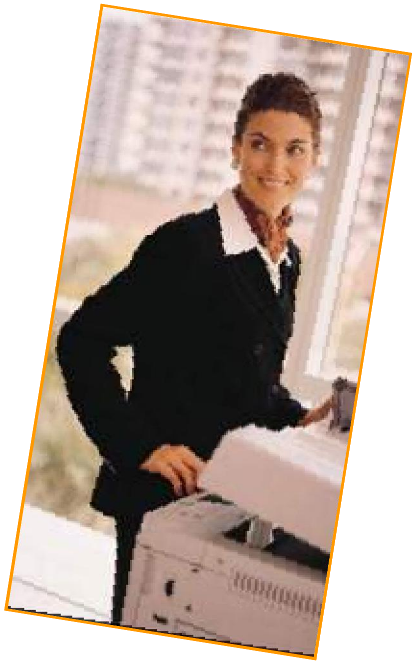
Contents			
Name	LTE Network Planning		
Purpose	To Introduce the LTE basic principle, network planning method and RNP solution		
Key Message	**LTE has the flat network architecture and physical layer applies OFDM technology, as well as the MIMO, ICIC, etc.** **LTE network planning includes coverage, capacity planning. Link budget and capacity estimation are introduced in these slides.** **In RNP solution, you can find the introduction of RNP tools, performance enhancement features and other solution that customer will concern, such as the interference avoidance and co-antenna analysis**		
Audience	Global C&Wi RNP engineers, product manager and account managers with wireless background knowledge		

Version Information			
Versions	**Creator/Staff ID**	**Approver/Staff ID**	**Release dept.**
V1.0_10/01/18	Cui Dongfeng/53824		

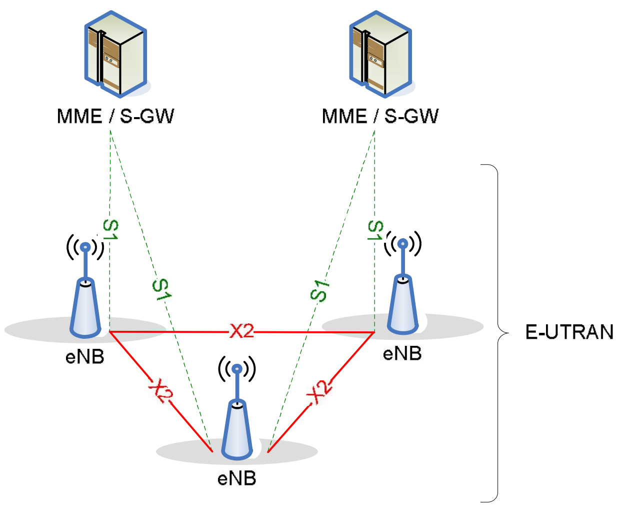
Content

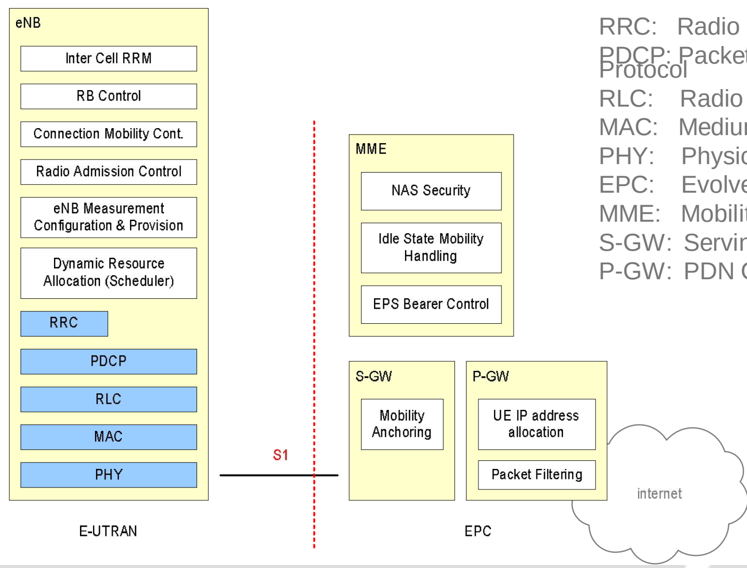


LTE Network Architecture

- **Main Network Element of LTE**
  - The E-UTRAN consists of **e-NodeB**s, providing the user plane and control plane.
  - The EPC consists of **MME**, **S-GW** and **P-GW**.
- **Network Interface of LTE**
  - The e-NodeBs are interconnected with each other by means of the **X2** interface, which enabling direct transmission of data and signaling.
  - **S1** is the interface between e-NodeBs and the EPC, more specifically to the MME via the S1-MME and to the S-GW via the S1-U

Compare with traditional 3G network, LTE architecture becomes much more simple and flat, which can lead to lower networking cost, higher networking flexibility and shorter time delay of user data and control signaling.

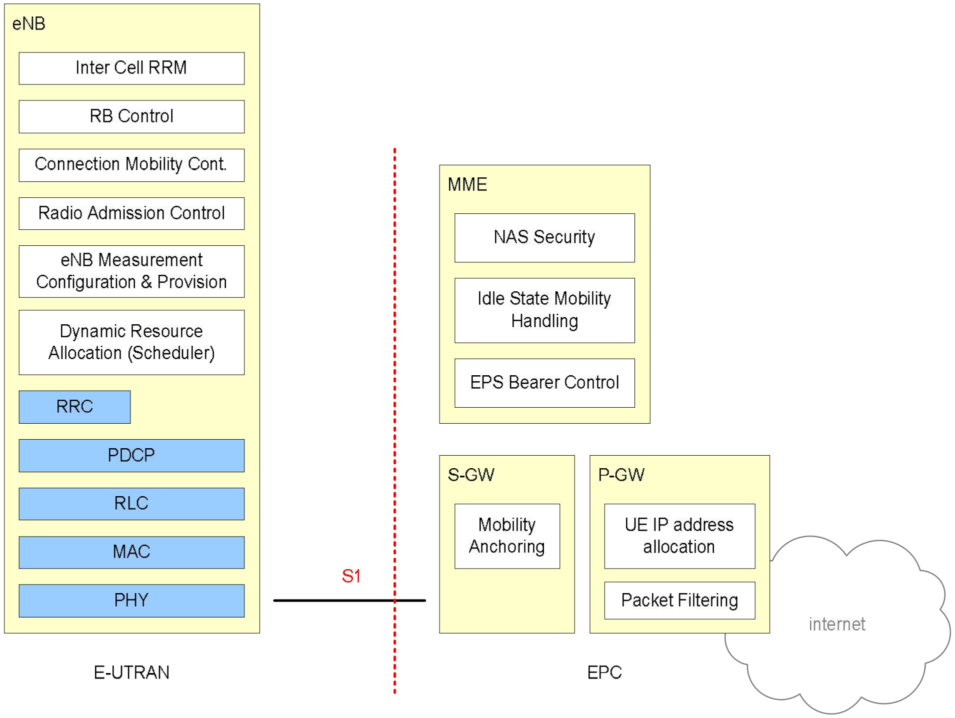




RRC: Radio Resource Control
PDCP: Packet Data Convergence Protocol
RLC: Radio Link Control
MAC: Medium Access Control
PHY: Physical layer
EPC: Evolved Packet Core
MME: Mobility Management Entity
S-GW: Serving Gateway
P-GW: PDN Gateway

LTE Network Element Function

- **e-Node hosts the following functions:**
  - Functions for Radio Resource Management: Radio Bearer Control, Radio Admission Control, Connection Mobility Control, Dynamic allocation of resources to UEs in both uplink and downlink (scheduling);
  - IP header compression and encryption of user data stream;
  - Selection of an MME at UE attachment;
  - Routing of User Plane data towards Serving Gateway;
  - Scheduling and transmission of paging and broadcast messages (originated from the MME);
  - Measurement and measurement reporting configuration for mobility and scheduling;



- **MME (Mobility Management Entity) hosts the following functions:**
  - NAS signaling and security;
  - AS Security control;
  - Idle state mobility handling;
  - EPS (Evolved Packet System) bearer control;
  - Support paging, handover, roaming and authentication.

- **P-GW (PDN Gateway) hosts the following functions:**
  - Per-user based packet filtering; UE IP address allocation; UL and DL service level charging, gating and rate enforcement;

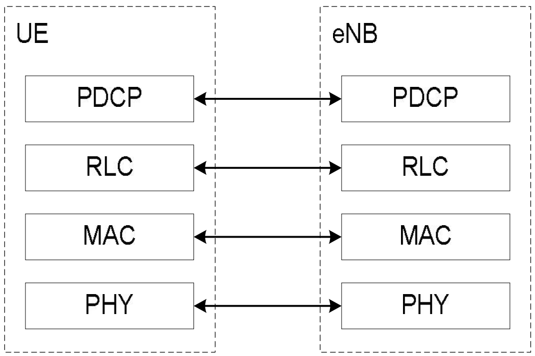
- **S-GW (Serving Gateway) hosts the following functions:**
  - Packet routing and forwarding; Local mobility anchor point for handover; Lawful interception; UL and DL charging per UE, PDN, and QCI; Accounting on user and QCI granularity for inter-operator charging.

Introduction of LTE Radio Protocol Stack

- **Two Planes in LTE Radio Protocol:**
  - **User-plane**: For user data transfer
  - **Control-plane**: For system signaling transfer

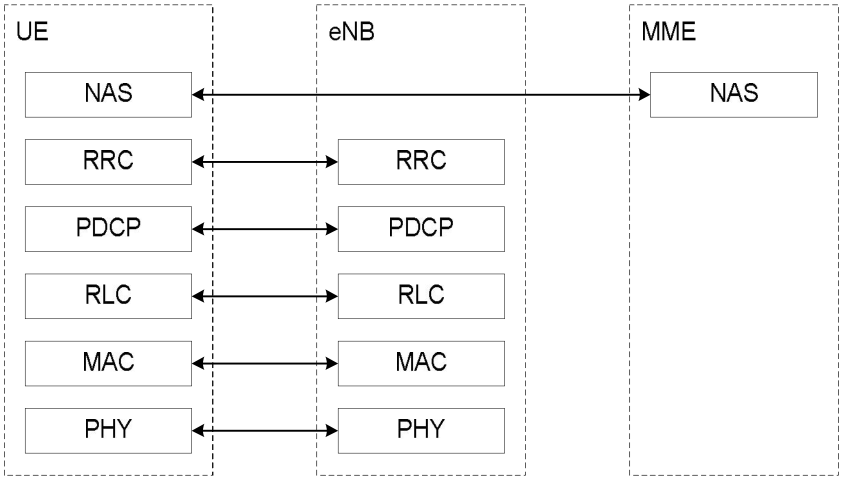
- **Main Functions of User-plane:**
  - Header Compression
  - Ciphering
  - Scheduling
  - ARQ/HARQ

User-plane protocol stack



- **Main Functions of Control-plane:**
  - RLC and MAC layers perform the same functions as for the user plane
  - PDCP layer performs ciphering and integrity protection
  - RRC layer performs broadcast, paging, connection management, RB control, mobility functions, UE measurement reporting and control
  - NAS layer performs EPS bearer management, authentication, security control

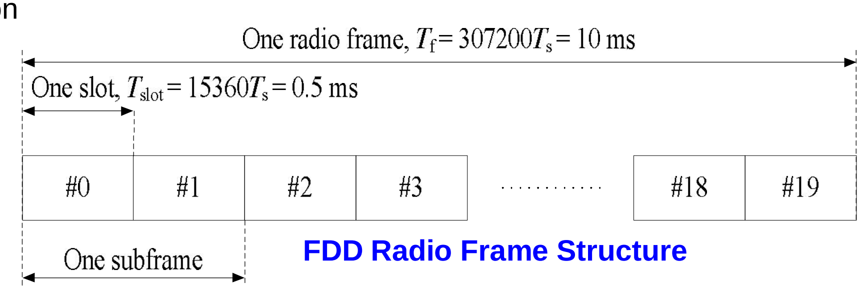
Control-plane protocol stack



Radio Frame Structure (1)

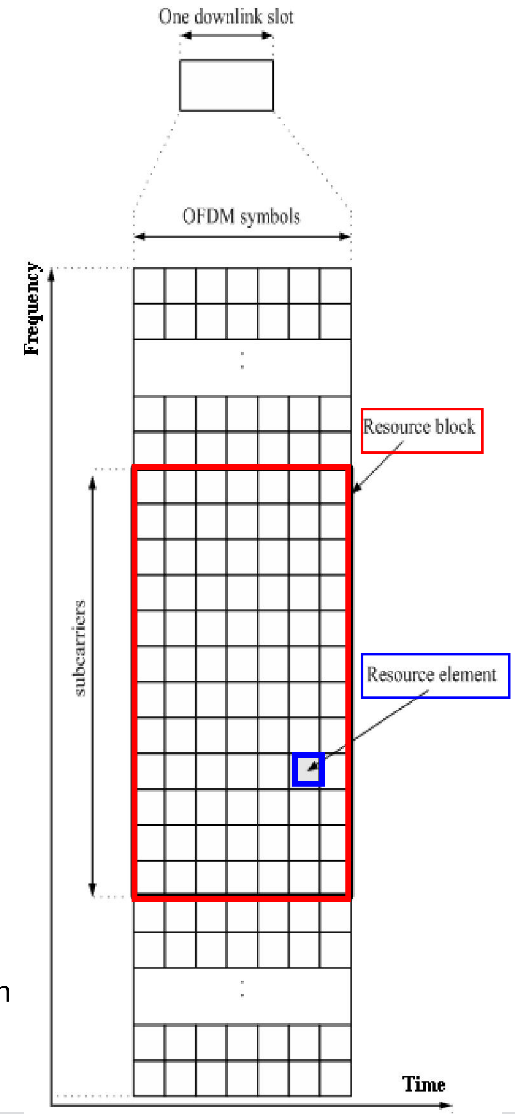
- **Radio Frame Structures Supported by LTE:**
  - Type 1, applicable to FDD
  - Type 2, applicable to TDD

- **FDD Radio Frame Structure:**
  - LTE applies OFDM technology, with subcarrier spacing Δf=15kHz and 2048-order IFFT. The time unit in frame structure is Ts=1/(2048* 15000) second
  - FDD radio frame is 10ms shown as below, divided into 20 slots which are 0.5ms. One slot consists of 7 consecutive OFDM Symbols under Normal CP configuration



FDD Radio Frame Structure

- **Concept of Resource Block:**
  - LTE consists of time domain and frequency domain resources. **The minimum unit for schedule is RB (Resource Block)**, which compose of RE (Resource Element)
  - RE has 2-dimension structure: symbol of time domain and subcarrier of frequency domain
  - One RB consists of 1 slot and 12 consecutive subcarriers under Normal CP configuration



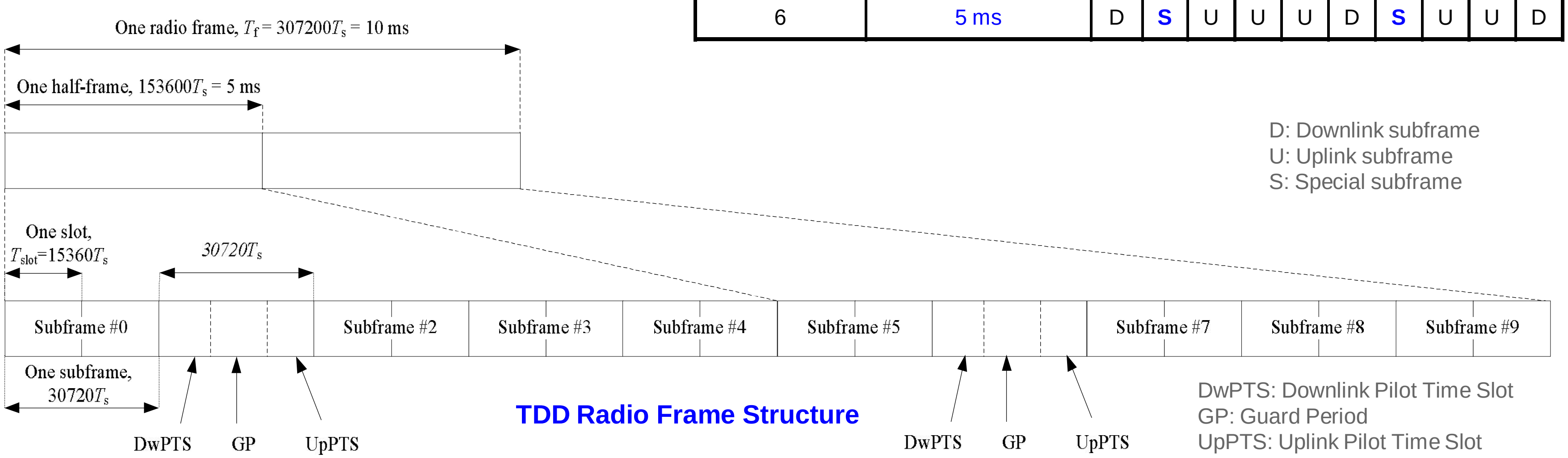
Radio Frame Structure (2)

- **TDD Radio Frame Structure:**
  - Applies OFDM, same subcarriers spacing and time unit with FDD.
  - Similar frame structure with FDD. radio frame is 10ms shown as below, divided into 20 slots which are 0.5ms.
  - The uplink-downlink configuration of 10ms frame are shown in the right table.

Uplink-downlink Configurations

Uplink-downlink configuration	Downlink-to-Uplink 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

D: Downlink subframe
U: Uplink subframe
S: Special subframe



TDD Radio Frame Structure

DwPTS: Downlink Pilot Time Slot
GP: Guard Period
UpPTS: Uplink Pilot Time Slot

Radio Frame Structure (3)

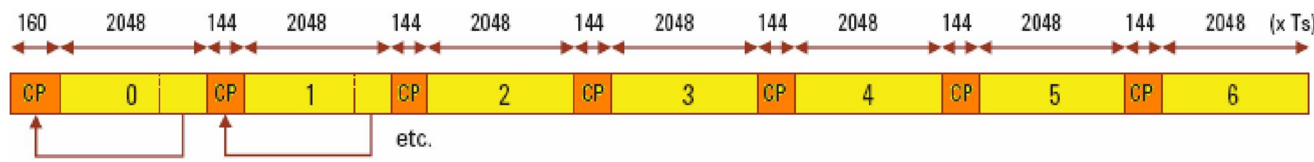
CP Length Configuration:

- Cyclic Prefix is applied to eliminate ISI of OFDM.
- CP length is related with coverage radius. Normal CP can fulfill the requirement of common scenarios. Extended CP is for wide coverage scenario.
- Longer CP, higher overheading.

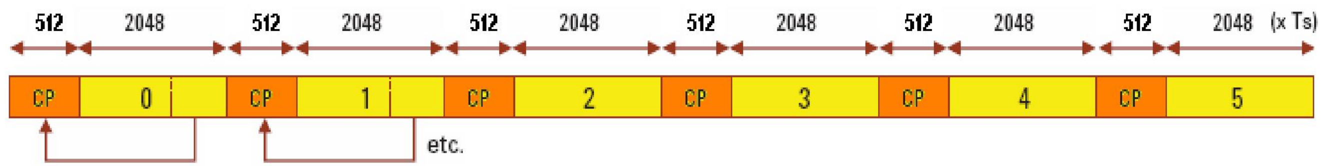
CP Configuration

Configuration		DL OFDM CP Length	UL SC-FDMA CP Length	Sub-carrier of each RB	Symbol of each slot
Normal CP	Δf=15kHz	160 for slot #0 144 for slot #1~#6	160 for slot #0 144 for slot #1~#6	12	7
Extended CP	Δf=15kHz	512 for slot #0~#5	512 for slot #0~#5	12	6
	Δf=7.5kHz	1024 for slot #0~#2	NULL	24 (DL only)	3 (DL only)

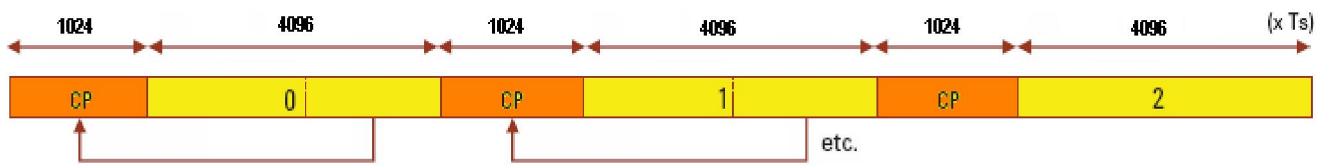
Slot structure under Normal CP configuration ($\triangle f$=15kHz)



Slot structure under Extended CP configuration ($\triangle f$=15kHz)

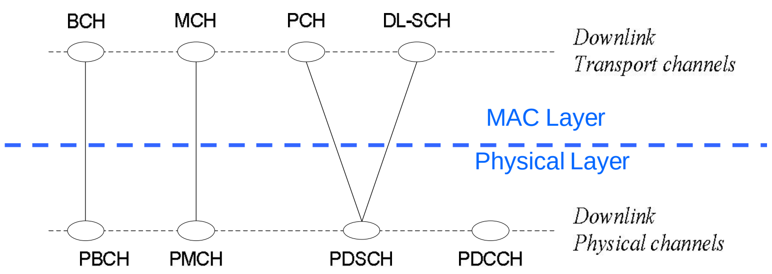


Slot structure under Extended CP configuration ($\triangle f$=7.5kHz)



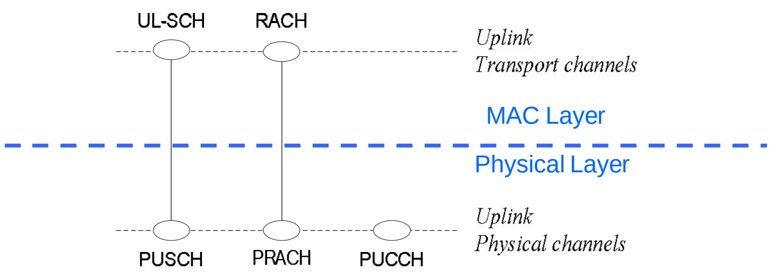
Brief Introduction of Physical Channels

- **Downlink Channels：**
  - Physical Broadcast Channel (**PBCH**): Carries system information for cell search, such as cell ID.
  - Physical Downlink Control Channel (**PDCCH**) : Carries the resource allocation of PCH and DL-SCH, and Hybrid ARQ information.
  - Physical Downlink Shared Channel (**PDSCH**) : Carries the downlink user data.
  - Physical Control Format Indicator Channel (**PCFICH**) : Carriers information of the OFDM symbols number used for the PDCCH.
  - Physical Hybrid ARQ Indicator Channel (**PHICH**) : Carries Hybrid ARQ ACK/NACK in response to uplink transmissions.
  - Physical Multicast Channel (**PMCH**) : Carries the multicast information.



Mapping between downlink transport channels and downlink physical channels

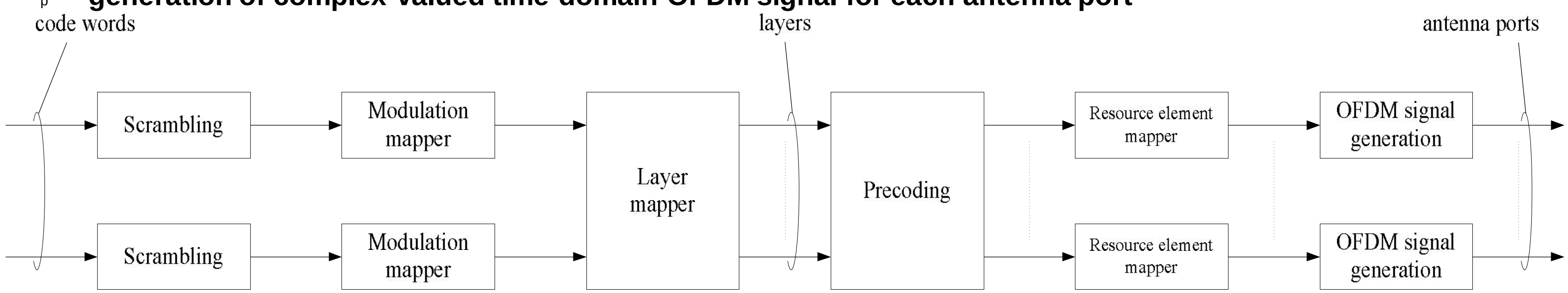
- **Uplink Channels：**
  - Physical Random Access Channel (**PRACH**) : Carries the random access preamble.
  - Physical Uplink Shared Channel (**PUSCH**) : Carries the uplink user data.
  - Physical Uplink Control Channel (**PUCCH**) : Carries the HARQ ACK/NACK, Scheduling Request (SR) and Channel Quality Indicator (CQI), etc.



Mapping between uplink transport channels and downlink physical channels

Downlink Physical Channel

- **Downlink 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**

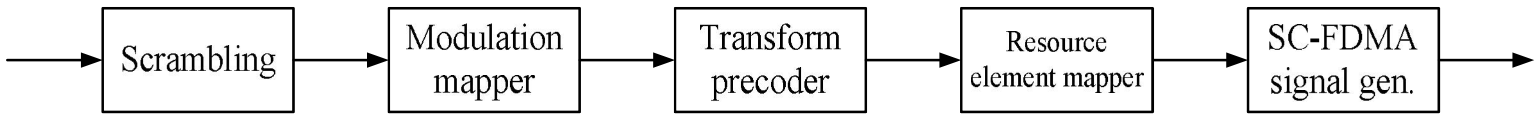


- **Modulation Scheme of Downlink Channel**
  - Shown at the right table

Phy Ch	Modulation Scheme	Phy Ch	Modulation Scheme
PBCH	QPSK	PCFICH	QPSK
PDCCH	QPSK	PHICH	BPSK
PDSCH	QPSK, 16QAM, 64QAM	PMCH	QPSK, 16QAM, 64QAM

Uplink Physical Channel

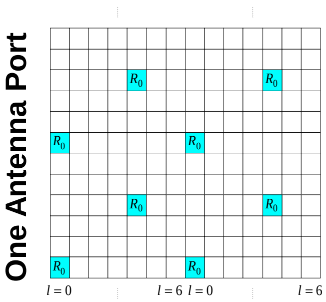
- **Uplink Physical Channel Processing**
  - **scrambling**
  - **modulation of scrambled bits to generate complex-valued symbols**
  - **transform precoding to generate complex-valued symbols**
  - **mapping of complex-valued symbols to resource elements**
  - **generation of complex-valued time-domain SC-FDMA signal for each antenna port**



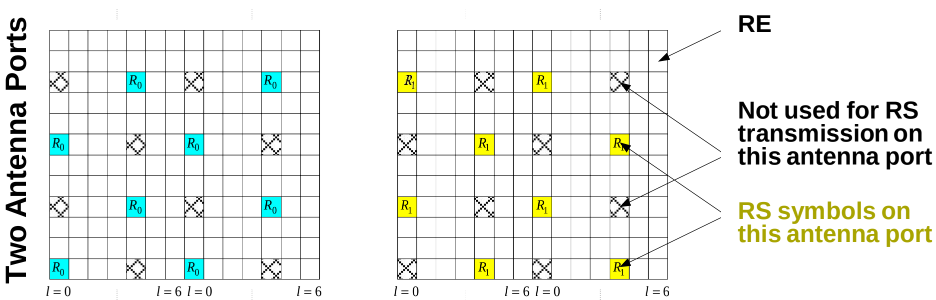
- **Modulation Scheme of Downlink Channel**
  - Shown at the right table

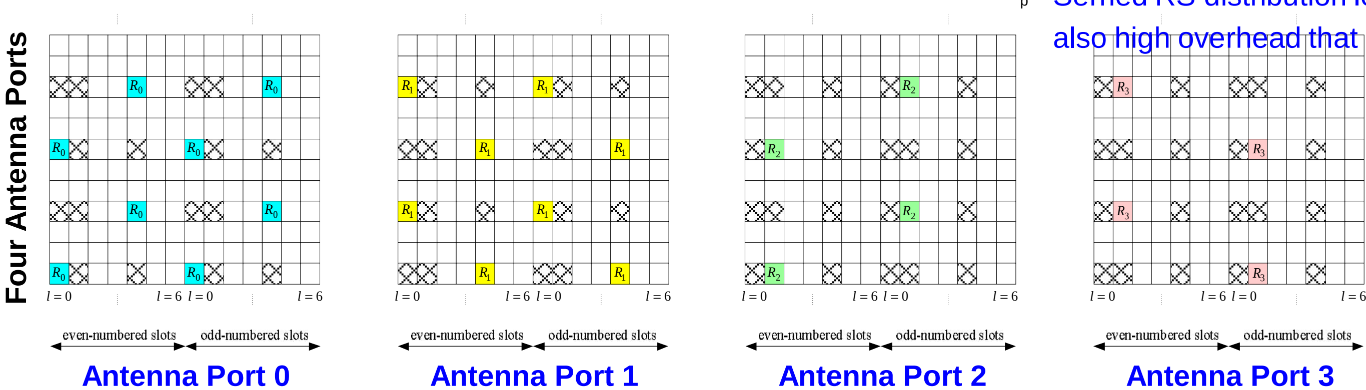
Phy Ch	Modulation Scheme
PUCCH	BPSK, QPSK
PUSCH	QPSK, 16QAM, 64QAM
PRACH	Zadoff-Chu

Downlink Physical Signals (1)



Cell-Specific RS Mapping in Time-Frequency Domain





Downlink RS (Reference Signal):

- Similar with Pilot signal of CDMA. Used for downlink physical channel demodulation and channel quality measurement (CQI)
- Three types of RS in protocol. Cell-Specific Reference Signal is essential and the other two types RS (MBSFN Specific RS & UE-Specific RS) are optional.

Characteristics:

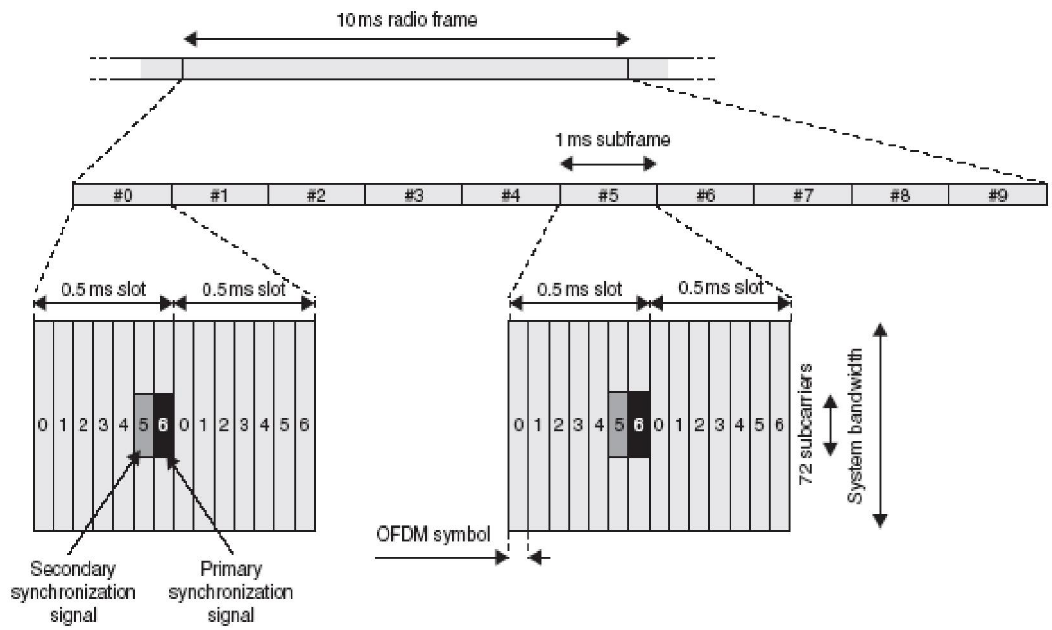
- Cell-Specific Reference Signals are generated from cell-specific RS sequence and frequency shift mapping. RS is the pseudo-random sequence transmits in the time-frequency domain.
- The frequency interval of RS is 6 subcarriers.
- RS distributes discretely in the time-frequency domain, sampling the channel situation which is the reference of DL demodulation.
- Serried RS distribution leads to accurate channel estimation, also high overhead that impacting the system capacity.

R1: RS transmitted in 1st ant port
R2: RS transmitted in 2nd ant port
R3: RS transmitted in 3rd ant port
R4: RS transmitted in 4th ant port

MBSFN: Multicast/Broadcast over a Single Frequency Network

Downlink Physical Signals (2)

- **Synchronization Signal:**
  - synchronization signals are used for time-frequency synchronization between UE and E-UTRAN during cell search.
  - synchronization signal comprise two parts:
    - **Primary Synchronization Signal**, used for symbol timing, frequency synchronization and part of the cell ID detection.
    - **Secondary Synchronization Signa** … ID.
- **Characteristics:**
  - The bandwidth of the synchronization signal is 62 subcarrier, locating in the central part of system bandwidth, regardless of system bandwidth size.
  - Synchronization signals are transmitted only in the 1st and 11rd slots of every 10ms frame.
  - The primary synchronization signal is located in the last symbol of the transmit slot. The secondary synchronization signal is located in the 2nd last symbol of the transmit slot.

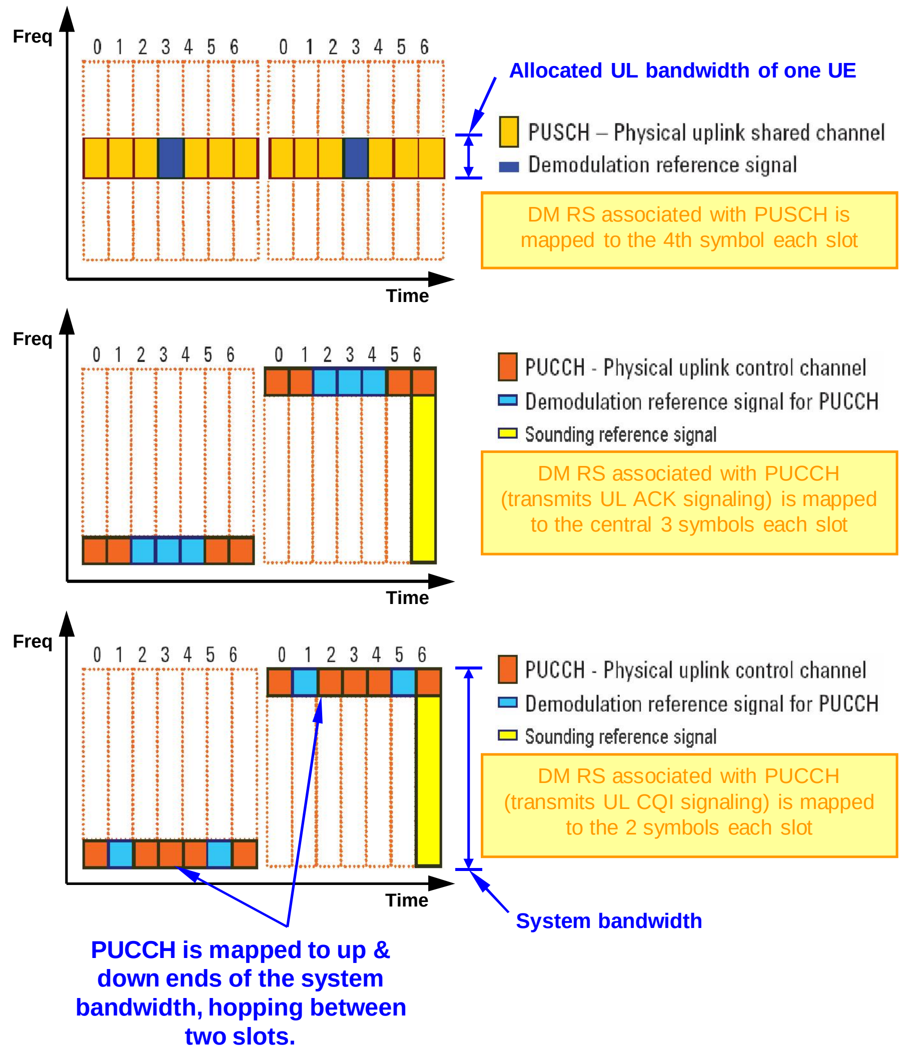


Synchronization Signals Structure

Uplink Physical Signals

- **Uplink RS (Reference Signal):**
  - The uplink pilot signal, used for synchronization between E-UTRAN and UE, as well as uplink channel estimation.
  - Two types of UL reference signals:
    - **DM RS** (Demodulation Reference Signal), associated with PUSCH and PUCCH transmission.
    - **SRS** (Sounding Reference Signal), without associated with PUSCH and PUCCH transmission.

- **Characteristics:**
  - Each UE occupies parts of the system bandwidth since SC-FDMA is applied in uplink. DM RS only transmits in the bandwidth allocated to PUSCH and PUCCH.
  - The slot location of DM RS differs with associated PUSCH and PUCCH format.
  - Sounding RS's bandwidth is larger than that allocated to UE, in order to provide the reference to e-NodeB for channel estimation in the whole bandwidth.
  - Sounding RS is mapped to the last symbol of sub-frame. The transmitted bandwidth and period can be configured. SRS transmission scheduling of multi UE can achieve time/frequency/code diversity.



Physical Layer Procedure — Cell Search

Basic Principle of Cell Search:

- Cell search is the procedure of UE synchronizes with E-UTRAN in time-freq domain, and acquires the serving cell ID.
- Two steps in cell search:
  - Step 1: Symbol synchronization and acquirement of ID within Cell Group by demodulating the Primary Synchronization Signal;
  - Step 2: Frame synchronization, acquirement of CP length and Cell Group ID by demodulating the Secondary Synchronization Signal.

About Cell ID：

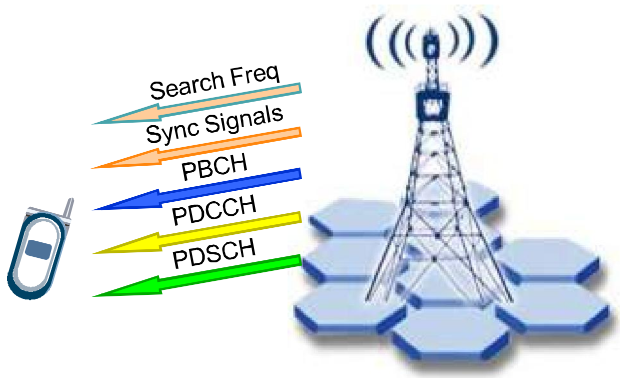
- In LTE protocol, the physical layer Cell ID comprises two parts: Cell Group ID and ID within Cell Group. The latest version defines that there are 168 Cell Group IDs, 3 IDs within each group. So **totally 168*3=504 Cell IDs exist.**

$$N_{ID}^{cell} = 3N_{ID}^{(1)} + N_{ID}^{(2)}$$

- $N_{ID}^{(1)}$ represents Cell Group ID, value from 0 to 167; $N_{ID}^{(2)}$ represents ID within Cell Group, value from 0 to 2.

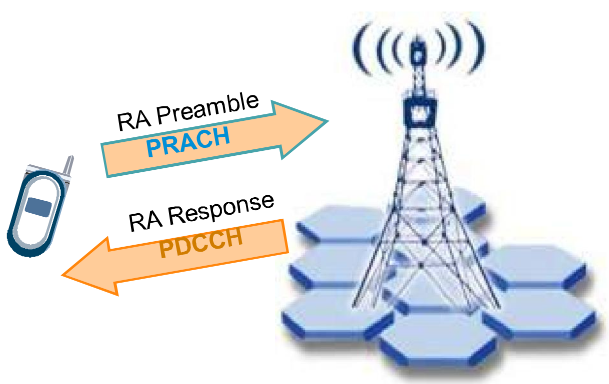
Initial Cell Search:

- The initial cell search is carried on after the UE power on. Usually, UE doesn't know the network bandwidth and carrier frequency at the first time switch on.
- UE repeats the basic cell search, tries all the carrier frequency in the spectrum to demodulate the synchronization signals. This procedure takes time, but the time requirement are typically relatively relaxed. Some methods can reduce time, such as recording the former available network information as the prior search target.
- Once finish the cell search, which achieve synchronization of time-freq domain and acquirement of Cell ID, UE demodulates the PBCH and acquires for system information, such as bandwidth and Tx antenna number.
- After the procedure above, UE demodulates the PDCCH for its paging period that allocated by system. UE wakes up from the IDLE state in the specified paging period, demodulates PDCCH for monitoring paging. If paging is detected, PDSCH resources will be demodulated to receive paging message.



Physical Layer Procedure — Radom Access

- **Basic Principle of Random Access :**
  - Random access is the procedure of uplink synchronization between UE and E-UTRAN.
  - Prior to random access, physical layer shall receive the following information from the higher layers:
    - Random access channel parameters: PRACH configuration, frequency position and preamble format, etc.
    - Parameters for determining the preamble root sequences and their cyclic shifts in the sequence set for the cell, in order to demodulate the random access preamble.
  - Two steps in physical layer random access:
    - UE transmission of random access preamble
    - Random access response from E-UTRAN



- **Detail Procedure of Random Access:**
  - Physical Layer procedure is triggered upon request of a preamble transmission by higher layers.
  - The higher layers request indicates a preamble index, a target preamble received power, a corresponding RA-RNTI and a PRACH resource .
  - UE determines the preamble transmission power is preamble target received power + Path Loss. The transmission shall not higher than the maximum transmission power of UE. Path Loss is the downlink path loss estimate calculated in the UE.
  - A preamble sequence is selected from the preamble sequence set using the preamble index.
  - A single preamble is transmitted using the selected preamble sequence with calculated transmission power on the indicated PRACH resource.
  - UE Detection of a PDCCH with the indicated RA-RNTI is attempted during a window controlled by higher layers. If detected, the corresponding PDSCH transport block is passed to higher layers. The higher layers parse the transport block and indicate the 20-bit grant.

RA-RNTI: Random Access Radio Network Temporary Identifier

Physical Layer Procedure — Power Control

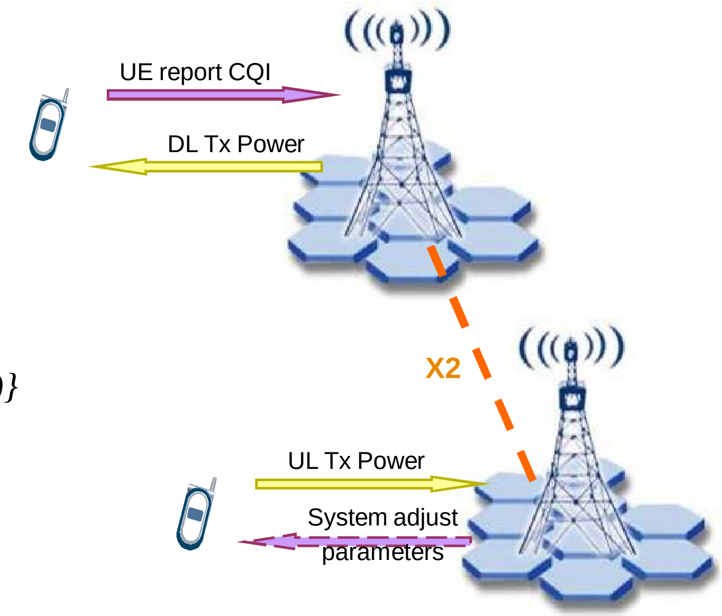
- **Basic Principle of Power Control:**
  - Downlink power control determines the EPRE (Energy per Resource Element);
  - Uplink power control determines the energy per DFT-SOFDM (also called SC-FDMA) symbol.

- **Uplink Power Control:**
  - Uplink power control consists of opened loop power and closed loop power control.
  - A cell wide overload indicator (OI) is exchanged over X2 interface for integrated inter-cell power control, possible to enhance the system performance through power control.
  - PUSCH, PUCCH, PRACH and Sounding RS can be controlled respectively by uplink power control. Take PUSCH power control for example:

$$P_{PUSCH}(i) = \min\{P_{MAX}, 10\log_{10}(M_{PUSCH}(i)) + P_{O\_PUSCH}(j) + \alpha(j) \cdot PL + \Delta_{TF}(i) + f(i)\}$$

  - PUSCH power control is the slow power control, to compensate the path loss and shadow fading and control inter-cell interference. The control principle is shown in above equation. The following factors impact PUSCH transmission power P_{PUSCH}: UE maximum transmission power P_{MAX}, UE allocated resource M_{PUSCH}, initial transmission power P_{O_PUSCH}, estimated path loss PL, modulation coding factor Δ_{TF} and system adjustment factor f (not working during opened loop PC)

- **Downlink Power Control:**
  - The transmission power of downlink RS is usually constant. The transmission power of PDSCH is proportional with RS transmission power.
  - Downlink transmission power will be adjusted by the comparison of UE report CQI and target CQI during the power control.



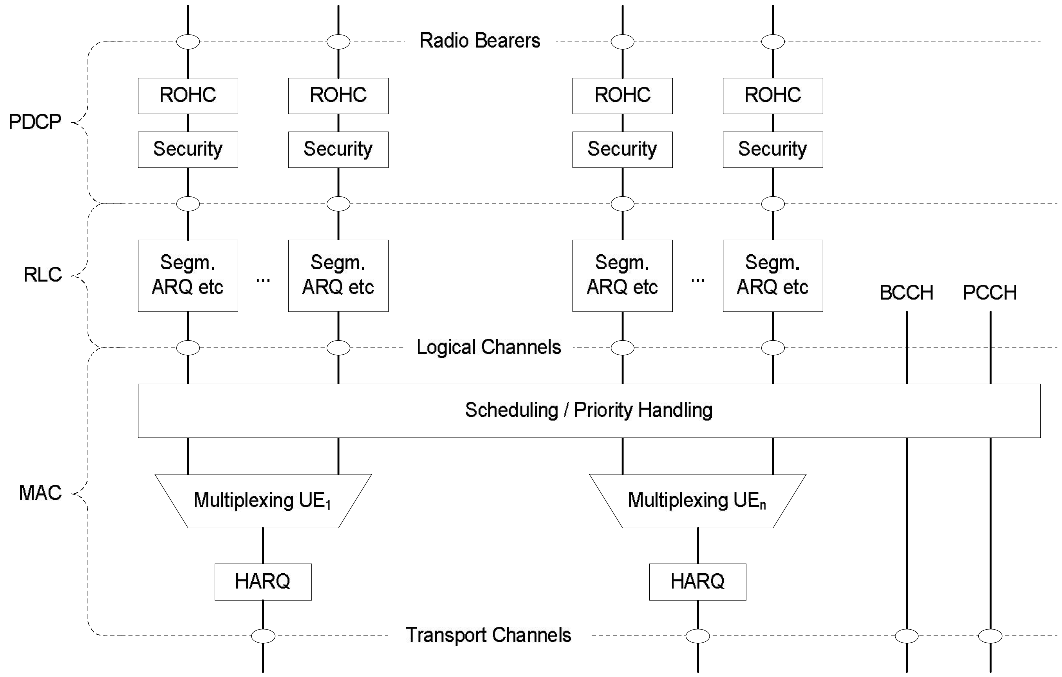
EPRE: Energy per Resource Element
DFT-SOFDM: Discrete Fourier Transform Spread OFDM

Overview of LTE Layer 2

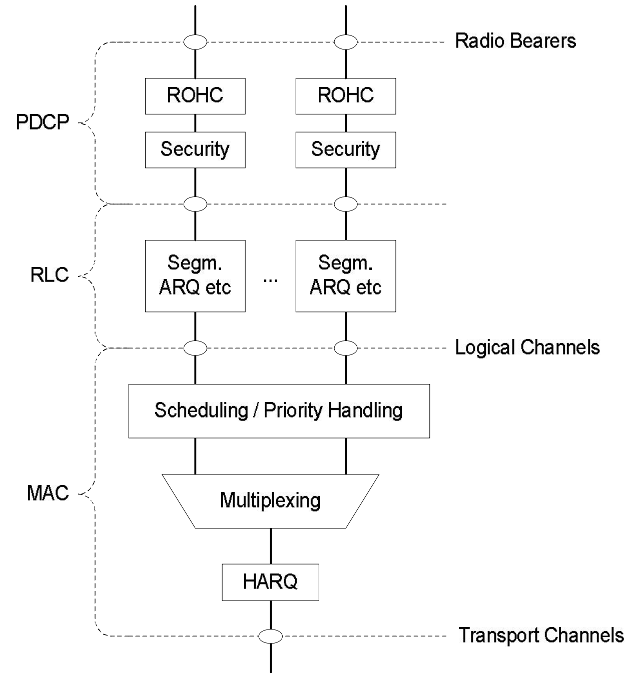
- **Layer 2 is split into the following layers:**
  - MAC (Medium Access Control) Layer
  - RLC (Radio Link Control) Layer
  - PDCP (Packet Data Convergence Protocol) Layer

- **Main Functions of Layer 2:**
  - Header compression, Ciphering
  - Segmentation and concatenation, ARQ
  - Scheduling, priority handling, multiplexing and demultiplexing, HARQ

Layer 2 Structure for DL



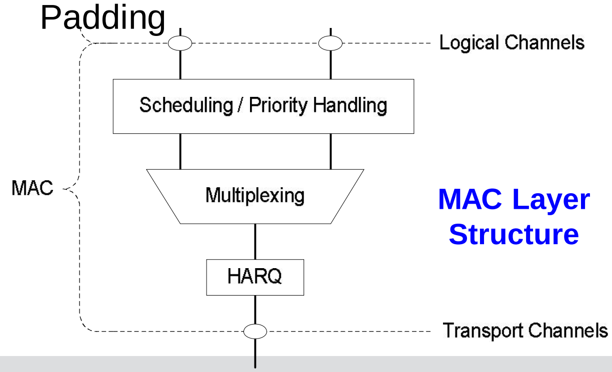
Layer 2 Structure for UL



Introduction of MAC Layer

Main functions of MAC Layer:

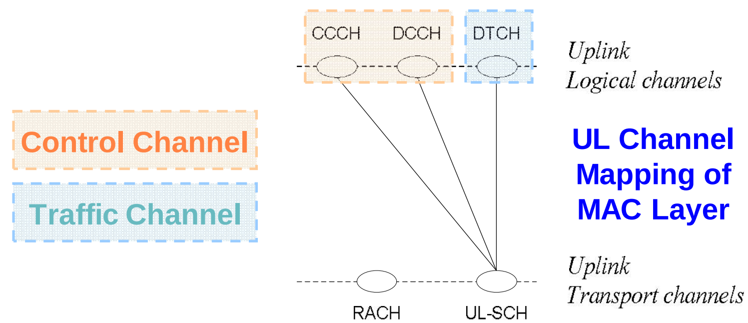
- Mapping between logical channels and transport channels
- Multiplexing/demultiplexing of RLC PDUs (Protocol Data Unit) belonging to one or different radio bearers into/from TB (transport blocks) delivered to/from the physical layer on transport channels
- Traffic volume measurement reporting
- Error correction through HARQ
- Priority handling between logical channels of one UE
- Priority handling between UEs (dynamic scheduling)
- Transport format selection
- Padding



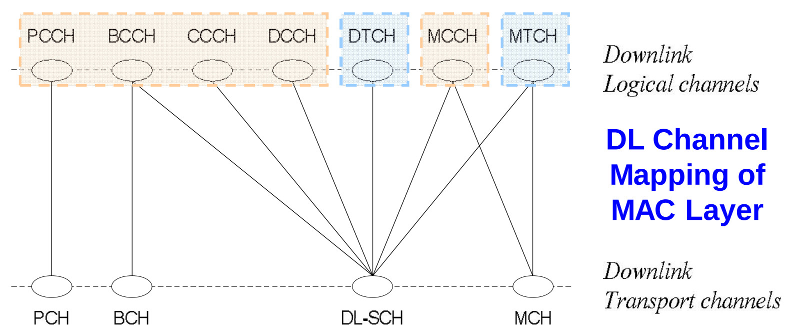
MAC Layer Structure

Logical Channels of MAC Layer:

- Control Channel: For the transfer of control plane information
- Traffic Channel: for the transfer of user plane information



UL Channel Mapping of MAC Layer

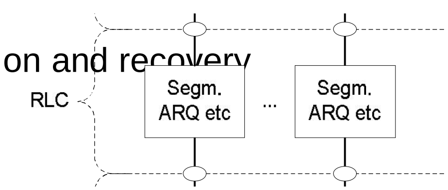


DL Channel Mapping of MAC Layer

Introduction of RLC Layer

Main functions of RLC Layer:

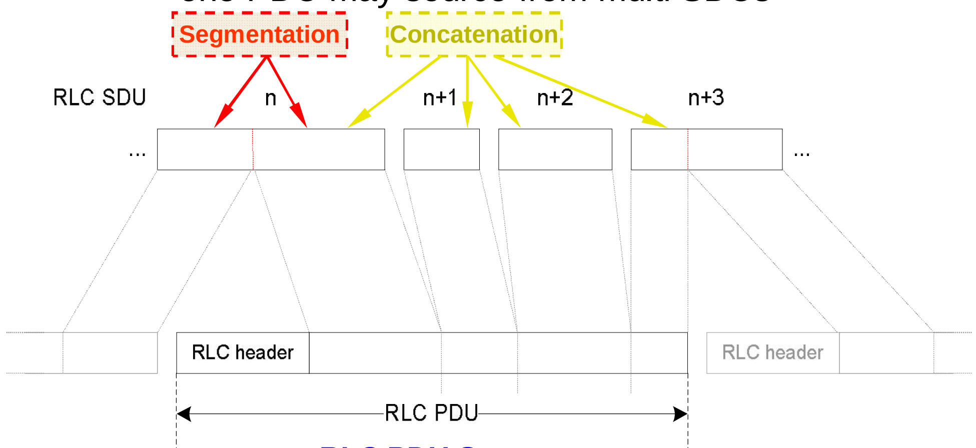
- Transfer of upper layer PDUs supports AM or UM
- TM data transfer
- Error Correction through ARQ (no need RLC CRC check, CRC provided by the physical)
- Segmentation according to the size of the TB: only if an RLC SDU does not fit entirely into the TB then the RLC SDU is segmented into variable sized RLC PDUs, no need padding
- Re-segmentation of PDUs that need to be retransmitted: if a retransmitted PDU does not fit entirely into the new TB used for retransmission then the RLC PDU is re-segmented
- Concatenation of SDUs for the same radio bearer
- In-sequence delivery of upper layer PDUs except at HO
- Protocol error detection and recovery
- Duplicate Detection
- SDU discard
- Reset



RLC Layer Structure

RLC PDU Structure:

- The PDU sequence number carried by the RLC header is independent of the SDU sequence number
- The size of RLC PDU is variable according to the scheduling scheme. SDUs are segmented /concatenated based on PDU size. The data of one PDU may source from multi SDUs



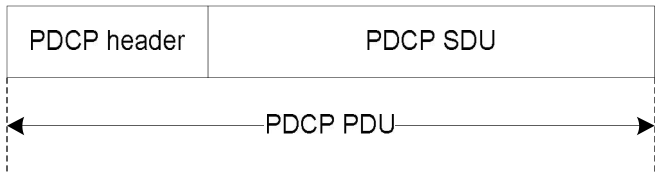
RLC PDU Structure

AM: Acknowledge Mode
UM: Un-acknowledge Mode
TM: Transparent Mode
TB: Transport Block
SDU: Service Data Unit
PDU: Protocol Data Unit

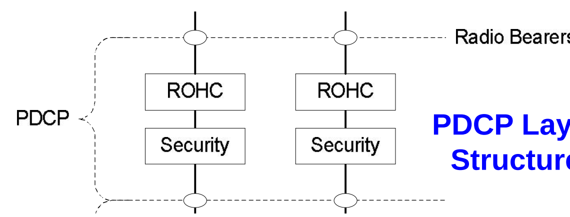
Introduction of PDCP Layer

- **Main functions of PDCP Layer:**
  - Functions for User Plane:
    - Header compression and decompression: ROHC
    - Transfer of user data: PDCP receives PDCP SDU from the NAS and forwards it to the RLC layer and vice versa
    - In-sequence delivery of upper layer PDUs at handover for RLC AM
    - Duplicate detection of lower layer SDUs at handover for RLC AM
    - Retransmission of PDCP SDUs at handover for RLC AM
    - Ciphering
    - Timer-based SDU discard in uplink
  - Functions for Control Plane:
    - Ciphering and Integrity Protection
    - Transfer of control plane data: PDCP receives PDCP SDUs from RRC and forwards it to the RLC layer and vice versa

- **PDCP PDU Structure:**
  - PDCP PDU and PDCP header are octet-aligned
  - PDCP header can be either 1 or 2 bytes long



PDCP PDU Structure

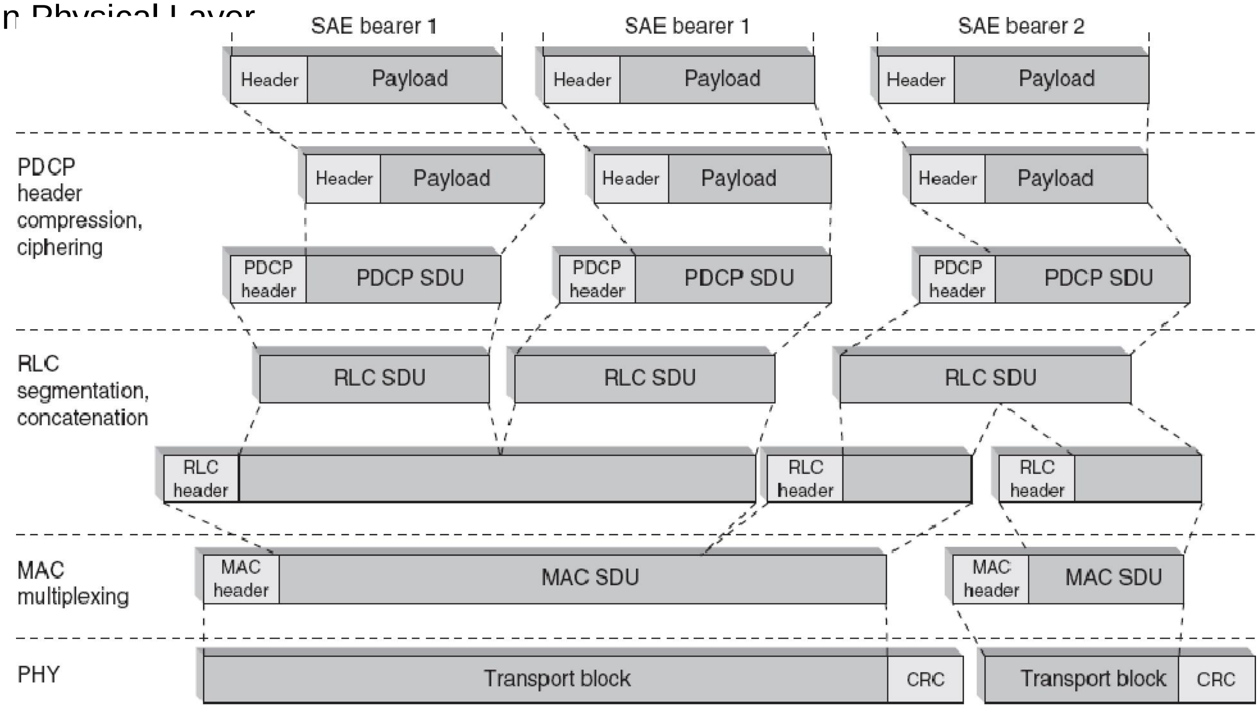


PDCP Layer Structure

ROHC: Robust Header Compression

Summary of Data Flow in Layer 1 & 2

- **Data Transfer in Layer 1 and Layer 2**
  - Data from the upper layer are headed and packaged, sent to the lower layer, vice versa.
  - Scheduler effect in the RLC, MAC and Physical Layers. User data packages are multiplexed in the MAC Layer.
  - CRC in Physical Layer

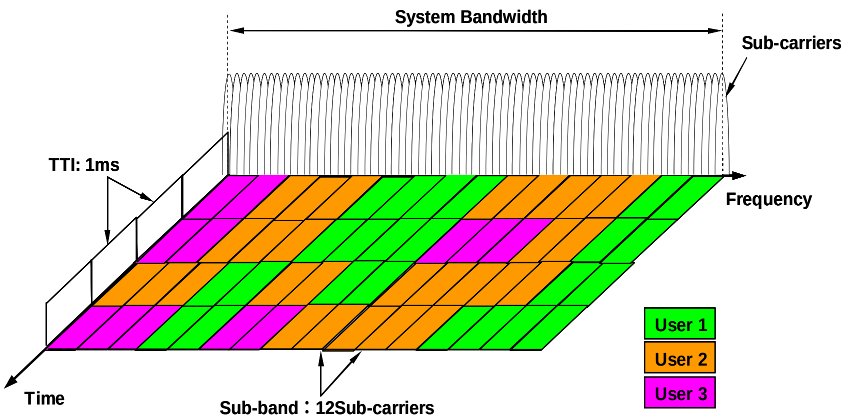


HUAWEI

LTE Key Technology — OFDMA & SC-FDMA

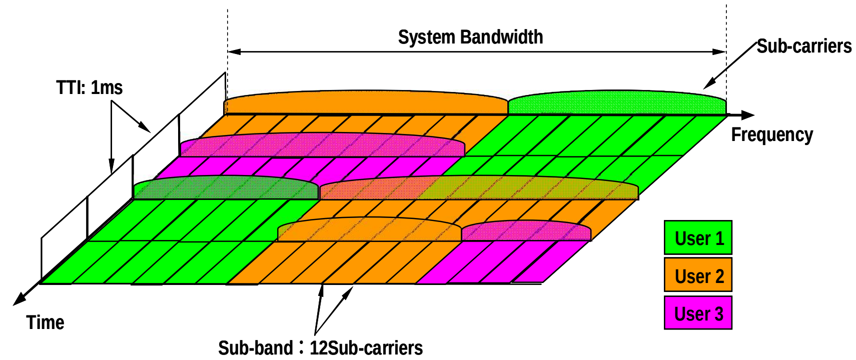
OFDM & OFDMA

- **OFDM** (Orthogonal Frequency Division Multiplexing) is a modulation multiplexing technology, divides the system bandwidth into orthogonal subcarriers. CP is inserted between the OFDM symbols to avoid the ISI.
- **OFDMA** is the multi-access technology related with OFDM, is used in the LTE downlink. OFDMA is the combination of TDMA and FDMA essentially.
- Advantage: High spectrum utilization efficiency due to orthogonal subcarriers need no protect bandwidth. Support frequency link auto adaptation and scheduling. Easy to combine with MIMO.
- Disadvantage: Strict requirement of time-frequency domain synchronization. High PAPR.



DFT-S-OFDM & SC-FDMA

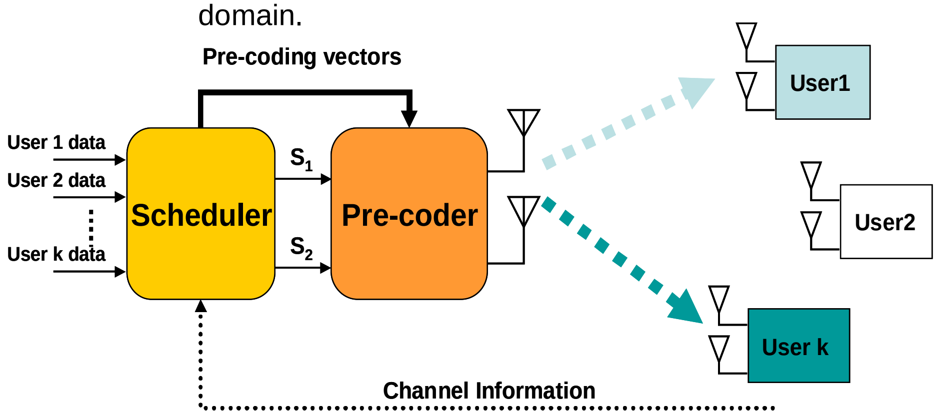
- **DFT-S-OFDM** (Discrete Fourier Transform Spread OFDM) is the modulation multiplexing technology used in the LTE uplink, which is similar with OFDM but can release the UE PA limitation caused by high PAPR. Each user is assigned part of the system bandwidth.
- **SC-FDMA**（Single Carrier Frequency Division Multiple Accessing） is the multi-access technology related with DFT-S-OFDM.
- Advantage: High spectrum utilization efficiency due to orthogonal user bandwidth need no protect bandwidth. Low PAPR.
- The subcarrier assignment scheme includes Localized mode and Distributed mode.



MIMO

Downlink MIMO

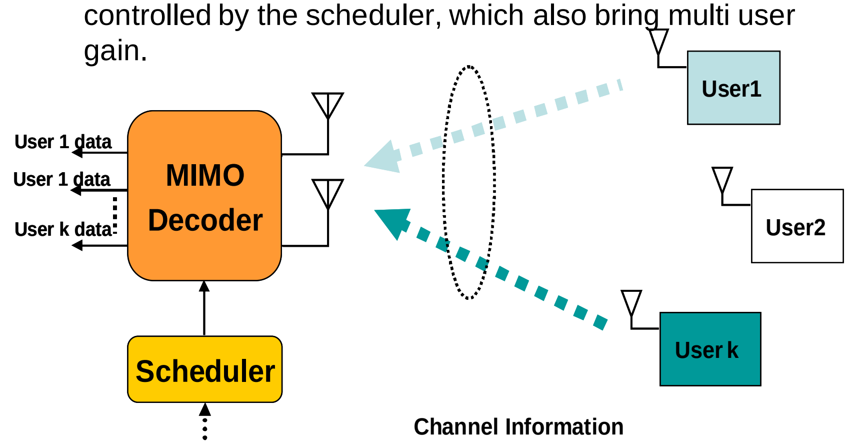
- MIMO is supported in LTE downlink to achieve spatial multiplexing, including single user mode SU-MIMO and multi user mode MU-MIMO.
- In order to improve MIMO performance, pre-coding is used in both SU-MIMO and MU-MIMO to control/reduce the interference among spatial multiplexing data flows.
- The spatial multiplexing data flows are scheduled to one single user In SU-MIMO, to enhance the transmission rate and spectrum efficiency. In MU-MIMO, the data flows are scheduled to multi users and the resources are shared within users. Multi user gain can be achieved by user scheduling in the spatial domain.



MU-MIMO

Uplink MIMO

- Due to UE cost and power consumption, it is difficult to implement the UL multi transmission and relative power supply. Virtual-MIMO, in which multi single antenna UEs are associated to transmit in the MIMO mode. Virtual-MIMO is still under study.
- Scheduler assigns the same resource to multi users. Each user transmits data by single antenna. System separates the data by the specific MIMO demodulation scheme.
- MIMO gain and power gain (higher Tx power in the same time-freq resource) can be achieved by Virtual-MIMO. Interference of the multi user data can be controlled by the scheduler, which also bring multi user gain.



Virtual-MIMO

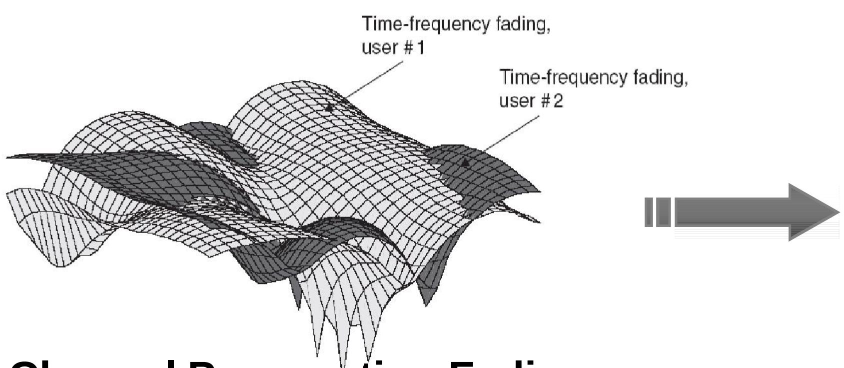
Schedule and Link Auto-adaptation

User Multiplexing and Scheduling

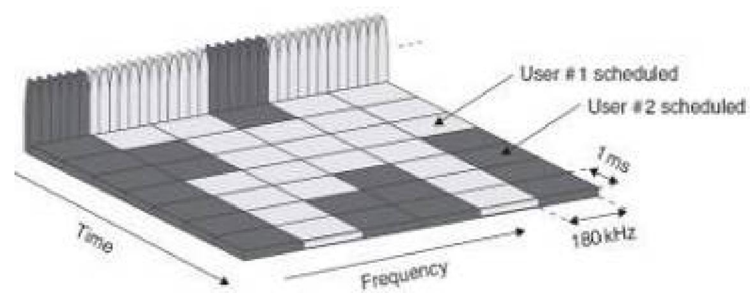
- Large system bandwidth (10/15/20MHz) of LTE will facing the problem of frequency selected fading. The fading characteristic on subcarriers of one user can be regarded as same, but different in further subcarriers.
- Select better subcarriers for specific user according to the fading characteristic. User diversity can be achieved to increase spectrum efficiency.
- The LTE schedule period is one or more TTI.
- The channel propagation information is feed back to e-NodeB through the uplink. Channel quality identity is the overheading of system. The less, the better.

Link Auto-adaptation

- LTE support link auto-adaptation in time-domain and frequency-domain. Modulation scheme is selected based on the channel quality in time/frequency-domain.
- In CDMA system, power control is one important link auto-adaptation technology, which can avoid interference by far-near effect. In LTE system, user multiplexed by OFDM technology. Power control is used to reduce the uplink interference from adjacent cell, to compensate path loss. It is one type of slow link auto-adaptation scheme.



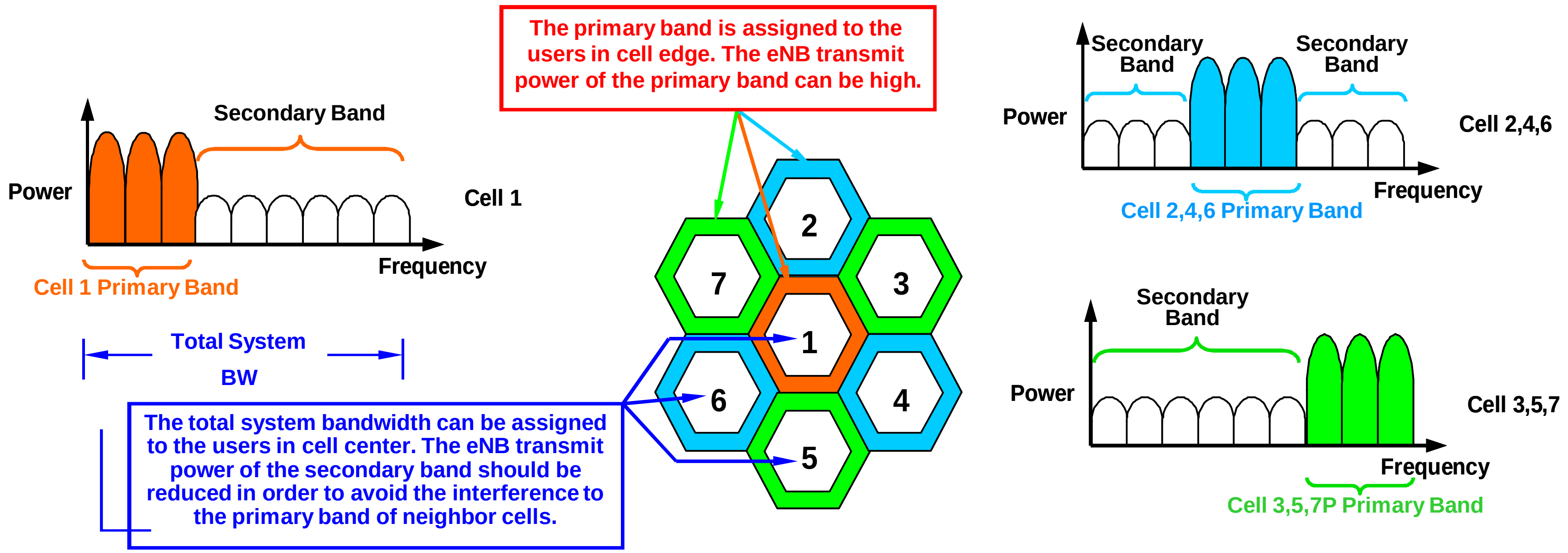
Channel Propagation Fading



User Multiplexing and Scheduling

Cell Interference Control

- **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.



Content

Content

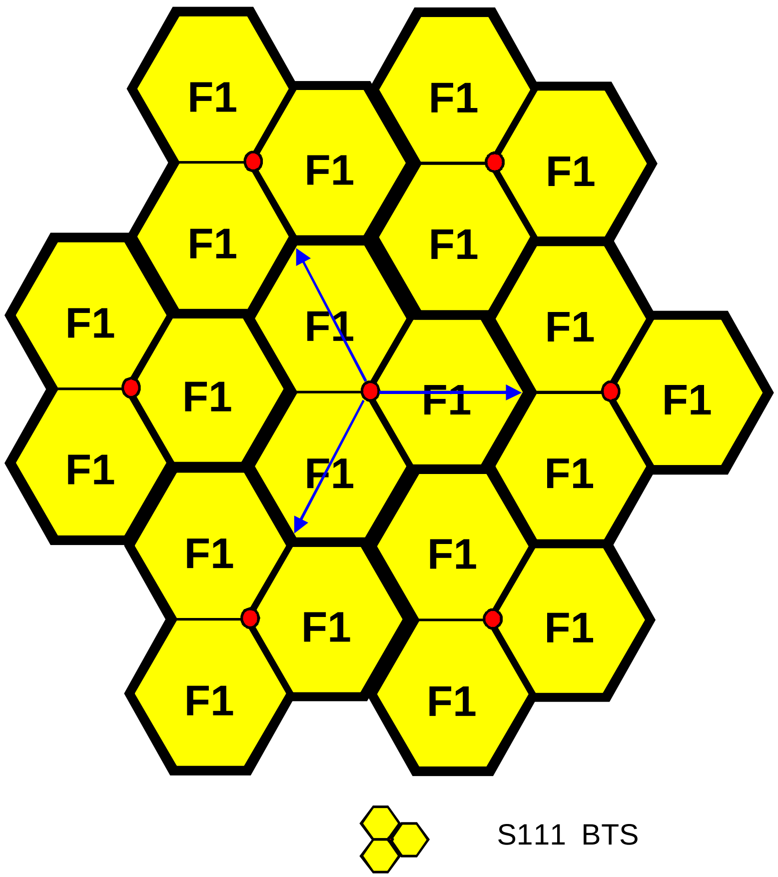
Frequency reuse mode 1*3*1

Advantages of 1*3*1

- High frequency efficiency, High sector throughput
- Do not need complex scheduling algorithm, system

Disadvantages of 1*3*1

- Co-frequency interference is hard
- Low Cell edge data rate, difficulty for continuous coverage.



Used in limit frequency band and discontinuous coverage scenario

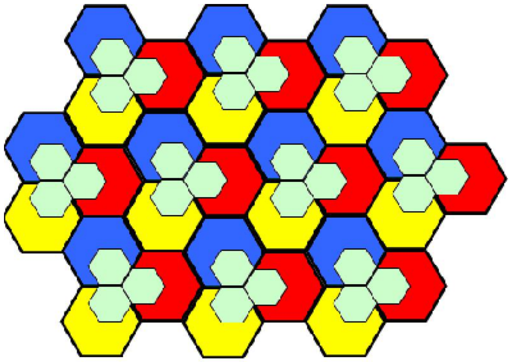
SFR (Soft Frequency Reuse)1*3*1

SFR 1*3*1 with ICIC

- DL ICIC：cell center use 2/3 band，cell edge use 1/3 band；so, in cell edge, frequency reuse 3, different cell edge use different frequency. Tx power in cell center lower than cell edge Tx power to control interference.
- UL ICIC： cell center use 2/3 band，cell edge use 1/3 band, so, in cell edge, frequency reuse 3, different cell edge use different frequency. Cell users in same BTS transmit in the odd / even frame scheduling respectively

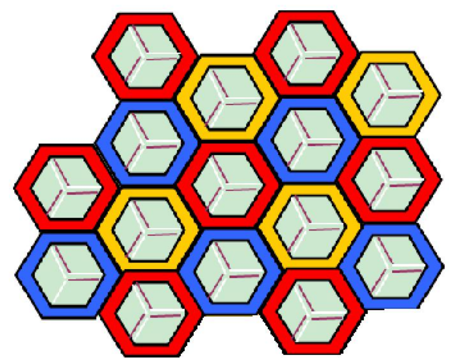
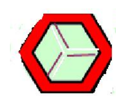
SFR 1*3*1 networking merit

- Lower down interference with ICIC
- High Frequency efficiency




DL SFR 1*3*1

Note: S111 BTS

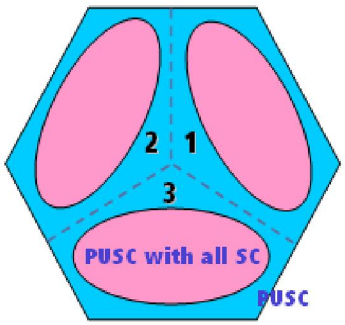
UL SFR 1*3*1

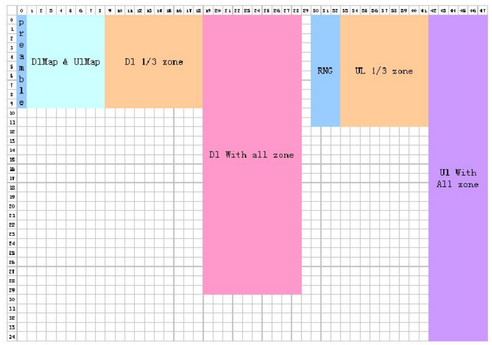
Note: S111 BTS

Huawei suggest SFR 1×3×1 networking

SFR 1*3*1 Vs FFR 1*3*1

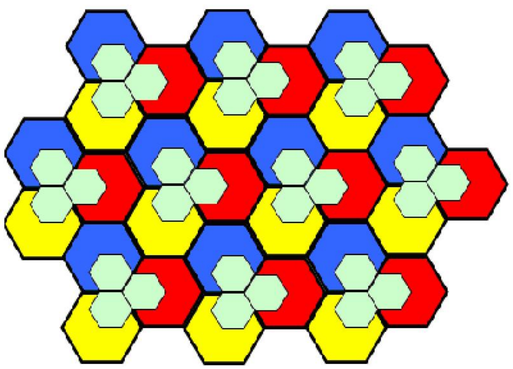
FFR 1*3*1 DL&UL



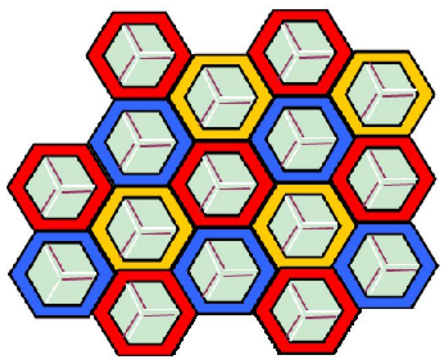


User in Cell center and cell edge within the cell separate by time domain ， different site cell edge separate by frequency domain;

SFR1*3*1 DL



SFR1*3*1 UL



DL cell center decrease Tx powe；UL in cell edge， different cell separate in frequency domain， User in Cell center and cell edge within the cell separate by time domain

Similarities

- Separate by the frequency domain / time domain for interference cancellation
- Cell centers use more bandwidth resources, cell edge use of about 1 / 3 frequency bands,

difference

- FFR use all the sub-carrier in cell center, SFR use 2/3 sub-carriers
- In DL/UL, FFR same reuse mode,, SFR use different mode
- DL Tx Power: SFR: cell center is lower than cell edge; FFR: cell center is same with cell edge
- UL frequency resource: FFR mode, in cell edge, fixed use 1/3 of the frequency band; In SFR mode, cell edge use partial band, normally near 1/3 of the frequency.

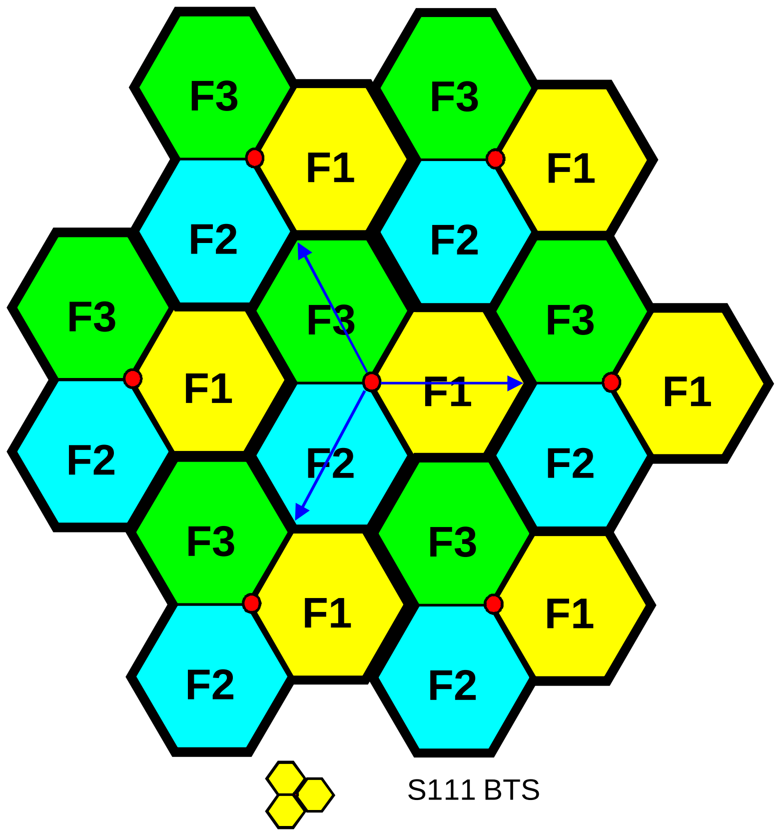
Frequency reuse mode 1*3*3

Advantage of 1*3*3

- Low co-frequency interference, good coverage
- High sector throughput

Disadvantage of 1*3*3

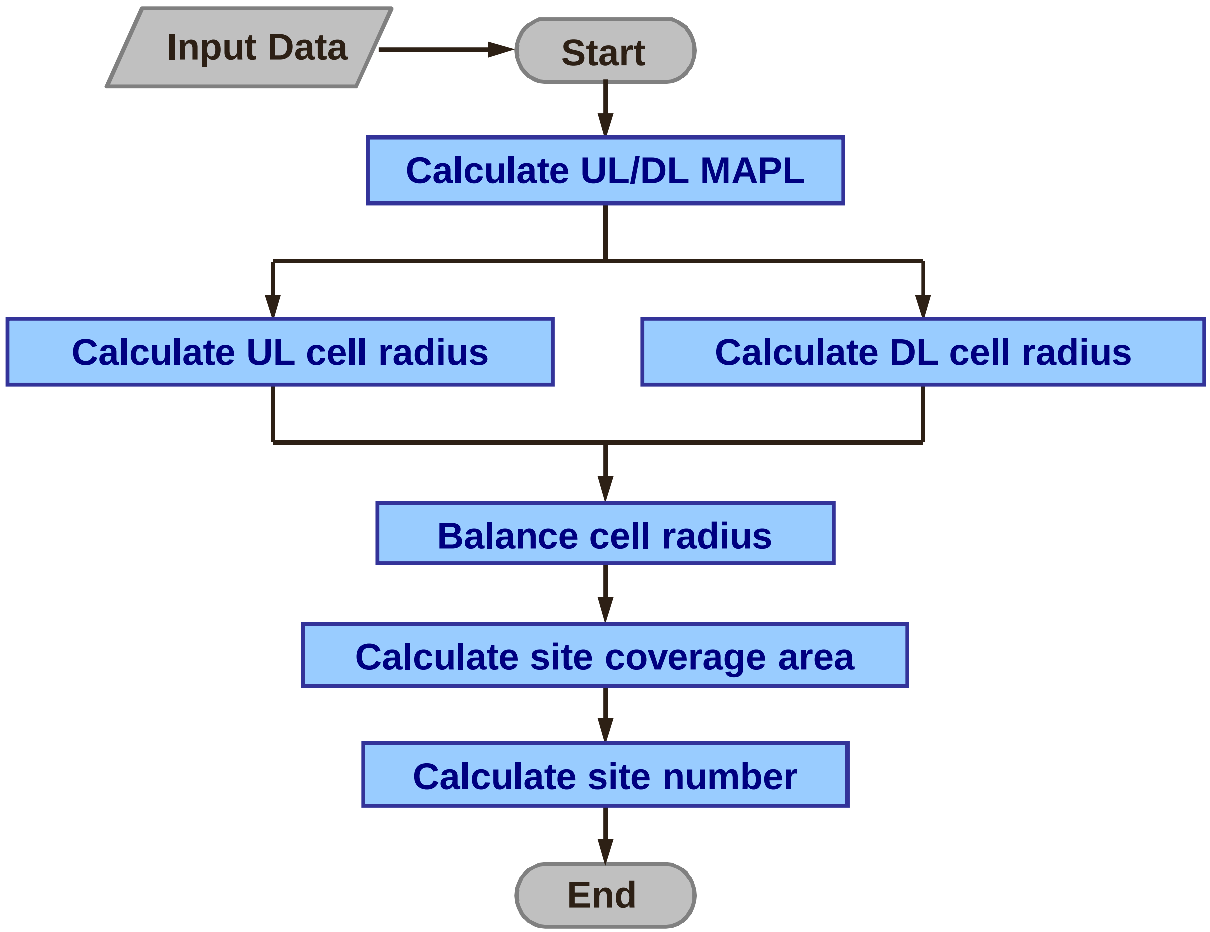
- Low frequency efficiency
- More frequency resource required



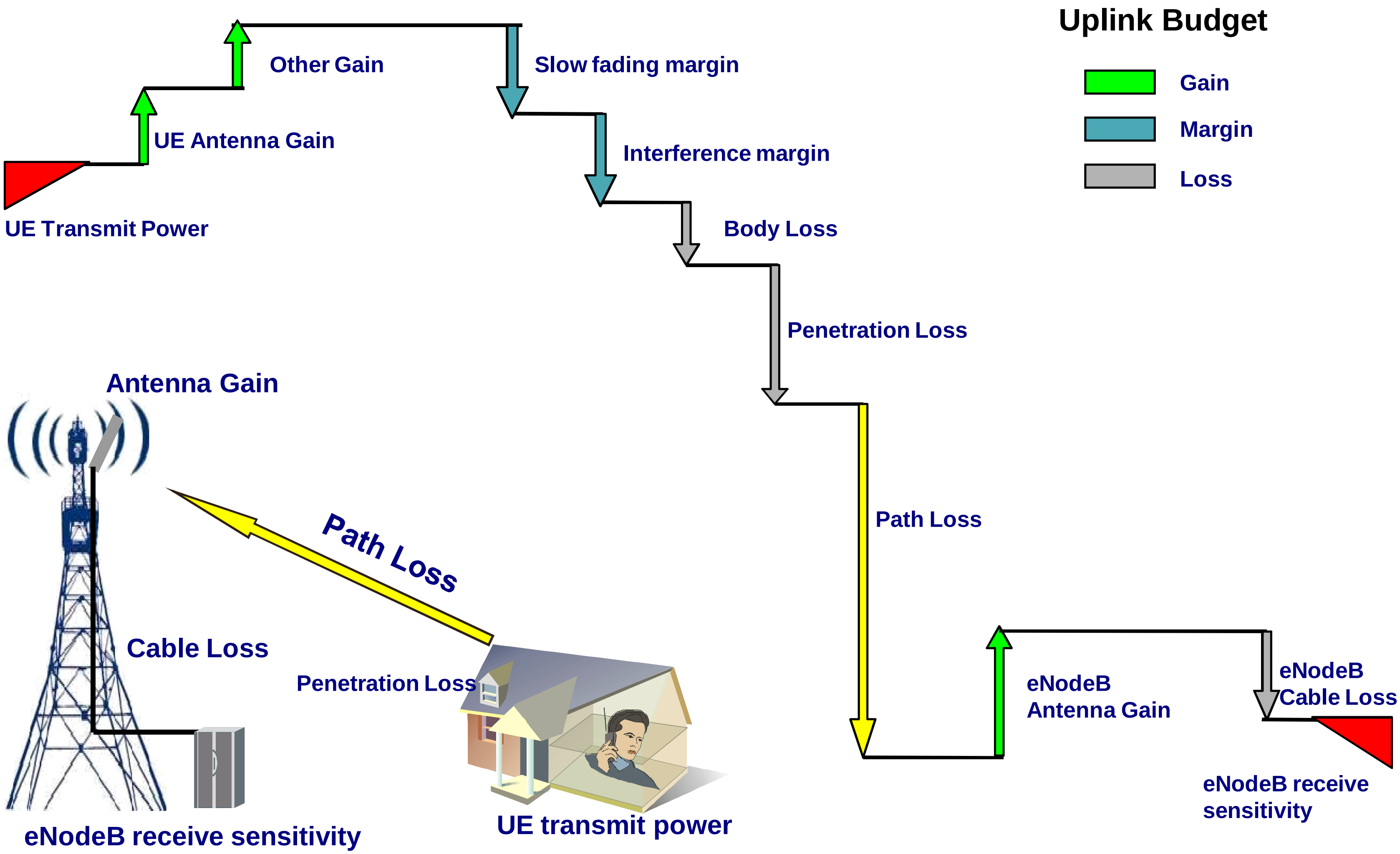
Used in rich frequency resource and discontinuous frequency band coverage

Content

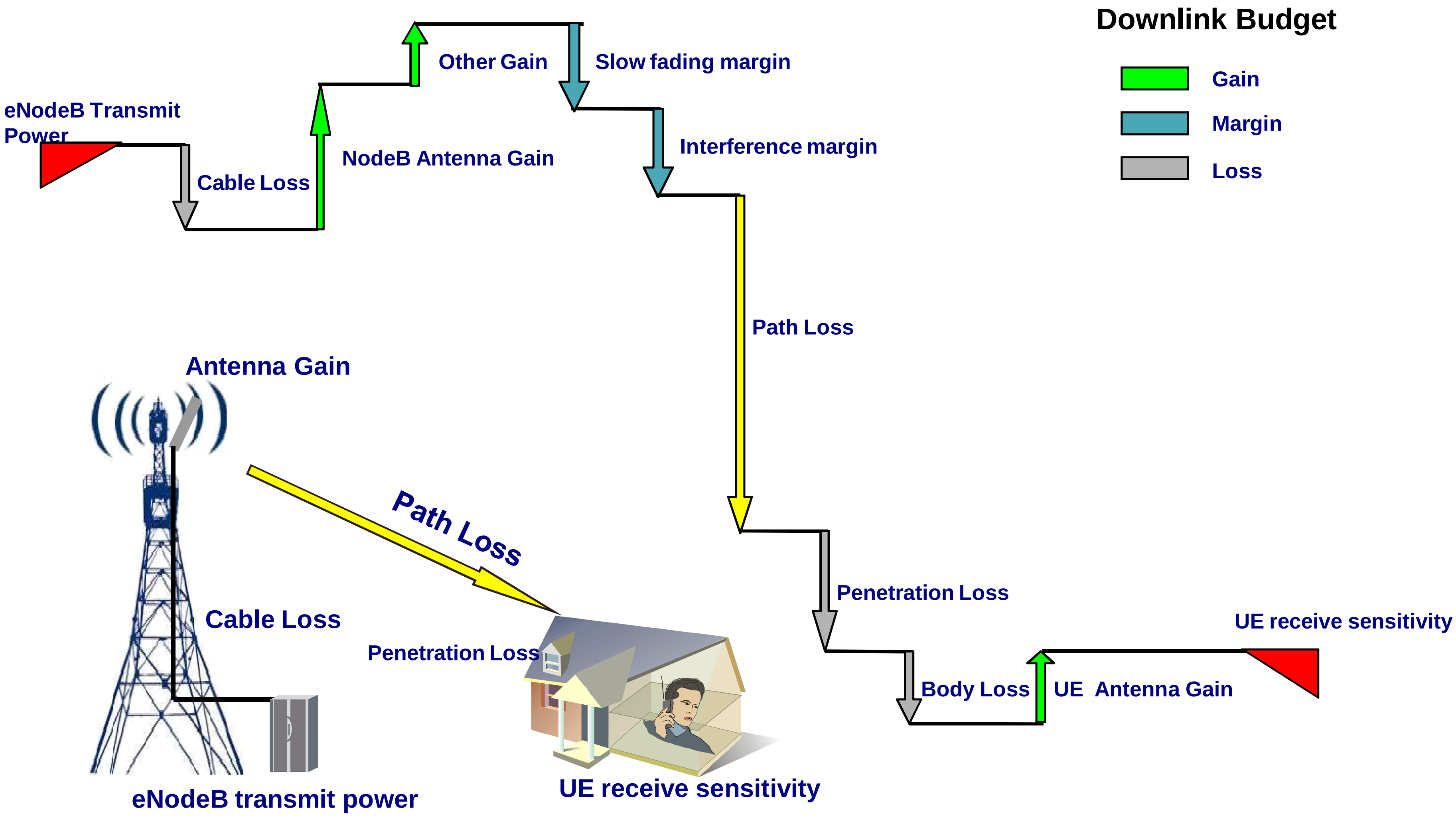
Link Budget Procedure



Link Budget Model: Uplink



Link Budget Model: Downlink



Link Budget Principle

- **Link budget is aim to calculate the cell radius.**
  - Cell radius can be calculated by MAPL with using propagation model
- **Two keys factors:**
  - MAPL
  - Propagation Model

MAPL: Maximum Allowed Path Loss
EIRP: Effective Isotropic Radiated Power
MSSR: Minimum Signal Strength Required

MAPL = EIRP - Minimum Signal Strength Required+ ∑Gain - ∑Loss - ∑Margin

§**EIRP** = Max Tx Power - Cable Loss - Body Loss + Antenna Gain

§**MSSR** = Rx Sensitivity - Antenna Gain + Cable Loss + Body Loss + Interference Margin

Cost231-Hata Model

$$Total = Lu - a(H_{UE}) + Cm$$

$$Lu = 46.3 + 33.9 \times \lg(f) - 13.82 \times \lg(H_{BS}) + (44.9 - 6.55 \times \lg(H_{BS})) \times \lg(d)$$

$$a(H_{UE}) = (1.1 \times \lg(f) - 0.7) \times H_{UE} - (1.56 \times \lg(f) - 0.8)$$

MAPL Calculation Process

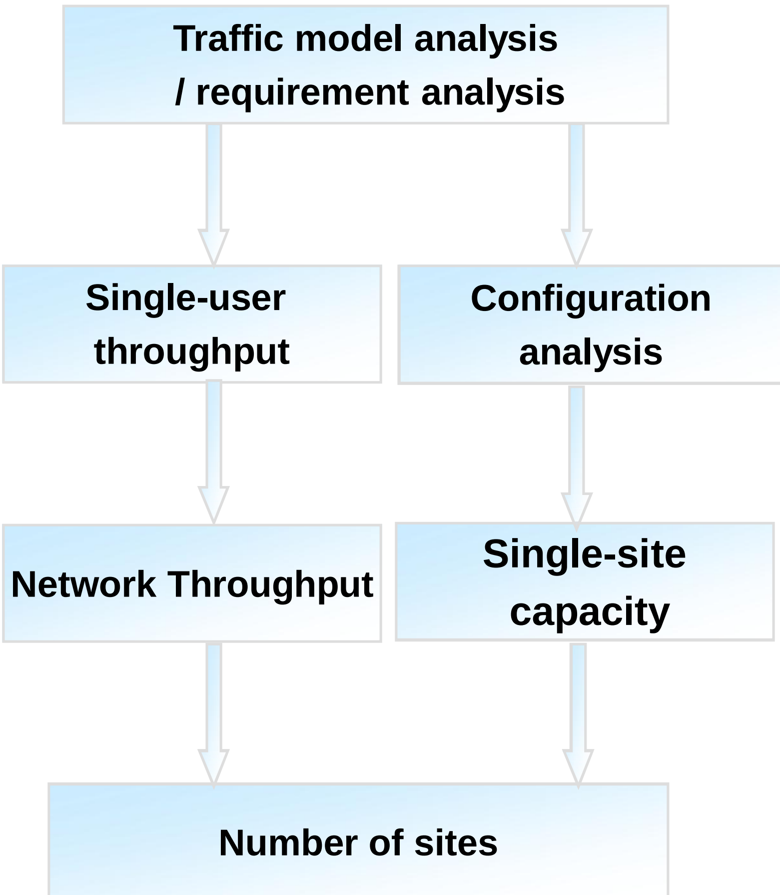
- **System parameter**
  - System Frequency Band, Band width, duplex mode
- **EIRP**
  - BS Tx Power, Antenna Gain, Feeder loss
- **Minimum Receiver Signal Level**
  - Receiver sensitivity, Noise Figure, Demodulation Threshold, Antenna gain, feeder loss, body loss.
- **System gain, Margin, Loss**
  - MIMO Gain, other gain
  - Shadow Fading Margin, Interference margin
  - Penetration losss

Coverage Planning Comparison LTE/CDMA / WiMAX

- LTE Protocal defined working band is from 700MHz~2.6GHz，including CDMA working band，but lower than WiMAX 3.5GHz。Because the working band vary largely, so the radio propagation capability is different in LTE/CDMA/Wimax.
- LTE and WiMAX adopt OFDMA as their access technology, for a single user, through system scheduling, using different No. of sub-carrier to meet the different coverage requirement. Compare with CDMA, CDMA users adjust Tx power in 1.2288M to meet the coverage requirement
- MIMO technology is used in LTE & WiMAX, different MIMO mode bring corresponding MIMO gains, like CDMA BS receiving diversity gain, which lower down the demodulation threshold.
- Modulation mode QPSK、16QAM and 64QAM employed by LTE and Wimax, CDMA use QPSK / 8-PSK / 16-QAM ，different modulation mode related to different data rate and different channel conditions
- In coverage planning process, LTE is same with CDMA and Wimax. For the technology difference, LTE is similar with Wimax, cause they all based on OFDMA and MIMO, the difference with CDMA is showed on the key system parameters.

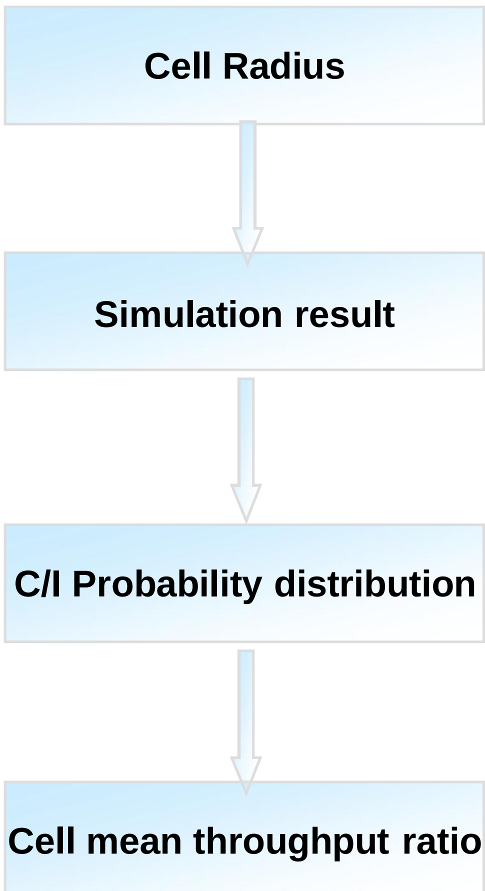
Content

Capacity Analysis Concept



- **Traffic model analysis/requirement analysis**: Specify customer requirements, e.g. Target users number, user BH active ratio, service bearing rate, overbooking, cell edge access rate, average data rate…
- **Single-user throughput** * No of BH Users = **Network throughput**
- **Configuration Analysis**: Frequency reused mode, Bandwidth, carrier configurations, MIMO configurations etc.
- **Single-site Capacity**: single site capacity calculated from system simulation after configuration analysis
- **Number of sites:** Network throughput requirement / Single site Capacity

Capacity Estimation Realization Process



- Obtain the cell radius in different scenarios according to the link budget.
- According to the radius, search the simulation data table and then obtain the cell CINR probability distribution. Currently, calculate the CINR distributing ratio with different cell radiuses in different scenarios according to the Matlable program provided by the RTT link budget.
- Calculate the cell mean throughput.

Formula of calculating the cell mean throughput

$$CellAvgThroughput = \sum_{i=1}^{N} P_i \times Throughput_i$$

- P_i is the probability corresponding to CINR
- $Throughput_i$ is the throughput calculated on a basis of CINR. According to different CINRs, search the table to obtain different modulation schemes and then obtain the $Throughput_i$ in different modulation schemes.

Key performance baseline

Scenario	Cell Radius (km) @ UL edge 64~512kbps				Avg. Cell Throughput DL/UL (Mbps) @10MHz BW			
	2.6GHz	2.1GHz	AWS	700MHz	2.6GHz	2.1GHz	AWS	700MHz
Dense Urban	0.21~0.33	0.26~0.4	0.3~0.46	0.66~1.01	16.92 / 9.76	18.39 / 10.61	17.62 / 10.87	17.35 / 12.17
Urban	0.39~0.58	0.47~0.71	0.55~0.82	1.20~1.79	16.92 / 9.76	18.39 / 10.61	17.62 / 10.87	17.35 / 12.17
SubUrban	1.47~2.25	1.8~2.76	2.09~3.2	4.61~7.06	12.97 / 6.92	14.10 / 7.52	16.82 / 8.70	17.27 / 10.67
Rural	3.16~4.83	4.42~5.93	4.78~7.3	9.48~14.51	12.97 / 6.92	14.10 / 7.52	16.82 / 8.70	17.27 / 10.67

About SFR 1x3x1	Application Scenarios	Remark
SFR 1×3×1introduces ICIC scheme based on traditional 1×3×1. Improves the cell edge user throughput with the cost of cell throughput.	- Lack of spectrum resource; - High requirement of cell edge user experiences.	UL: enhance cell edge rate about 10%, but cell throughput degrade about 5% DL : enhance cell edge rate about 20%, but cell throughput degrade about 10%

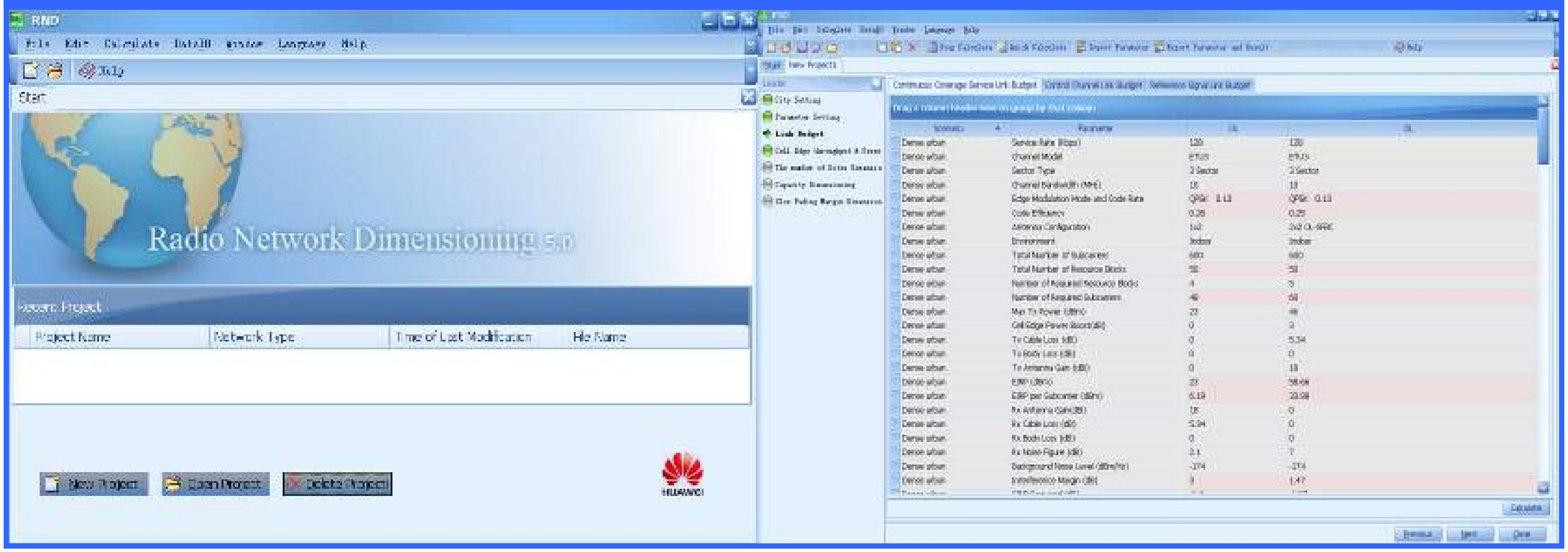
Max. Active User (RRC_Connected User) per cell	1.4MHz	3MHz	5MHz	10/15/20MHz
eRAN 1.0	-	-	200	400
eRAN 2.0	168	360	600	1200

Content

RND: LTE Dimensioning Tool

- **RND tool is Supporting:**
- Network dimensioning in different design types for different application scenarios
- Independent calculation or inheriting of calculation results among modules
- Network dimensioning in multiple cities and networking scenarios simultaneously
- Importing/exporting parameters and calculation results, and importing the parameters and calculation results into the RNP output template.

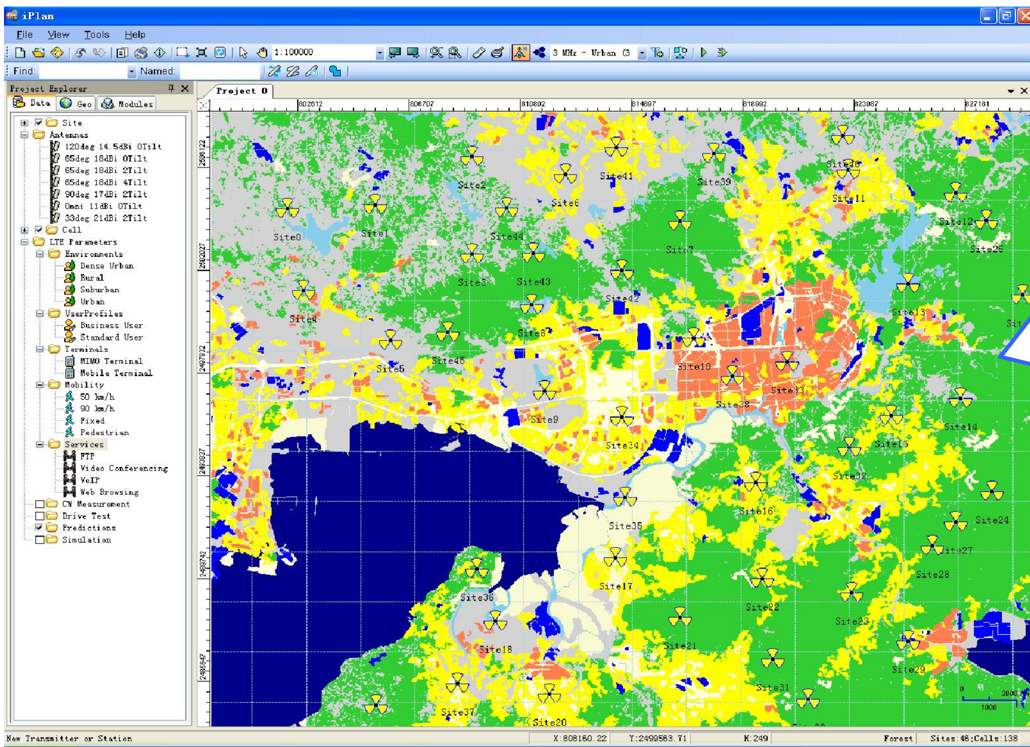
RND is the LTE dimensioning tool developed by Huawei

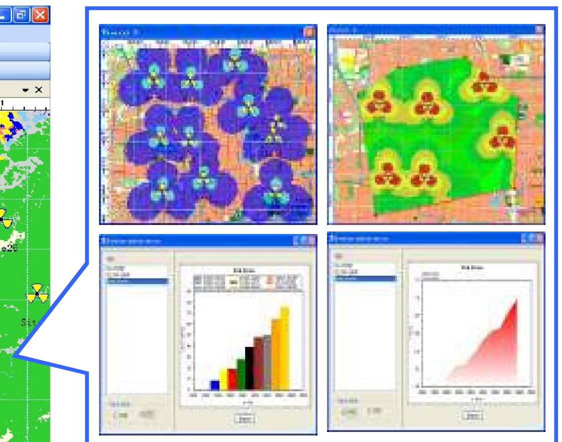


U-Net: Professional LTE RNP Tool

What is U-Net?

- **U-Net is the professional LTE simulation tool developed by Huawei.**
- **U-Net is based on the abundant global RNP experiences.**



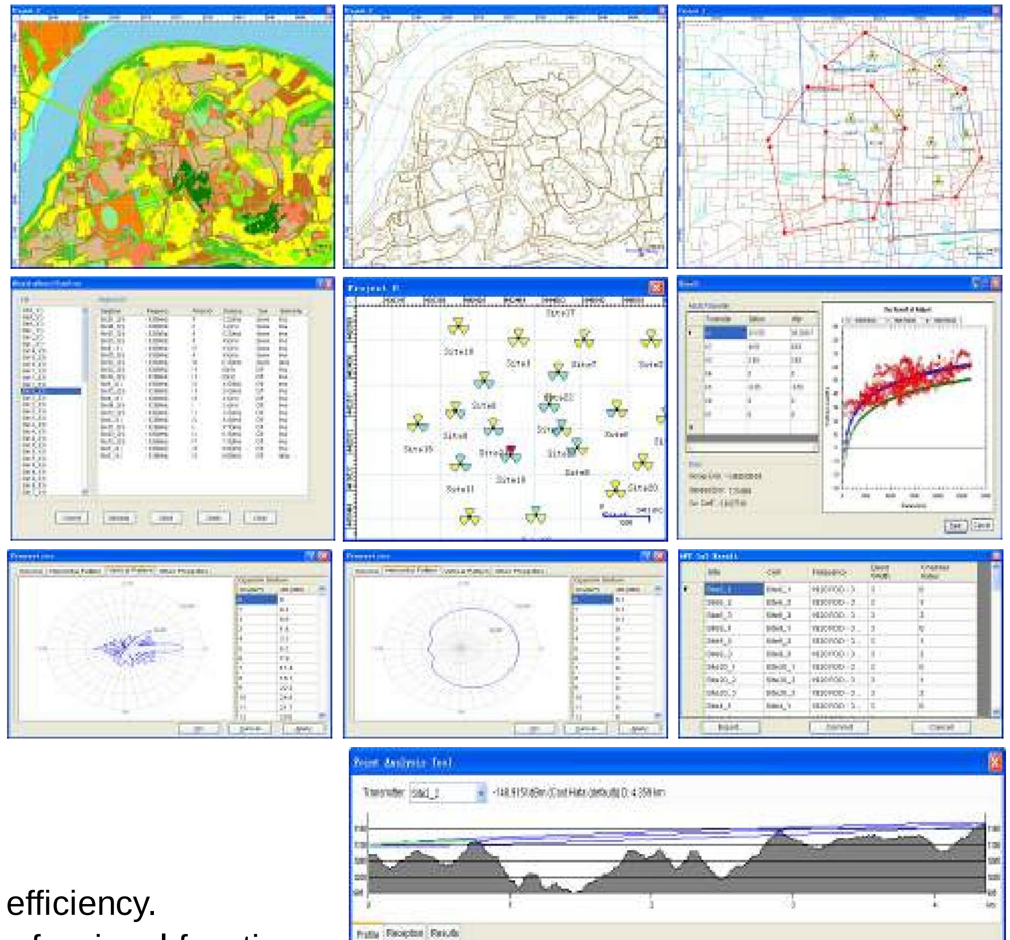


U-Net: Powerful and Saving

What can U-Net do?

Function:

- **Network modeling:**
  - GIS
  - Antenna model
  - Network element management
  - Service model management
  - Propagation model tuning & mngt.
- **Coverage Prediction:**
  - Path loss calculation
  - Polygon operation
  - Coverage plot generation
  - Point analysis
  - Monte Carlo simulation
- **LTE Specific Planning:**
  - PCI planning
  - Neighbor list planning
  - Frequency planning

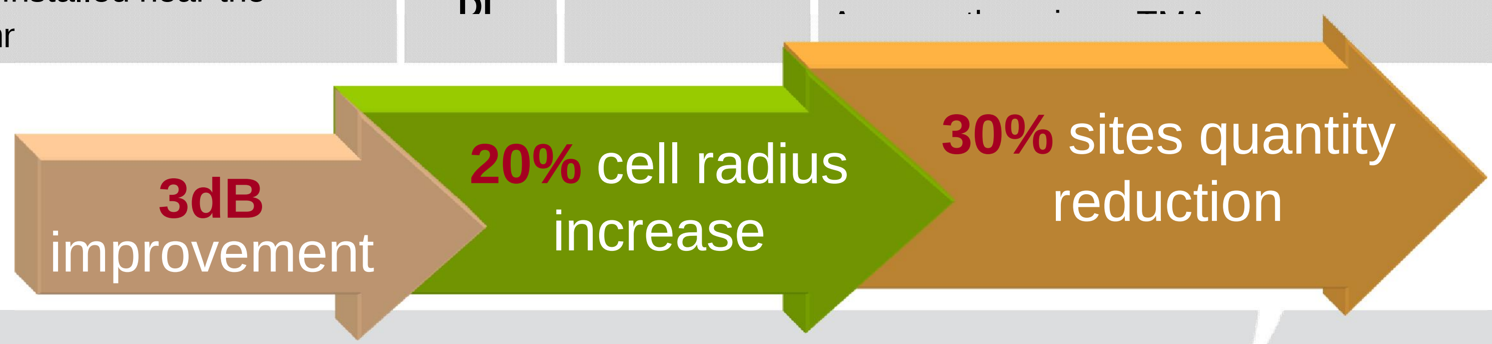


Benefit:

- Accurate prediction
- Easy operation and friendly interface
- Saving HR cost due to higher planning efficiency.
- Lower technical level requirement by Professional functions

Huawei LTE Enhancement Features

Performance Enhancement Feature	UL / DL	Expected Improvement	Comments
<u>Interference cancellation</u> IRC	**UL**	**1~5dB**	The more serious interference condition, the more obvious the IRC gain will be.
<u>Receive diversity</u> 4 receiving antennas	**UL**	**2.5dB**	3 dB in theory. Considered the co-relate between real antenna, 2.5dB is the practical gain.
<u>Advanced scheduling</u> Frequency domain packet schedule	**UL & DL**	**1~3dB**	2~3dB gain when cell edge user throughput = 500Kbps, 1~2dB gain when cell edge user throughput = 1Mbps
<u>Power Convergence</u> 4 TTIs Bundling	**UL**	**1.5~3dB**	Bundle several TTIs together for a single VoIP packet transmission. Power convergence.
<u>DBS flexibility</u> RRU installed near the antenr	**UL & DL**	**2.5dB**	Rooftop site, typical cable loss for BTS is 3dB, for RRU is 0.5dB (jumper loss).



Avoid Interference

Co-site solution is recommended by Huawei

Co-site Scenario:	Non Co-site Scenario:
• Avoid far-near effect, less interference	• Adjacent frequency interference will be much higher

Guard band Requirement for Co-existing Systems (MHz)

Co-existing Systems	System Standards		LTE Bandwidth			
	LTE	Other system	5MHz	10MHz	15MHz	20MHz
LTE + GSM	protocol	protocol	0.2	0.2	0.2	0.2
	Huawei Product	**protocol**	**0**	**0**	**0**	**0**
LTE + UMTS	protocol	protocol	0.33	0.08	0.17	0.42
	Latest MSR protocol		**0**	**0**	**0**	**0**
LTE + CDMA	protocol	Huawei Product	0.24	0.49	0.74	0.99
	Huawei Product	**Huawei Product**	**0**	**0**	**0**	**0**
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LTE TDD 2.3G + TD-SCDMA 2.3G	protocol	protocol	0	0	0	0

Guard band can be eliminated by deploying Huawei RAN products

Co-Antenna/Feeder Analysis

Co-antenna/feeder with 2G/3G system

Co-antenna Analysis

- **Benefit:**
  - No more antenna installation space
- **Risk:**
  - Additional diplexers cause insertion loss
  - Can not adjust azimuth independently
- **Suggestion:**
  - Wide band or multi band depends on the frequency spectrums
  - 4-port antenna is recommended for supporting independent downtilt
  - Same electrical specification with original.

Co-feeder Analysis

- **Benefit:**
  - Saving feeder cost
- **Risk:**
  - High feeder loss in 2.6GHz. (Table below)
  - 0.6~1.0dB loss caused by additional diplexers/TMAs (0.3dB/diplexer), which bring negative impact on 2G/3G coverage
- **Suggestion:**
  - RRU installed near to antenna
  - Co-feeder is not recommended in general scenarios.

Manufacturer	Type	Size	Insertion loss (dB/100m)											
			450	700	800	900	1700	1800	2000	2100	2300	2500	3400	5000
Andrew	LDF4	1/2"	4.749	6.009	6.456	6.855	9.744	10.058	10.666	[illegible]	11.535	12.09	14.401	18.01
	FSJ4	1/2"	7.592	9.683	10.431	11.101	16.027	[illegible]	[illegible]	[illegible]	19.138	20.11	24.198	30.493
	AVA5	7/8"	2.44	3.093	3.325	3.533	5.04	[illegible]	[illegible]	[illegible]	[illegible]	6.27	7.487	9.396
	AL5	7/8"	2.703	3.421	3.676	3.903	5.551	[illegible]	[illegible]	[illegible]	6.573	6.89	8.21	10.273
	LDP6	5/4"	1.784	2.285	2.465	2.627	3.825	[illegible]	[illegible]	[illegible]	4.588	4.828	/	/
	AL7	13/8"	1.599	2.037	2.193	2.333	3.36	3.472	3.692	3.798	4.006	4.208	/	/

Feeder loss is 3dB higher in 2.6GHz

Separate Antenna/Feeder Analysis

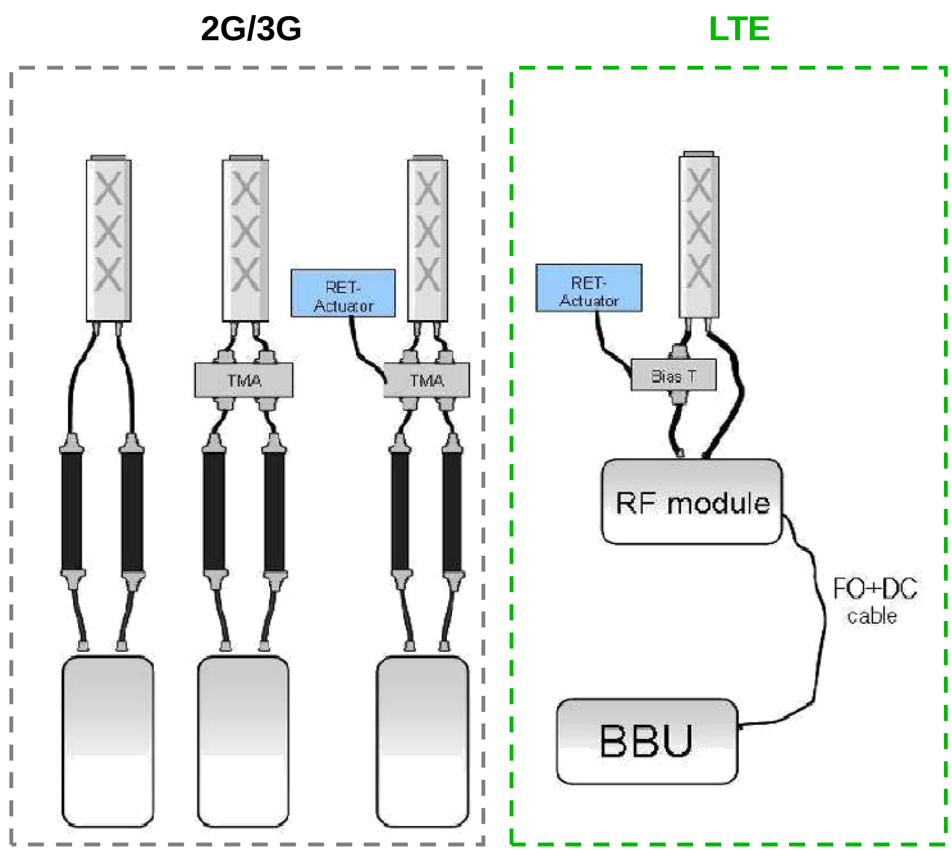
Advantage:

- ✔ Individual network planning for LTE:
  - No additional feeder and connector loss for LTE;
  - No negative impact to 2G/3G network.
- ✔ Convenience and accuracy network optimization for LTE:
  - Individual antenna adjustment

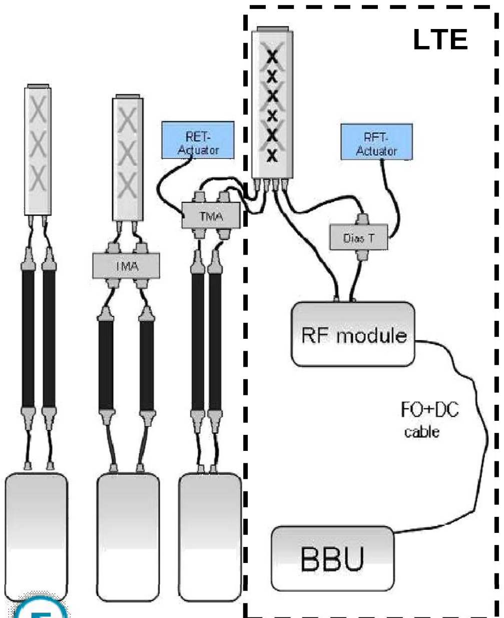
Disadvantage:

- ✖ Require more tower installation space;
- ✖ Require higher tower load.

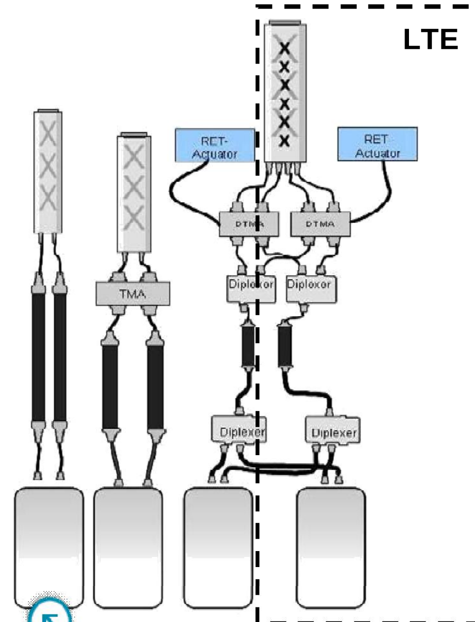
Separate antenna/feeder for LTE



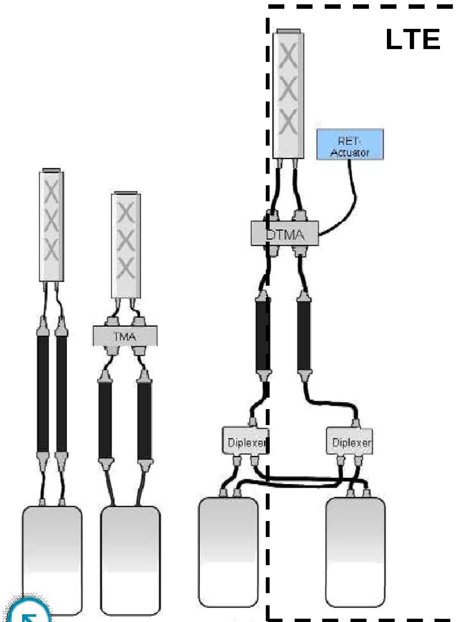
Typical Co-antenna/feeder Solutions



4 ports antenna
RRU inst. near antenna



4 ports antenna
Co-feeder



2 ports antenna
Co-feeder

Risks:

Additional loss by co-feeder will:

- Reduce **11~14%** cell radius
- Increase **26~35%** site quantity

(2.6GHz, 30m 7/8'' feeder)

Conclusion:

- Select the Co-antenna/feeder solution based on the real situation
- Need to evaluate and balance the benefits and risks of the solution

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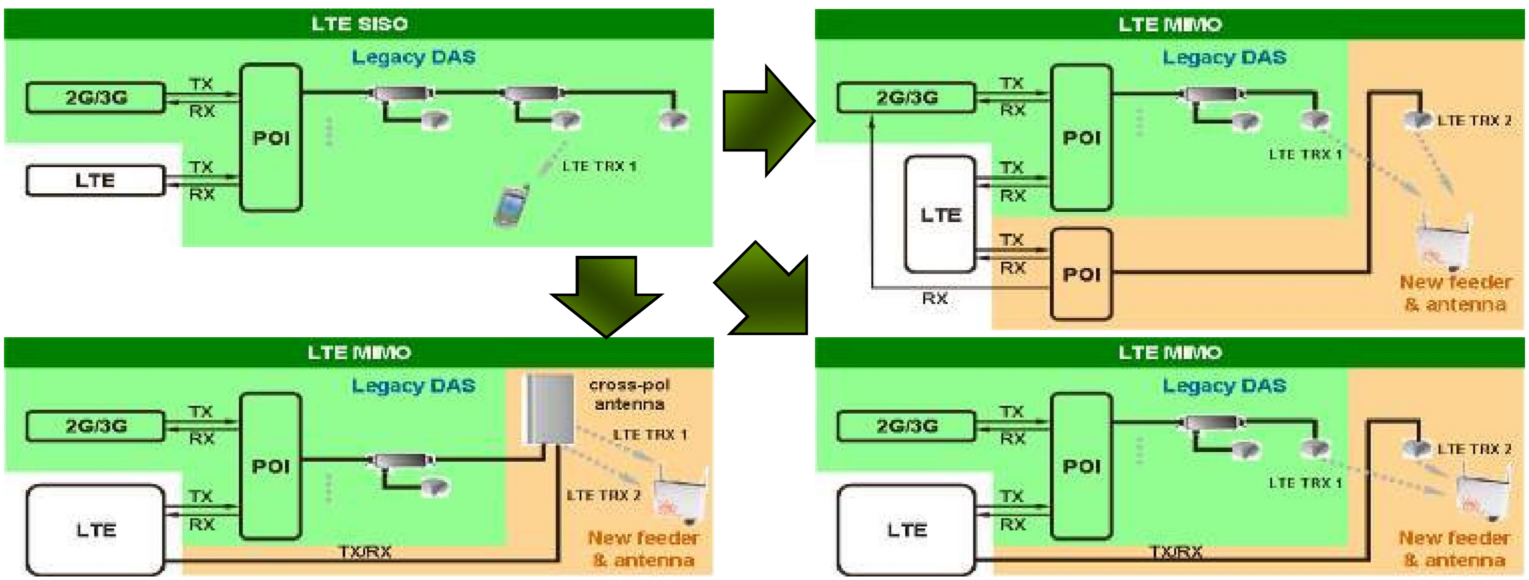
Reuse and Upgrade Legacy DAS

Challenges

- High frequency (2.6GHz) caused additional feeder and insertion loss.
- Legacy DAS structure is difficult to implement MIMO technology.
- Upgrade legacy DAS is costly.

Solution

- Higher transmit power compensate feeder and insertion loss.
- First Stage: DL and UL SISO.
- Next Stage: DL and UL MIMO when multi antenna DAS is ready.



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Thank you

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