LTE Radio Principles and Initial Tuning

HUAWEI TECHNOLOGIES CO., LTD.

Target

Know about the background and network architecture of LTE.

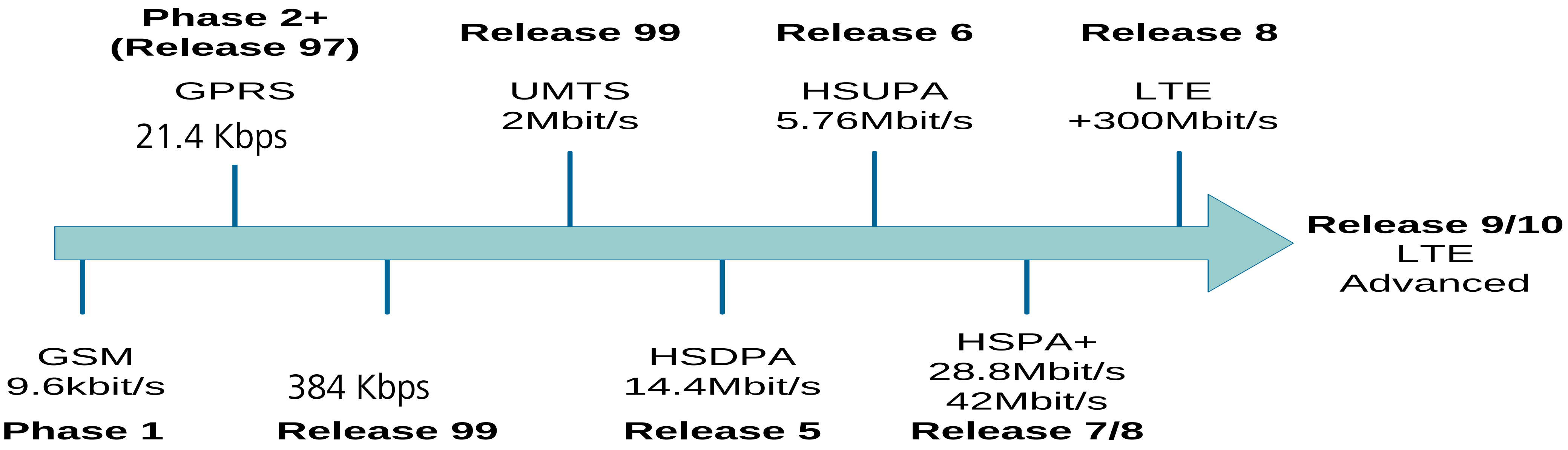
Master the basic principle of LTE physical layer and layer 2.

Know about the key technology of LTE air interface

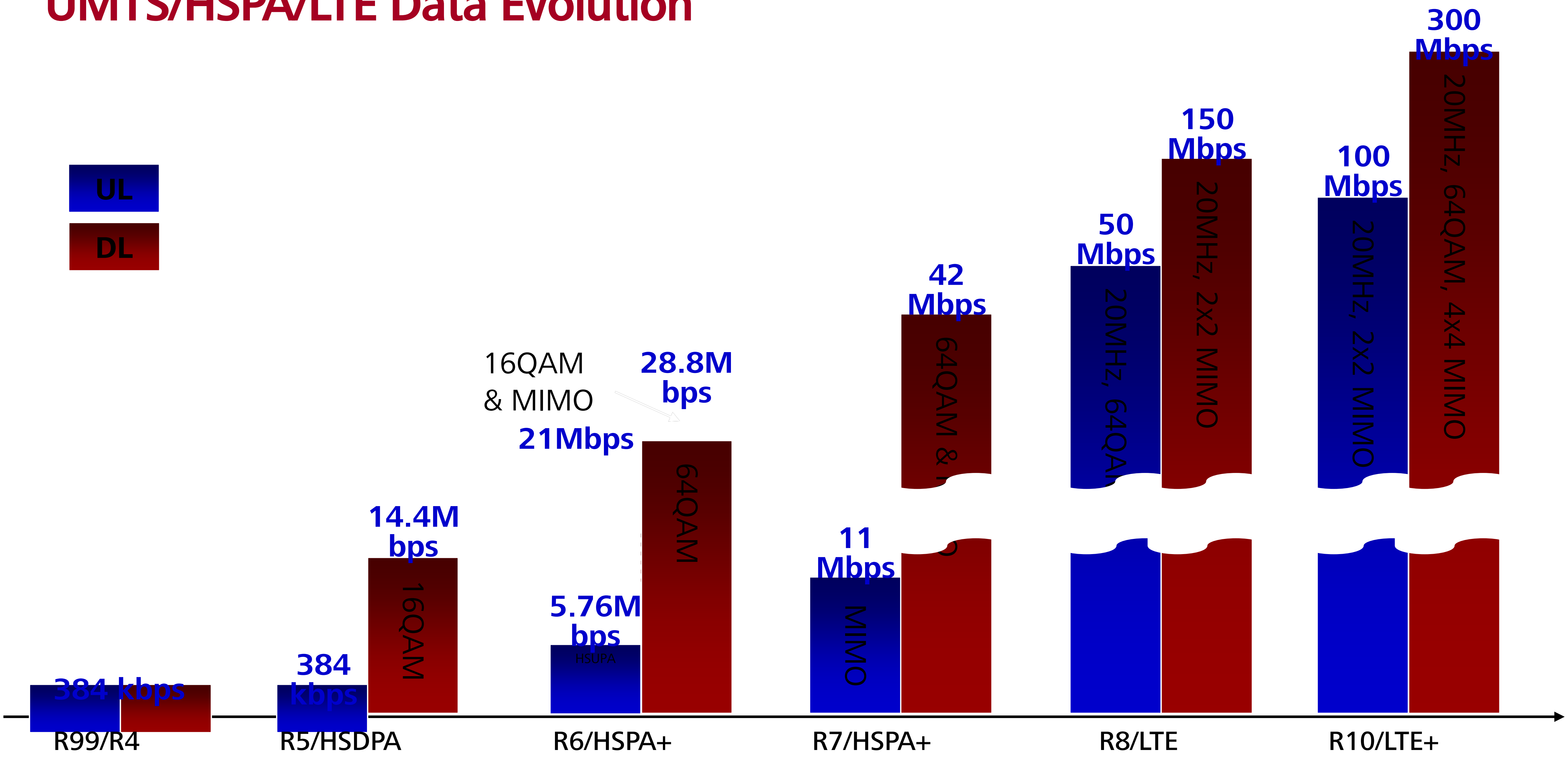
Content

3GPP Releases (1)

- **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



UMTS/HSPA/LTE Data Evolution

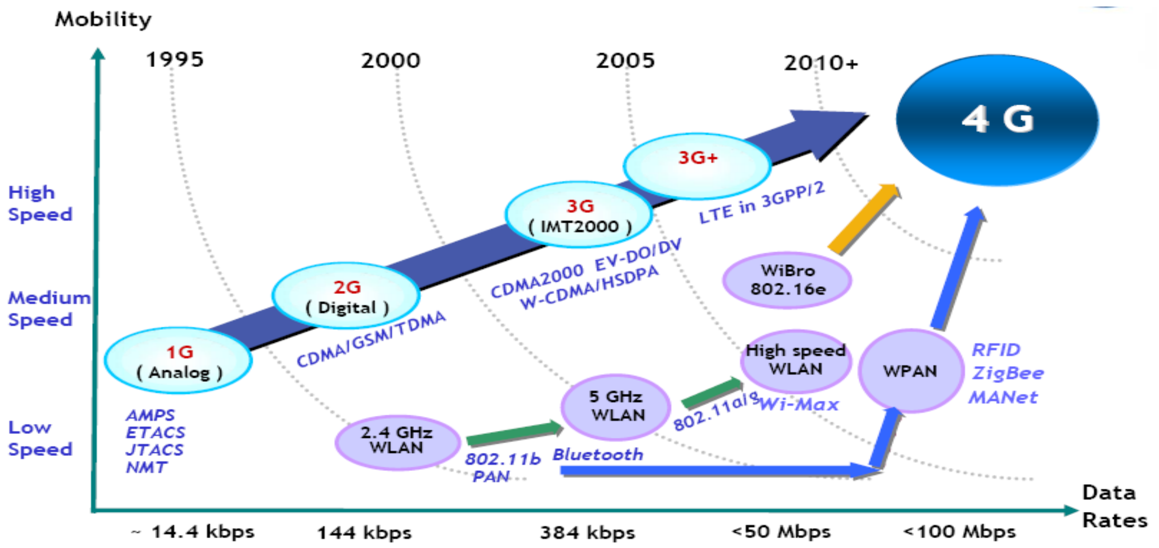


LTE Background Introduction

- **What is LTE?**
  - **LTE (Long Term Evolution)** is known as the evolution of radio access technology conducted by 3GPP.
  - The radio access network will evolve to **E-UTRAN** (Evolved UMTS Terrestrial Radio Access Network), and the correlated core network will evolved to **SAE** (System Architecture Evolution).

What can LTE do?

- Flexible bandwidth configuration: supporting 1.4MHz, 3MHz, 5MHz, 10Mhz, 15Mhz and 20MHz.
- Peak date rate (within 20MHz bandwidth): 150Mbps for downlink and 50Mbps for uplink.
- Circuit services is implemented in PS domain: VoIP.
- Lower cost due to simple system structure

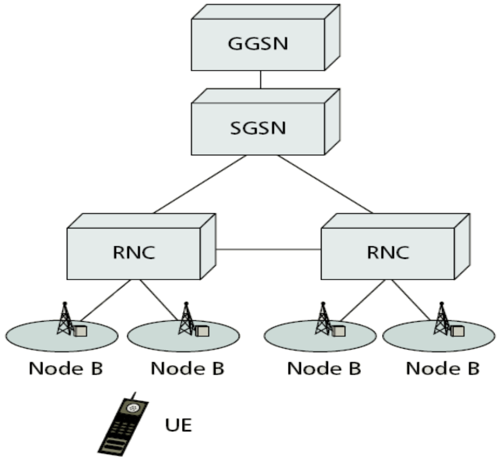


LTE Network Architecture

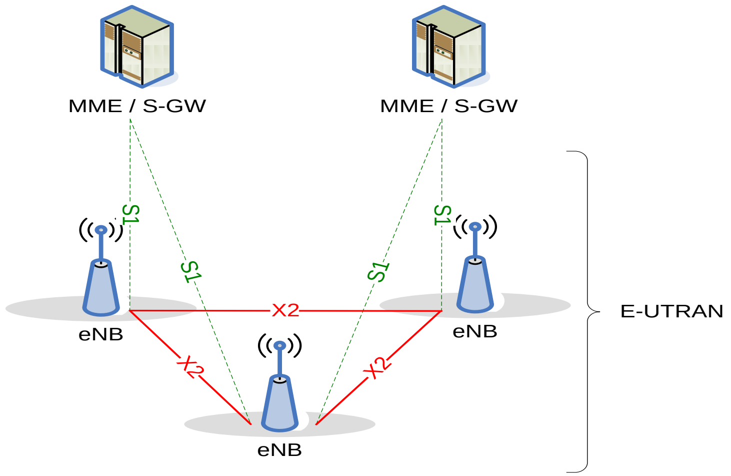
- **Main Network Element of LTE**
  - The E-UTRAN consists of **e-NodeBs**, providing the user plane and control plane.
  - The EPC consists of **MME**, **S-GW** and **P-GW**.

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-



UMTS



LTE

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.

LTE Network Element Function

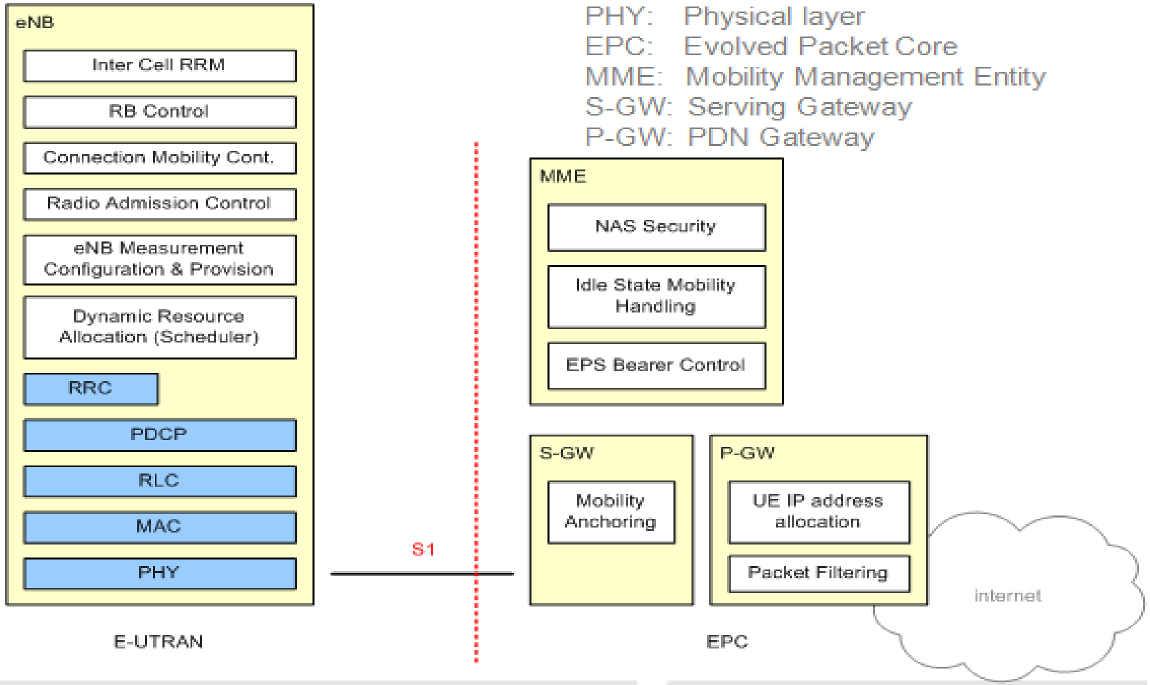
- **e-Node hosts the following functions:**
  - Functions for Radio Resource Management & Radio Admission Control, Connection Mobility Control, Dynamic allocation of resources to UEs in both uplink and downlink (scheduling);
  - Selection of an MME at UE attachment;
  - Routing of User Plane data towards 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:**
  - Idle state mobility handling;
  - 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

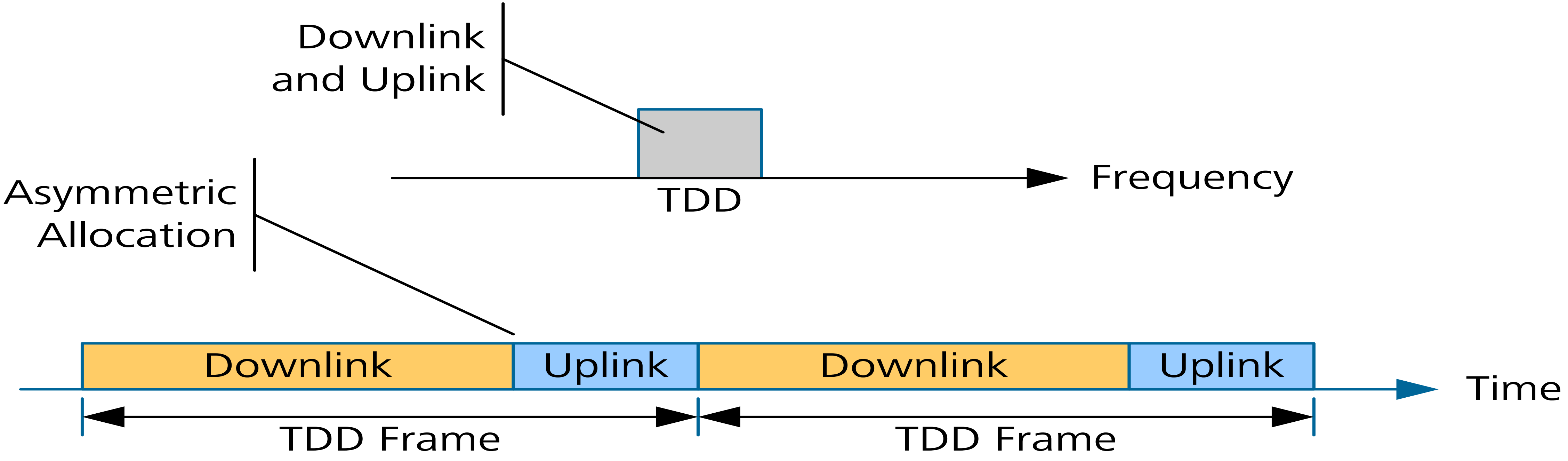
RRC: Radio Resource Control
PDCP: Packet Data Convergence Protocol
RLC: Radio Link Control
MAC: Medium Access Control
PHY: Physical layer
EPC: Evolved Packet Core
MME: Mobility Management Entity
S-GW: Serving Gateway
P-GW: PDN Gateway



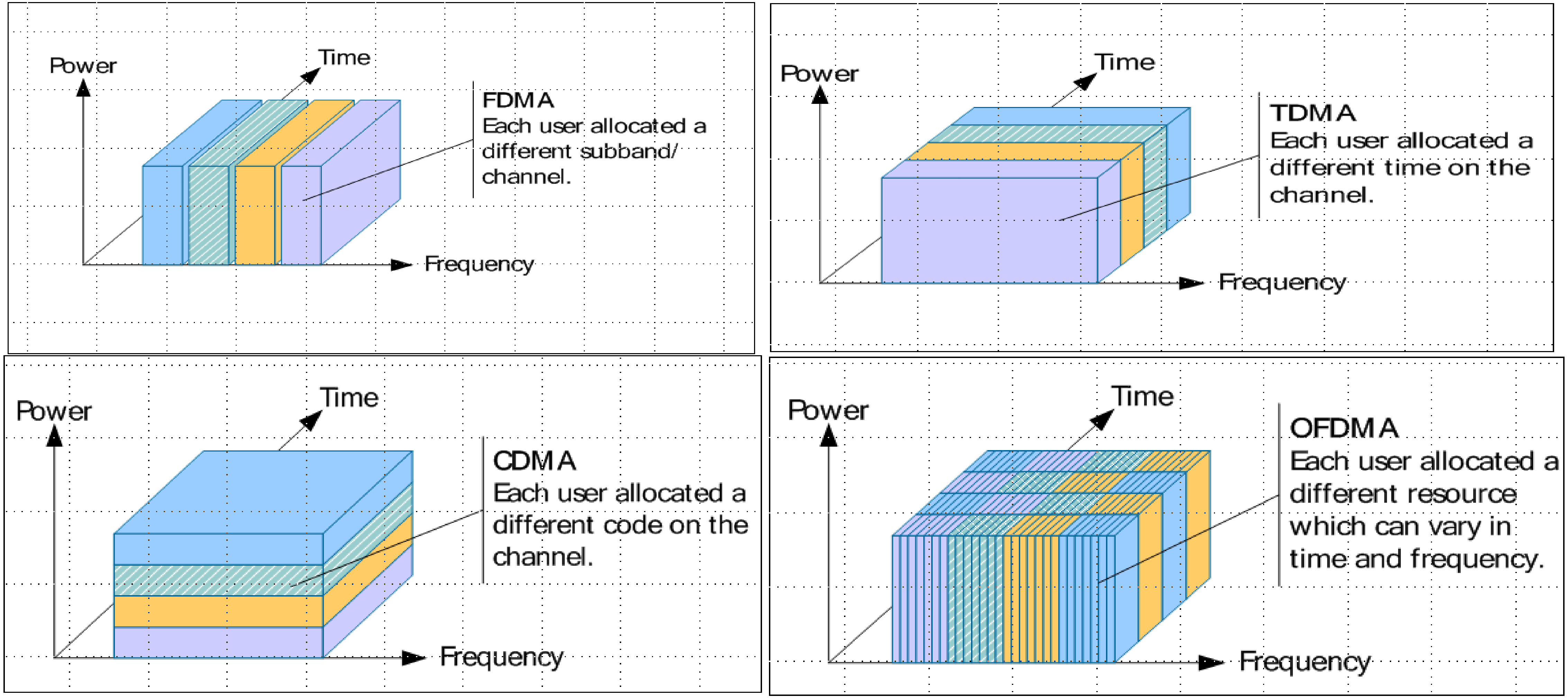
Content

Transmission Modes: Frequency Division Duplex

Transmission Modes: Time Division Duplex



FDMA TDMA CDMA and OFDMA

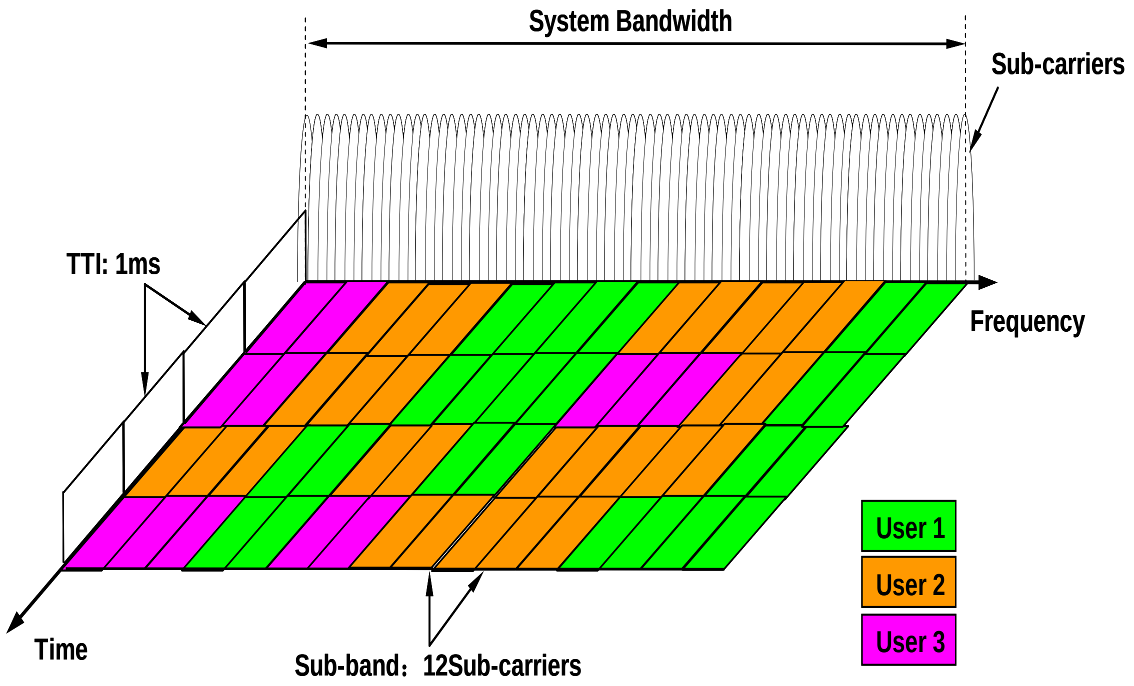


OFDMA

- 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.



LTE Modulation Schemes

- The sub-carriers are modulated with a certain modulation scheme
  - maps the data bits into a carrier phase and amplitude (symbols)
- E-UTRAN user data channels supports QPSK, 16QAM and 64QAM
- 16QAM allows for twice the peak data rate compared to QPSK
- 64QAM allows for three times the data rate compared to QPSK
- Higher order modulation more sensitive to interference
  - Useful mainly in good radio channel conditions
    (high C/I, Little or no dispersion, Low speed)
    e.g. Close to cell site & Micro/Indoor cells
- BPSK is used for some signaling (PHICH)

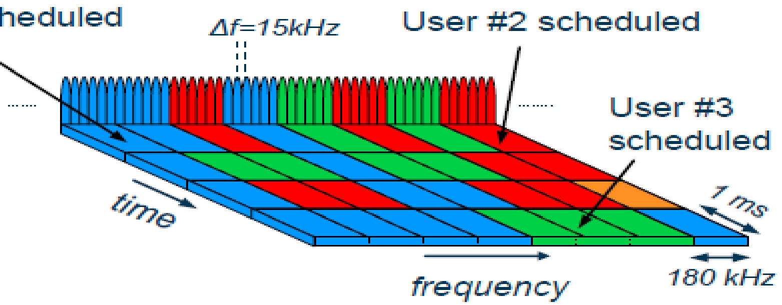
Three different modulation schemes are supported in LTE:

- ➢ QPSK (Quadrature Phase shift keying)
- ➢ 16-QAM (16 Quadrature Amplitude Modulation)
- ➢ 64-QAM (64 Quadrature Amplitude Modulation)

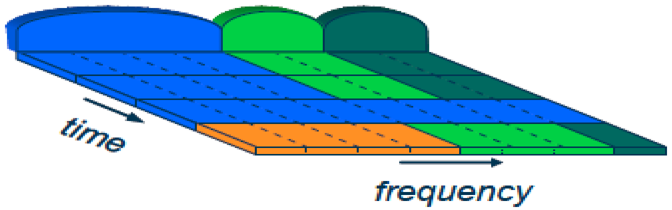
In E-UTRAN, the modulation is carried out per sub-carrier in the OFDM signal. This means that each 15 kHz subcarrier is modulated with either QPSK, 16-QAM or 64-QAM.

LTE Principles

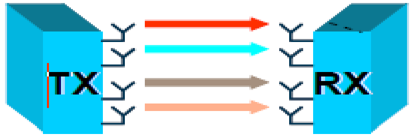
- Downlink: *Adaptive OFDM*
  - *Channel-dependent scheduling and link adaptation in time and frequency domain*



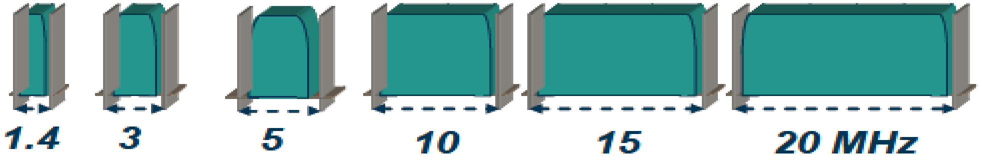
- Uplink: SC-FDMA with dynamic bandwidth (Pre-coded OFDM)
  - *Low PAPR ➡ Higher power efficiency*
  - *Reduced uplink interference (enables intra-cell orthogonality)*



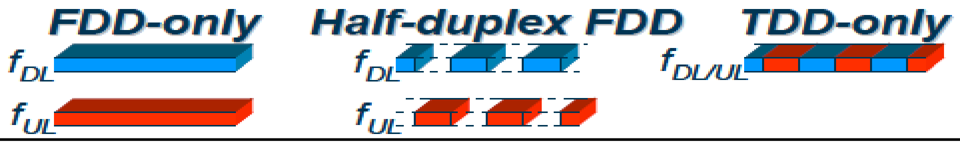
- Multi-Antennas, both RBS and terminal
  - *MIMO, antenna beams, TX- and RX diversity, interference rejection*
  - *High bit rates and high capacity*



- Flexible bandwidth
  - *Possible to deploy in 6 different bandwidths up to 20 MHz*

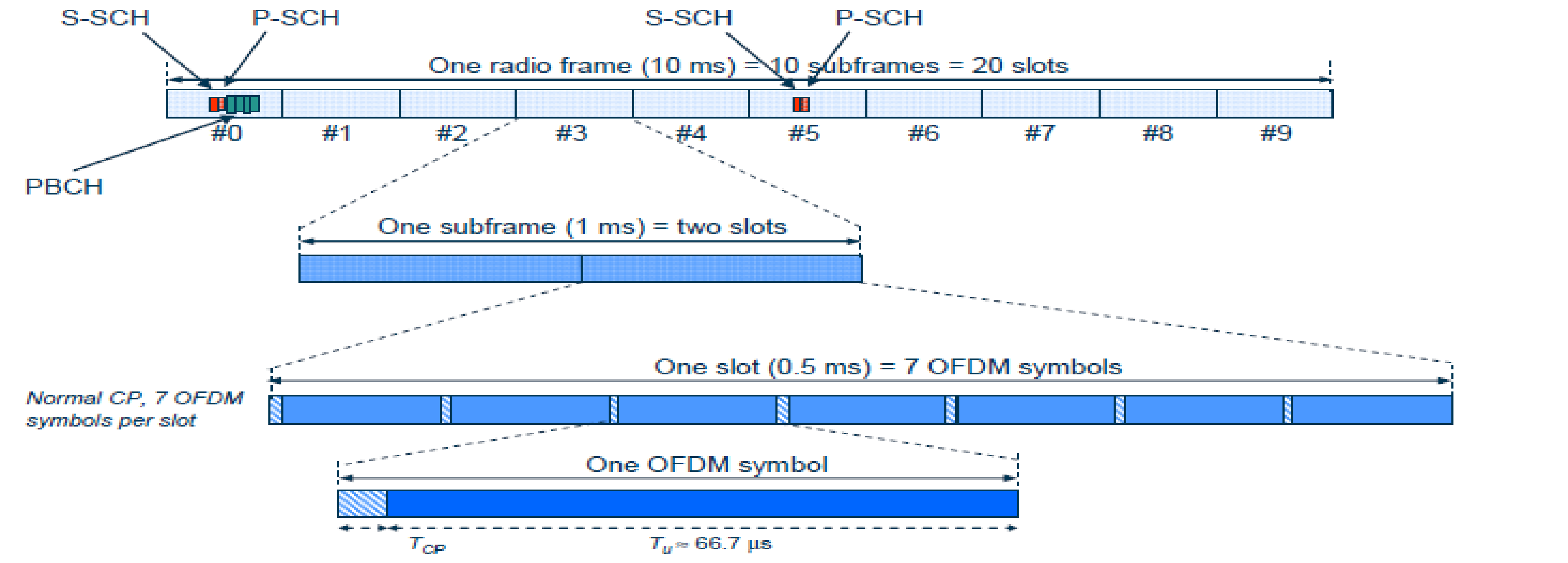


- Harmonized FDD and TDD concept
  - *Maximum commonality between FDD and TDD*



- Minimum UE capability: BW = 20 MHz

LTE Time-Domain Structure



- PBCH sent in subframe #0, slot 1, symbol 0-3 over 4 consequtive radio frames (40 ms)
- SCH sent in subframe #0 and #5, slot 0 and 10, symbol 5-6 (4-5 in case of extended CP)

Each (radio) *frame of length Tf* = 10 ms consists of ten equally-sized *subframes of length Tsubframe = 1* ms. Each subframe, in turn, consists of two equally-sized *slots of* length Tslot = 0.5 ms.

CP is copy of the last part of symbol in order to preserve Sub-carriers orthogonality and avoid impact of Inter Symbol Interference.

Achievable & Supported Peak Data Rates

Achievable LTE Peak Data Rates

	DL		UL
Bandwidth	2x2	4x4	1x2
5 MHz	37 Mbps	72 Mbps	18 Mbps
10 MHz	73 Mbps	147 Mbps	36 Mbps
20 MHz	150 Mbps	300 Mbps	75 Mbps

UE Supported Peak Data Rates (Mbps)

LTE UE Category	1	2	3	4	5
DL	10	50	100	150	300
UL	5	25	50	50	75

Peak data rates depends on the following factors:

- Available Bandwidth
- High Order Modulation
- MIMO Configuration (No. of transmitter and receiver antenna)
- UE Category

Frequency Band of LTE

From LTE Protocol:

- Duplex mode: FDD and TDD
- Support frequency band form 700MHz to 2.6GHz
- Support various bandwidth: 1.4MHz, 3MHz, 5MHz, 10MHz, 15MHz, 20MHz

Protocol is being updated, frequency information could be changed.

TDD Frequency Band

E-UTRA Band	Uplink (UL) F_{UL_low} – F_{UL_high}			Downlink (DL) F_{DL_low} – F_{DL_high}			Duplex Mode
33	1900 MHz	–	1920 MHz	1900 MHz	–	1920 MHz	TDD
34	2010 MHz	–	2025 MHz	2010 MHz	–	2025 MHz	TDD
35	1850 MHz	–	1910 MHz	1850 MHz	–	1910 MHz	TDD
36	1930 MHz	–	1990 MHz	1930 MHz	–	1990 MHz	TDD
37	1910 MHz	–	1930 MHz	1910 MHz	–	1930 MHz	TDD
38	2570 MHz	–	2620 MHz	2570 MHz	–	2620 MHz	TDD
39	1880 MHz	–	1920 MHz	1880 MHz	–	1920 MHz	TDD
40	2300 MHz	–	2400 MHz	2300 MHz	–	2400 MHz	TDD

FDD Frequency Band

E-UTRA Band	Uplink (UL) F_{UL_low} – F_{UL_high}			Downlink (DL) F_{DL_low} – F_{DL_high}			Duplex Mode
1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	FDD
5	824 MHz	–	849 MHz	869 MHz	–	894MHz	FDD
6	830 MHz	–	840 MHz	875 MHz	–	885 MHz	FDD
7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	FDD
8	880 MHz	–	915 MHz	925 MHz	–	960 MHz	FDD
9	1749.9 MHz	–	1784.9 MHz	1844.9 MHz	–	1879.9 MHz	FDD
10	1710 MHz	–	1770 MHz	2110 MHz	–	2170 MHz	FDD
11	1427.9 MHz	–	1452.9 MHz	1475.9 MHz	–	1500.9 MHz	FDD
12	698 MHz	–	716 MHz	728 MHz	–	746 MHz	FDD
13	777 MHz	–	787 MHz	746 MHz	–	756 MHz	FDD
14	788 MHz	–	798 MHz	758 MHz	–	768 MHz	FDD
…	…			…			…
17	704 MHz	–	716 MHz	734 MHz	–	746 MHz	FDD
…	…			…			…

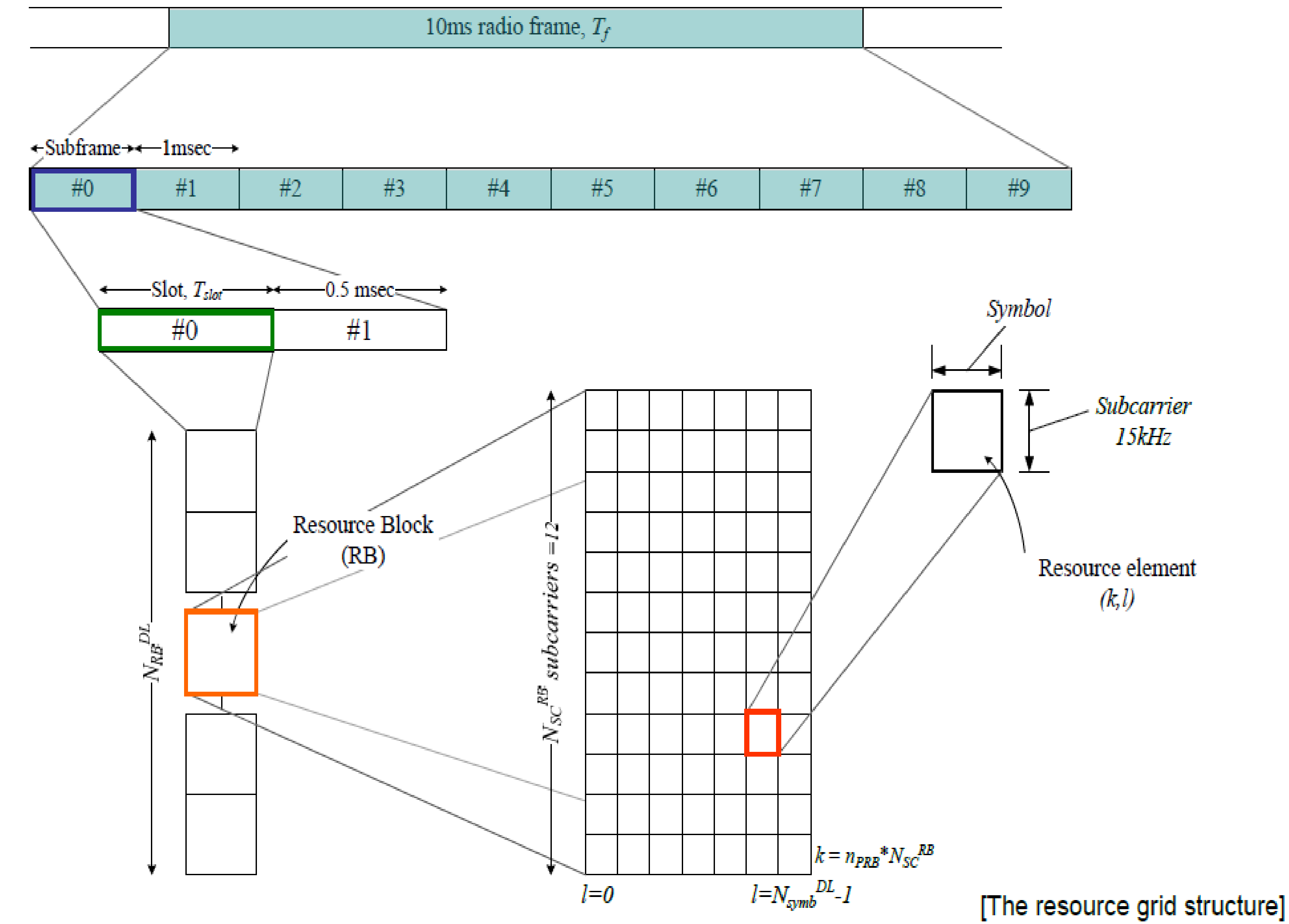
LTE Radio Resources

The radio resources are defined in the time- and frequency domain and divided into so called resource blocks.

For LTE, the downlink subcarrier spacing is Δf = 15 kHz.

Resources Block correspond to 12 Sub-carriers during 1 slot (0.5ms).

Resources Block Bandwidth is equal to 180KHz (12 Sub-carriers *15KHz Sub-carrier Bandwidth)



[The resource grid structure]

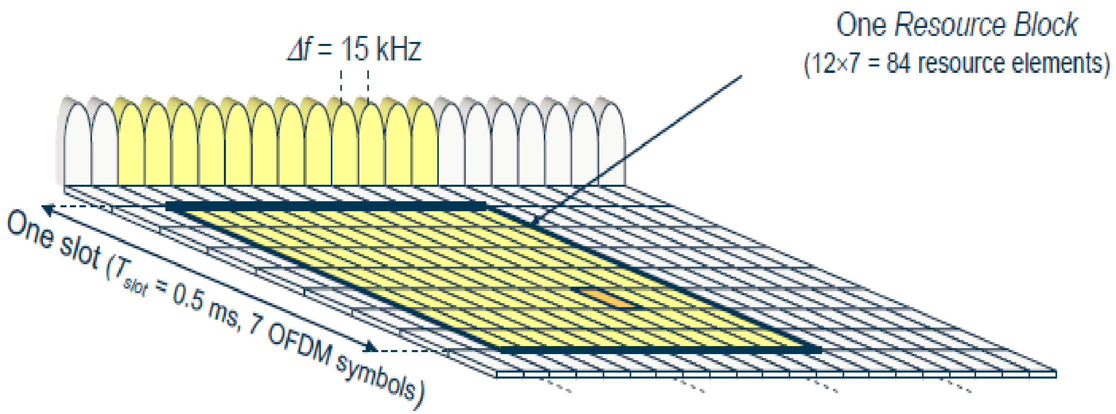
LTE Radio Resources

Each resource element corresponds to one OFDM subcarrier during one OFDM symbol interval.

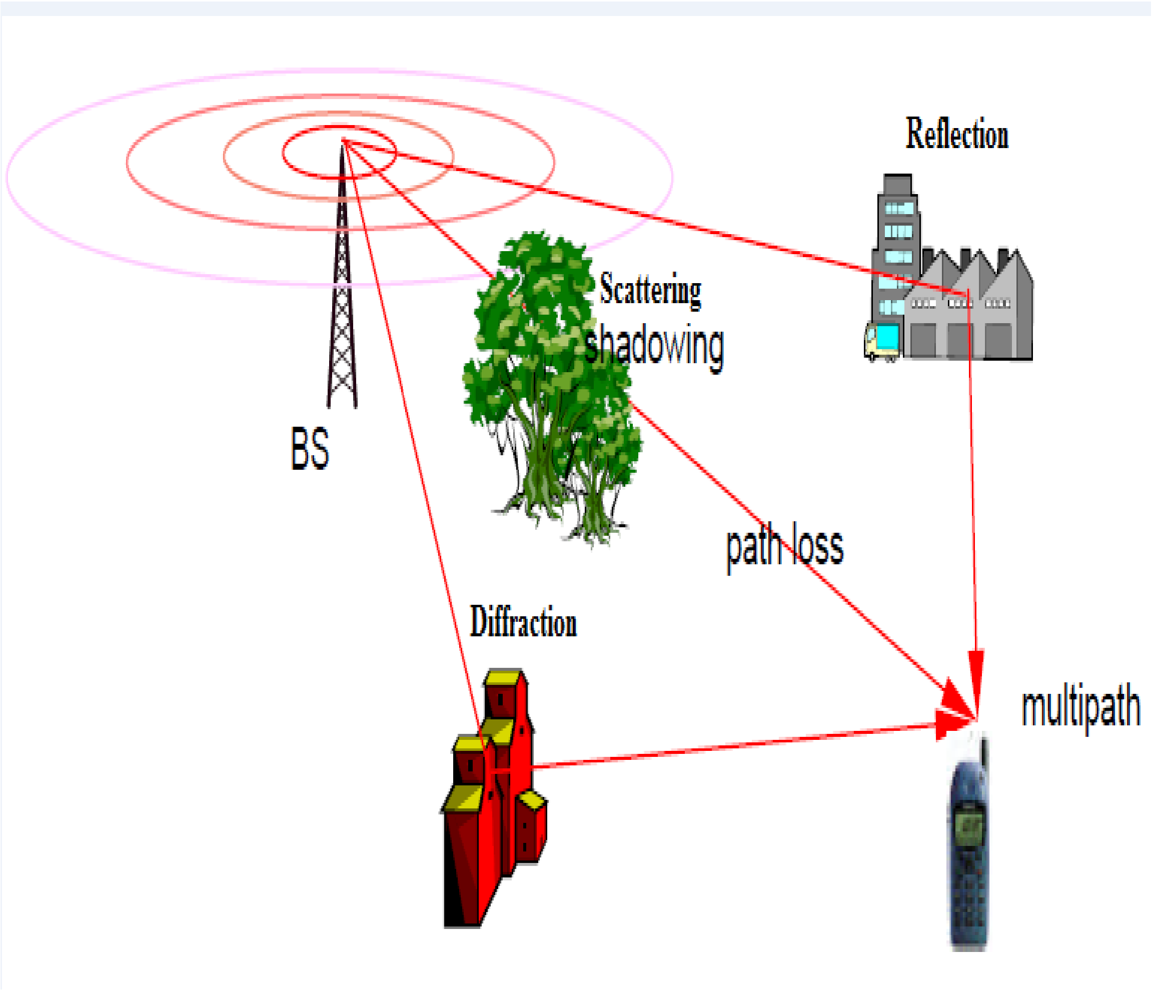
Resources Elements is equal to 84 (12 Sub-carriers * 7 OFDM Symbols)

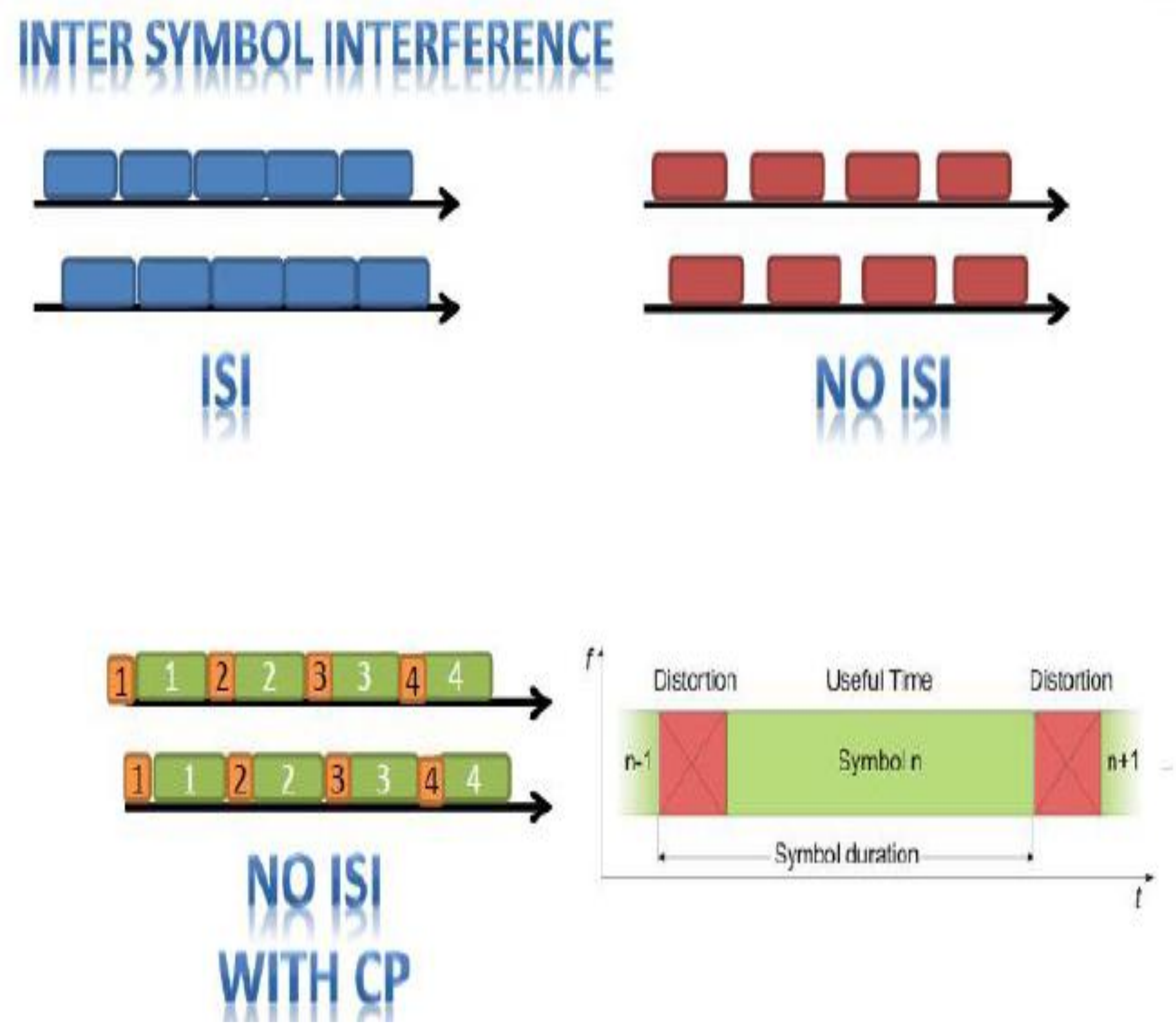
The smallest unit that can be allocated by the scheduler is two consecutive Resource Blocks (12 sub-carriers during 1ms).

- One Resource Block is 12 sub-carriers during one 0.5 ms slot
- The basic TTI (Transmission Time Interval) for DL-SCH is 1 ms
  - TTI is a *transport channel property*
  - Subframe is a *physical channel property*
  - One (or two) transport blocks per TTI sent to L1

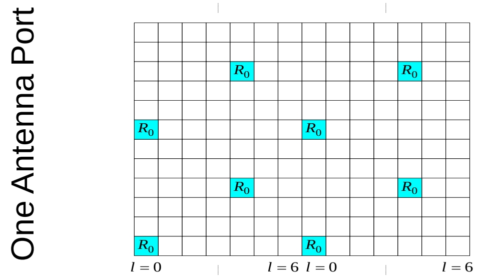


ISI Removal With CP

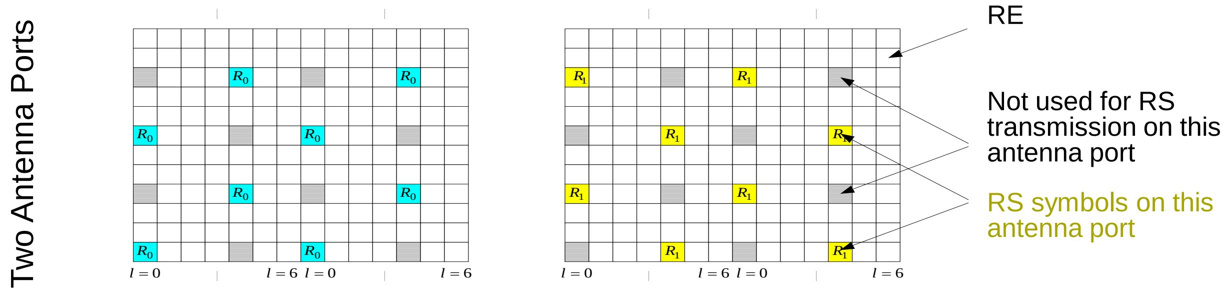


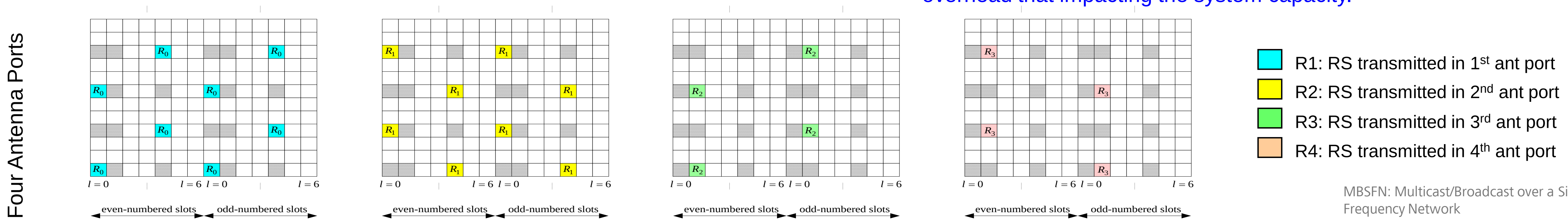


Downlink Physical Signals (1)



Cell-Specific RS Mapping in Time-Frequency Domain





Antenna Port 0　Antenna Port 1　Antenna Port 2　Antenna Port 3

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.

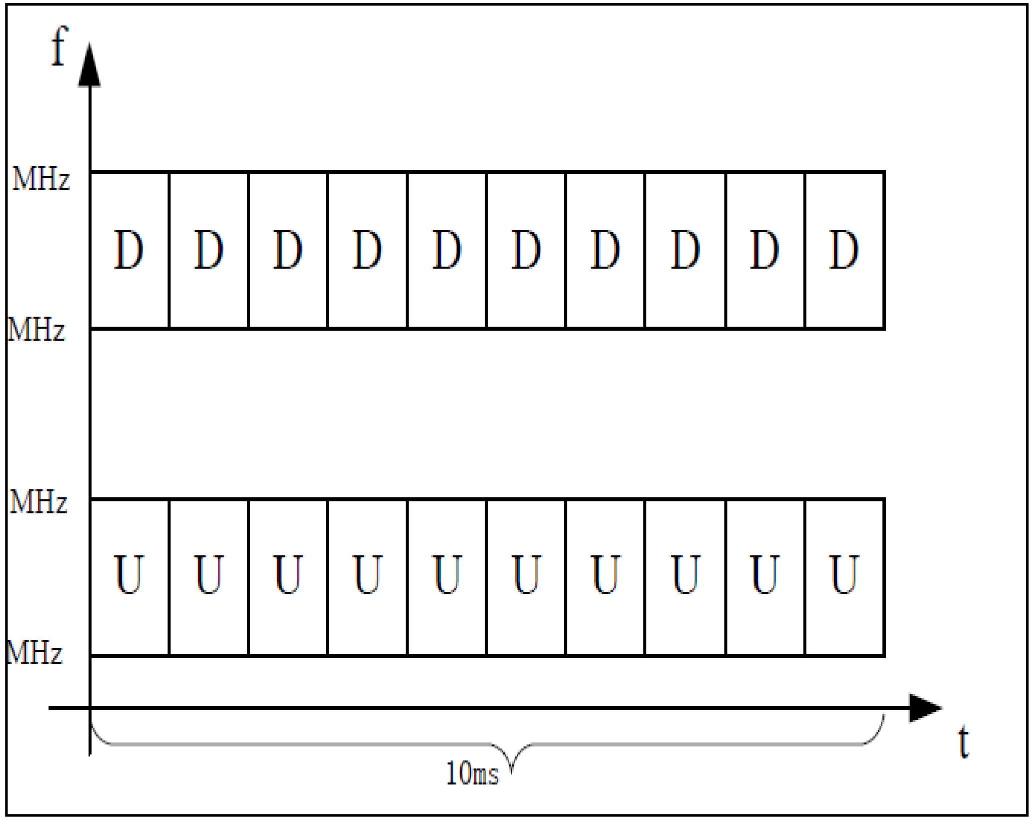
Characteristics:

- 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.

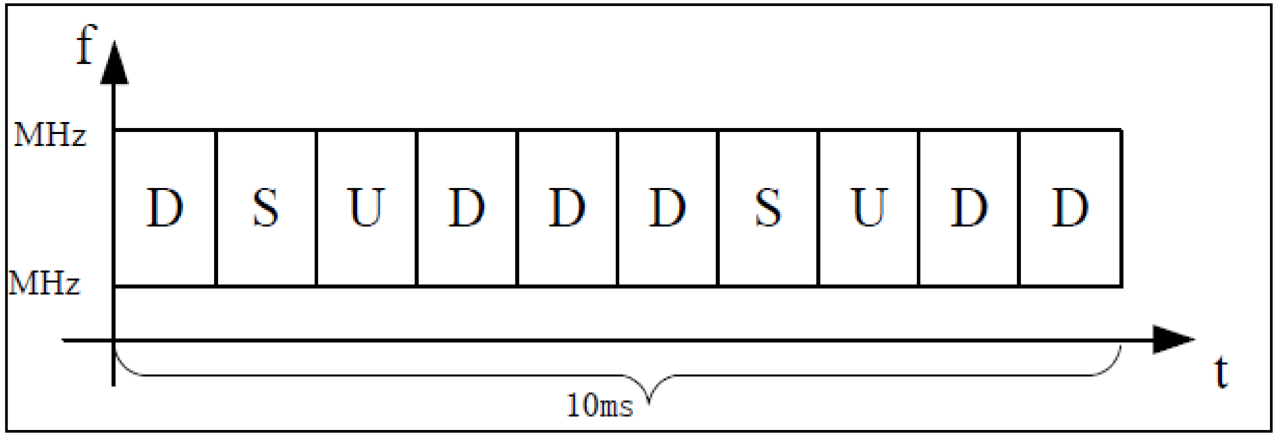
MBSFN: Multicast/Broadcast over a Single Frequency Network

LTE TDD & FDD Frame Structure

LTE FDD Frame



LTE TDD Frame



In TDD Case;

- D denotes a downlink subframe,
- U denotes an uplink subframe,
- S denotes a special subframe

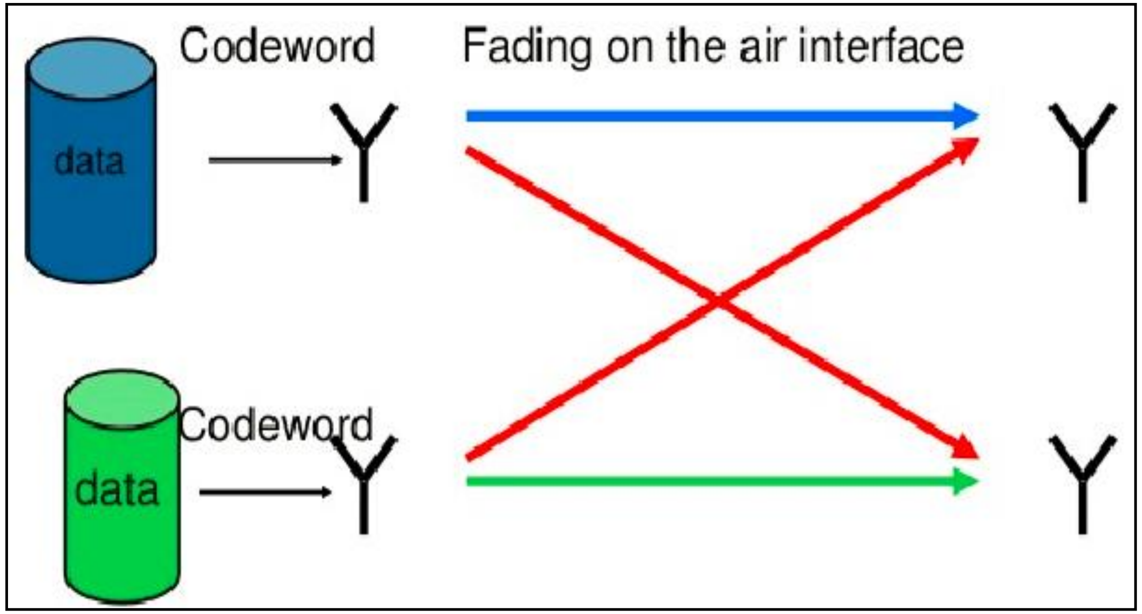
What is MIMO?

MIMO is MULTIPLE INPUT MULTIPLE OUTPUT which support the use of multiple antennas at both transmitter and receiver (up to four antennas).

With Multiple Antennas in DL and UL, it is possible to achieve spatial Multiplexing, also referred to as MIMO. This method create data pipes in radio interface.

MIMO Spatial Multiplexing can be used either for double data rate or for transmit diversity at bad Signal to interference Ratio.

eNodeB Receive Same signal at two antennas and make combining to enhance uplink by receiver diversiry.



Benefits of MIMO

Spatial Multiplexing Gain

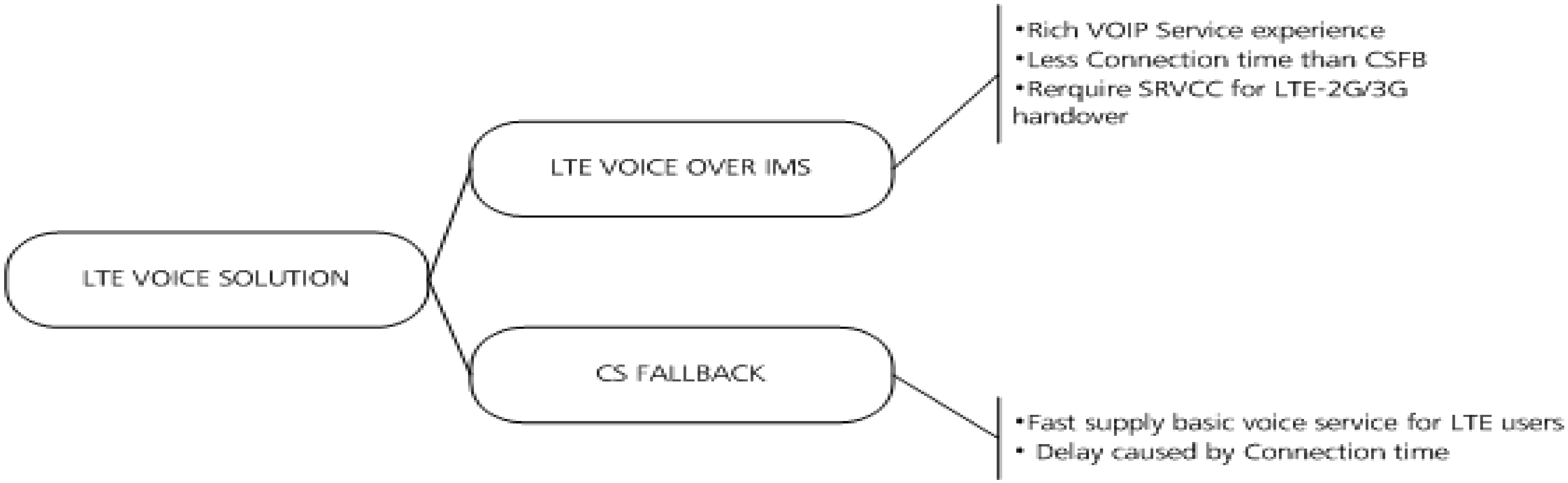
- Improve System peak Throughput. The data rate can at optimal circumstances be multiplied by the number of layers.

Diversity Gain

- Improve SINR (Signal to Interference Ratio) at cell edge by combining signals from different antennas, based on the correlations between signals and the non-correlations between noises.

LTE Voice Solution

- **From a technological perspective, there are two standard solutions to provide CS services for E-UTRAN UEs:**

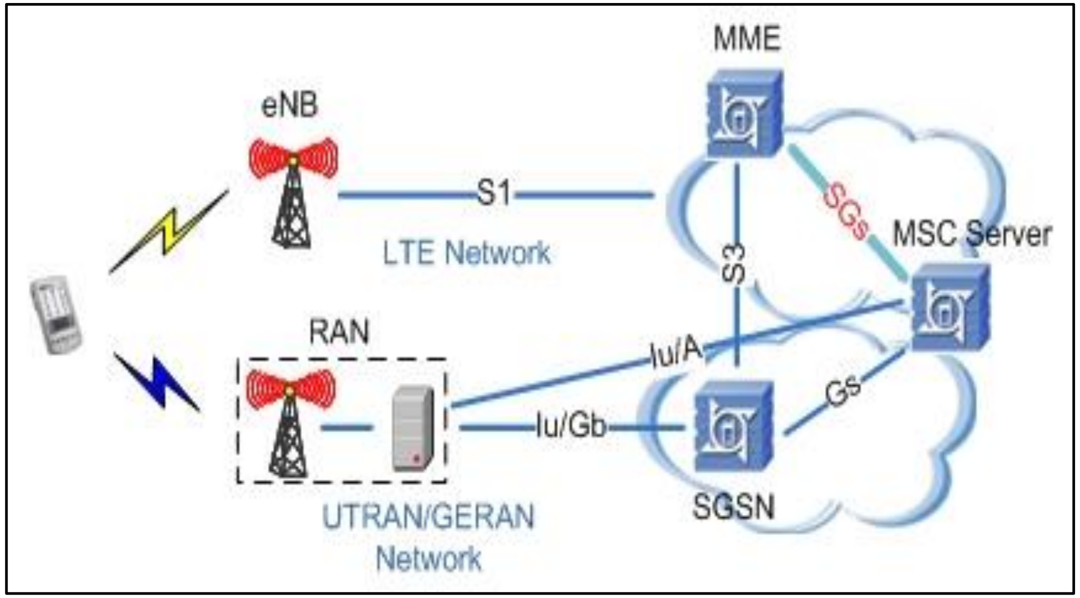


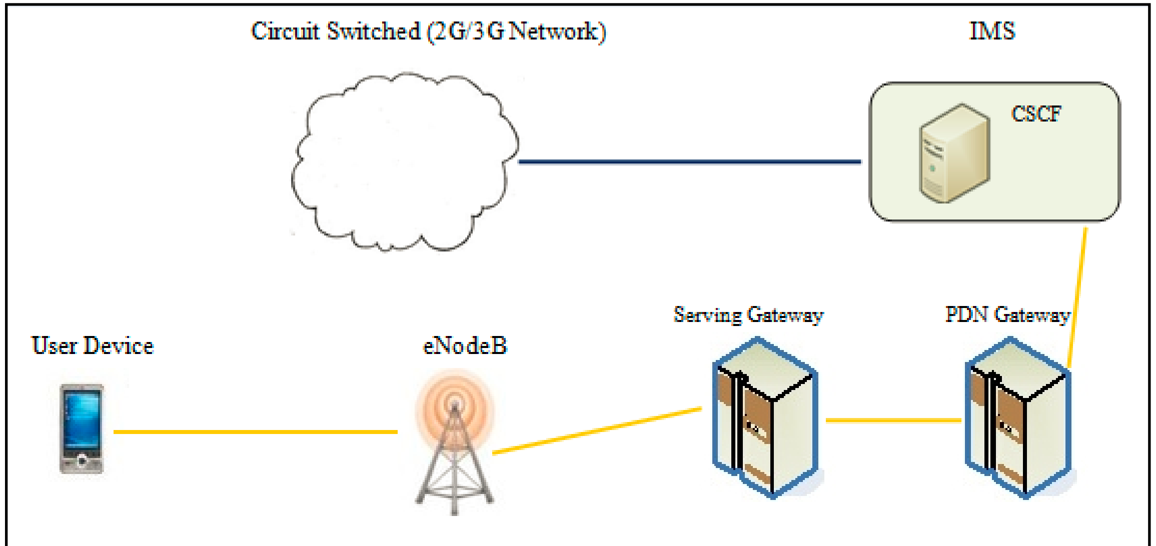
CSFB (CS Fallback) Feature

LTE is PS domain network, but it can provide CS Services for E-UTRAN UEs by using VoIP over IMS (IP Multimedia Subsystem) or CSFB standards.

CSFB is chosen by operators to serve as an solution for CS service access, to protect their investments in existing CS networks (GSM & UMTS) and reduce their investments in LTE.

CS Fallback (CSFB) Feature allows a CS voice call, to move temporary to another RAT System (WCDMA or GSM) that can support CS services. This requires LTE and WCDMA or GSM coverage overlap.



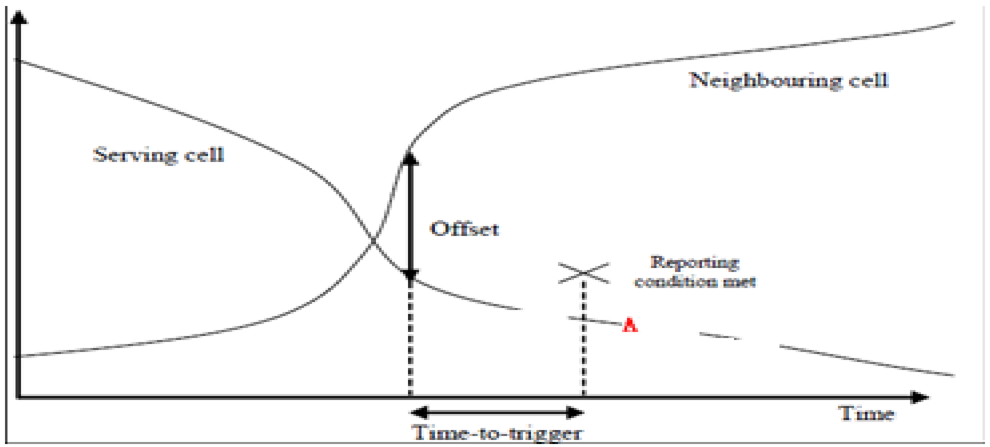


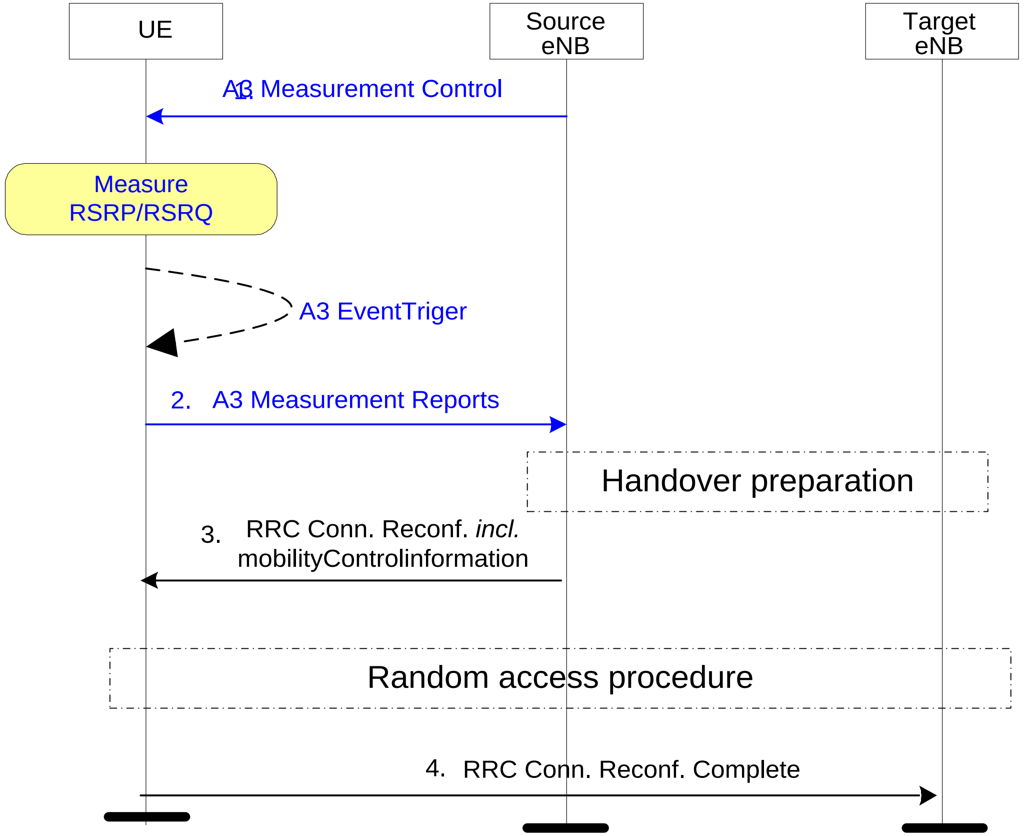
IMS Based VoLTE – Basic Architecture

Intra-frequency Handovers

Handover parameters are used to control when to report MRs and initiate handovers.

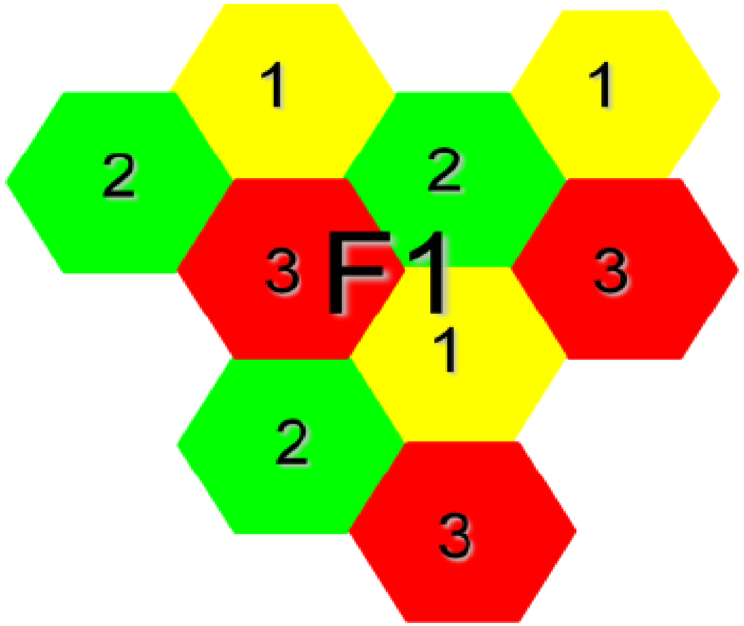
- Intra-frequency handover triggering process (event A3)





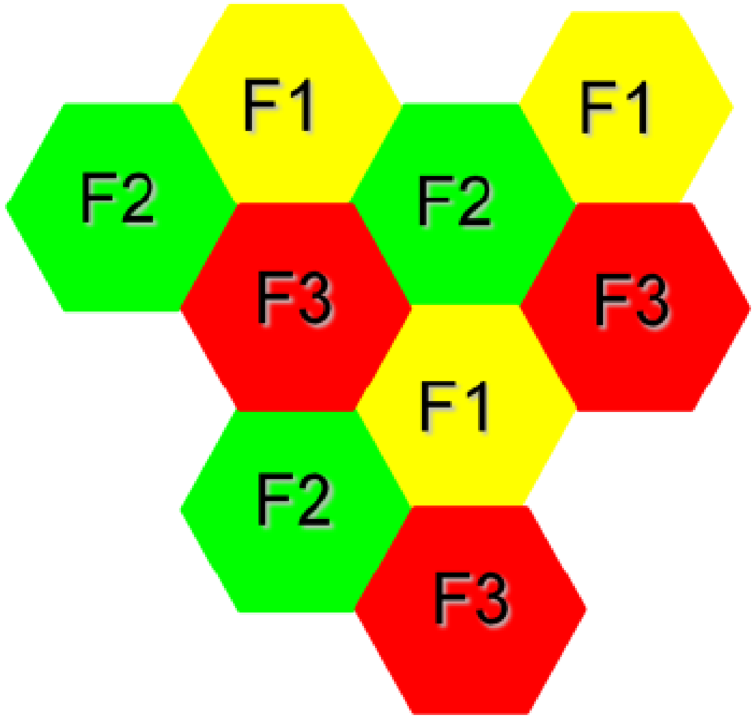
Content

Intra-Frequency Networking



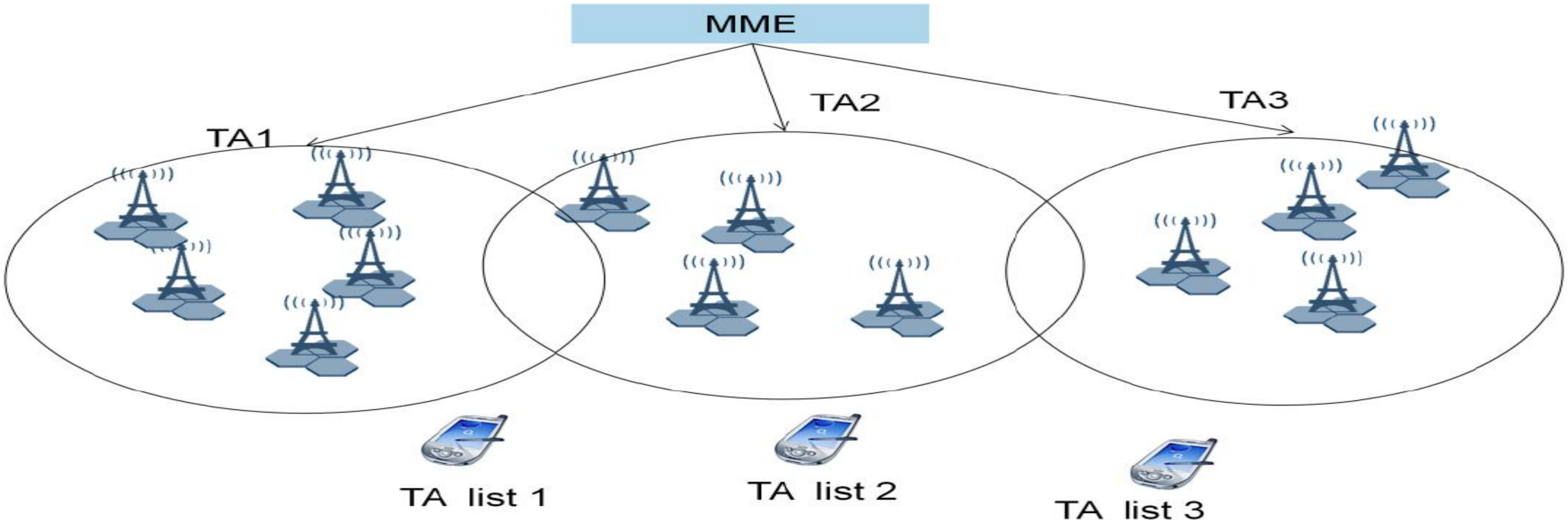
- Advantages:
  - All frequency band can be used in each cell, achieve high frequency efficiency.
  - Easy schedule mechanism
  - Easy implementation of handover
- Disadvantage:
  - Large interference on the edge cell
  - Difficult for consecutive coverage

Inter-Frequency Networking



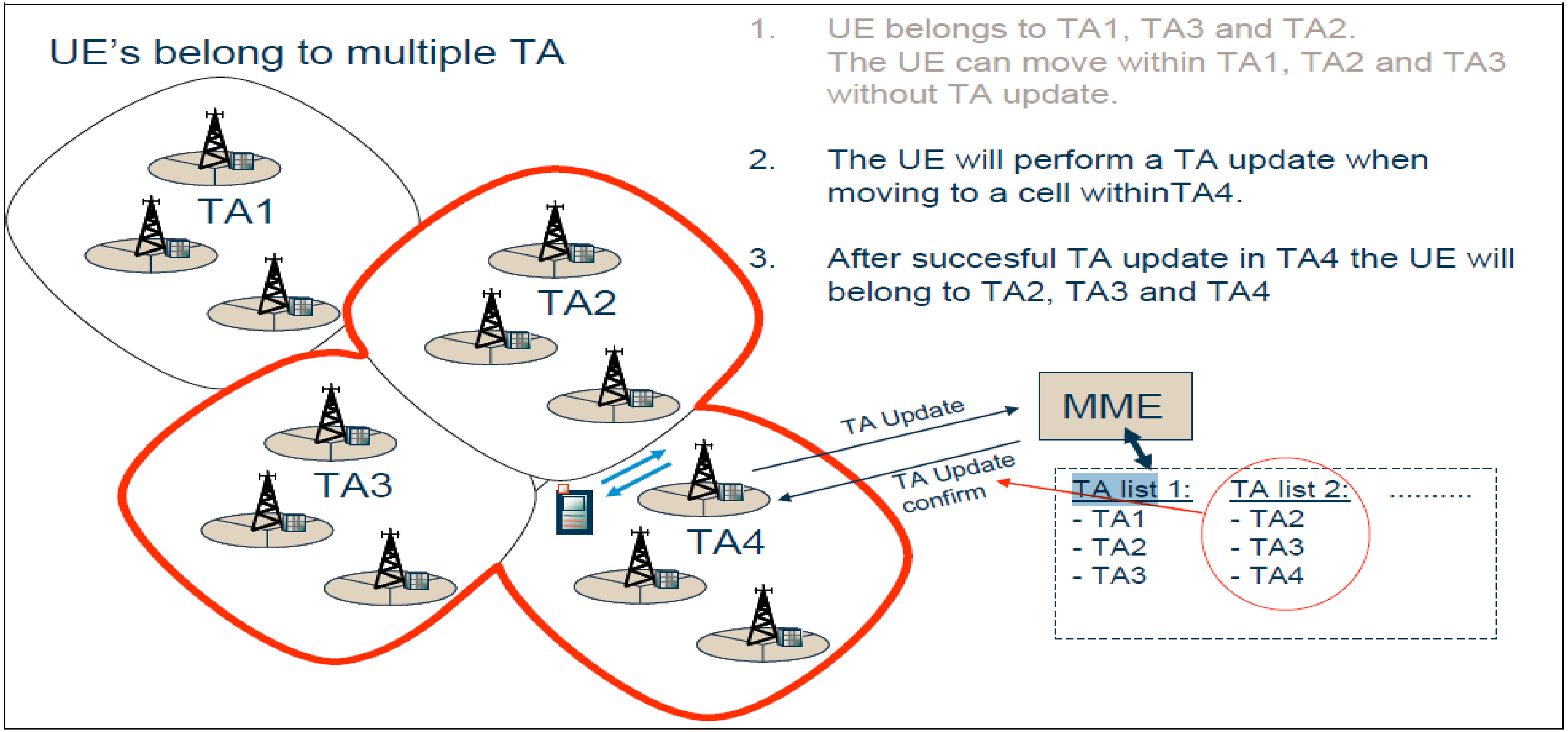
- Advantage:
  - Better cell performance achieved
- Disadvantage:
  - Large frequency band is needed that lower the frequency efficiency

TA Planning_ Basic Conception



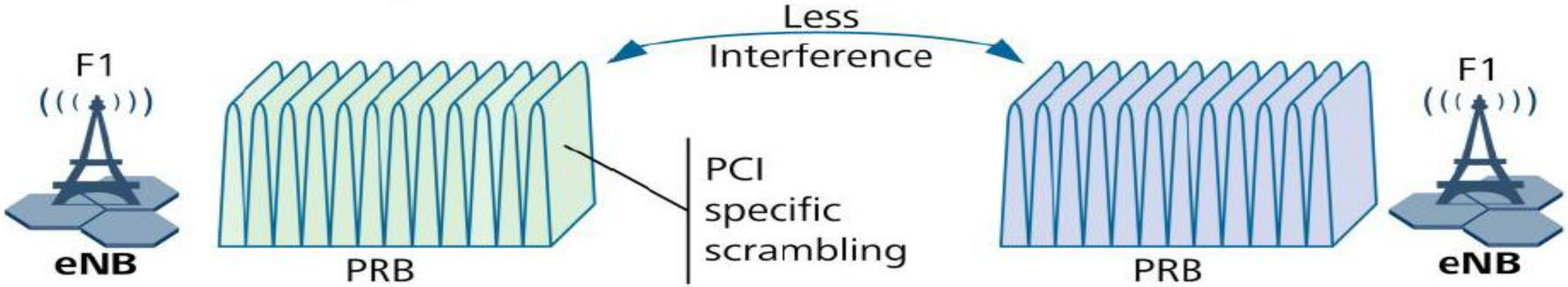
TA: Similar to the location area and routing area in 2G/3G networks, the tracking area (TA) is used for paging. TA planning aims to reduce location update signaling caused by location changes in the LTE system.

Tracking Area List Concept



In order to avoid excessive TA Update signaling by UEs on tracking area borders so TA-list concept is introduced.

PCI Planning_ Scrambling Overview



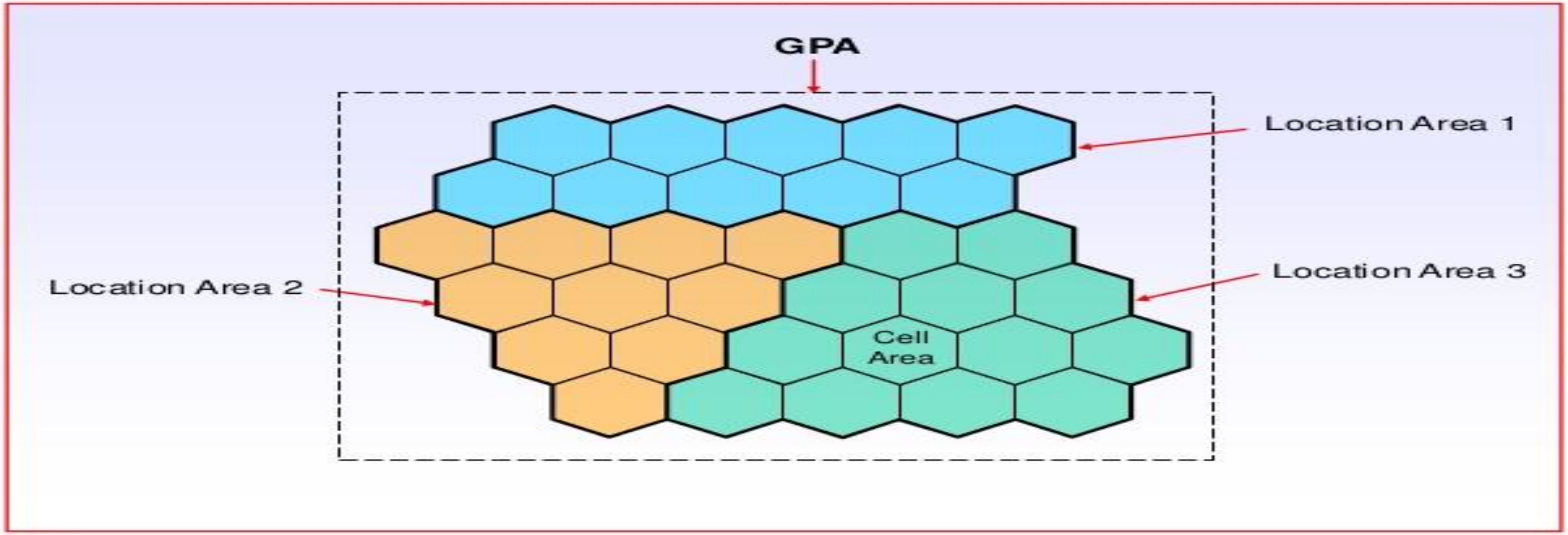
- PCI (Physical Cell ID) is, in terminal, determined by reading PSS and SSS (Primary and Secondary Synchronization Signal) and by calculating following formula: PCI = 3*SSS + PSS;
- SSS values ranges from 0 to 167,
- PSS value ranges from 0 to 2,
- therefore PCI can reach values from **0 to 503.**

PCI: Physical Cell ID, is used to generate scrambling code to identify the different cell.

Paging

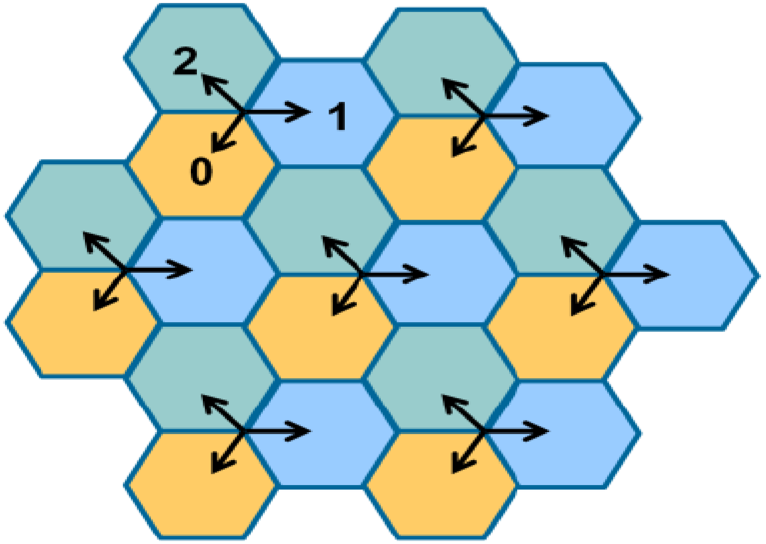
- MME initiates a paging message according to the TAL information, the eNodeB transmits the paging message to the UE ,in all the cells belonging to the TAs in the TAL.

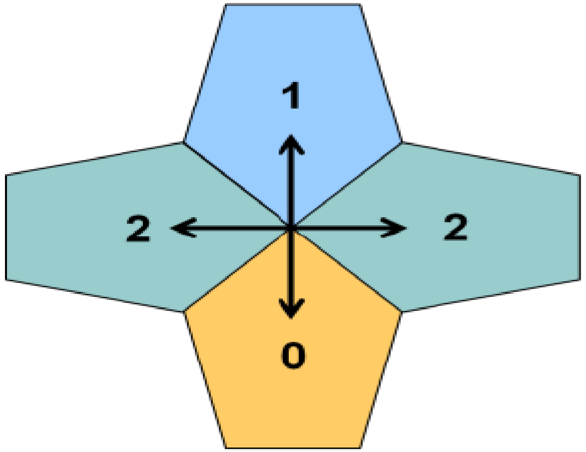
Location Areas and Cell Areas



PCI Planning Principle

- Modulo3 planning principle reduces all PCIs into 3 groups. Groups for which PCI mod 3 equals to **0, 1 or 2**, respectively. Such a limitation comply with typical planning configuration into 3 sector sites.





- In 4 sector configuration, cells with same mod3 must point opposite directions

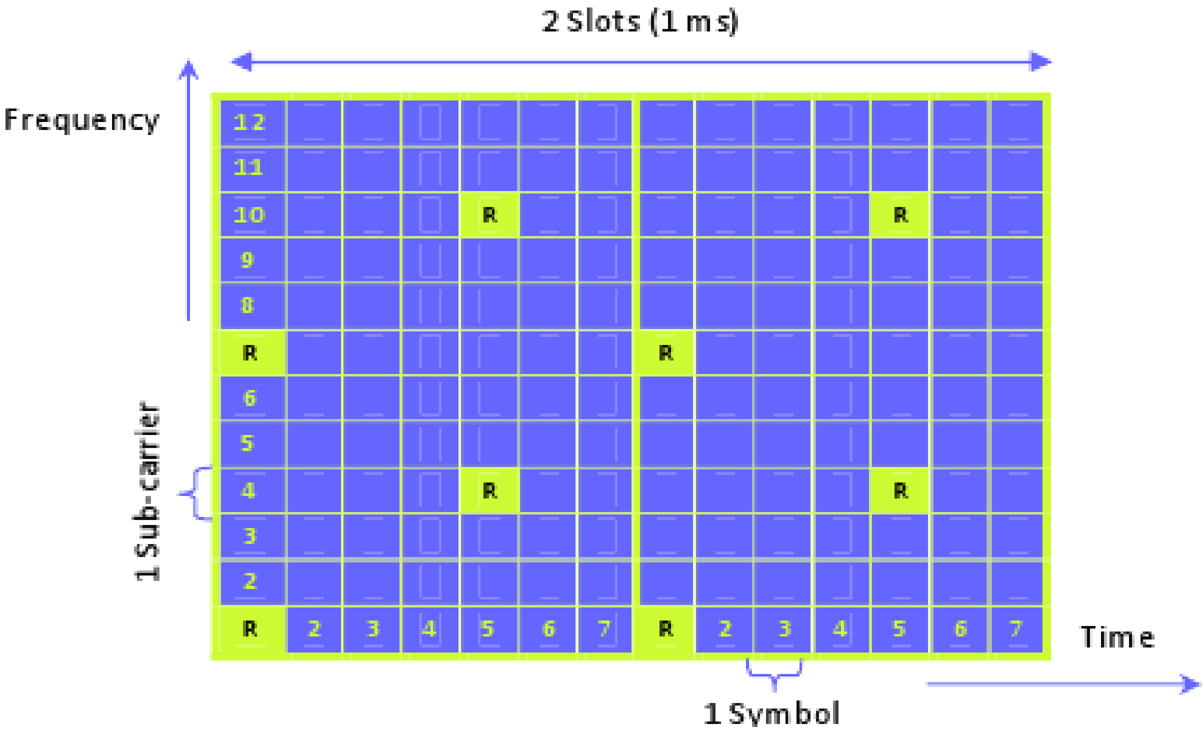
Content

LTE RF Optimization objects

- **1-Coverage based on RSRP.**
- **2-Interferance with coverage (SINR).**
- **3-Handover issue with coverage.**

Reference Signal Received Power (RSRP)

- **3GPP:*"The RSRP (Reference Signal Received Power) is determined for a considered cell as the linear average over the power contributions (Watts) of the resource elements that carry cell specific Reference Signals within certain bandwidth."***
- ***In simple terms* Reference Signal (RS) is mapped to Resource Elements (RE). This mapping follows a specific pattern (see below). The UE will measure all the REs that carry the RS and average the measurements to obtain an RSRP reading.**



❑**RSRP is used for :* measure of signal strength*cell selection and reselection process* aid in the handover procedure.**

❑RSRP gives us the signal strength, not the quality of the signal.

❑**UE usually measures RSRP, and report the value ranging from 0 to 97 and each of these values are mapped to a specific range of real RSRP value as shown in the following table**

Reported value	Measured quantity value	Unit
RSRP_00	RSRP < -140	dBm
RSRP_01	-140 ≤ RSRP < -139	dBm
RSRP_02	-139 ≤ RSRP < -138	dBm
…	…	…
RSRP_95	-46 ≤ RSRP < -45	dBm
RSRP_96	-45 ≤ RSRP < -44	dBm
RSRP_97	-44 ≤ RSRP	dBm

SINR=SIGNAL TO (INTERFERANE +NOISE) RATIO

- S: indicates the power of measured usable signals. Reference signals (RS) and physical downlink shared channels (PDSCHs) are mainly involved
- I: indicates the power of measured signals or channel interference signals from other cells in the current system
- N: indicates background noise, which is related to measurement bandwidths and receiver noise coefficients

RF Optimization Methods

- Antenna Tilt Adjustment.
- Power Adjustment.
- Antenna Height Adjustment.
- Antenna Azimuth Adjustment.
- Change site and antenna position, Site position.

Factors Effecting coverage

- Path Loss
- Frequency Band
- Distance between UE and enodeB.
- Scenarios (Urban, Rural)
- Antenna gain

Antenna Tilt

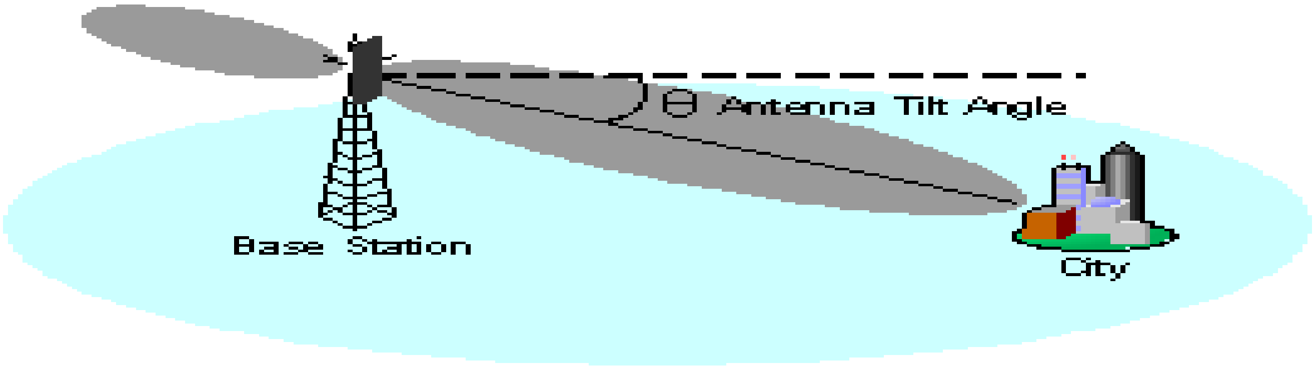
❑Antenna tilt is defined as the angle of the main beam of the antenna with respect to the horizontal plane, positive angles refer to downtilt and vice versa.

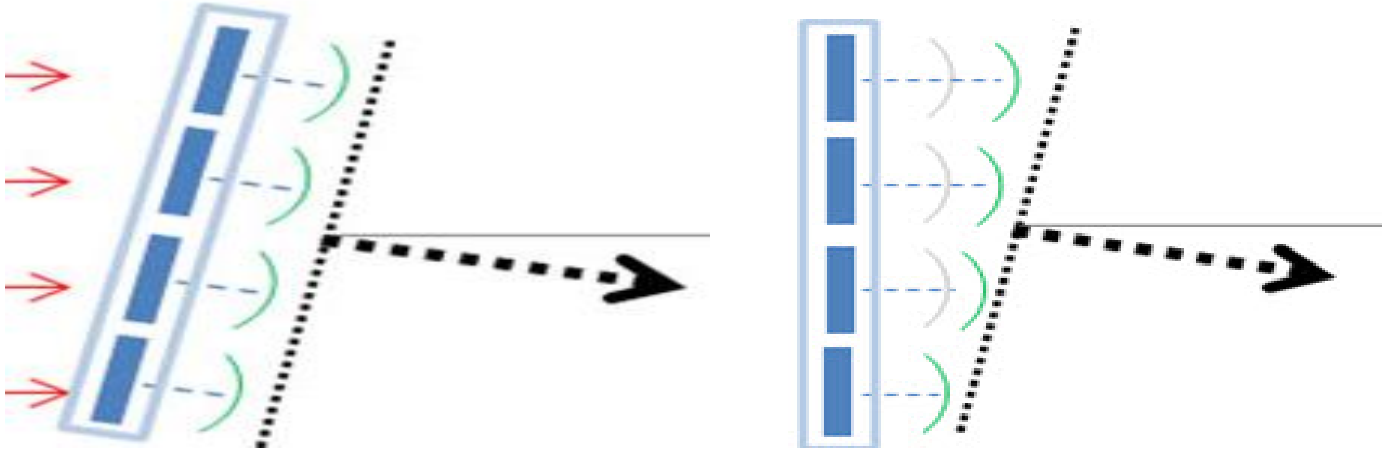
❑Antenna tilt can be adjusted mechanically and/or electrically.

❑Mechanical tilt need for tower climbing and base station visit.

❑Electrical tilting 3 types :

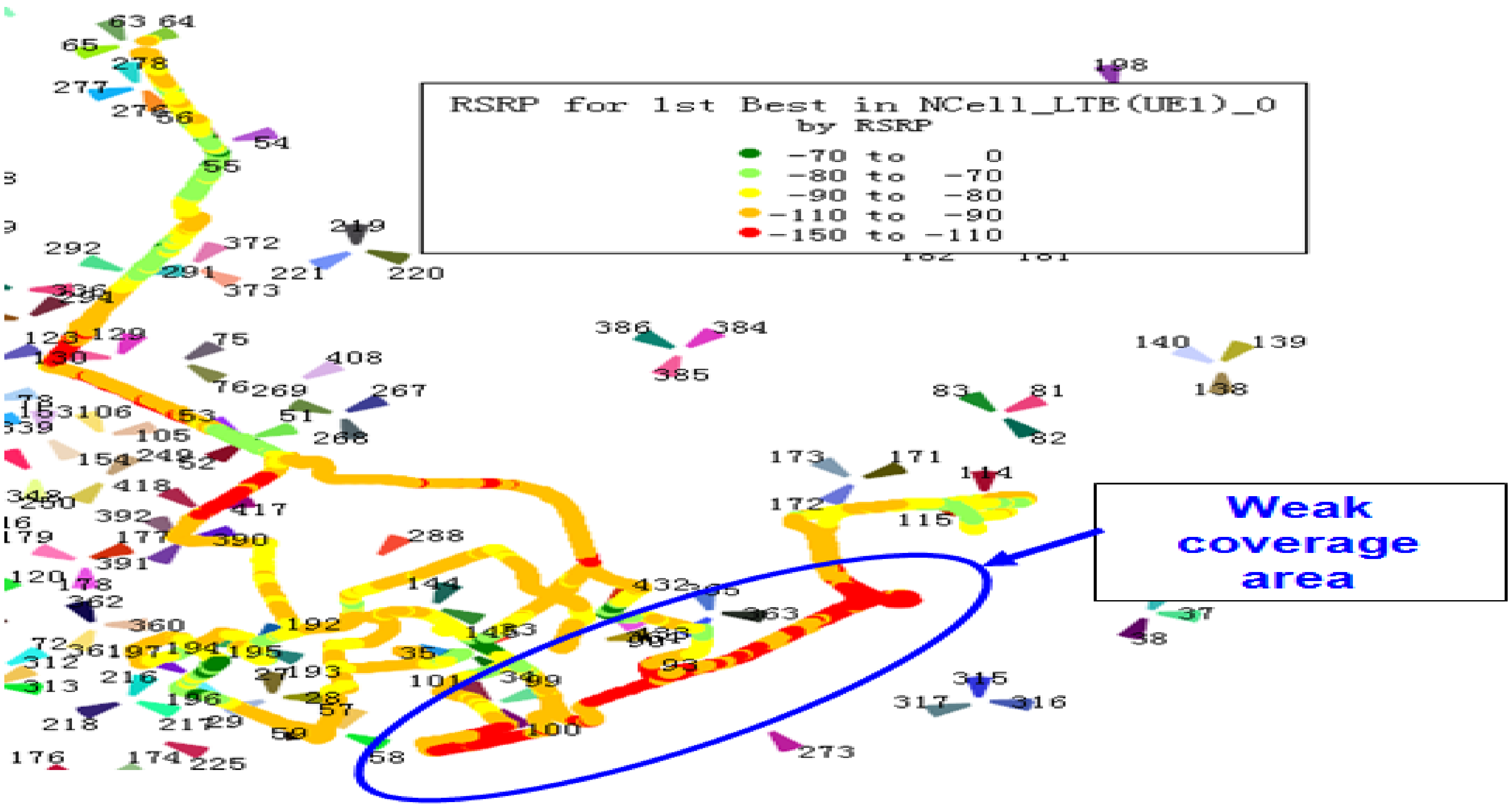
- remote electrical tilt
- Manually Adjusted ET
- Fixed Electronic Tilt





Classification of coverage problems

1-Weak Coverage and Coverage holes when RSRP less than -110dBm

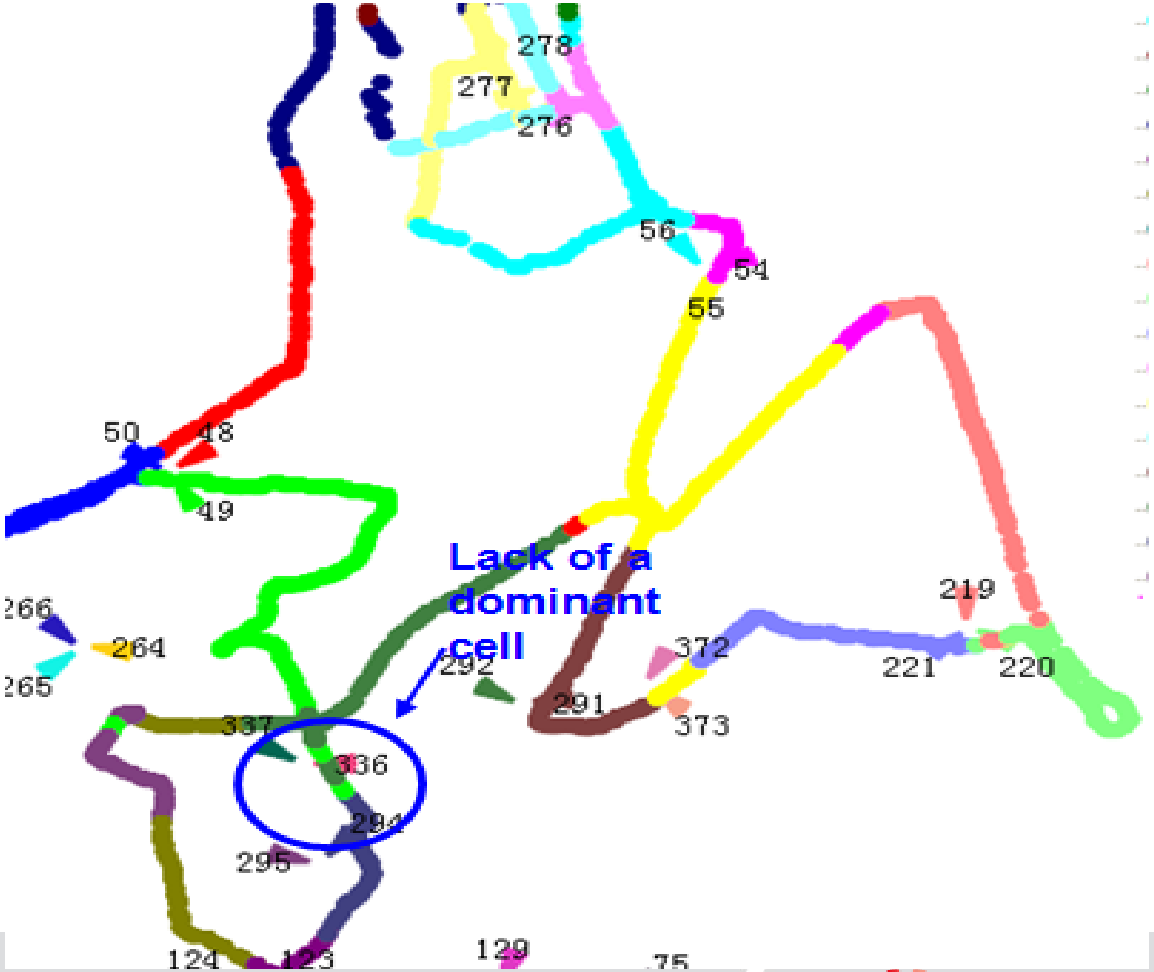


Resolving Week coverage

- Analyze geographical Environment
- Check the coverage planning with simulation tool.
- Adjust antenna azimuths and tilts, increase height, and use high gain antenna
- Deploy new site if the coverage cannot be solved by adjusting antenna
- increase coverage and overlapping between sites but ensure moderate Handover
- Using of indoor solutions and leaky feeders for blind spots.

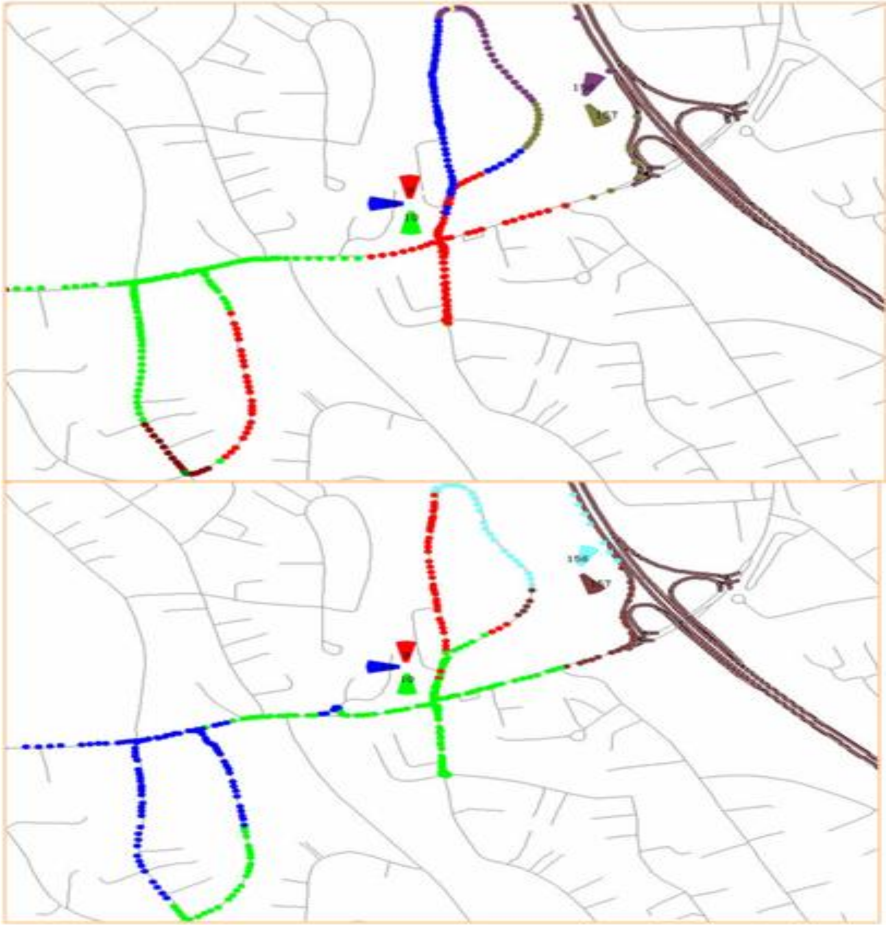
2-Lack of Dominant Cell

- **Without Dominate cell, the s-cell signal level will become same as n-cell, Lead to frequent cell reselection, handover..**
- **Solution : Adjust antenna tilts and azimuths to increase coverage for the stronger signal cell and decrease coverage with other cells.**



3-Cross Feeders

- **The Cross Feeder happen when there is a mismatch between the cell information (PCI) in the databuild/system and the cell information being radiated by a sector.**
- **This problem happens because the physical feeder connection does not correspond with the cell or sector that it should be assigned**
- **Cross feeders are a human error**
- **It can be diagnosed by Drive test**
- **Solution : Submit the problem to the Wireless product support engineers**

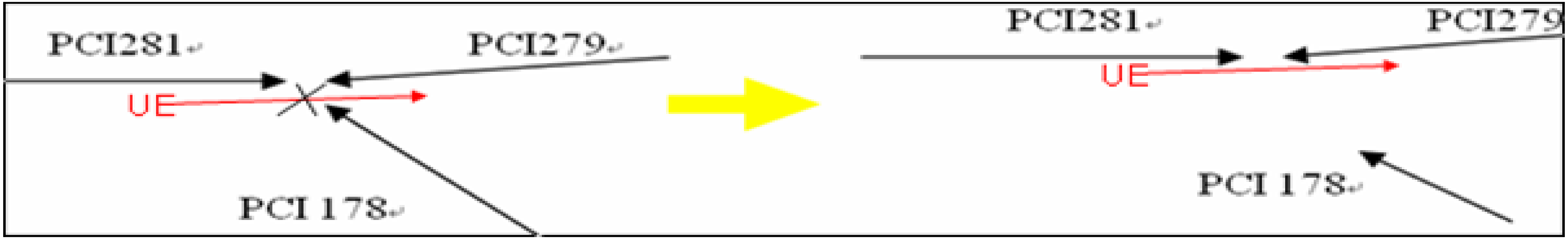


Resolving Signal Quality (SINR)

- **1-Optimize PCI**
- **2-Adjust the antenna parameters**
- **3-Add Dominate Coverage**
- **4-Adust power.**

Handover Problem Caused by coverage

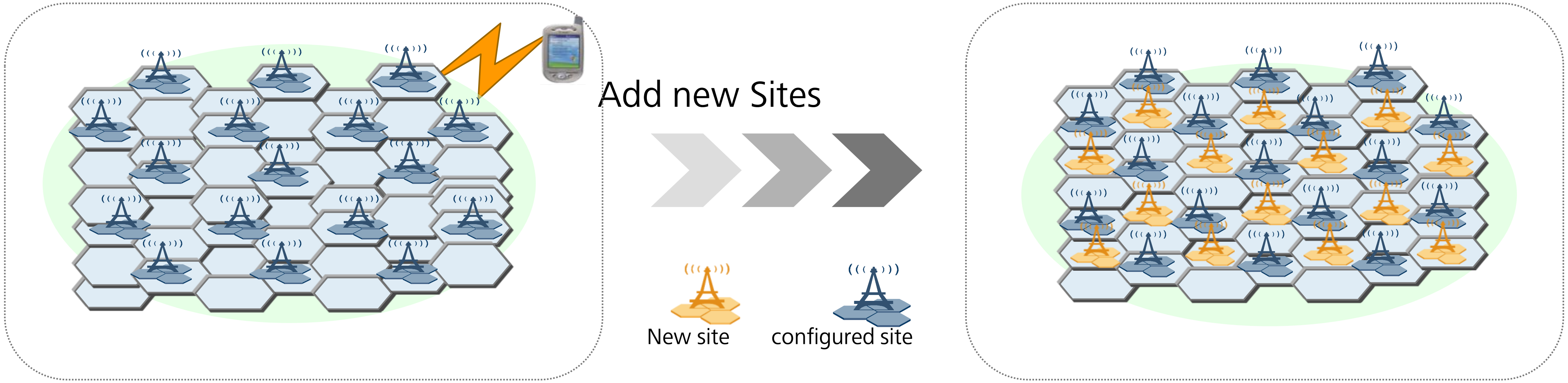
- Cell 281 is the source cell, cell 279 is the target cell.
- During test, Hanover from cell 281 to 279 fail.
- Signal strength (RSRP) and quality not adjusted enough for cell 279 in the handover area, and its interfering with cell 178.
- The solution will be adjust antenna tilt to decrease the coverage of cell 178.



SON（ Self-Organising Networks ）

- **SON Brief Introduction**
  - SON (Self Organization Network) is the functions of LTE that required by the NGMN (Next Generation Mobile Network) operators.
  - From the point of view of the operator's benefit and experiences, the early communication systems had bad O&M compatibility and high cost.
  - New requirements of LTE are brought forward, mainly focus on FCAPSI (Fault, Configuration, Alarm, Performance, Security, Inventory) management:
    - Self-planning and Self-configuration, support plug and play
    - Self-Optimization and Self-healing
    - Self-Maintenance

SON_ANR (Automatic Neighbor Relation)



Description:

- Auto configure and optimize Neighbor relations, intra-LTE and inter-RAT
- X2 automatic setup
- Operator defined rules and monitoring supported

Benefits:

- Fast definition of Neighbor Relations
- up to 95% lower cost of neighbor relation planning and optimization
- Improve customer experience by reducing HO failure caused by missing neighbor relations

SON_Automatic Detection of PCI Collisions

- A PCI collision means the serving cell and a neighboring cell have the same PCI but different ECGIs. PCI collisions may be caused by improper network planning or abnormal neighboring cell coverage (also known as cross-cell coverage). If two neighboring cells have the same PCI, interference will be generated.
- When a PCI collision occurs, the eNodeB cannot determine the target cell for a handover. In this situation, the handover performance deteriorates and the handover success rate is reduced.
- After a PCI collision is removed, the following conditions are met:
  - The PCI is unique in the coverage area of a cell.
  - The PCI is unique in the neighbor relations of a cell.

SON_Automatic Detection of PCI Collisions Cont.

Automatic Detection of PCI Collisions

- After a neighbor relation is added to the NRT, the eNodeB compares the PCI of the new neighboring cell with the PCIs of existing neighboring cells in the case of *IntraRatEventAnrSwitch* is set to ON. If the new neighboring cell and an existing neighboring cell have the same ECGI but different PCIs, the eNodeB reports a PCI collision to the M2000. The M2000 collects statistics about PCI collisions and generates a list of PCI collisions.

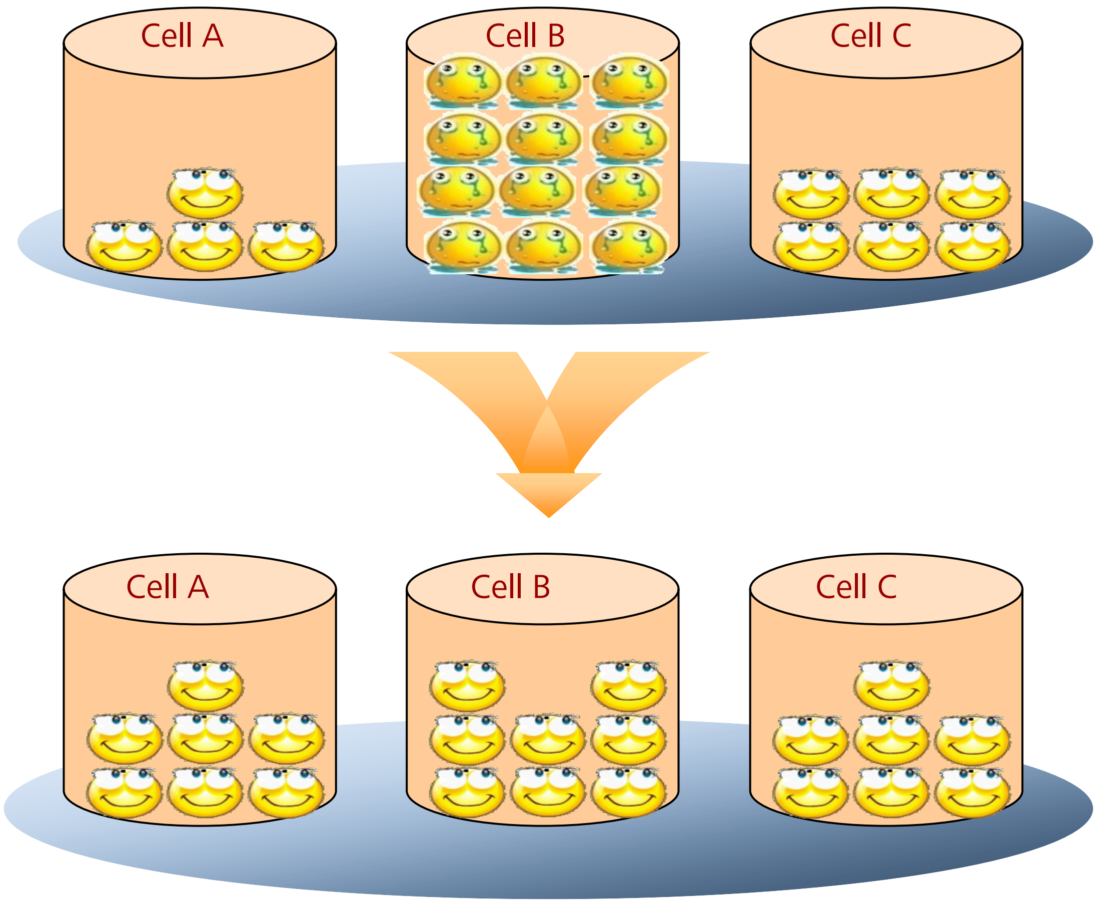
Reallocating PCIs

- PCI reallocation is a process of reallocating a new PCI to a cell whose PCI collides with the PCI of another cell. The purpose is to remove PCI collisions.
- The M2000 triggers the PCI reallocation algorithm to provide suggestions on PCI reallocation.

Note:

- After the PCI of a cell is changed, the cell needs to be reestablished and the services carried on the cell are disrupted. Therefore, the PCI reallocation algorithm only provides reallocation suggestions. A PCI can be reallocated manually or automatically through a scheduled task configured on the M2000.

SON_MLB(Mobility Load Balancing)



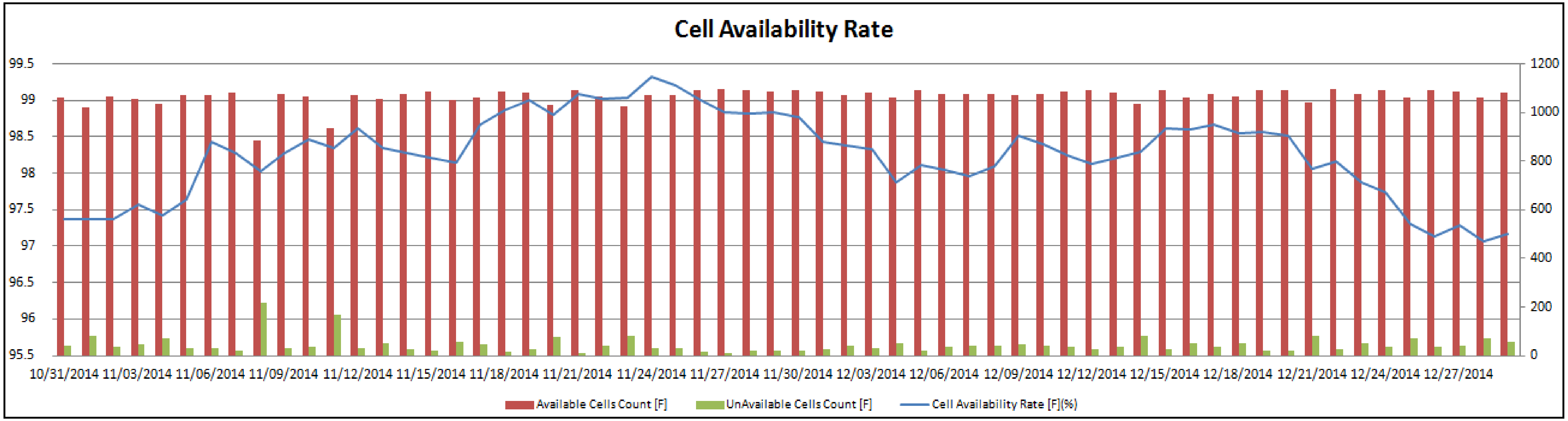
Description:

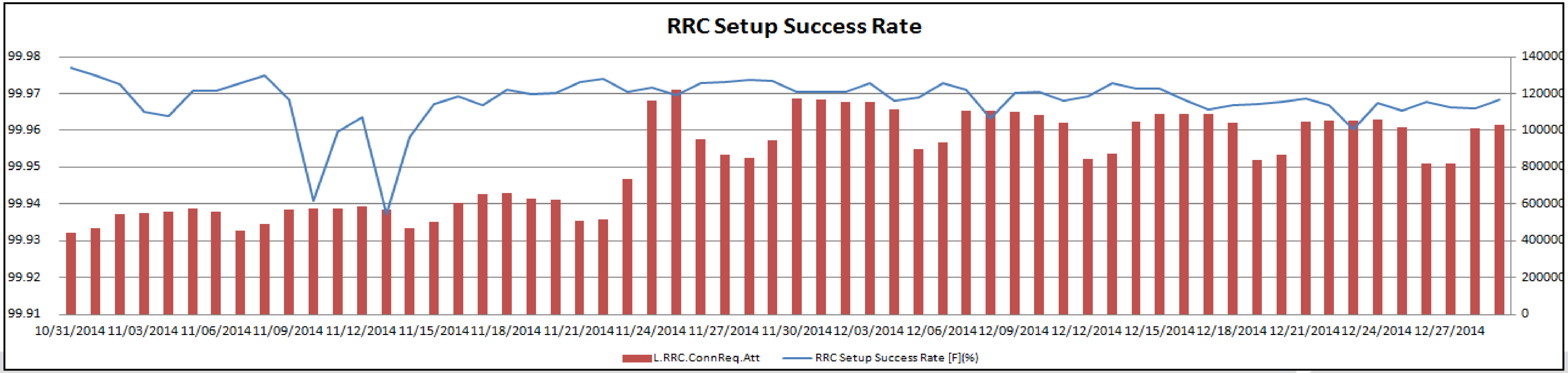
- Exchange cell load information over X2
- Offload congested cells
- Optimize cell reselection / handover parameters

Benefits:

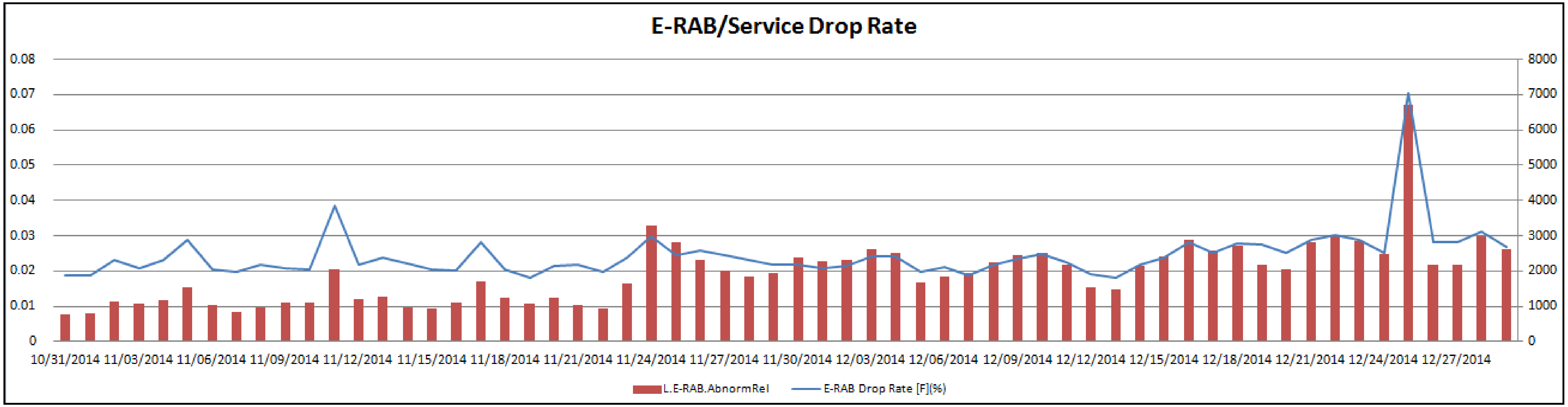
- Increase 10% system capacity and 10%-20% access success rate in unbalance scenario
- Improve customer experience by reducing call drop rate, handover failure rate, and unnecessary redirection caused by unbalanced load

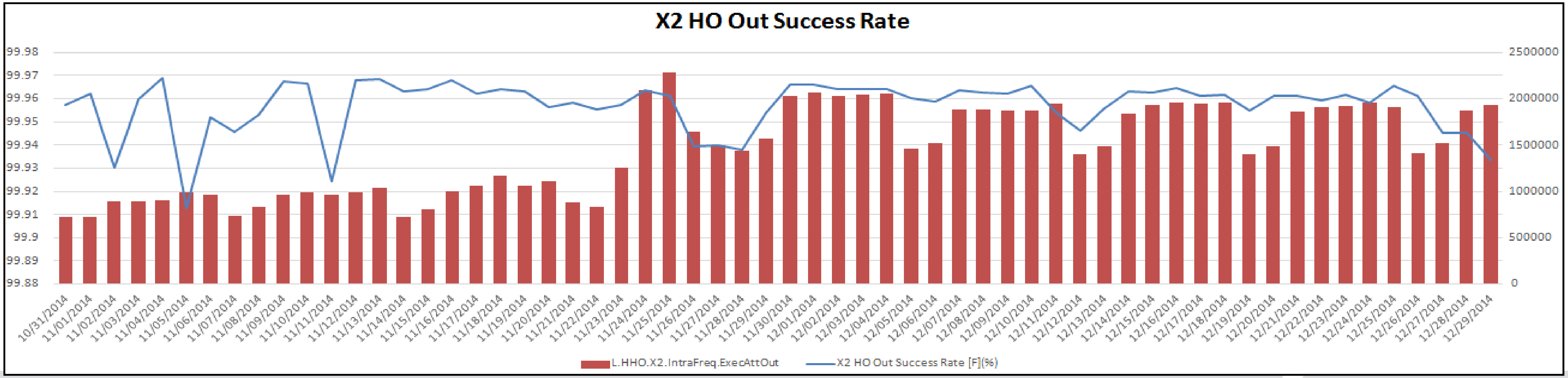
LTE Network Qos Main KPIs



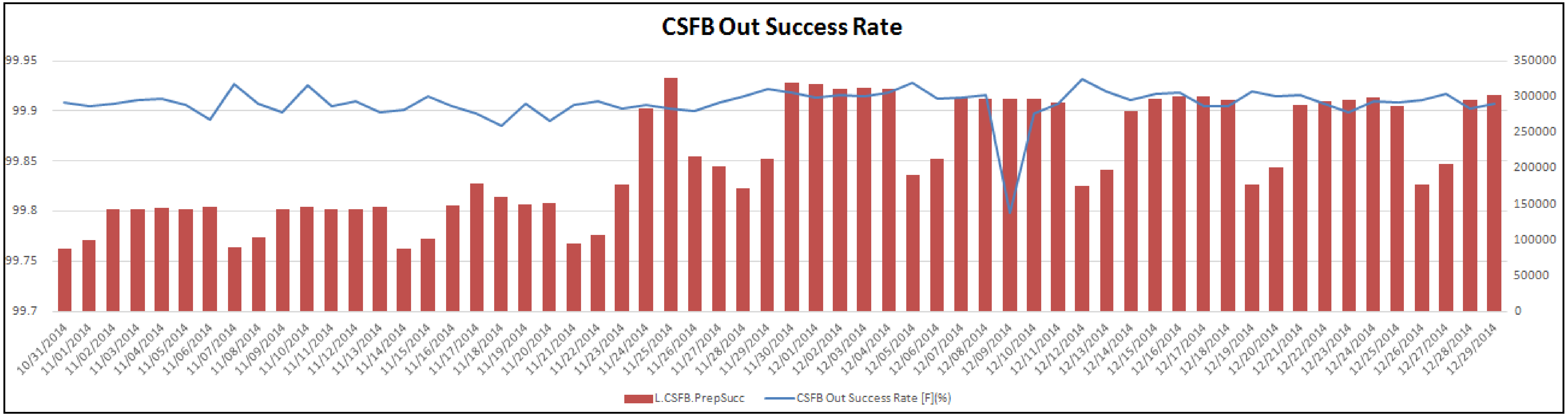


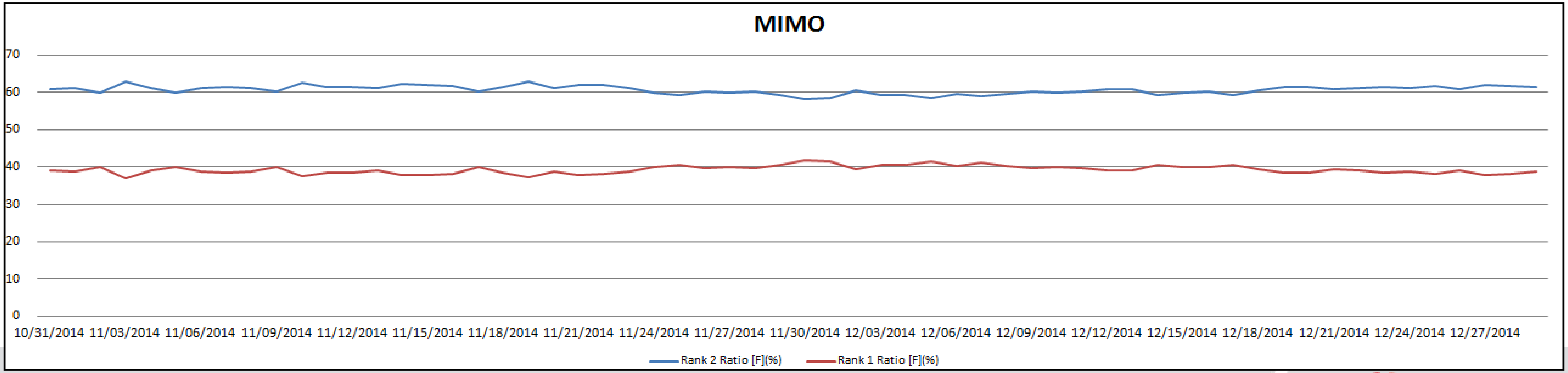
LTE Network Qos Main KPIs





LTE Network Qos Main KPIs





Thank you