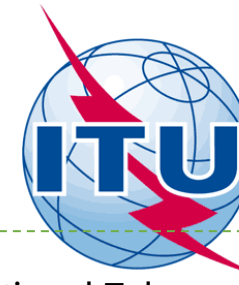




# Technology of 4G LTE

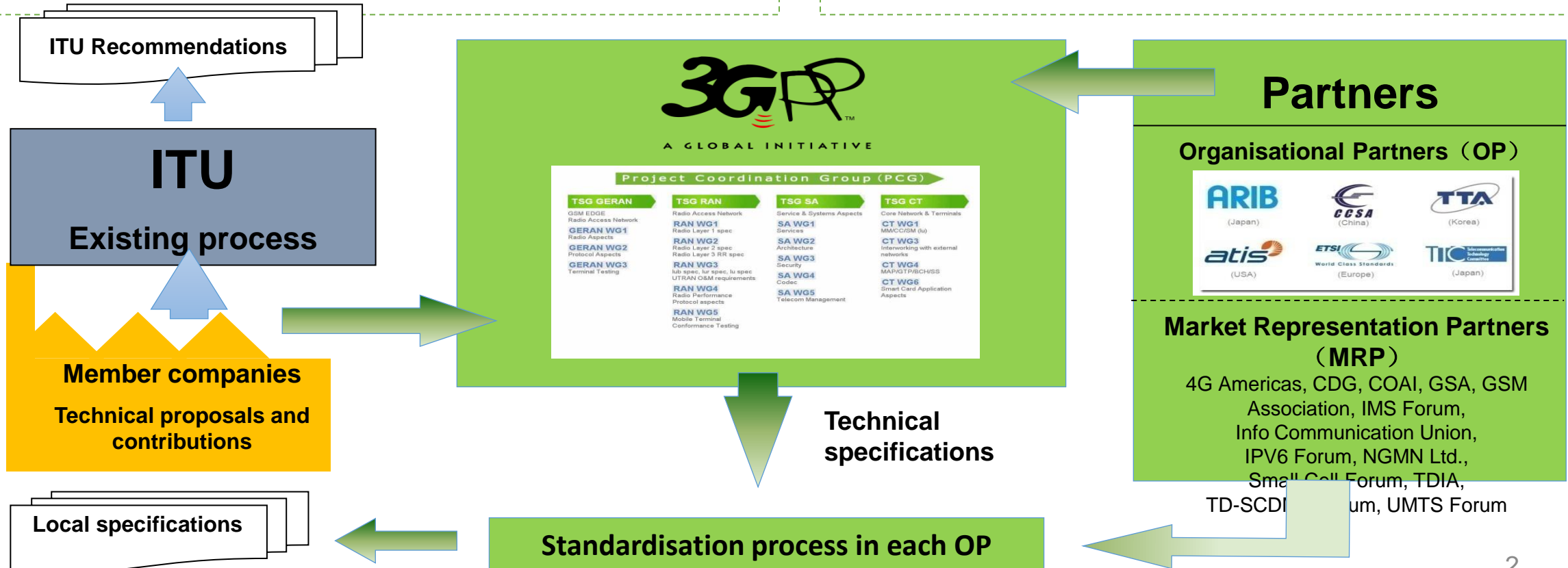
SiYuan YANG  
CAICT

# 3GPP&ITU



- principle members of the 3GPP
  - ARIB, ATIS, CCSA, ETSI, TTA , TTC
  - 389 companies
  - 13 Marketing member , CDG, GSA, TDIA etc..

- ITU is (the International Telecommunication Union) a specialized agency to develop international telecommunication standards.
- The ITU does not set standards, 3GPP will develop standard file, submitted to the ITU, become an international communication advice/standards





## Course Objectives:

- **Background and requirements of 4G LTE**
- **Development of LTE**
- **Hot topics on LTE**
- **Key technology of 4G LTE**

# THE definition and background of LTE



- **LTE=Long Term Evolution**, is a new generation of broadband mobile communication standard set by 3GPP with high data rate and low delay, packet domain optimization characteristics .

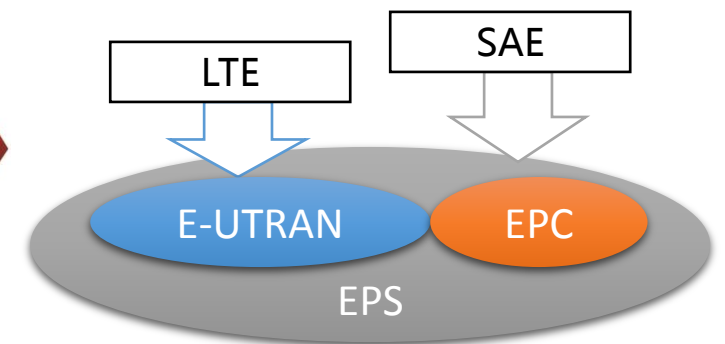
## The concepts which are easy to confuse :

- E-UTRA= Evolved Universal Terrestrial Radio Access;
- E-UTRAN= Evolved Universal Terrestrial Radio Access **Network** ;
- EPC= Evolved Packet Core ;
- EPS= Evolved Packet System =E-UTRAN+EPC;
- SAE=System Architecture Evolution



- **Why did LTE set in 2004?**

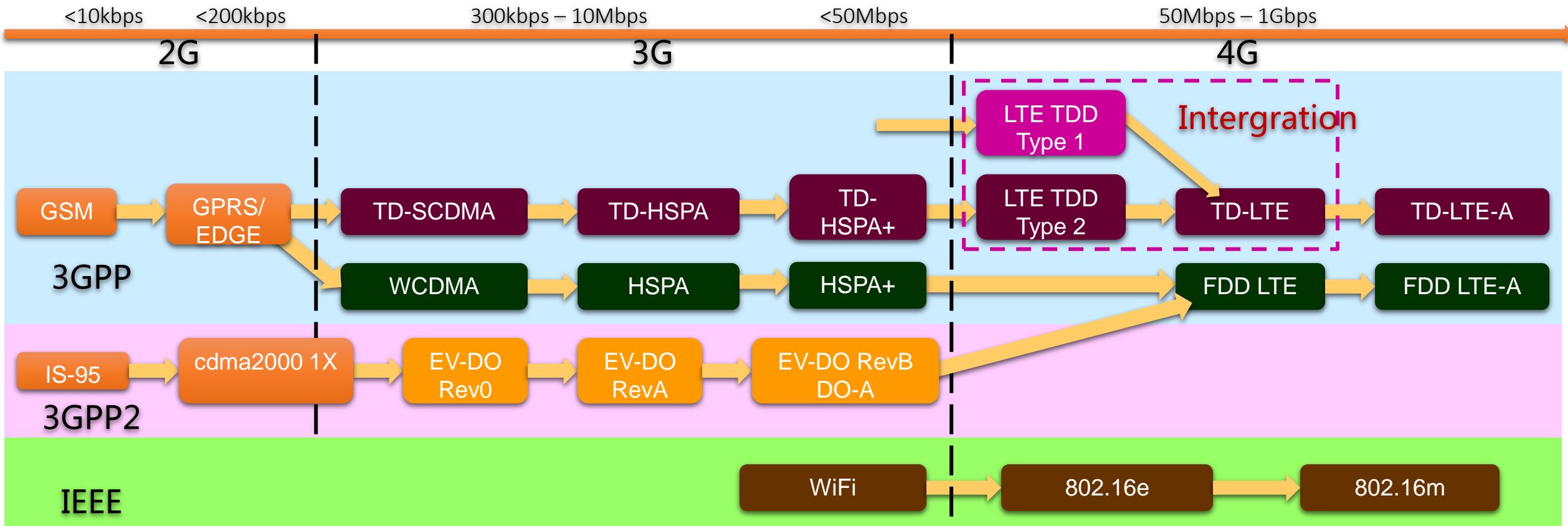
- Point 1: The rise of mobile Internet service .
- Point 2: The challenge of WiMAX Technology .
- Point 3: The completion of technical reserves——OFDM、 MIMO



# LTE has become the mainstream of broadband mobile communication standard



- Today, LTE has been successful in the competition with WiMAX and has become the preferred broadband mobile communications technology for the mainstream carriers in the world.
- By the end of 2007, the intergration of two TD-LTE types enhanced the influence of TD-LTE.

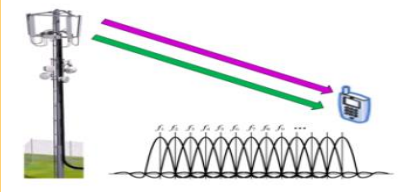


# Technical innovation of LTE



- LTE is a technology based on OFDM, using a flat network architecture without RNC. LTE is a technological revolution, not just evolution

**OFDMA +MIMO**



↓

- 170~340Mbps
- Spectrum efficiency = 2~3 times to HSPA



High Speed Internet



A large number of simultaneous users

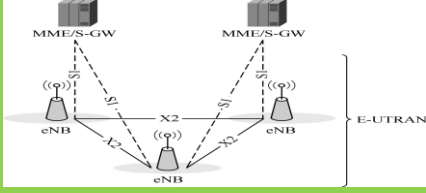


Real time service



Self configuration and optimization

**All IP flat network architecture**



↓

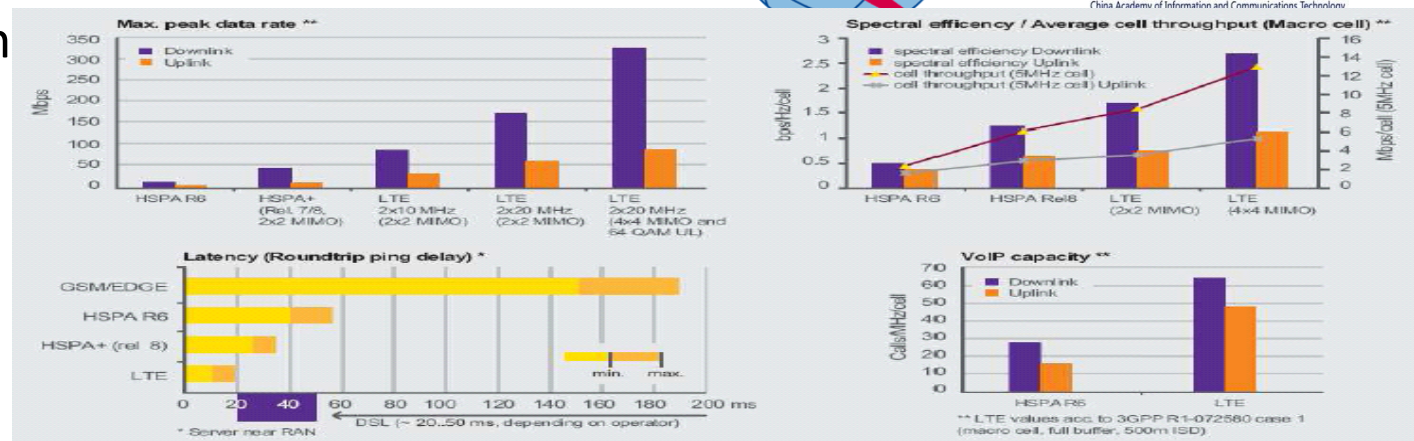
- Low transmission and control delay
- New base station interface : X2



# LTE requirements and technical indicators



- LTE's core technology needs have been basically realized, but some of the technology is still in the process of optimization.
- Bandwidth, peak rate and delay performance are significantly improved.



Requirements of LTE standard	progress
Support 1.4MHz-20MHz bandwidth	Completed
Peak data rate: uplink >50Mbps, downlink >100Mbps	Completed
The spectral efficiency is 2-4 times of HSDPA/HSUPA	Basically completed, but only 1 to 2 times to HSPA + gain
Improve the bit rate of cell edge	Continuous optimization
User plane time delay less than 5ms(one way),control plane tme delay less than 100ms.	User plane time delay is about 20ms(1loop)
Reduce cost, realize the evolution from low cost 3G	Hardware expansion & Software upgrade
Balance between performance improvement and backward compatibility	Most compatibility is not implemented.
Cancel CS (circuit switched) domain, CS domain operations in the PS (packet switching) domain implementation, such as the use of VoIP	Completed(Volte)
The system is optimized for low speed mobile scene while supporting the high-speed mobile scene	Basically completed



## Course Objectives:

- Background and requirements of 4G LTE
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- Key technology of 4G LTE



# LTE Global developments



## Global LTE networks development

- Until July 2016, a total of 170 countries and regions in the world opened 521 of LTE networks
- This year, there are 74 new operators to launch commercial LTE services
- Over 100 LTE-A networks have supported Cat 6 (300 Mbps downlink peak rate) smart phones
- At present, the most widely used frequency of LTE is 1800 MHz, and the second is 2.6 GHz, 800 MHz frequency band.

## Global LTE user development

- As of the end of July 2016, the total number of global LTE users reached 1 billion 450 million.

# LTE IN CHINA



## LTE networks development in CHINA (May 2016)

- CMCC: As of May this year, China Mobile completed a total of **1 million 284 thousand** 4GLTE base station construction. 78.7% outdoor BS, 21.3% indoor BS.
- CUCC: China Unicom's 4G investment amounted to 3 billion 600 million yuan. Mobile completed a total of **503 thousand** 4GLTE base station construction. 88.9% outdoor 11.1% indoor BS.
- CTCC: China Telecom's 4G investment amounted to 4 billion 840 million yuan. Mobile completed a total of **514 thousand** 4GLTE base station construction. 73.5% outdoor 26.5% indoor BS.

## LTE user development in CHINA

- CMCC: 4G (TD-LTE) customer number up to 407 million.
- CUCC: 4G (TD-LTE) customer number up to 67 million 380 thousand.
- CTCC: 4G (TD-LTE) customer number up to 110 million 260 thousand.



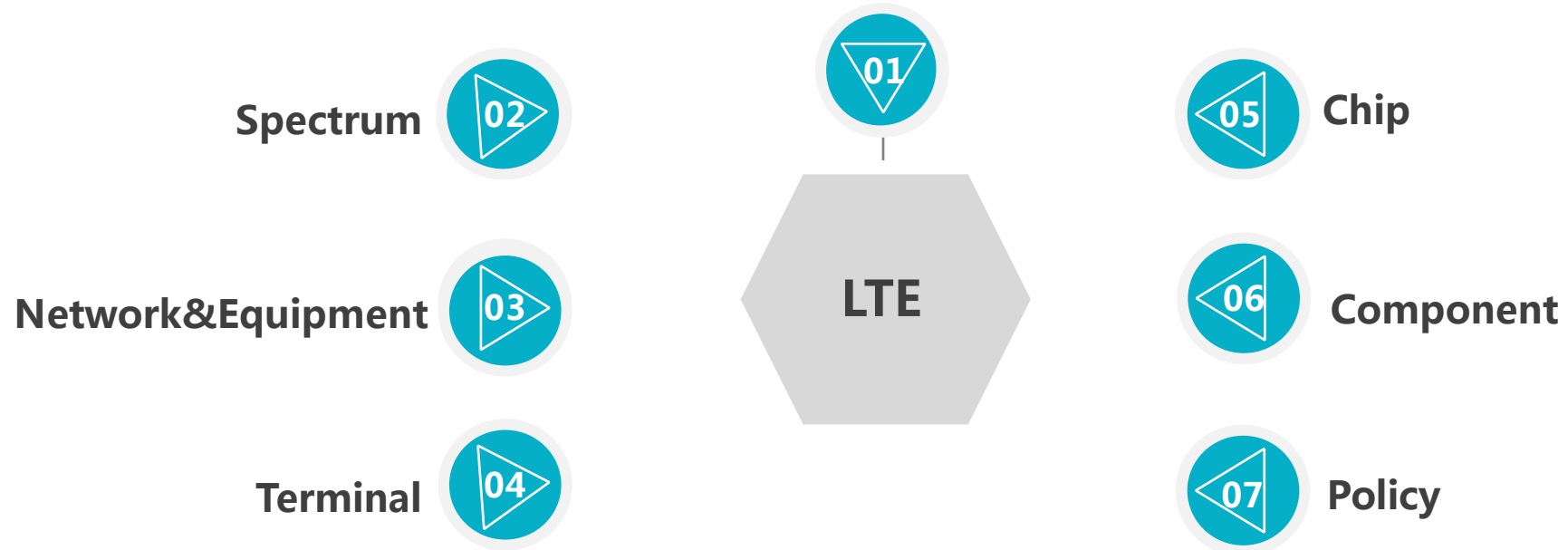
## Course Objectives:

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- Development of LTE
- **Hot topics on LTE**
- Key technology of 4G LTE

# Hot topics on LTE



## Technology & Standard





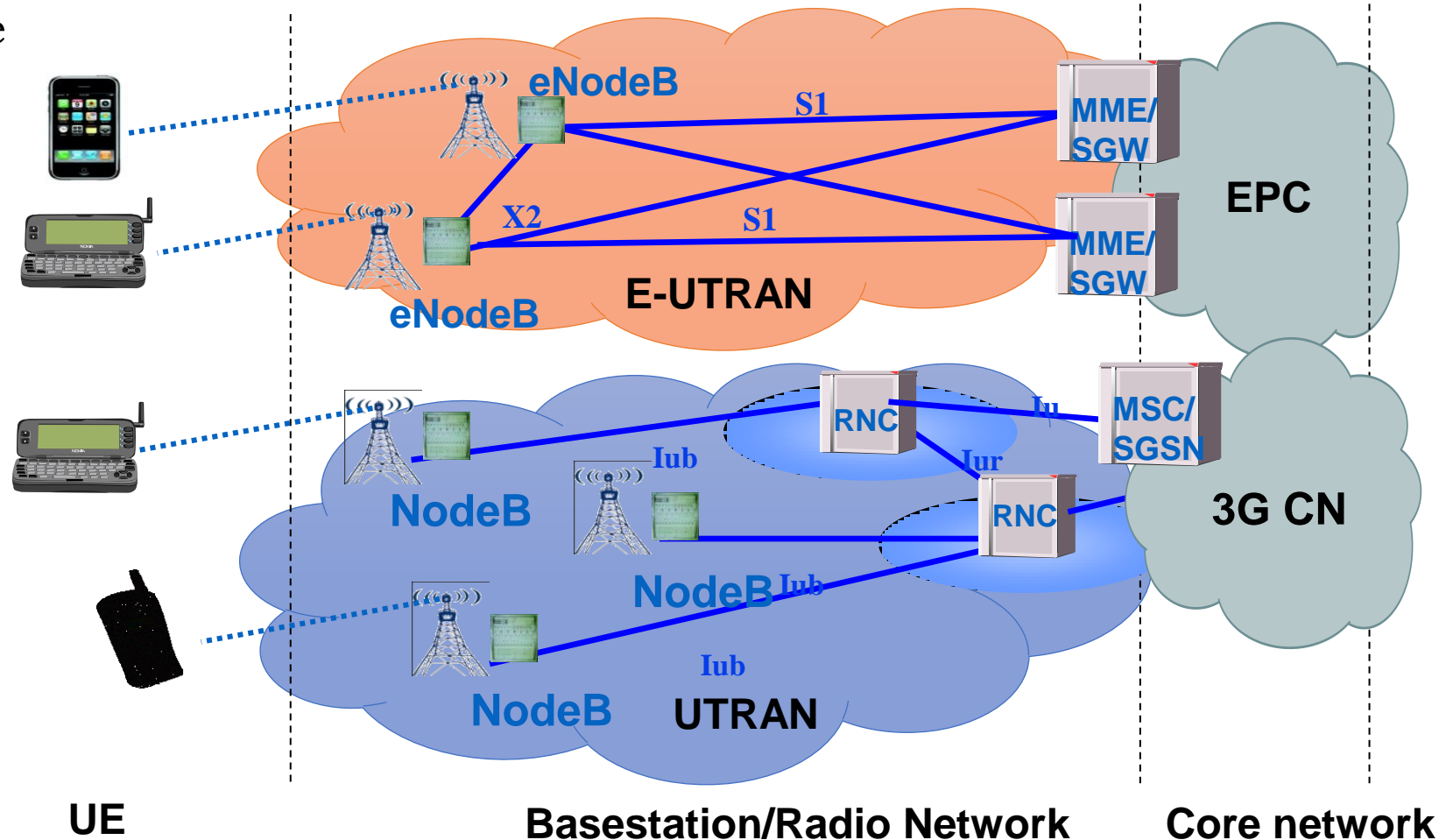
## Course Objectives:

- Background and requirements of 4G LTE
- Development of LTE
- Hot topics on LTE
- **Key technology of 4G LTE**
  - **Flat network**
  - OFDM
  - MIMO
  - Intra-frequency network & interference suppression
  - Voice Solution

# LTE key technologies: flat network



- Cancel RNC, most of the features into the eNodeB, the rest move to EPC
- Cancel CS domain
- Separation of user and control interface——SGW (Service gateway) and MME (Mobility Management Entity) 。
- Access network and core network, 'multi-multi' connection



## Course Objectives:



- Background and requirements of 4G LTE
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- **Key technology of 4G LTE**
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  - **OFDM**
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# LTE key technologies: OFDM



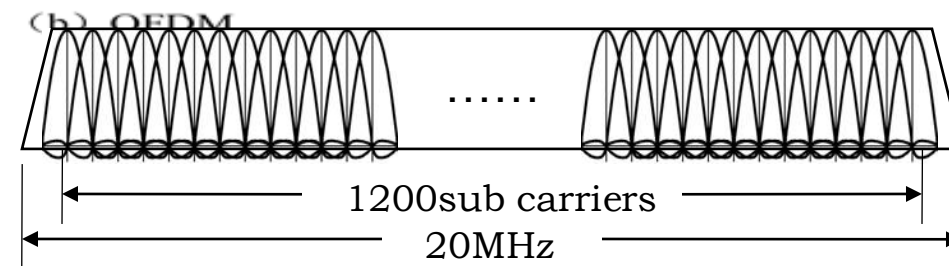
- OFDM (orthogonal frequency division multiplexing) is a frequency division (FDM) system, which is one of the most widely used communication technologies
  - Frequency division is a technology using a few frequency parallel transmission to achieve broadband
  - Easy to find applications in real life.
- In the traditional FDM system, the carrier needs a lot of protection bands, and the spectrum efficiency is very low.
- The OFDM system allows the carrier to be adjacent or even partially overlap, which can provide a higher spectral efficiency. Relative to the independent carrier, these interconnected carriers are referred to as "sub carriers".



- How to achieve this characteristic? Rely on FFT



- A LTE 20MHz downlink carrier (18MHz available actually) consists of 1200 sub carrier.







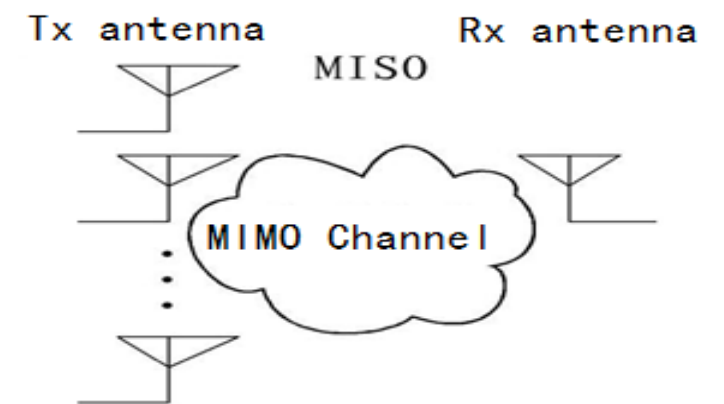
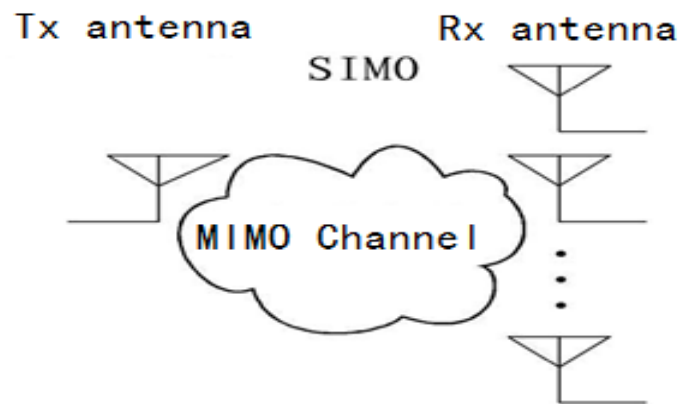
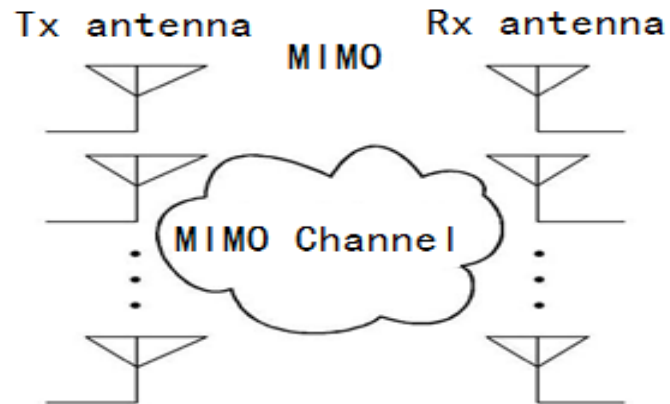
## Course Objectives:

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- Hot topics on LTE
- **Key technology of 4G LTE**
  - Flat network
  - OFDM
  - **MIMO**
  - Intra-frequency network & interference suppression
  - Voice Solution

# MIMO : Definition



- Generalized definition : MIMO=Multiple-Input Multiple-Output,is commonly called ‘Multi antenna technology ’
  - ⊕ Multiple inputs and multiple outputs may be derived from multiple data streams, or multiple versions of one data stream.
  - ⊕ According to this definition, all kinds of multi antenna technology can be counted as MIMO Technology
- Narrow definition: multi layer MIMO
  - ⊕ Multiple signal streams in parallel transmission
  - ⊕ According to this definition, only the spatial multiplexing and space division multiple access can be counted as MIMO
- special case : SIMO (Single input and multiple out ) & MISO (Multiple Input and single output )



# MIMO

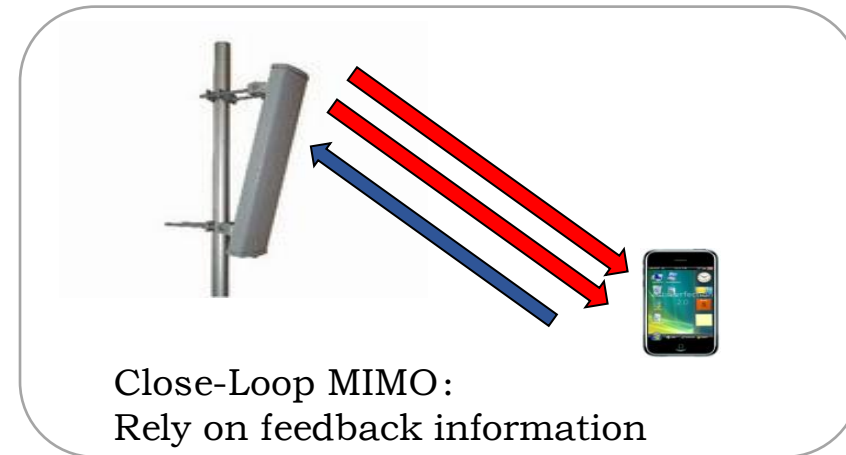
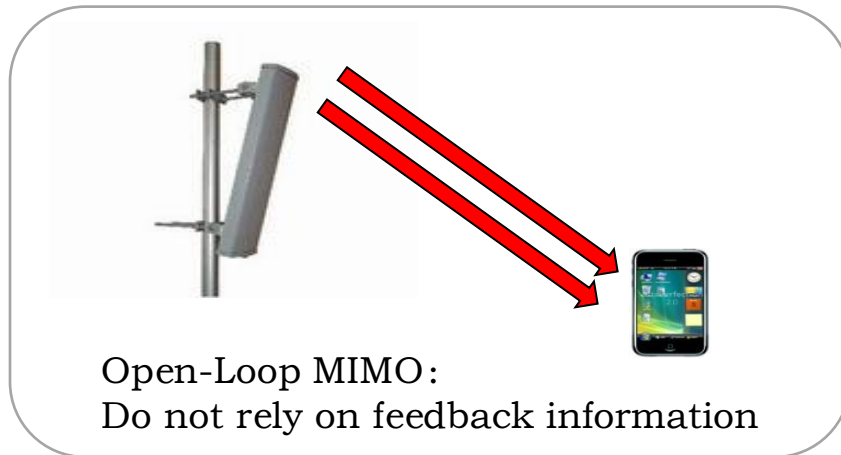


## ■ Classification from effect :

- ⊕ Spatial Diversity——Improve the link quality, enhance coverage, indirectly improve the spectrum efficiency
- ⊕ Beamforming ——Improve the link quality, enhance coverage, indirectly improve the spectrum efficiency
- ⊕ Space Division Multiplexing——Improve the user data rate, directly improve the spectrum efficiency
- ⊕ Space division multiple access ——Improve the user capacity, directly improve the spectrum efficiency
  - Above all kinds of MIMO technology can improve the spectrum efficiency of the system directly or indirectly.

## ■ Classification from there 's channel prior information or not at sender:

- ⊕ **Close-Loop MIMO**: Channel prior information is obtained by feedback or channel interaction.
- ⊕ **Open-Loop MIMO**: No channel prior information



## Course Objectives:

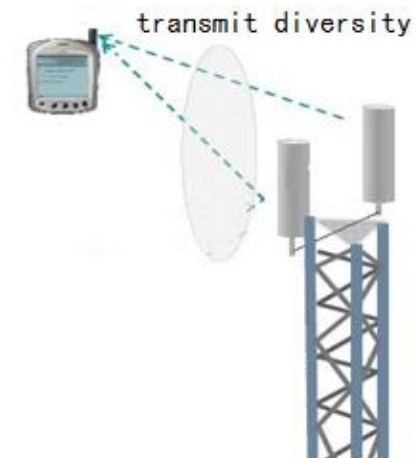


- **Key technology of 4G LTE**
  - Flat network
  - OFDM
  - **MIMO**
    - **Spatial Diversity**
    - Space Division Multiplexing
    - Beam forming
  - Intra-frequency network & interference suppression
  - Voice Solution

# MIMO : Spatial diversity



- **Definition:** By the non correlation between antennas , using multiple antennas to transmit or receive one data stream ,avoiding the effect of single channel fading on the whole link.
- **Effect:** Improve link quality , rather than improving the link capacity . It also can improve the link budget, increase cell coverage.
- **Receive diversity :** Using multiple antennas to receive one signal stream ,avoiding the depth fading of a single antenna.
- **Transmit diversity :** Using multiple antennas to receive one signal stream ,avoiding the depth fading of a single antenna.
  - ⊕ classification: Simple diversity , Coding diversity, Selection diversity , Beam diversity
- **Transmit diversity uses open loop mode generally :** So it is very suitable to use in the broadcast channel / control channel and the high speed scene.





## Course Objectives:

- **Key technology of 4G LTE**
  - Flat network
  - OFDM
  - **MIMO**
    - Spatial Diversity
    - **Space Division Multiplexing**
    - Beam forming
  - Intra-frequency network & interference suppression
  - Voice Solution

# MIMO : Space Division Multiplexing



铁血丹心



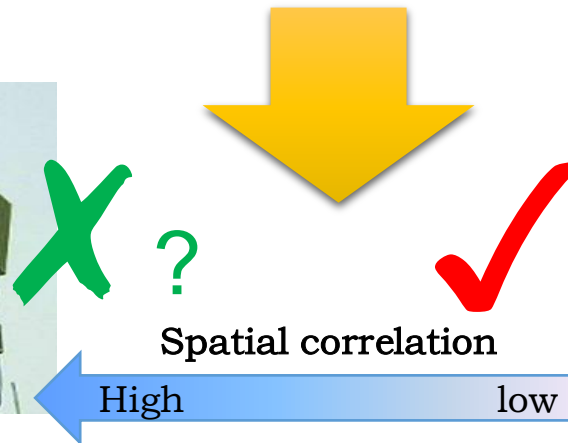
- **Definition:** By using the non correlation between the large pitch antenna array element, transmitters send multiple data streams in parallel to a UE/basestation for Link capacity enhancement.
- The core problem of SDM is to reduce the interference between antennas.

## Regularities:

The larger the distance between the antennas, the smaller the correlation between the antennas, the smaller the interference between the antennas. ◦



Small antenna spacing ( $\lambda/2$ ) :  
Suitable for beam forming



Large antenna spacing ( $>10\lambda$ ) :  
suitable for SDM



## Course Objectives:

- **Key technology of 4G LTE**
  - Flat network
  - OFDM
  - **MIMO**
    - Spatial Diversity
    - Space Division Multiplexing
    - **Beam forming**
  - Intra-frequency network & interference suppression
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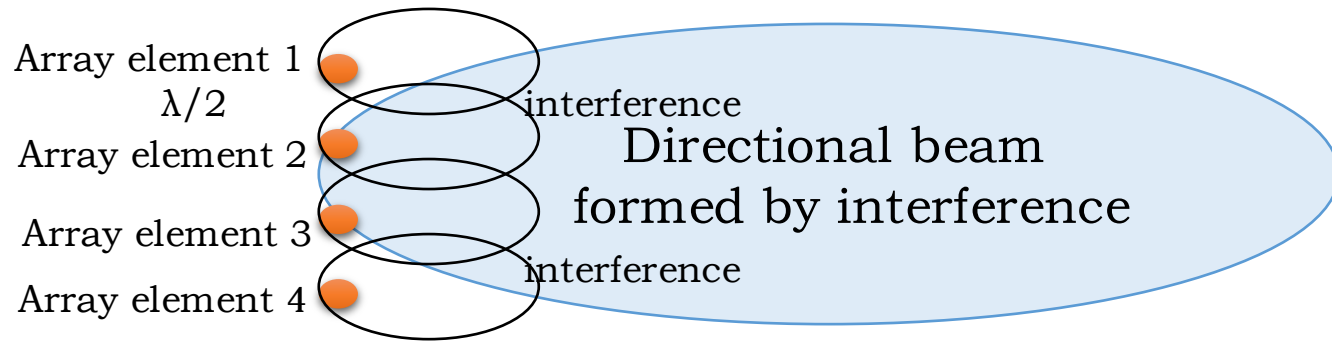


# MIMO : Beam forming

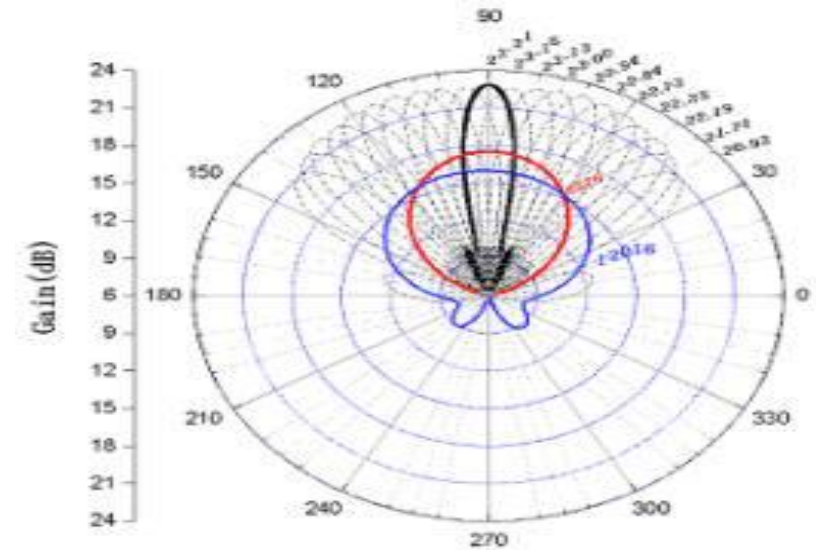


- **Definition:** Beam forming is commonly known as “smart antenna” .

Beamforming is a signal precoding technology based on the antenna array, it can produce a directional beam by adjusting the weighting coefficient of each antenna array, thus to obtain obvious array gain .



**Beamforming schematic**

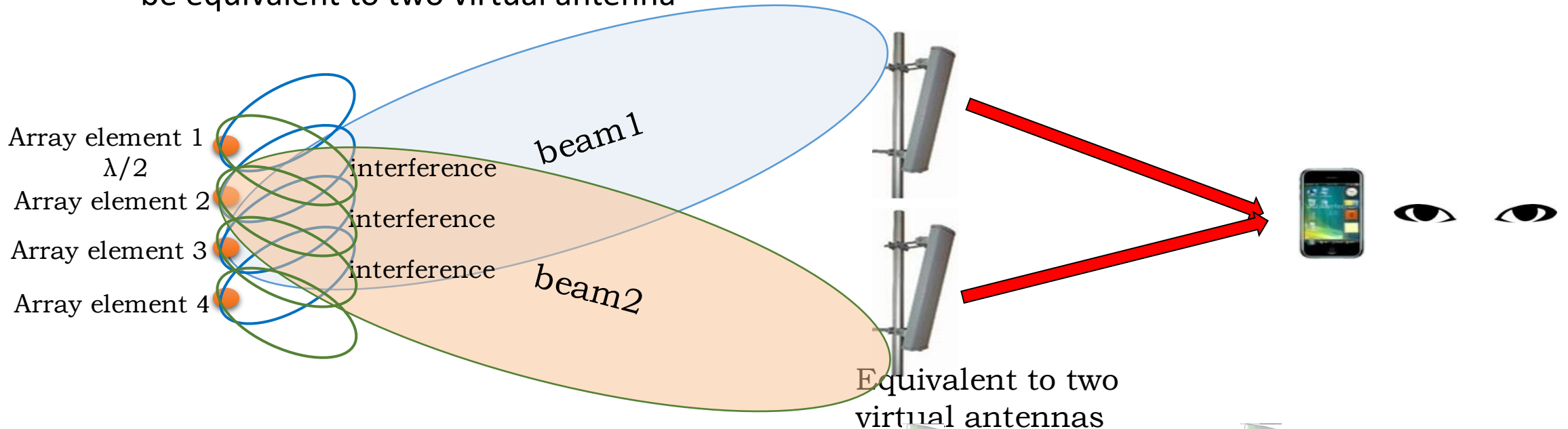


**Concentrated energy, enhanced coverage**

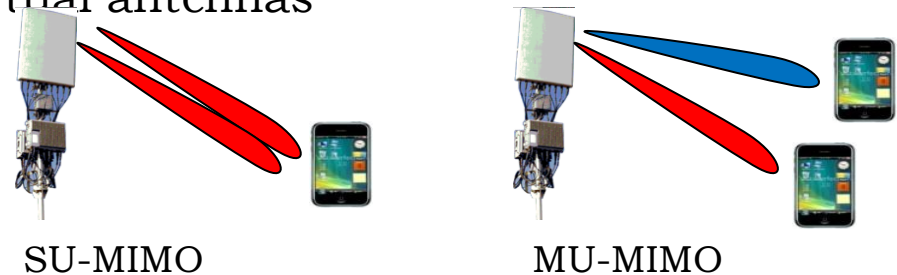
# MIMO : Dual streams beamforming



- Dual streams beamforming=Beamforming+Spatial multiplexing /Space division multiple access =LTE TM8
  - Dual streams beamforming put two set of antenna weights in one antenna array element.It can be equivalent to two virtual antenna



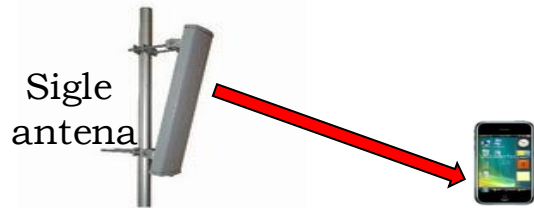
- Two beams can point to one user, or two users :



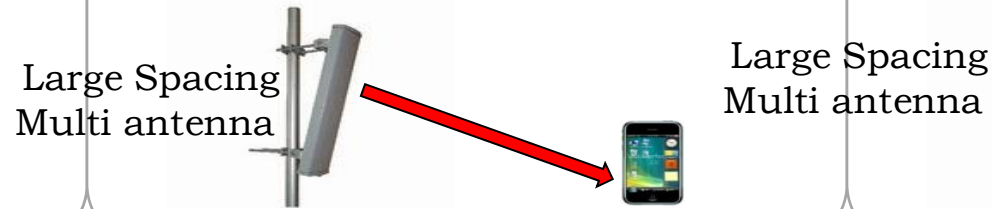
# MIMO



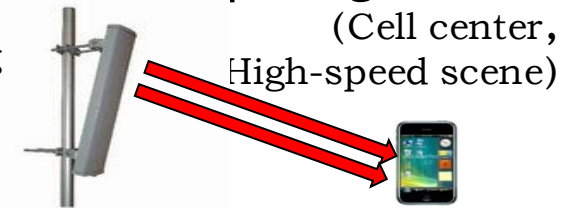
**TM1: Single antenna transmission**



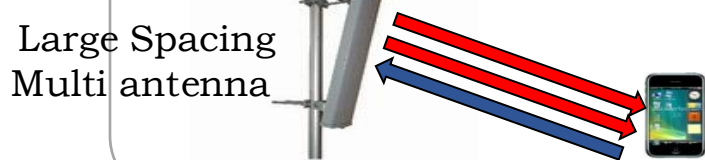
**TM2: SFBC**  
(control channel, Cell edge)



**TM3: Open loop space division multiplexing**  
(Cell center, High-speed scene)



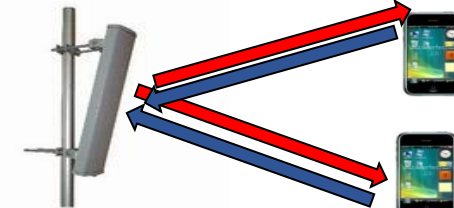
**TM4: Closed loop space division multiplexing**  
(Low speed scene)



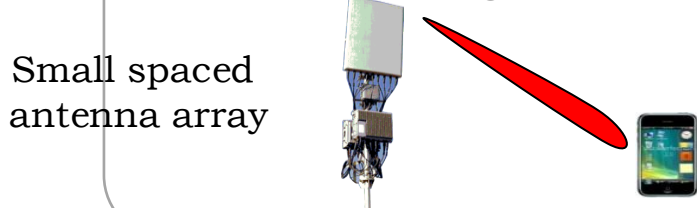
**TM5: Single layer closed loop**  
(Cell edge. low-speed scene)

**TM7-9 using smart antenna**

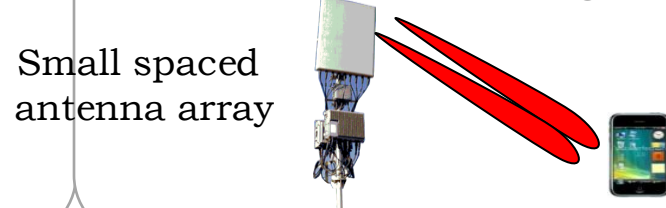
**TM6: closed loop MU-MIMO**  
(Low-speed scene)



**TM7: Single Layer stream beamforming**  
(Cell edge)



**TM8: double layer stream beamforming**



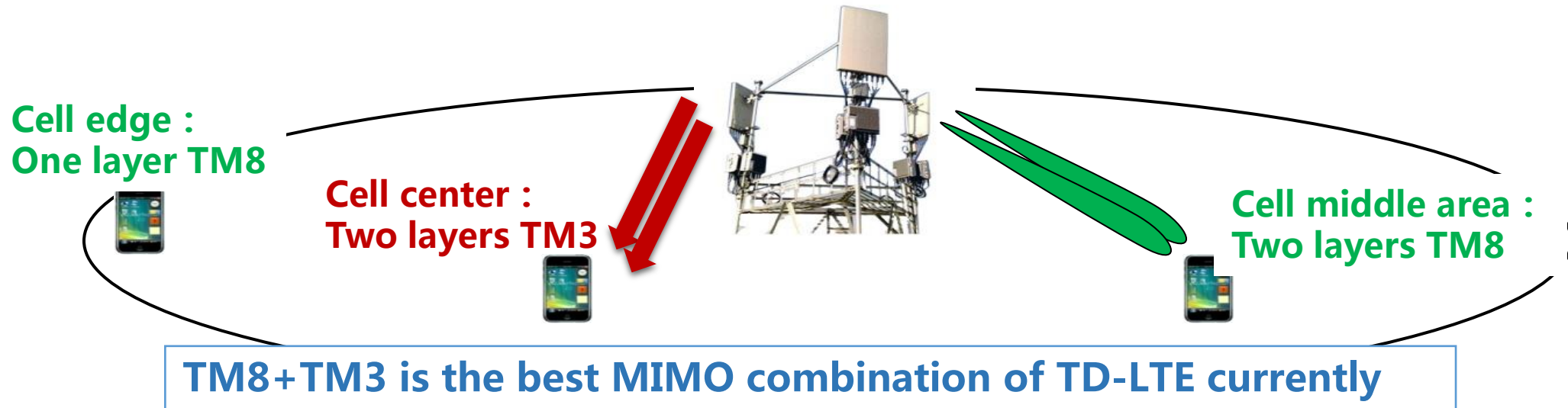
**TM9**  
(Low-speed scene)



# MIMO



- For example in China, TM3+TM8 is verified as an optimized MIMO combination for TD-LTE.



# Course Objectives:



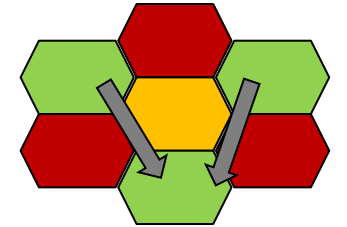
- Background and requirements of 4G LTE
- Development of LTE
- Hot topics on LTE
- **Key technology of 4G LTE**
  - Flat network
  - OFDM
  - MIMO
  - **Intra-frequency network & interference suppression**
  - Voice Solution

# LTE Intra-frequency network



- In the cellular mobile communication system, the intra-frequency interference is inevitable and can only be overcome.

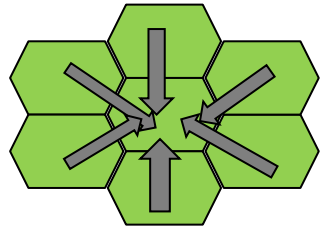
The core of the cellular communication system is the frequency reuse between cells. .



Frequency reuse inevitably leads to intra-frequency interference, which is inevitable

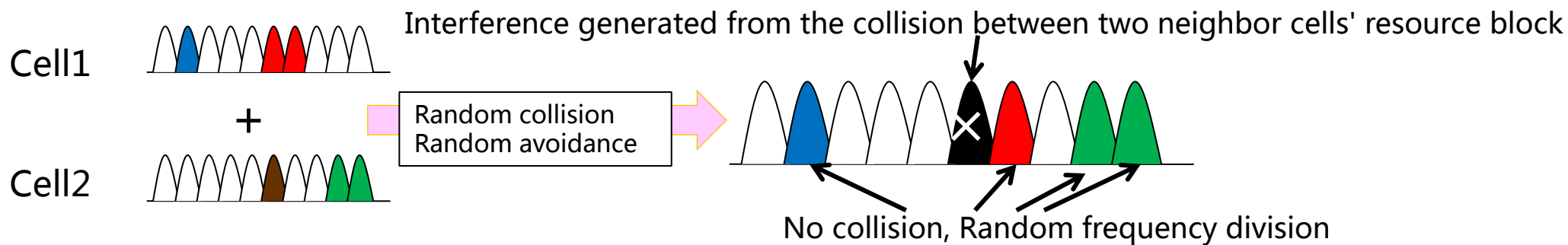
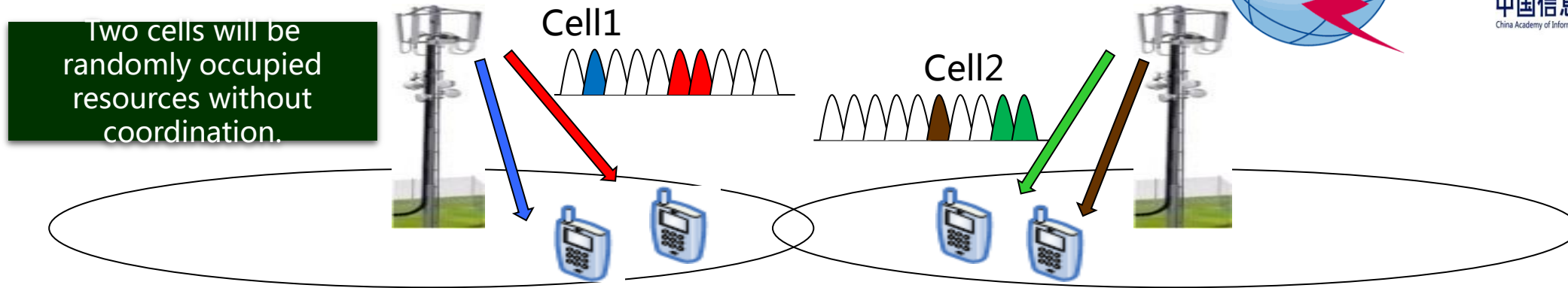
The intra-frequency network can achieve the highest spectrum efficiency, while bringing the most serious of the intra-frequency interference

The intra-frequency interference can be reduced by using a larger frequency reuse coefficient, but the spectral efficiency can be lost. .



**The key problem in the intra-frequency network is whether it can restrain the intra-frequency interference effectively in the condition of frequency reuse factor 1.**

# LTE Intra-frequency network : OFDMA Networking mechanism



The common and interferenced resource block from one UE are always encoded jointly.

therefore

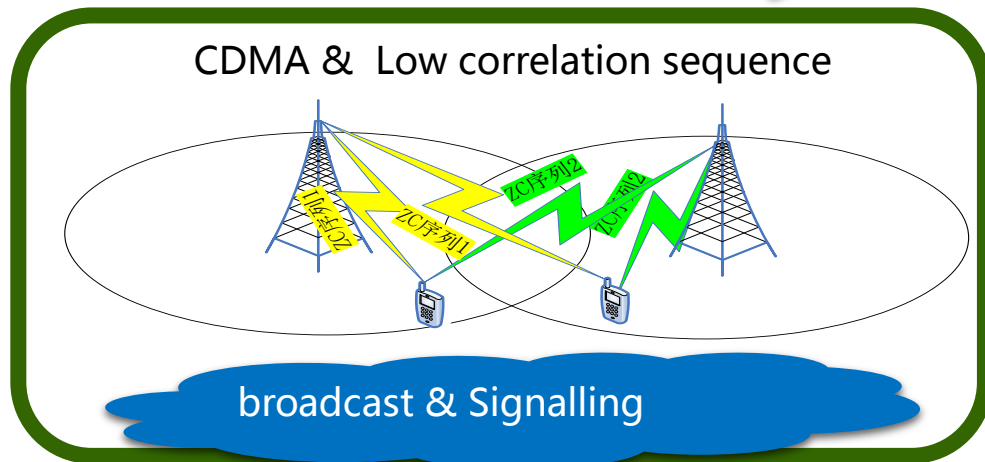
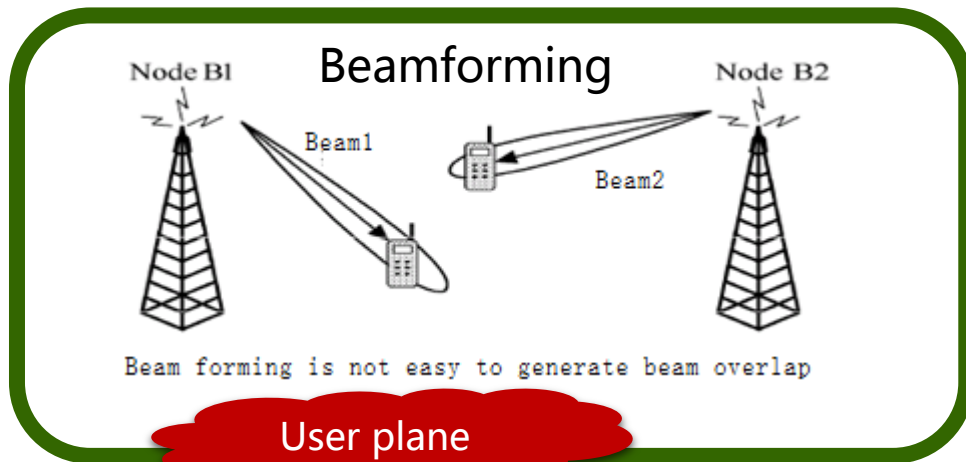
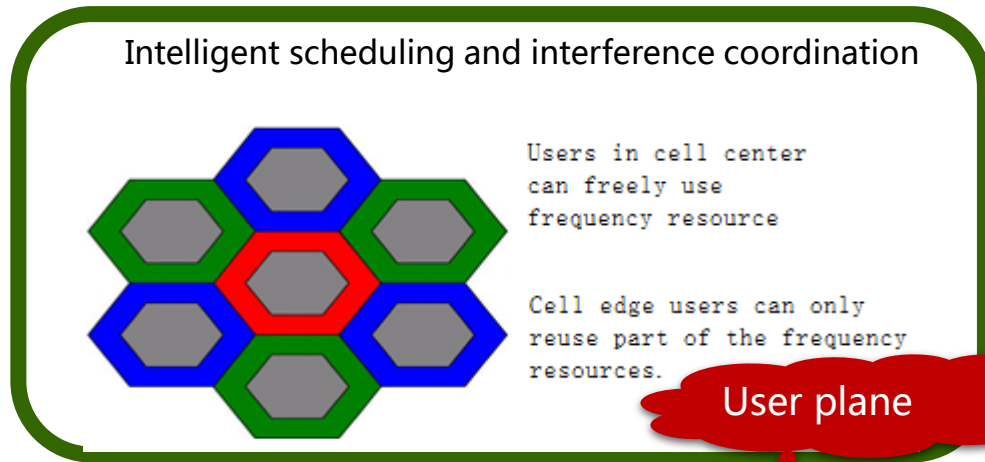
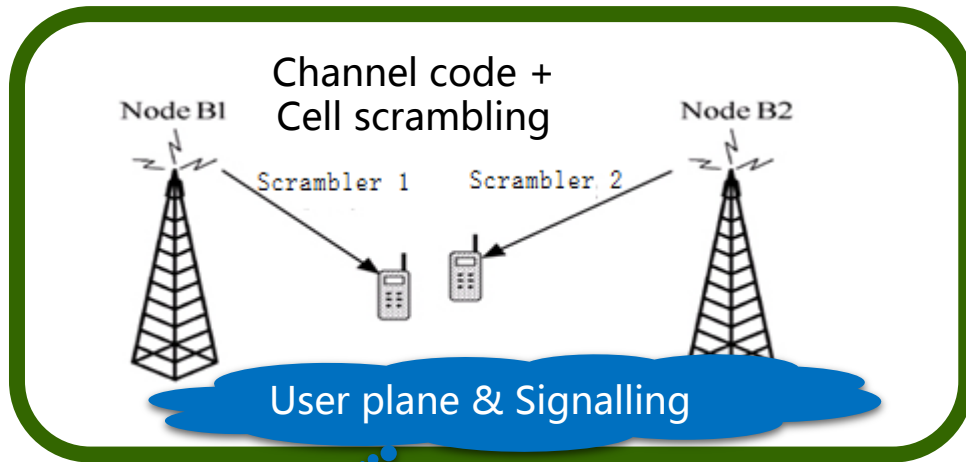
If interference of the resource block is small, it can be recovered through the channel coding error correction.

- The effect of OFDMA system on the Intra-frequency network depends on the load of the system:
  - The lower the load, the smaller the intra-frequency interference
  - The higher the load, the greater the intra-frequency interference

# LTE Intra-frequency network : Enhanced interference suppression technique



- Besides the OFDMA networking mechanism, LTE system can also use a series of enhanced technology to suppress the intra-frequency interference :





# Course Objectives:



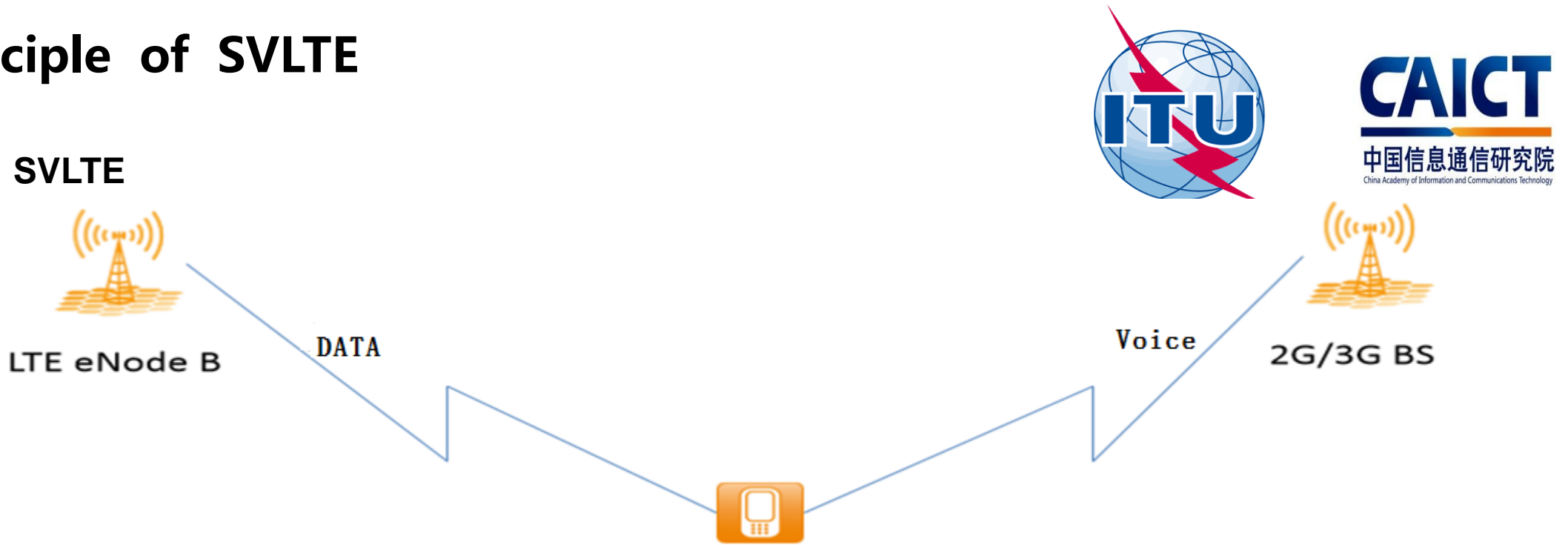
- **Key technology of 4G LTE**
  - Flat network
  - OFDM
  - MIMO
  - Intra-frequency network & interference suppression
- **Voice Solution**
  - **Dual standby**
  - CSFB
  - VoLTE

# Dual standby strategy



- Single kard Dual standby strategy : Using one Sim card allows UE work on both the LTE network and the 2/3G network. Data services use LTE network, voice services use 2/3G network.
  - SVLTE: 2/3G network is CDMA system
  - SGLTE: 2/3G network is GSM/UTRAN system
  - Advantages: No special requirements for network equipment , IMS is unnecessary
  - Disadvantages: High cost of mobile phone ;High power consumption
- SGLTE: simultaneous GSM and LTE, LTE and GSM synchronization support , Terminal contains two chips. One is to support the LTE multi-mode chip, one is the GSM chip.
- SVLTE: Simultaneous Voice and LTE, Dual standby mode. Mobile phones can work in the LTE and CS mode at the same time. Data services use LTE network, voice services use 2/3G network.

# Principle of SVLTE



SVLTE can support voice and data at the same time

- UE has two radion interfaces (LTE&2G/3G)
- Independent registration in two network
  - 2G or 3G network provide voice services
  - LTE network provide data services
- Inter network does not require interoperability

# Course Objectives:

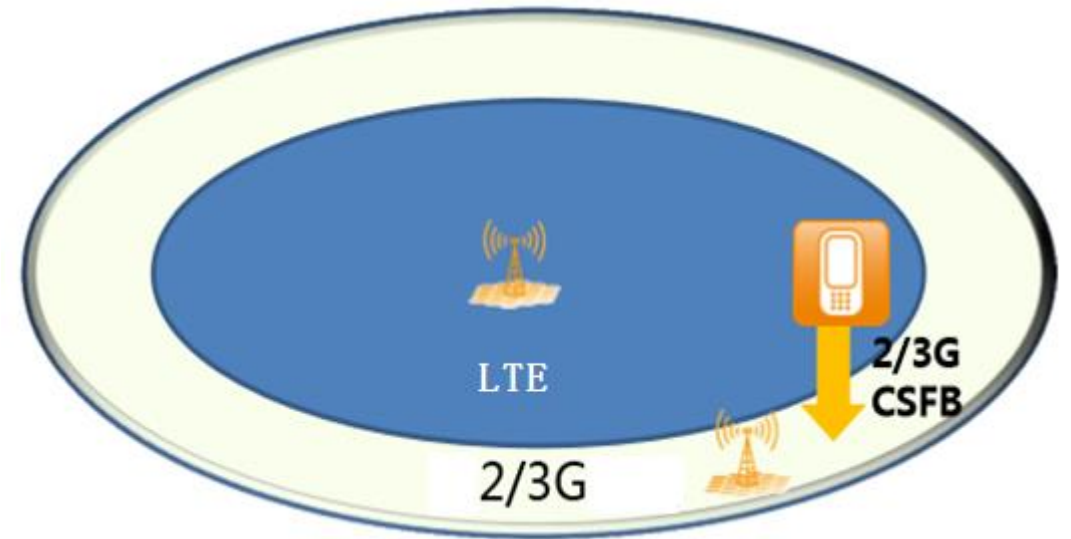


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  - Dual standby
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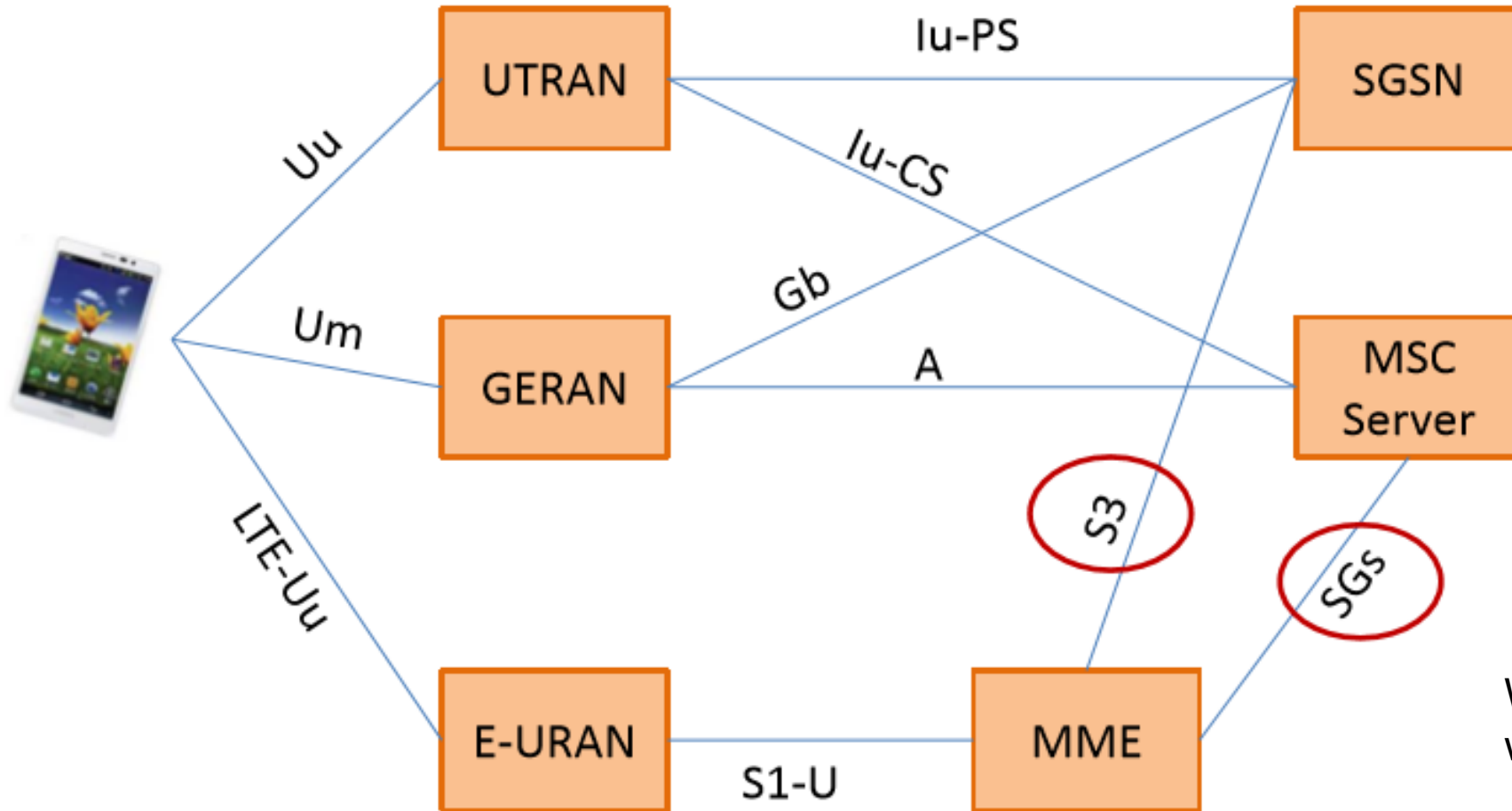


## CSFB

- CSFB=Circuit Switched Fall Back
- CSFB can make voice service on the LTE terminal in the traditional circuit domain system.
- CSFB process
  - UE register to the traditional CS domain
    - UE attached in the LTE
  - UE can originate calls in the CS system (MO)
    - Leave LTE system
  - UE can be called in the CS system (MT)
    - Leave LTE system



# CSFB system architecture



When CSFB occurs, the network will create a SGs Association

# Course Objectives:



- **Key technology of 4G LTE**
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  - Dual standby
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## Voice over LTE ( VoLTE )

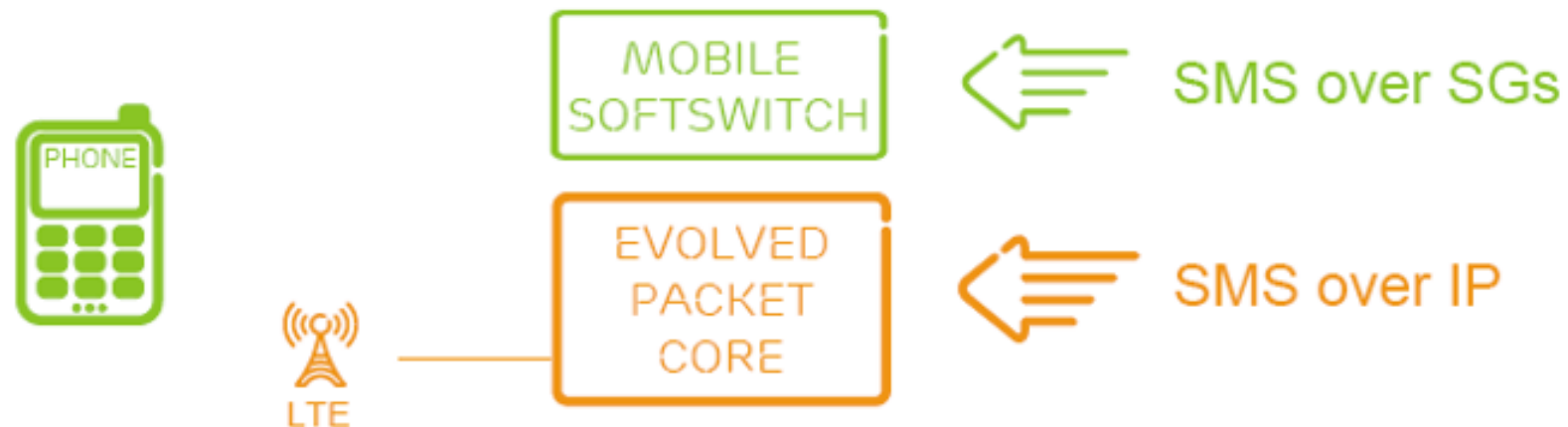
- LTE is a network that only provides packet domain, and is not supported in the circuit domain.
- VoLTE is to support VoIP voice function in LTE packet domain.
- Ideally, it should be like the 2G/3G network, voice and data services are both hosted in the LTE network.
  - Voice and data services are hosted in one LTE network solution is VoLTE
  - The alternatives are CSFB and SVLTE.
- VoLTE is a voice and video call enhancement technology, it fully utilize the advantages of LTE and improve the user experience sharply.



# SMS over LTE



- SMS over LTE can be achieved through the following two ways :
  - SMS over IMS
    - UE & Network needs to support IMS IM-SM-GW
  - SMS based on CSFB architecture: Scheme based on SGs interface
    - SMSC MSC MME UE: Equivalent to the SMS system in the 2G/3G
    - UE needs to support the joint CSFB attachment
- SMS over SGs or IMS is independent.





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Photo:



Siyuan Yang



• THANKS.

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