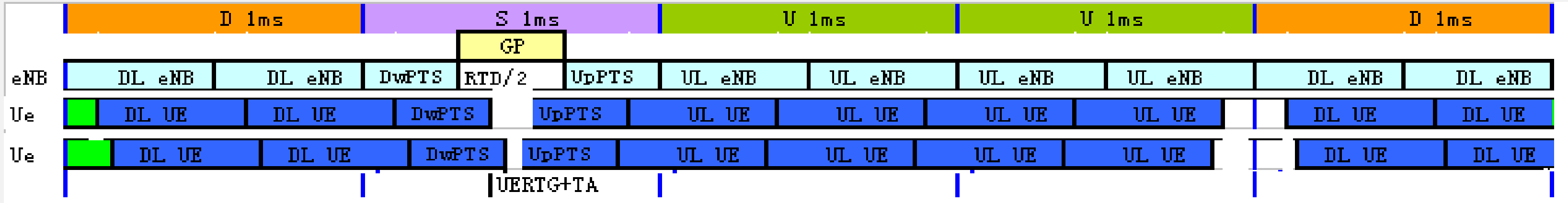
- In one TDD frame it contains one or two special subframes, which can be divided into 3 parts:
  - DwPTS： DL pilot slot
  - UpPTS: UL pilot slot
  - GP: Guard protect slot

Special Sub-frame — DwPTS & UpPTS



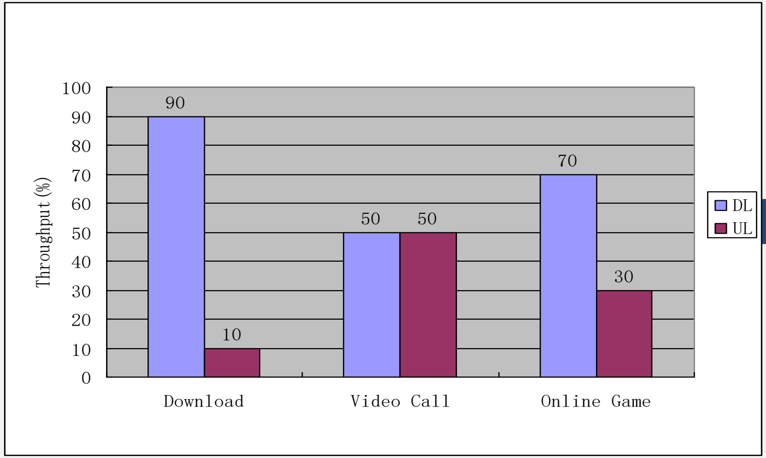
Special-subframe configuration	DwPTS	GP	UpPTS
0	3	10	1
1	9	4	1
2	10	3	1
3	11	2	1
4	12	1	1
5	3	9	2
6	9	3	2
7	10	2	2
8	11	1	2

Special Sub-frame — GP



- Guarantee that uplink signals from different UEs which are far away from the eNB's antenna are aligned on the air interface of eNodeB
- Provide an uplink-and-downlink conversion time (There is a very short conversion time Tud (less than 20 µs) in the conversion from the uplink to the downlink of eNodeB)
- The length of GP determines the eNB's cell radius. The maximum cell radius supported by LTE TDD is 100 km
- Avoid uplink/downlink interference between eNodeBs

Adjustable Sub-frame Configuration for LTE TDD



Configuration	Switch-point periodicity	Subframe number									
		0	1	2	3	4	5	6	7	8	9
0	5 ms	D	S	U	U	U	D	S	U	U	U
1	5 ms	D	S	U	U	D	D	S	U	U	D
2	5 ms	D	S	U	D	D	D	S	U	D	D
3	10 ms	D	S	U	U	U	D	D	D	D	D
4	10 ms	D	S	U	U	D	D	D	D	D	D
5	10 ms	D	S	U	D	D	D	D	D	D	D
6	5 ms	D	S	U	U	U	D	S	U	U	D

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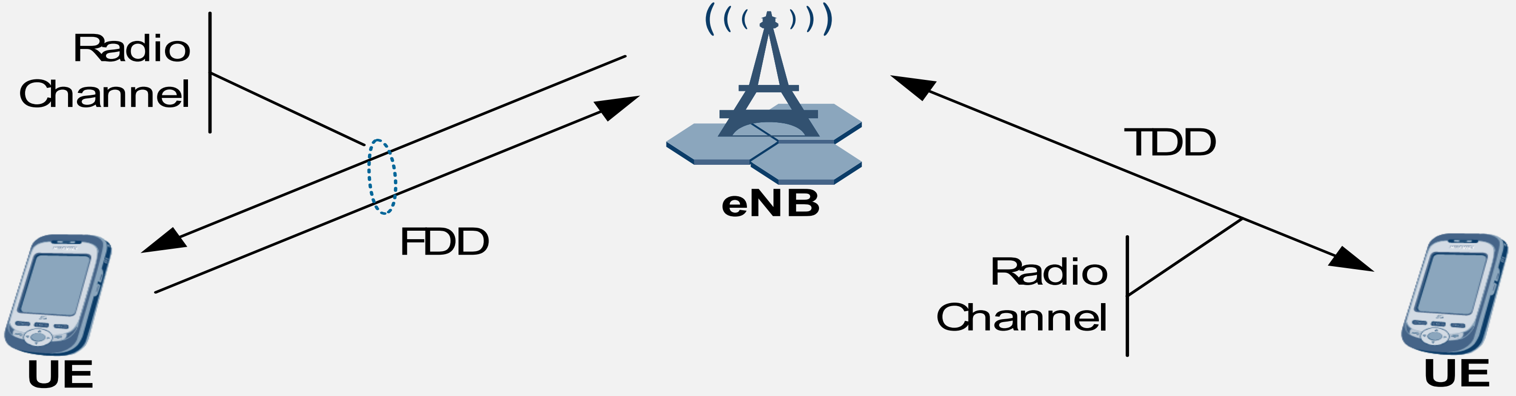
LTE channel summary and type (1/3)

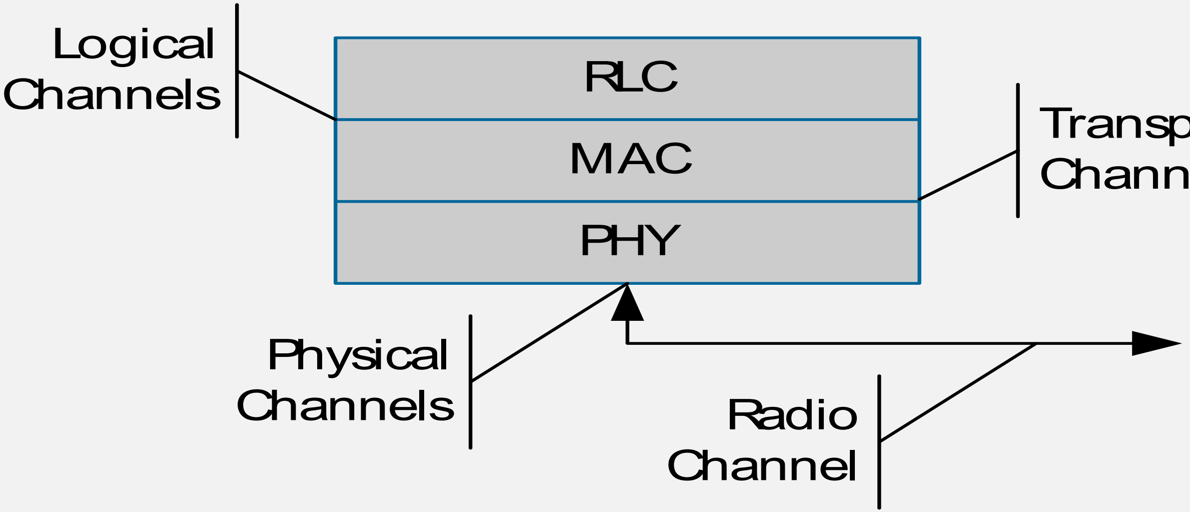
Channels info overview

- Logical Channels
- Transport Channels
- Physical Channels
- Radio Channels

Radio Channels difference between LTE FDD&TDD



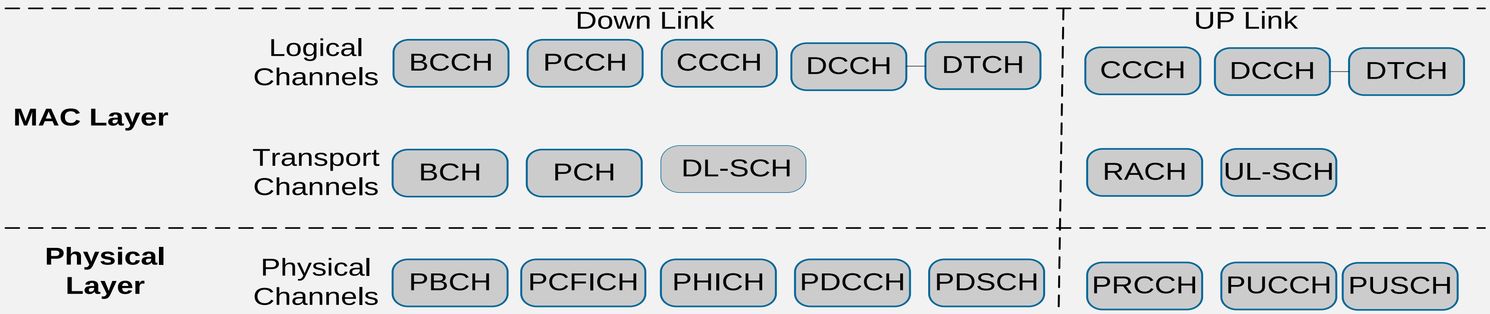
LTE channel summary and type (2/3)



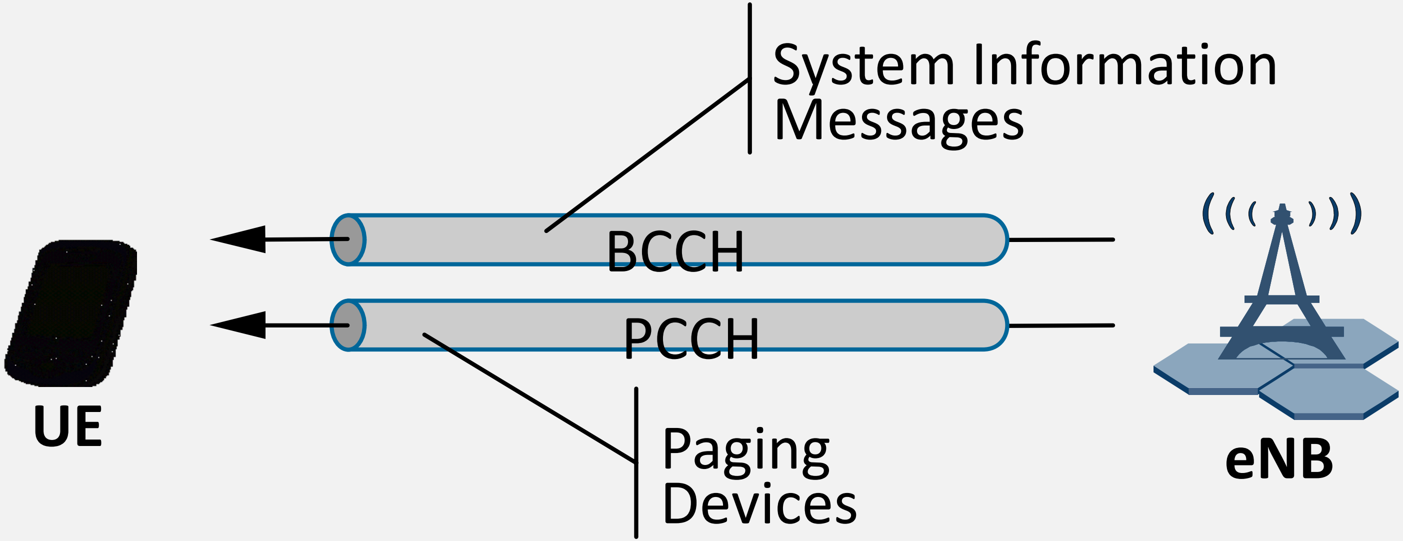
➢Logical Channels are classified as either Control Logical Channels, which carry control data such as RRC (Radio Resource Control) signaling, or Traffic Logical Channels which carry User Plane data.

LTE channel summary and type(3/3)

Different Channels definitions in Physical layer and logical layer

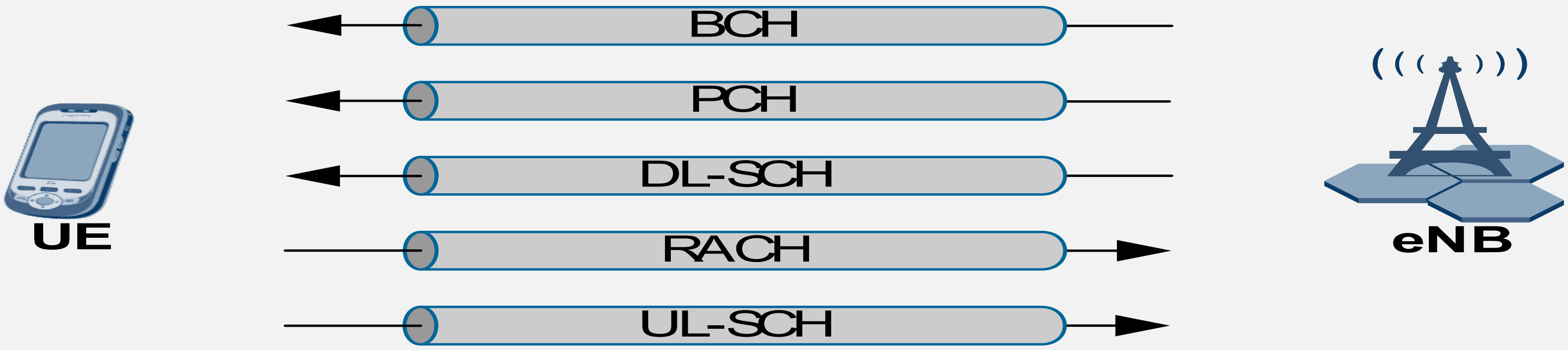


Control Logical Channels



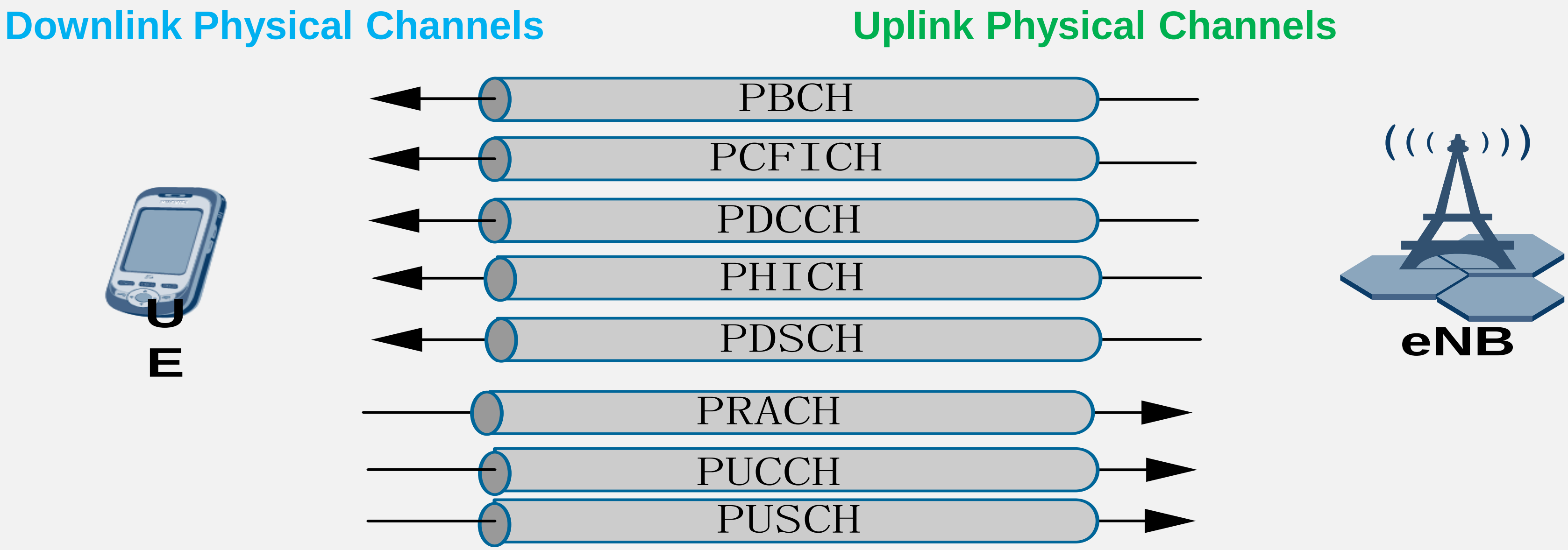
- ➢BCCH (Broadcast Control Channel) - this is a downlink channel used to send of SI (System Information) messages from the eNB (Evolved Node B). These are defined by RRC.
- ➢PCCH (Paging Control Channel) - this is a downlink channel used by the eNB to broadcast paging information.

Transport Channel (LTE Release 8)



- **BCH (Broadcast Channel)** - this is a fixed format channel which occurs once per frame and it is used to carry the MIB (Master Information Block). Note that the majority of system information messages are carried on the DL-SCH (Downlink - Shared Channel).
- **PCH (Paging Channel)** - which is used to carry the PCCH, i.e. paging messages. It also utilizes DRX (Discontinuous Reception) to improve UE battery life.
- **DL-SCH (Downlink - Shared Channel)** - is the main downlink channel for data and signaling. It supports dynamic scheduling, as well as dynamic link adaptation. In addition, it utilizes HARQ (Hybrid Automatic Repeat Request) operation to improve performance. As previously indicated, it also facilitates the sending of system information messages.
- **RACH (Random Access Channel)** - carries limited information and is used in conjunction with Physical Channels and preambles to provide contention resolution procedures.
- **UL-SCH (Uplink Shared Channel)** - similar to the DL-SCH, this channel supports dynamic scheduling (eNB controlled) and dynamic link adaptation by varying the modulation and coding. In addition, it too supports HARQ (Hybrid Automatic Repeat Request) operation to improve system performance.

Physical channel

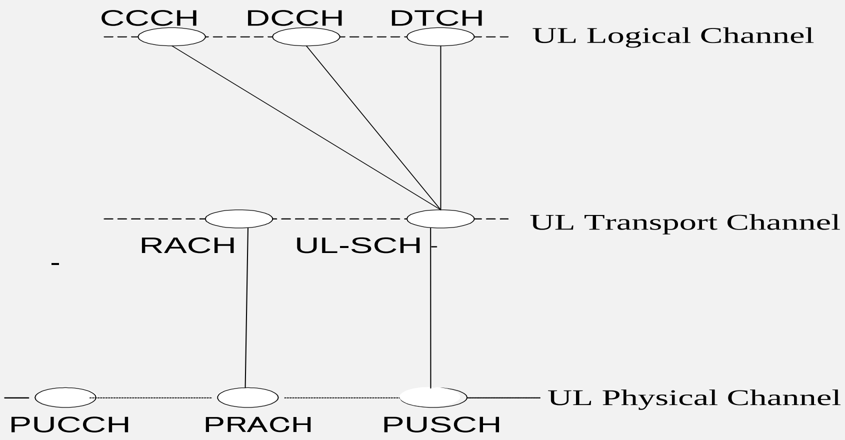


- PBCH (Physical Broadcast Channel)
- PCFICH (Physical Control Format Indicator Channel)
- PDCCH (Physical Downlink Control Channel)
- PHICH (Physical Hybrid ARQ Indicator Channel)
- PDSCH (Physical Downlink Shared Channel)

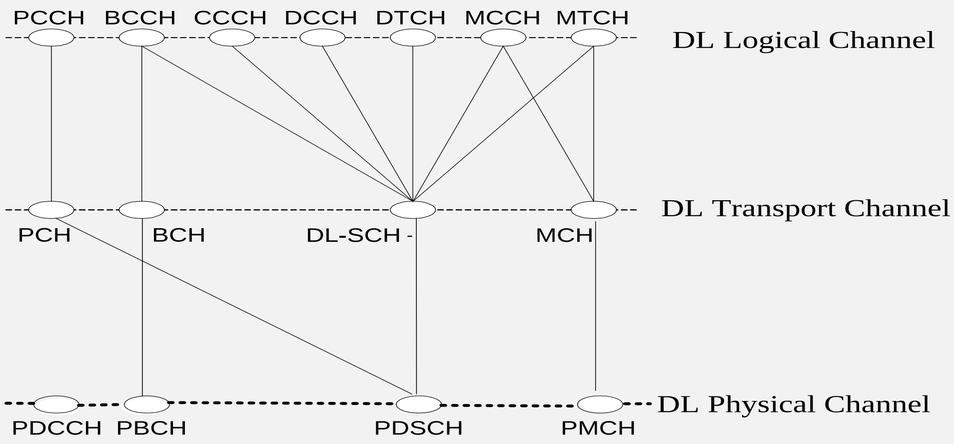
- PRACH (Physical Random Access Channel)
- PUCCH (Physical Uplink Control Channel)
- PUSCH (Physical Uplink Shared Channel)

Channel Mapping of UL&DL

Channels Mapping and works in UL



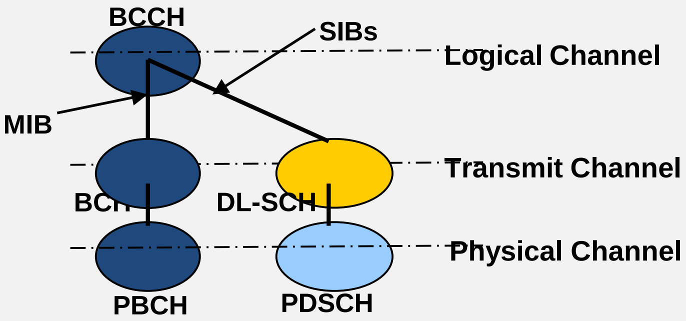
Channels Mapping and works in DL



Physical Broadcast Channel (PBCH)

- System broadcast message includes MIB carried by PBCH, and SIB1-SIB13 carried by PDSCH;
- **PBCH**
  - PBCH transit MIB only
  - PBCH transfers on the central frequency band only, and occupying 72 sub carriers.
  - PBCH maps to the four sub frames in 40ms.
    - The #0 sub-frame of each wireless frame occupies 4 consecutive OFDM symbols.
    - The time starting position of the 40ms cycle is obtained by blind detection. There is no signaling indication.
    - Data that is mapped to each sub-frame can be self decoded

- **PDSCH**
  - All other system broadcasting message except MIB
  - Mapping to DL-SCH, and final mapping to PDSCH
  - SIB1 is transmitted independently in a fixed period, with a transmission period of 80ms and transmission in even number of wireless frames
  - Other SIB dynamic dispatch sending



Physical channel functions summary

DL physical channel Name		Functions Remark
PBCH	Physical broadcast channel	Broadcast message for bearer system
PCFICH	Physical control format indicator channel	Resources for indicating downlink control channel usage
PHICH	Physical Hybrid ARQ Indicator Channel	For uplink data transmission ACK/NACK information feedback
PDCCH	Physical Downlink Control Channel	For transmission of uplink and downlink scheduling, power control and other control signaling
PDSCH	Physical Downlink Shared Channel	For downlink user data Carrying
PMCH	Physical multicast channel	For transmitting broadcast multicast services
RS	Reference Signal	For downlink data demodulation, measurement and time-frequency synchronization
SCH	Synchronization Signal	For time frequency synchronization and cell search

UL physical channel Name		Functions Remark
PRACH	Physical Random Access Channel	For access information of random access
PUCCH	Physical Uplink Control Channel	L1/L2 control signaling for HARQ feedback, CQI feedback, dispatching request indication, etc.
PUSCH	Physical Uplink Shared Channel	Used to carry uplink user data
DMRS	Demodulation Reference Signal	For uplink data demodulation, time and frequency synchronization, etc.
SRS	Sounding Reference Signal/	For uplink channel measurement, time and frequency synchronization, etc.

Use of different physical channels

- **Physical channel involved in cell search**
  - SCH -> PBCH -> PCFICH -> PDCCH -> PDSCH *(Get system message)*
- **Physical channel involved in random access**
  - PRACH -> PCFICH -> PDCCH -> PDSCH -> PUSCH
- **Physical channel involved in downlink data transmission**
  - PCFICH -> PDCCH -> PDSCH -> PUCCH
- **Physical channel involved in uplink data transmission**
  - PCFICH -> PDCCH -> PUSCH -> PHICH

Questions

- **Which of the following are downlink transport channels?**
- a. BCH.
- b. PCH.
- c. RACH
- d. UL-SCH.
- e. DL-SCH

Questions

- **Which of the following are physical UL channels?**

  a. PDCCH

  b. PUCCH.

  c. PRACH.

  d. PUSCH.

  e: PDSCH

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PART-1 LTE system principle

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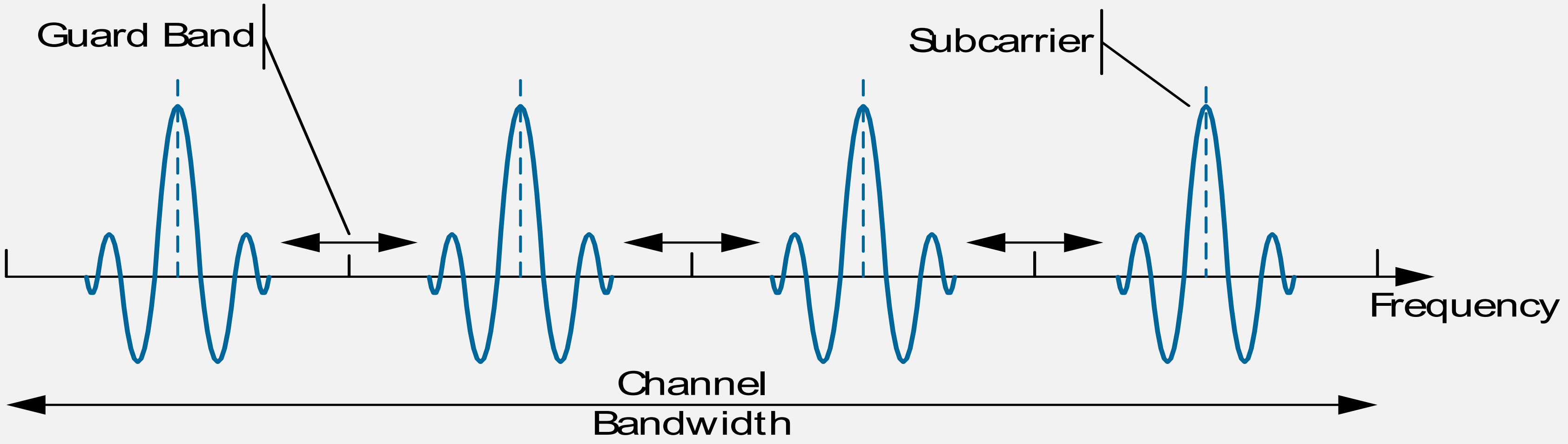
Downlink OFDMA-Frequency Division Multiplexing (1/3)

Sample of FDM with four subcarriers: These can be used to carry different information and to ensure that each subcarrier does not interfere with the adjacent subcarrier, a guard band is utilized.

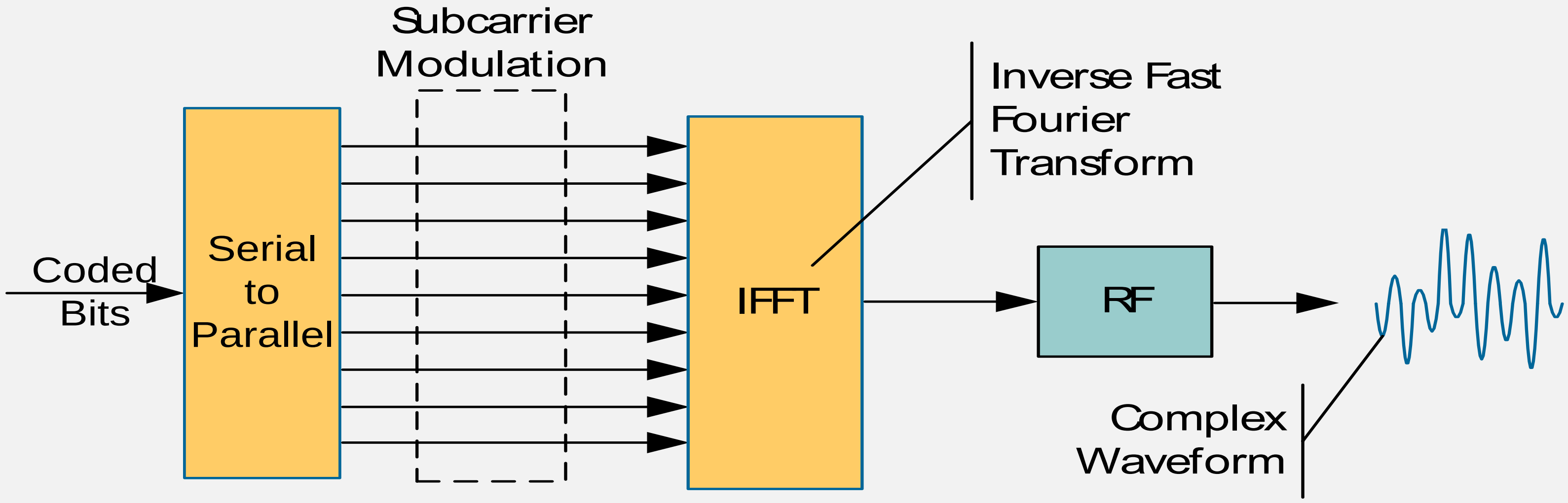


OFDM is based on FDM (Frequency Division Multiplexing) , and is a method whereby multiple frequencies are used to simultaneously transmit information.

For the traditional frequency division multiplexing (FDM) multi-carrier system, to prevent interference, a guard bandwidth is reserved between each sub-carriers. Therefore, the spectral efficiency is low.

Downlink OFDMA—OFDMA Signal Generation (2/3)

Inverse Fast Fourier Transform to OFDMA Signaling



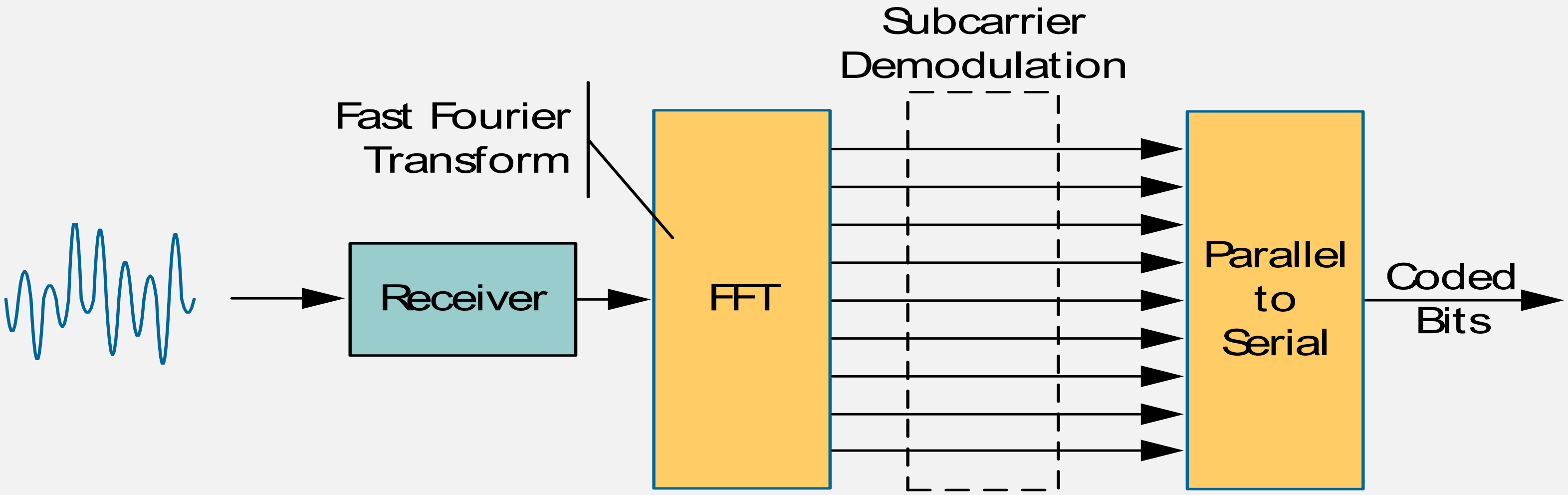
OFDM subcarriers are generated and decoded using mathematical functions called FFT (Fast Fourier Transform) and IFFT (Inverse Fast Fourier Transform).

IFFT is used in the transmitter to generate the waveform.

Figure illustrates how the coded data is first mapped to parallel streams before being modulated and processed by the IFFT

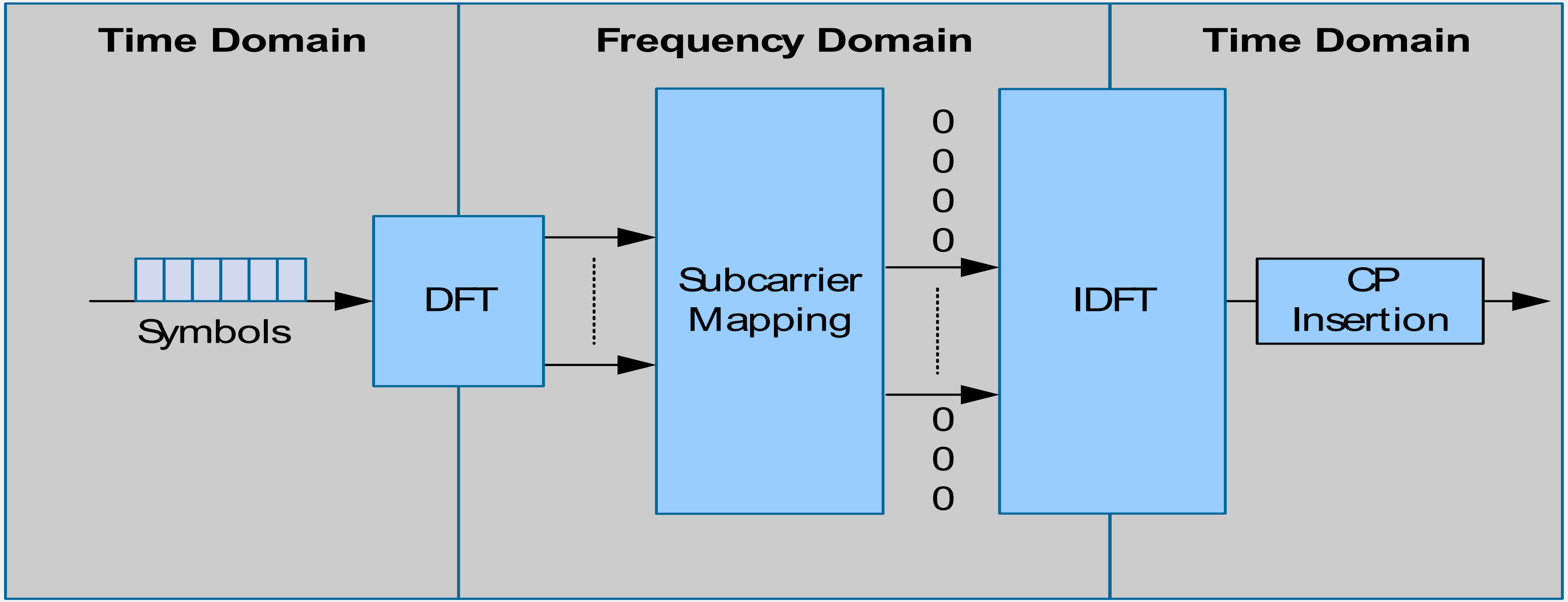
Downlink OFDMA—OFDMA Signal Generation (3/3)

Fast Fourier Transform to OFDMA Signaling



At the receiver side, this signal is passed to the FFT which analyses the complex/combined waveform to generate the original streams

Uplink SC_FDMA: SC-FDMA Subcarrier Mapping Concept (1/3)



DFT (Discrete Fourier Transform)

IDFT (Inverse Discrete Fourier Transform)

Uplink SC_FDMA: SC-FDMA Signal Generation (2/3)

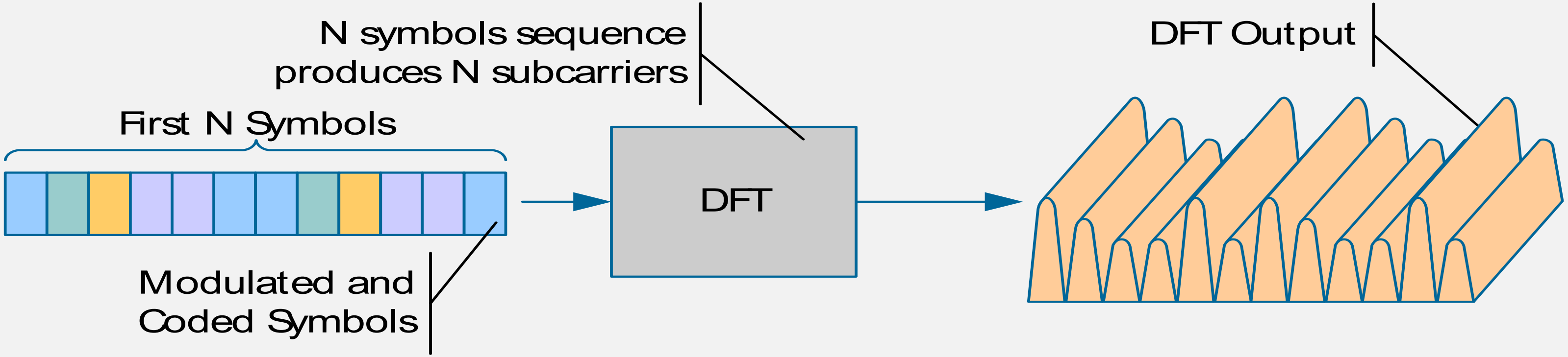
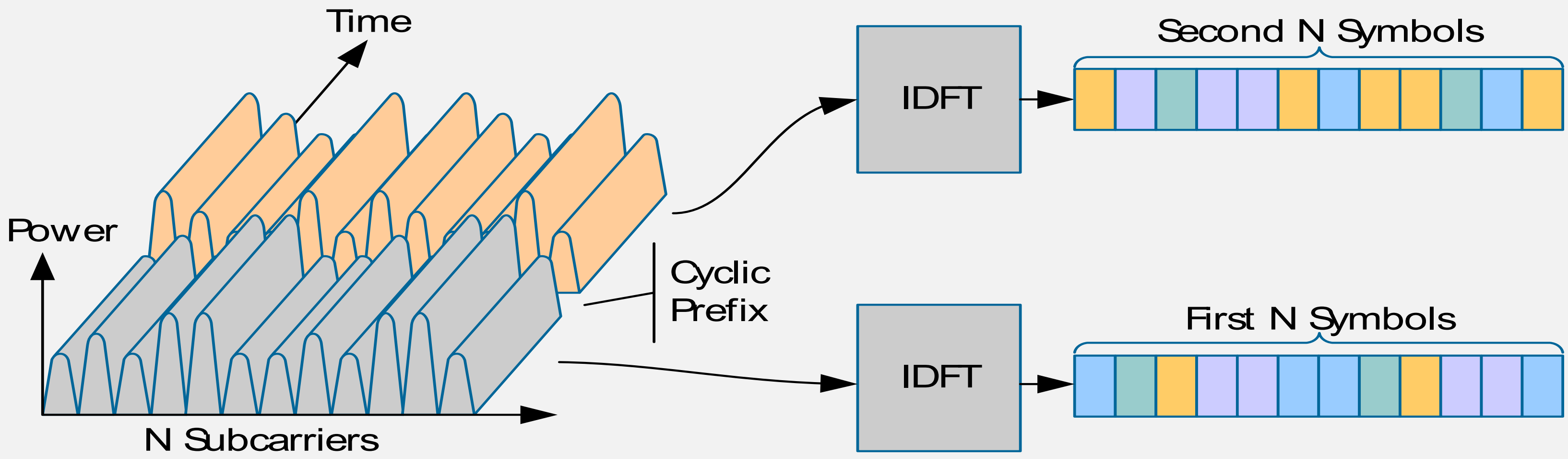


Figure illustrates the concept of the DFT, such that a group of N symbols map to N subcarriers. However depending on the combination of the N symbols into the DFT, the output will vary. As such, the actual amplitude and phase of the N subcarriers is more like a “code word”.

Uplink SC_FDMA: SC-FDMA Signal Generation (2/3)



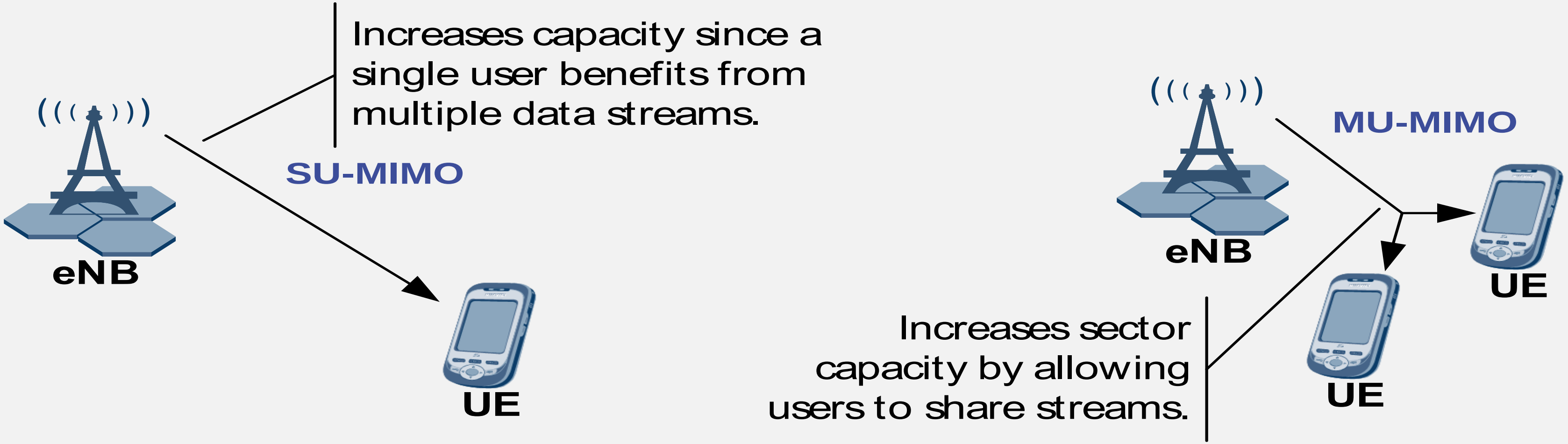
At the eNB, the receiver takes the N subcarriers and reverses the process. This is achieved using an IDFT (Inverse Discrete Fourier Transform) which effectively reproduces the original N symbols. Figure illustrates the basic view of how the subcarriers received at the eNB are converted back into the original signals.

Note that the SC-FDMA symbols have a constant amplitude and phase and like ODFMA, a CP (Cyclic Prefix) is still required.

Uplink SC_FDMA(3/3)

- Benefit
  - Low sensitivity to carrier frequency offset
  - Low peak-to-average power ratio (PAPR)
  - Increase the efficiency of power amplifier(PA)
  - Increased coverage for power-limited terminal
- Disadvantage
  - Frequency efficiency is lower than OFDM in DL

Multiple Input Multiple Output(MIMO)(1/3)



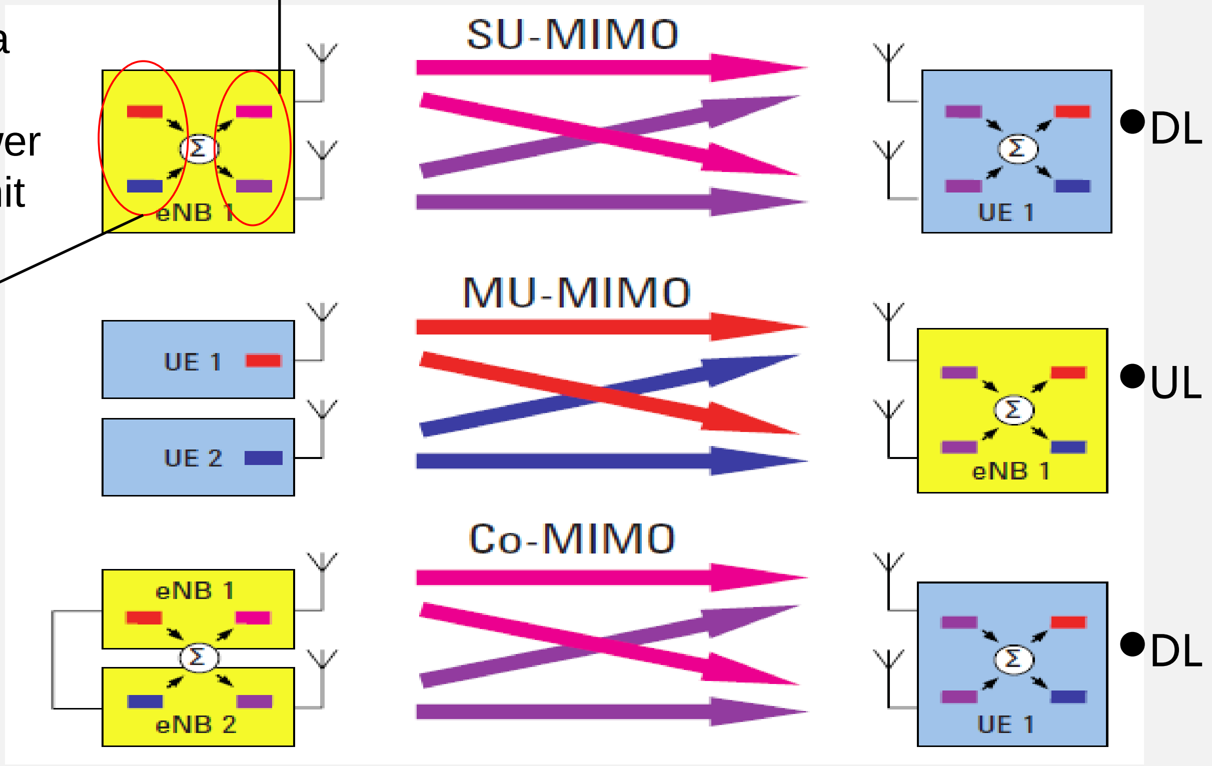
MIMO relates to the use of multiple antennas at both the transmitter (Multiple Input) and receiver (Multiple Output). The terminology and methods used in MIMO can differ from system to system, however most fall into one of two categories:

- SU-MIMO (Single User - Multiple Input Multiple Output) - this utilizes MIMO technology to improve the performance towards a single user.
- MU-MIMO (Multi User - Multiple Input Multiple Output) - this enables multiple users to be served through the use of spatial multiplexing techniques.

SU-MIMO/MU-MIMO/Co-MIMO(2/3)

After pre-coding, the two data streams are mixed and transmitted with different power and phase at different transmit antennas.

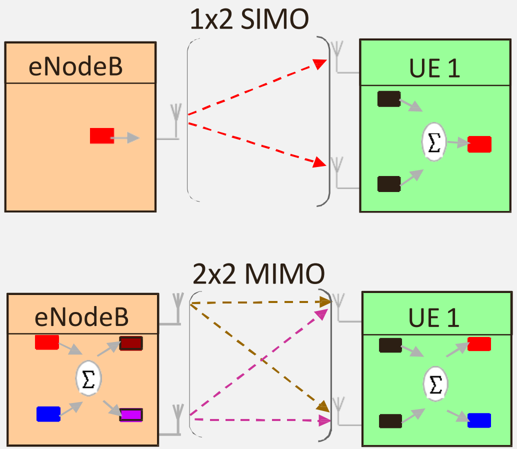
2 different data streams



Multi input and Multi output (MIMO)(3/3)

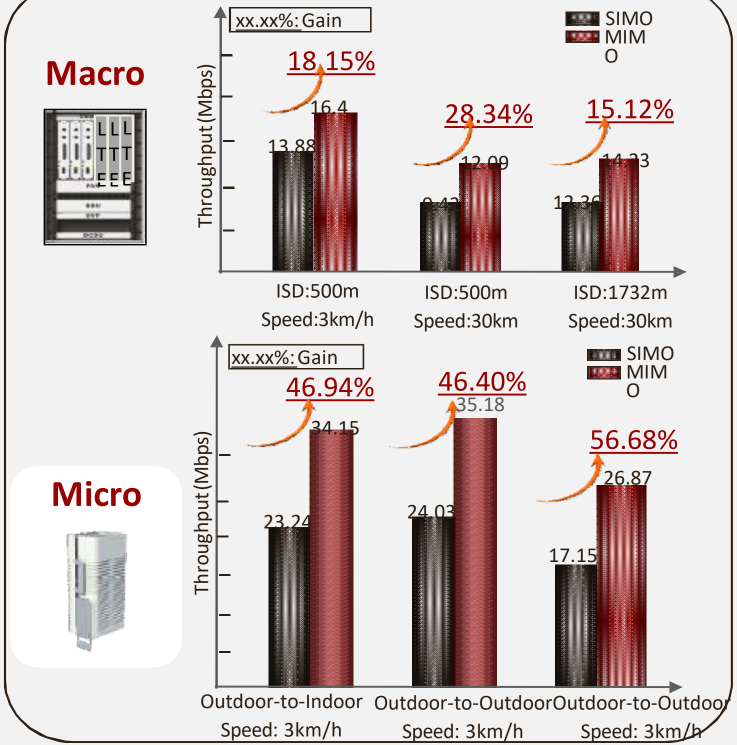
MIMO Benefits, the Key to Improve Cell Throughput

-- System Gain: 2X2 MIMO over SIMO



In typical urban area:

- 15%~28% gain over SIMO @ Macro
- ~50% gain over SIMO @ Micro



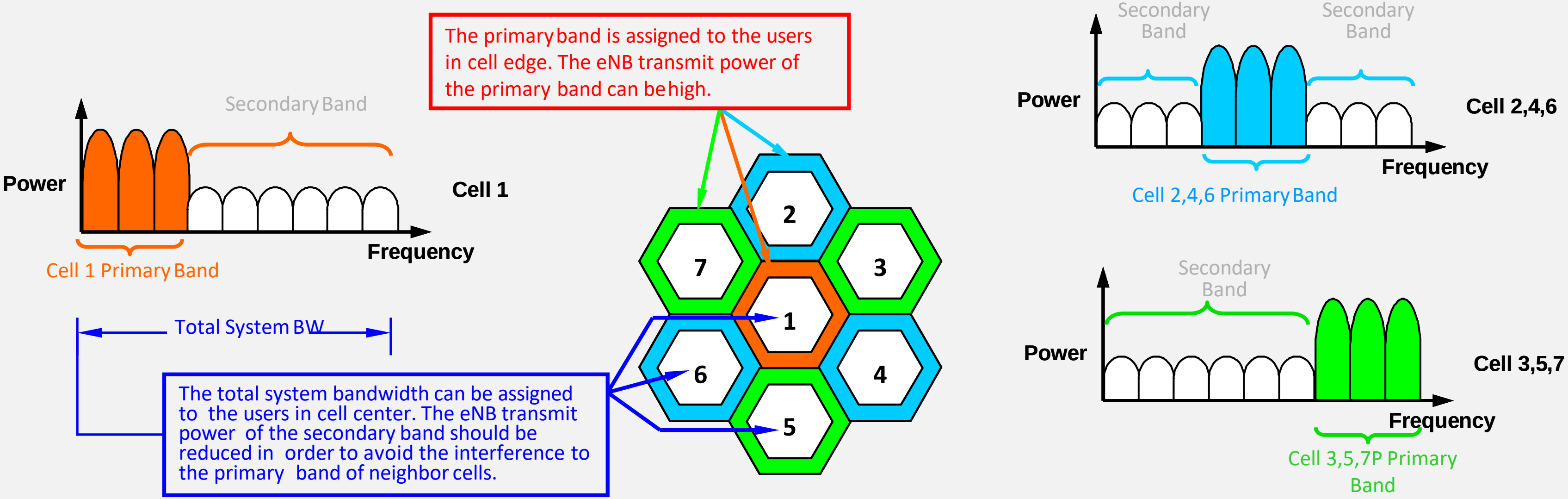
Inter-Cell Interference Coordination(ICIC)

ICIC（Inter-Cell Interference Coordination）

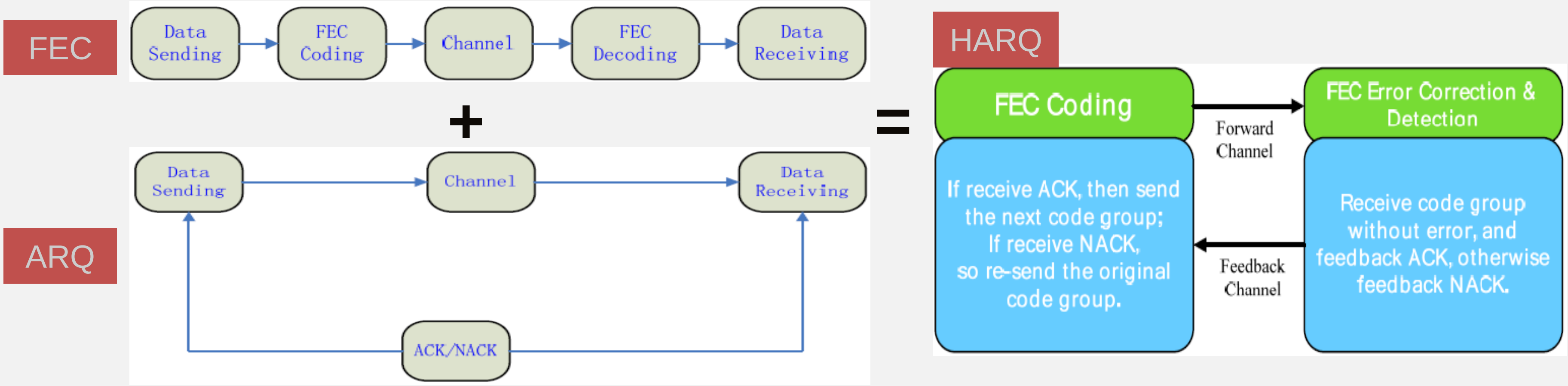
- ICIC is one solution for the cell interference control, is essentially a schedule strategy. In LTE, some coordination schemes, like SFR (Soft Frequency Reuse) and FFR (Fractional Frequency Reuse) can control the interference in cell edges to enhance the frequency reuse factor and performance in the cell edges.

SFR Solution

- SFR is one effective solution of inter-cell interference control. The system bandwidth is separated into primary band and secondary band with different transmit power.



Hybrid automatic repeat request (HARQ):



➢Forward error correction (FEC): The transmitter adds an error correcting code on the data during data coding, and the receiver automatically corrects the error if any. If the error in the data fails to be corrected, the transmitter is unable to be notified of retransmitting the data. The reliability is low.

➢Automatic repeat request (ARQ): The receiver checks data for errors. If data contains an error, the receiver directly informs the transmitter to retransmit the data. The reliability is high but the efficiency is low.

➢Hybrid automatic repeat request (HARQ): It is an effective combination of ARQ and FEC, and is a reliable, high-efficient error-correcting system.

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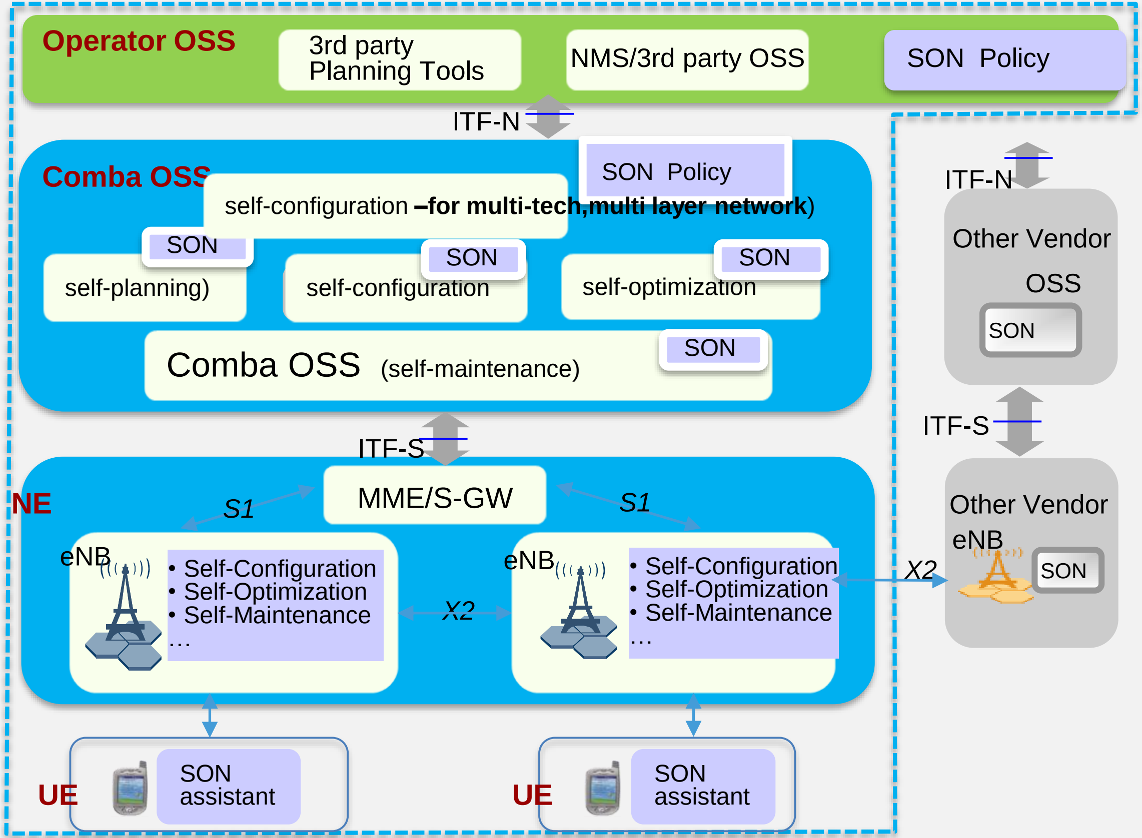


Comba SON supports open interfaces, X2, S1, Uu, ITF-N according to standard protocols.

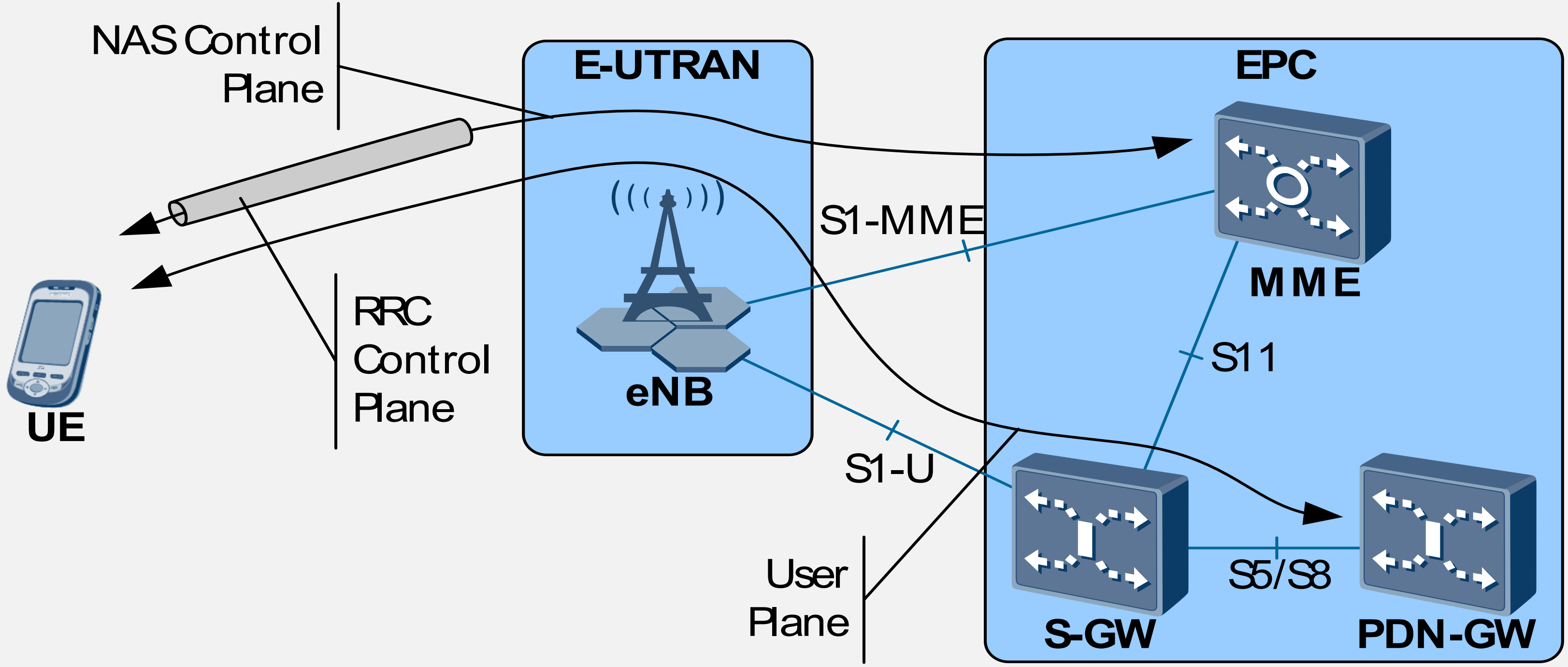
- Hybrid and E2E solution to maximize SON functionality
- ITF-N interface adaptive to operator OSS, minimal impacts
- Flexible to planning tools
- Multi-vendor capable through S1/X2 interfaces
- Layered SON policy control

Questions

- **Which functions are the SON features?**
- a. Self-Planning.
- b. Self-Maintenance.
- c. Self-Optimization.
- d. Self-Configuration.
- e. Self-Identify

Catalog

LTE/SAE signaling & traffic flow summary



UE attach flow (1/2)

- **Functions of the attachment process:**
  - UE is registered in the EPS network.
  - In the process of network attachment, a default EPS bearer will be established, which provides a permanent IP connection.
  - In MME and UE, the user's MM context and EPS bearer context are created. In SGW and PGW, the user's EPS bearer context is created.

UE attach flow (2/2)

Details Attach procedures flow

Control plane connection establishment

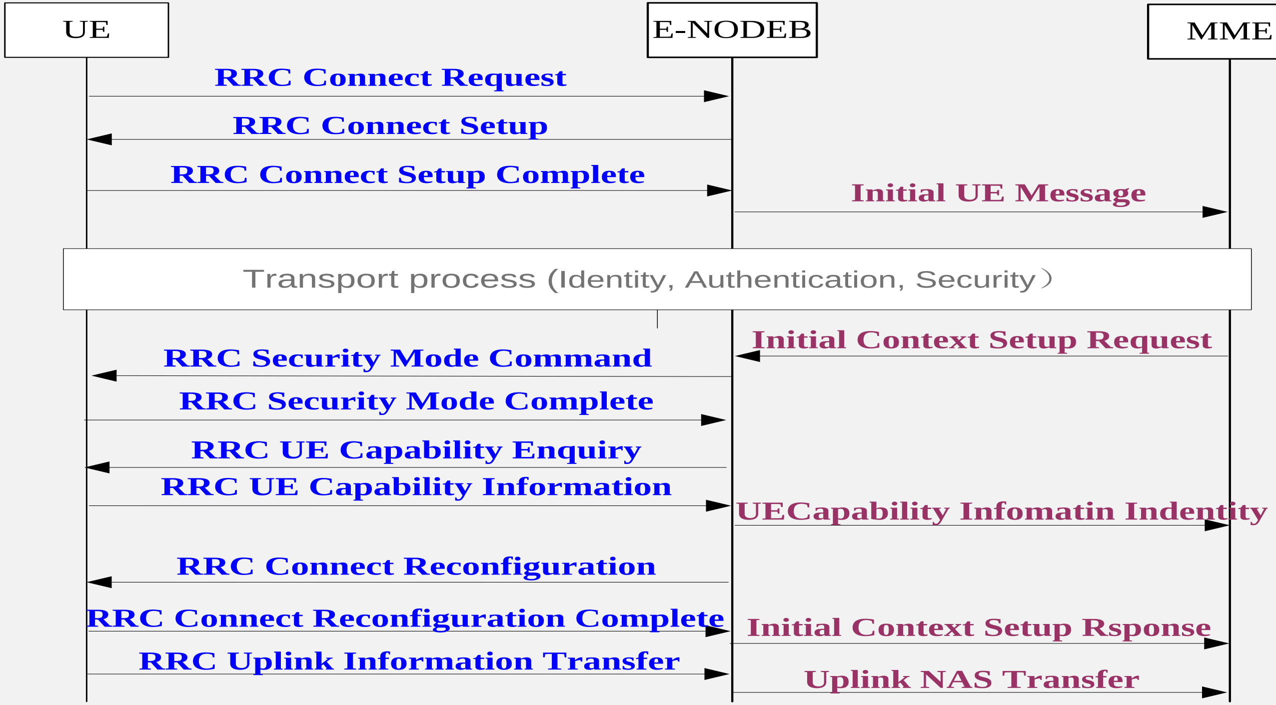
(RRC connection establishment and S1 signaling connection establishment)

Public Process

(authentication process and security mode process)

User plane connection establishment

(E-RAB establishment, note is default load establishment)



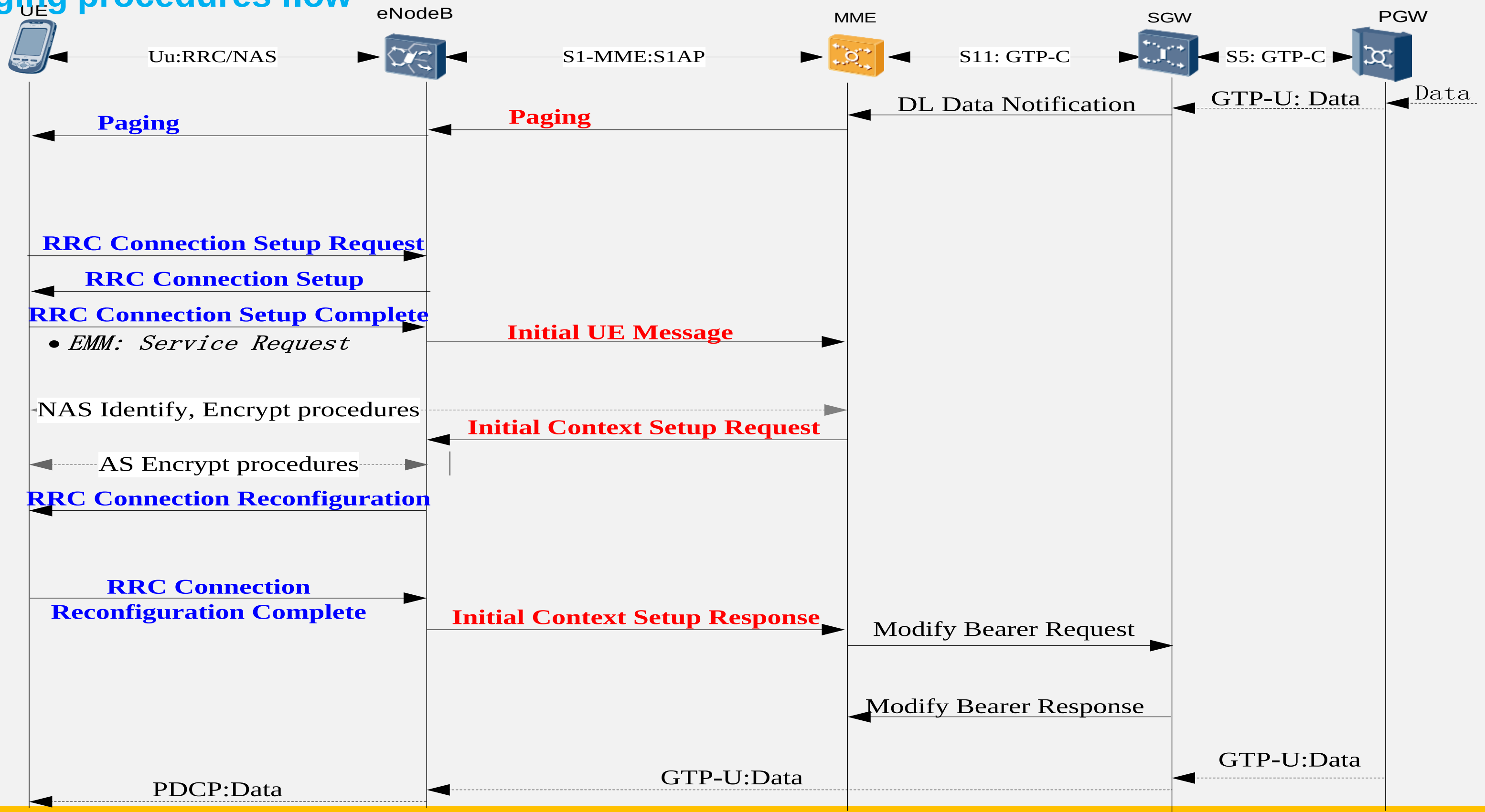
UE Paging flow(1/2)

Functions of Paging procedures flow

- **Purpose:**
  - To transmit paging information to a UE in RRC_IDLE and/ or to inform UEs in RRC_IDLE and UEs in RRC_CONNECTED about a system information change or about an ETWS (Earthquake and Tsunami Warning System) primary notification
- **Main IE:**
  - ue-Identity
  - cn-Domain
  - pagingCause
  - systemInfoModification
  - ETWS notification

UE Paging flow(2/2)

Details Paging procedures flow



UE Tracking area update(TAU) flow(1/3)

TAU functions Summary and causes of TAU

- When the UE moves from one TA List to another, it must be re-registered on the new TA to notify the network, so as to change the location information of the eNB, This whole process is Tracking Area Update (TAU).

UE would send TAU request to start Track Area Update in case of any in any case of any condition satisfied

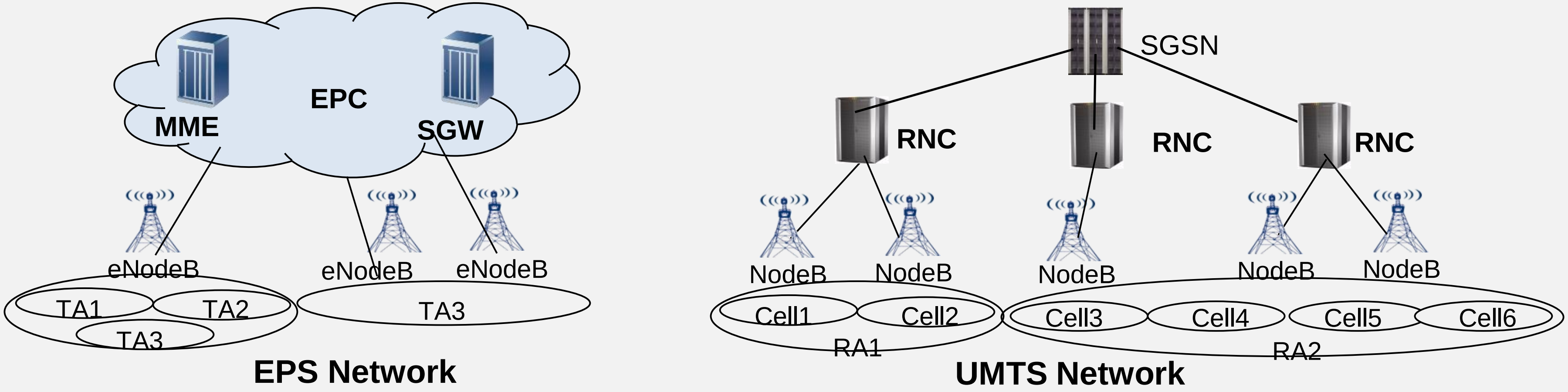
1. Move to the new TA List
2. Period update time out in cycle tracking area
3. UE reselection from other system cells to E- UTRAN cell
4. RC connection Release due to load balancing
5. UE Capacity information changes from EPC part
6. DRX parameters modification or changes

Tracking Area Update(TAU)

UE Tracking area update(TAU) flow(2/3)

Details TAU procedures flow

- To confirm the location of the mobile station, LTE network coverage will be divided into many **tracking areas (TA).** TA function is similar to 3G location area (LA) and routing area (RA), and is the basic unit of location update and paging in LTE system.
- TAC (Tracking Area Code) is used to indicate the TA, and TA could contains one or more cells,
- TAI is the only identity of TA in network，TAI＝MCC+MNC+TAC，6 bytes in total;



UE Tracking area update(TAU) flow(3/3)

Details TAU procedures flow

- The TAU process can be divided into three steps:
  - Random access;
  - RRC connection establishment;
    - The reason for establishing RRC is Mo-Signaling;
  - TAU update;
- TAU processes usually do not require authentication , and the connection will be released immediately after TAU completed;

(For more details info, you would refer to signaling procedure training docs)

UE Handover flow (1/2)

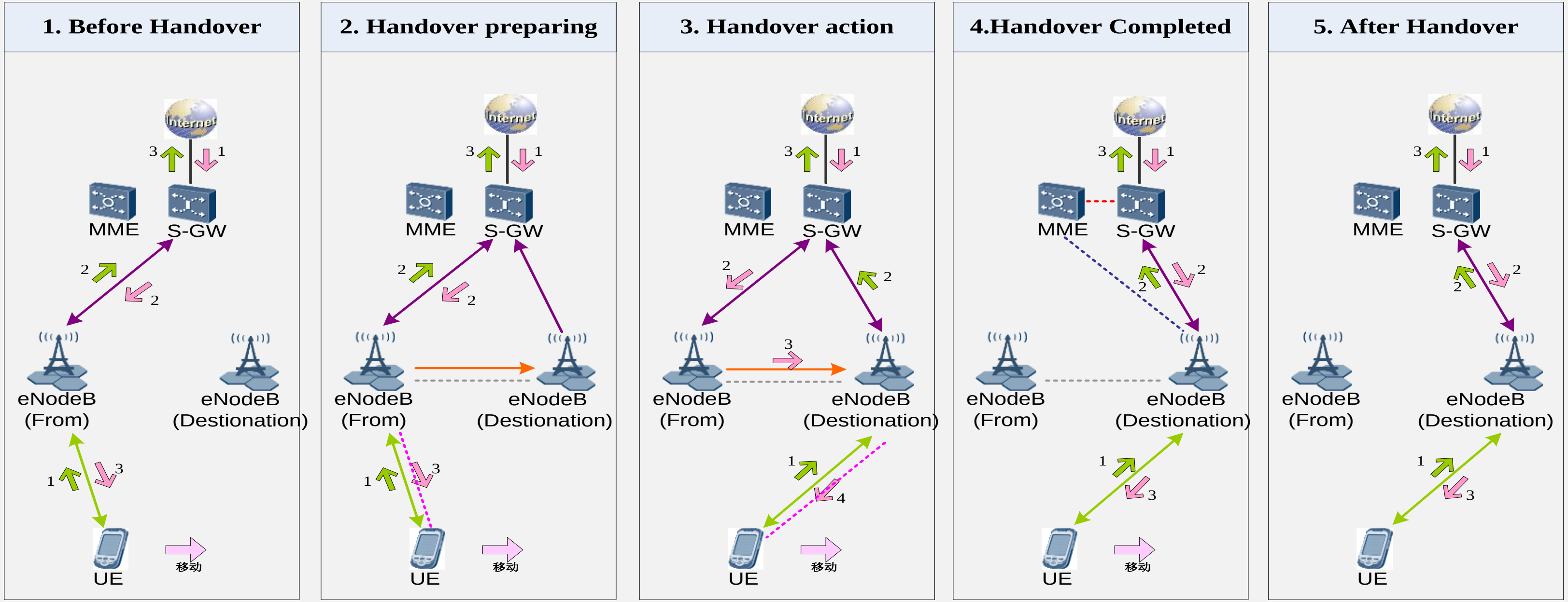
Handover Definition and types

- **Definition of handover**
  - Means that UE moves across different cells in connection state, so as to complete the updating of UE context.
- **Handover classification in LTE**
  - **Intra-RAT (Intra system handover)**
    - Inter cell handover in eNodeB;
    - Inter cell handover between eNodeB through X2 interface (MME does not change);
    - Inter cell handover between eNodeB through S1 interface (MME/SGW may change);
      - If the X2 link is not configured, the handoff between eNodeB switches to S1 port switching.

      Note: if X2 and S1 link are configured at the same time, the handoff between eNodeB will take the priority of X2 handover.
  - **Inter-RAT(Inter-system handover)**
  - WCDMA switching; GSM/EDEG switching; CDMA2000 switching.

UE Handover flow (2/2)

Handover procedures flow



Summary: LTE ecosystem leads to better life

- Operators

- Network Equipment Vendors

- UE devices vendors

- Chipset Vendor

Open Communication

- **Q & A**

Comba

Thank You！