4G-LTE

Long Term Evolution

TELCOMA

Introduction

Background

1. 1G is analog wireless communication system like AMPS, TACS, etc.
2. Due to disadvantages of 1G, 2G comes into existence which is totally digital.
3. A very 1st technology in 2G for voice is GSM.
4. GSM is efficient to transmit voice but the main focus is on transmitting data.
5. Very 1st step towards data is 2.5G i.e. GPRS i.e. transmission of packets through radio or air interface

(contd...)

Background

6. Maximum speed achieved by using GPRS is only 40 kbps (practically).
7. 3G gives the maximum speed of 400 kbps that is 10 times more than 2.5G.
8. In between 2.5G and 3G, there is 2.75G which is EDGE (Enhanced Data for GPRS/GSM Evolution).
9. GPRS and EDGE combined to resolve data services in 2G.
10. Maximum data rate provided by EDGE is 200kbps (theoretical).
11. Practically, the data rate provided by EDGE is 170 kbps and by 3G is 384 kbps.

(contd...)

Background

12. For 3G, there is a partnership between five countries an this partnership is named as 3GPP (3rd Generation Partnership Project).
13. 3G UMTS achieved a practical data rates of 384 kbps.
14. After 3G, 4G is evolved. Japan had made bullet trains and they have given a target to provide internet connectivity with that much speed.
15. The only aim of 4G is to provide high speed data for high mobility users.
16. So, 1st step towards 4G is 3.5G i.e. combination of HSDPA/ HSUPA that provides data rates of 2mbps.

(contd…)

Background

17. After that there comes 3.75G which is HSPA+ i.e. advanced high speed packet access.
18. Then 3.9G is launched as pre 4G or 4G LTE.
19. 4G comes with the name of 4G LTE-A.

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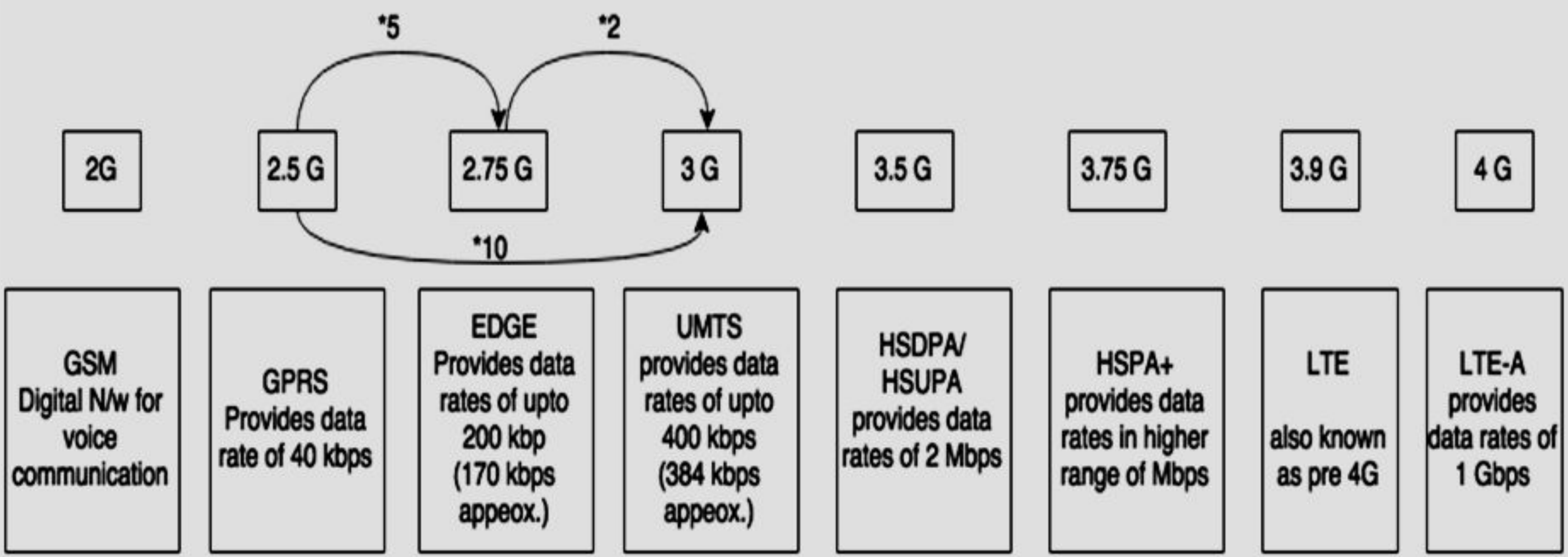
Background


*5
*2
2G
2.5 G
2.75 G
3 G
3.5 G
3.75 G
3.9 G
4 G
*10
GSM Digital N/w for voice communication
GPRS Provides data rate of 40 kbps
EDGE Provides data rates of upto 200 kbp (170 kbps appeox.)
UMTS provides data rates of upto 400 kbps (384 kbps appeox.)
HSDPA/ HSUPA provides data rates of 2 Mbps
HSPA+ provides data rates in higher range of Mbps
LTE also known as pre 4G
LTE-A provides data rates of 1 Gbps

Evolution

1. 3G is evolved with a name of R-99 (R stands for release).
2. After that number of releases were started from R-5 which is HSDPA which focuses on downlink speed only.
3. After that there comes R-6 which is HSUPA that focuses on uplink speed.
4. R-7 is a combination of HSPA and MIMO technology.
5. R-8 and R-9 are combination of HSPA and spectral flexibility. For voice transmission CSFB is used.

(contd...)

Evolution

6. R-10/ R-11 is 4G LTE-A that has a feature of VOLTE or IP telephony services.
7. The main aim of 4G LTE is data and for voice we have to fall back to 3G. This is known as CSFB.

LTE Characteristics

1. Vision of LTE is DARPA (Defense Advanced Research Projects Agency)
2. All the external routers and hubs are removed from the network which are the weaknesses of 2G/3G cellular systems.
3. LTE cell phones:
   a. Have transreceivers
   b. Routers for other devices

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LTE Characteristics

4. Full use of the spectrum
   a. No wastage of frequencies
   b. To fully utilize the spectrum unlike FDMA/TDMA and to make system less complex unlike CDMA, OFDMA is used in which frequency components should be orthogonal so that they can't interfere.
5. MIMO technology is used due to which the transmission as well as reception levels are increased so that in both way the speed will increase.

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LTE Characteristics

6. Less complex infrastructure
   a. From the radio network part, BSC/RNC was removed to reduce complexity of the network.
   b. Only e-NodeB is used.
7. Faster Handovers
   a. 4G is mainly used for high mobility services so that high speed internet access will be achieved.
   b. So faster HO is required with less Latency.

(contd...)

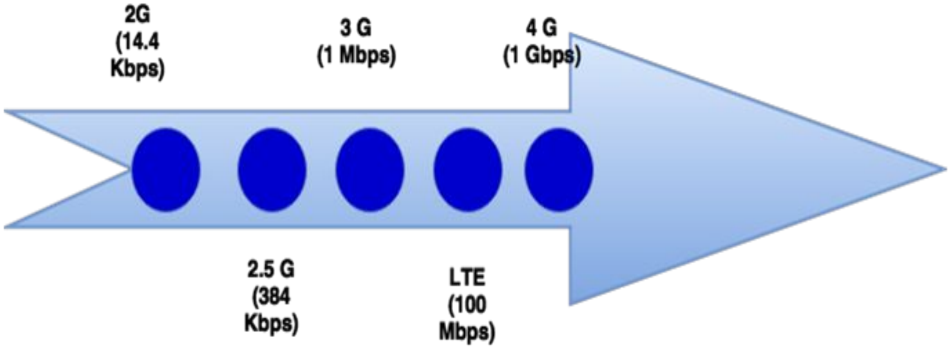
LTE Characteristics

8. IP Telephony
    a. Circuit Switching in 2G/3G cellular systems should be replaced with IP telephony.
    b. But this can be achieved only in LTE-A.

Fundamentals

What is 4G?

1. High Throughput (High Data Rates)
   a. Data rate is 1Gbps for stationary users .
   b. Data rate is 100Mbps for High mobility users.
2. Fully Packet Switched.
3. Works with IP.
4. It is a next level after UMTS 3G technology.



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LTE Features

1. Basic architecture is mainly divided into 2 parts:
   a. Radio Network
   b. Core Network
2. Instead of upgrading the system architecture of 2G and 3G, a new network architecture is evolved.
3. This evolution of new network architecture is called SAE (System Architecture Evolution).

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LTE Features

4. As high data rates are required, number of nodes should be less and faster and system architecture should be as simple as possible.
5. So all the nodes and entities required for packet switching should be organized in a smarter way.
6. In 2G cellular systems, there are BSC and BTS in RAN part and in 3G cellular systems, there are node B and RNC.
7. Therefore, all the handover decisions are with RNC or BSC.

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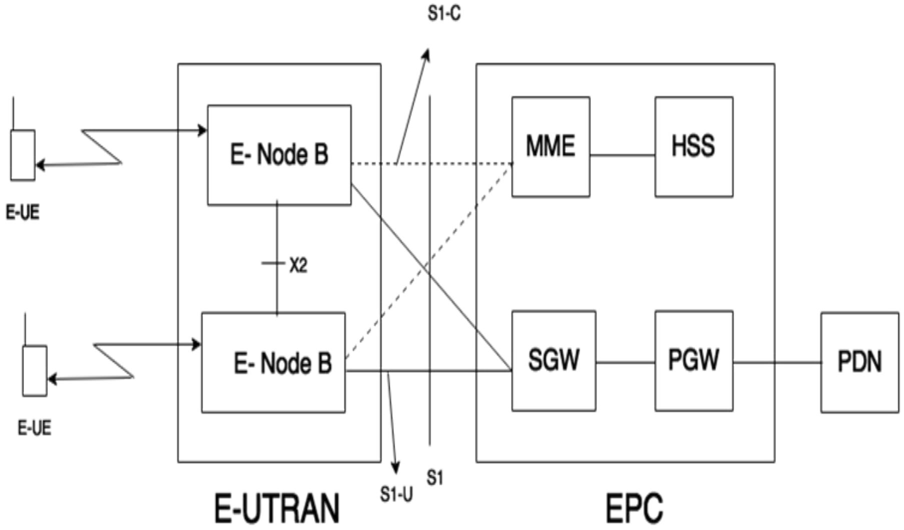
LTE Features

8. So to reduce the latency of handovers, all the handover and power controlling decisions are taken by only one node.
9. So RNC was removed from the network architecture of 4G.

LTE Architecture

1. E-UE (Evolved User Equipment):
   a. LTE handset
   b. Connected to E-UTRAN.
2. E-UTRAN:
   a. Radio access network of 4G.
   b. Connected to a core network.



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LTE Architecture

c. Has only one part (E-node B) and that node is not connected to any controller

3. EPC (Evolved Packet Core):
   a. New core which is packed switched
4. E-Node B
   a. Supports air interface
   b. Provides radio resource management functions, handovers.
   c. Serves as radio network controller.

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LTE Architecture

c. Communicates both with MME and SGW for signaling and data, respectively.

e. Interface between 2 E- Node Bs is X2.

5. Various databases attached with EPC:
   a. MME (Mobility Management Equipment):
      i. Manages mobility and provides security
      ii. Operates in control plane and provides authentication.

(contd...)

LTE Architecture

b. HSS (Home Station Subsystem):

  i. Provides location update.

  ii. Stores each and every information related to the user (IMEI, IMSI etc.).

c. SGW (Serving Gateway):

  i. Provides Mobility.

  ii. Responsible for Routing and Forwarding.

  iii. Connected to Public Data Network (PDN) through PGW for data.

(contd...)

LTE Architecture

d. PGW (PDN Gateway):

   i. Provides connectivity to Internet.

   ii. Provides QoS and mobility between 3G and 4G

6. All these entities are interconnected in EPC with each other.
7. Interface between E-UTRAN and EPC is S1 interface that is for signaling part S1-C interface is used and for data part S1-U interface is used.

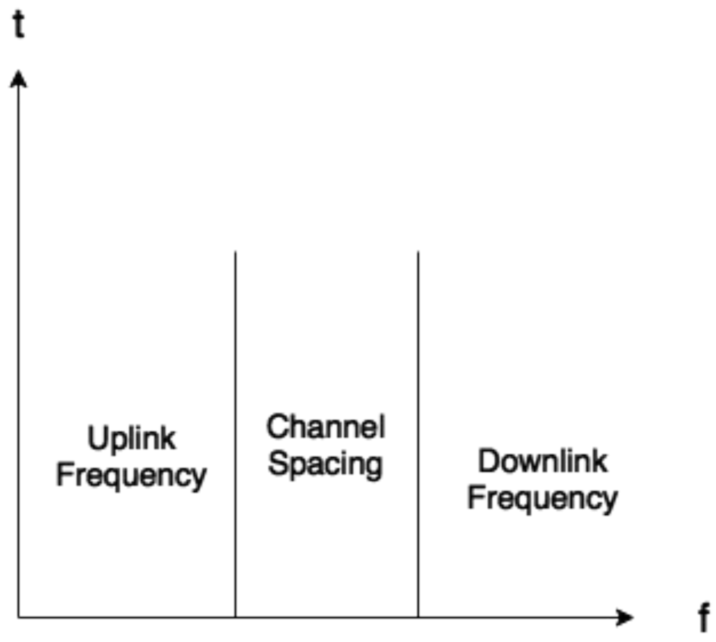
Frequency Bands

Introduction

1. LTE offers data rates of 100 Mbps for high mobility users and 1 Gbps for stationary users.
2. In order to carry this speed, a resource is required which is the frequency.
3. So, 3GPP offers frequency band in 2 modes i.e. FDD and TDD.
   a. FDD (Frequency Division Duplex): frequency is divided
   b. TDD (Time Division Duplex): time is divided

FDD

1. In this, frequency is to be divided.
2. Both the uplink and downlink frequencies are separated with a separation between them which is called channel spacing.



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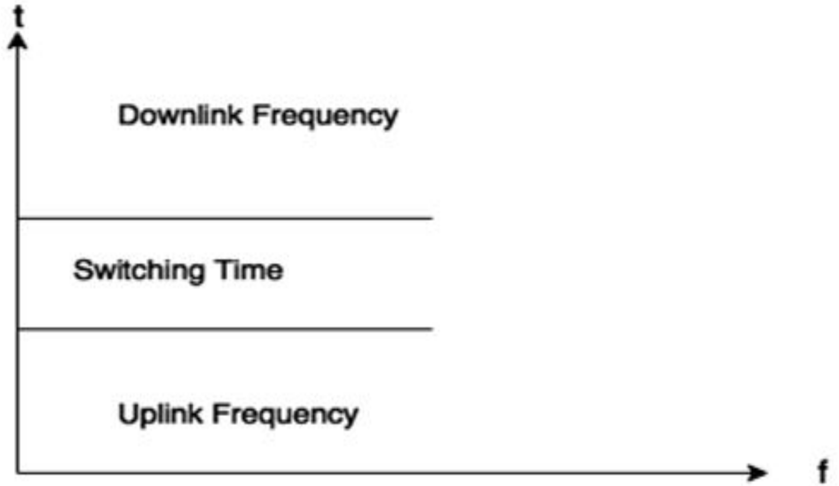
FDD

3. Channel spacing is needed to avoid the interference between both uplink and downlink frequencies.
4. For instance, 2100 MHz band is divides as 1920-1980 MHz (Uplink) and 2110-2170 MHz (Downlink) and there is a channel spacing of 30 kHz to avoid interference.
5. Number of bands are available in FDD mode
6. Out of these, B.6 is not applicable and B.7, B.14, B.21 are commonly used bands that works on 700 MHz frequency band.

TDD

1. In this case, time is to be divided.
2. Half of the time is used to carry uplink data and half of the time to carry downlink data and in between there is a space which is called a switching time (in order to jump from uplink time to downlink time and vice-versa).



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TDD

3. For instance, band1920-1980 MHz carries uplink as well as downlink data but with the division of time.
4. Number of bands ranges from B.33 to B.43 are available.
5. According to the need and usage of the operator any band can be used.

Frequency Spectrum

1. Usage of Spectrum:

2G (GSM/GPRS/EDGE)	CDMA	3G (UMTS)	4G (LTE)
Fixed BW of 200 kHz	Fixed BW of 1.25 MHz	Fixed BW of 5 MHz	Variable BW of 1.4, 3, 5, 10, 15, 20 MHz

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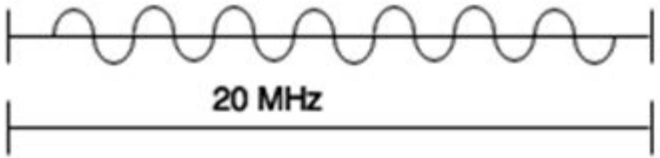
Frequency Spectrum

2. For instance, there are 2 areas.
3. In area 1 (metro area), high mobility service data is to be provided for good speed internet access. So, high bandwidth is offered.
4. In 2nd area speed is not required. So, low BW is offered to that area.

Subcarriers

1. Subcarriers are used to carry data as well as signaling.
2. Suppose there is a 20 MHz Bandwidth and there are number of subcarriers in this bandwidth.



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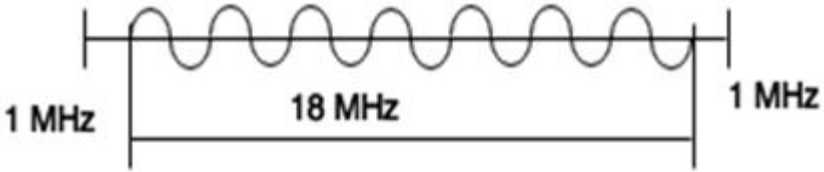
Subcarriers

3. To calculate number of subcarriers, as per the rules of 3GPP, 10% of the total BW is left, i.e.

   10% of 20MHz = 2MHz (leave)

4. Therefore, total available BW is 20 MHz, and useful BW is 18 MHz.



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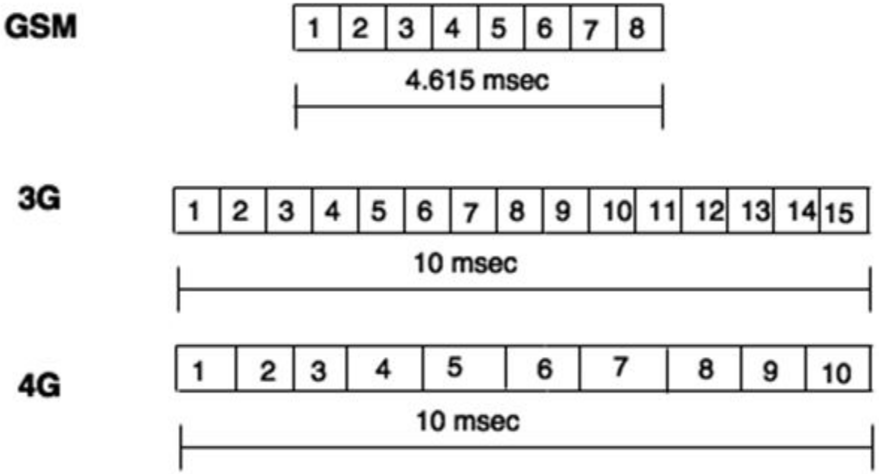
Subcarriers

5. Number of Subcarriers = total useful BW/15 kHz (each subcarrier is of 15 kHz) = 1200
6. For 15 MHz, number of subcarriers are 900 and 600 for 10 MHz and so on.
7. The number of subcarriers decreasing with decrease in BW because with decrease in BW speed will also goes on decreasing.

Frame Format

1. Figure shows the frame format of 2G, 3G and 4G.
2. There are 8 time slots in 2G of 4.615 msec duration and 3G has 15 TS with duration of 10 msec.
3. But in 4G there are 10 blocks of duration of 10 msec. It doesn't contain any time slots.



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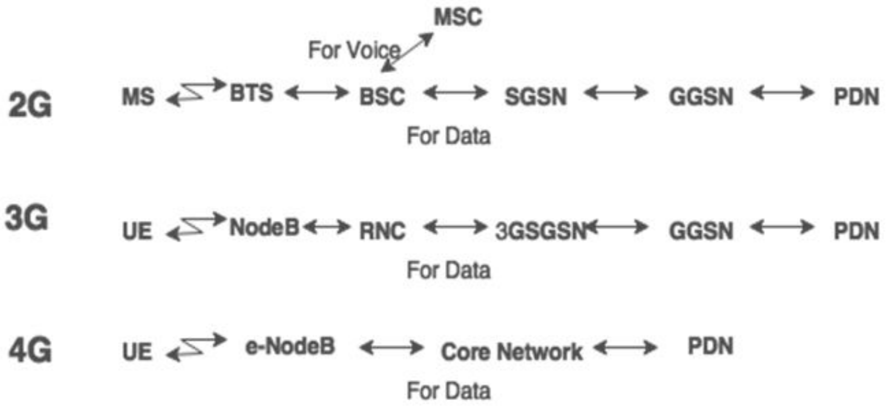
Frame Format

4. 1 block is of 1 msec. So, this block of 1 m sec is called TTI (Transmit Time Interval).
5. Only 1 block can transmit data as well as signaling.
6. TTI of 2G and 3G can also be calculated
7. For 2G, TTI = 4.615/8 = 0.577 msec.
8. For 3G, TTI = 10/15 = 0.667 msec.
9. It is clear that TTI of 4G is higher than all the previous generations. Hence the speed is faster when using 4G.

Architecture

Background

1. The main aim of 4G is high mobility and this can be achieved by reducing complexity of the network.
2. Complexity can be reduced by reducing the number of nodes in the network.



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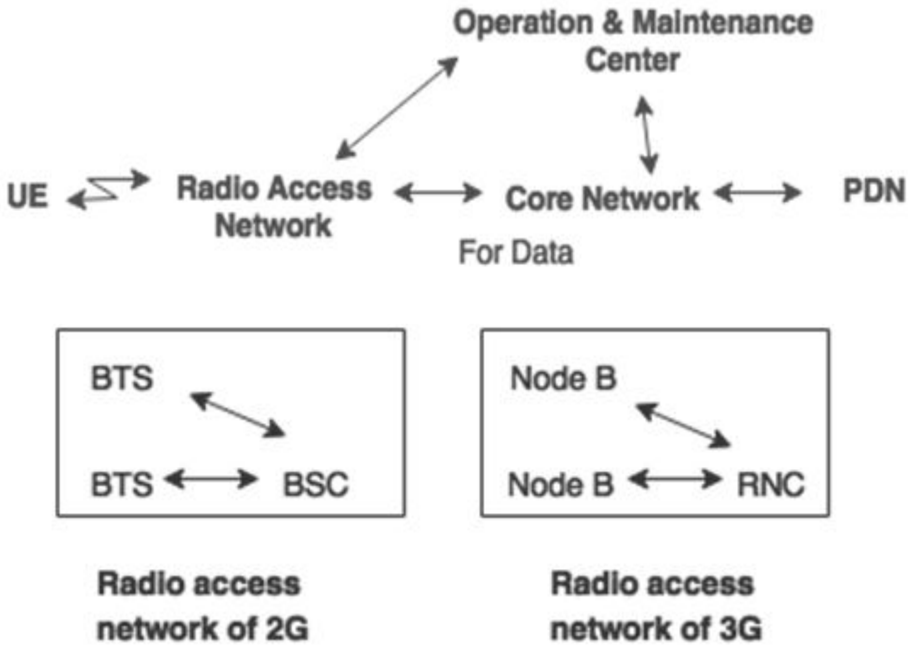
Background

3. In 2G, there are four nodes between user and external data network.
4. In 3G also, there are four nodes between user and external data network.
5. In 4G, number of nodes are reduced by eliminating RNC/BSC from the previous 3G/2G networks, respectively.
6. As moving from 2G to 3G, we have to change the RAN part.

Comparison

1. The basic requirements for any network are shown in the figure.
2. For 2G, RAN part is BSS and Core part is NSS.
3. RAN part of both 2G and 3G are shown here.



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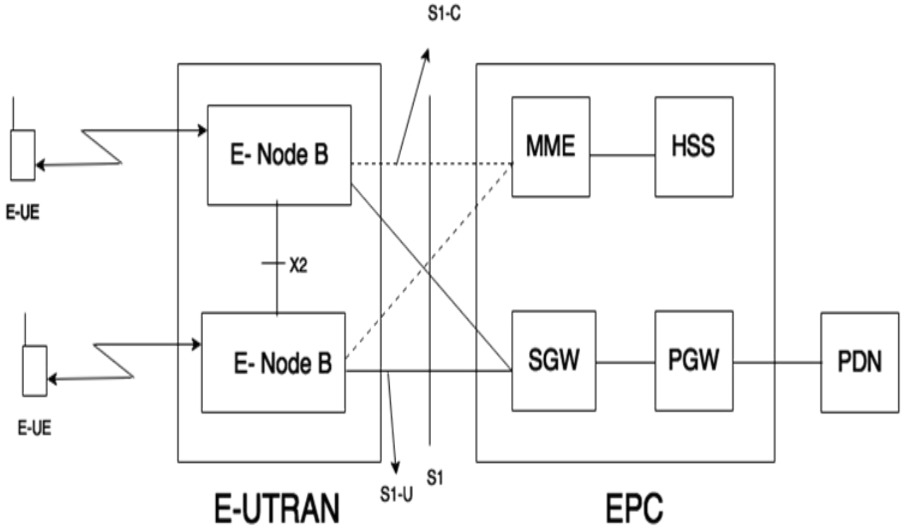
Comparison

4. In both cases, user is controlled by one node which is again controlled by another separate node.
5. But, there is a single controller in 4G i.e. eNB so that handovers should be faster.
6. In 2G/3G cellular networks, when MS wants HO measurement reports that have Rx level and Rx quality are sent to BTS which are further forwarded to BSC.
7. BSC checks there MRs and asks for HOs that take some time which is not the case in 4G.

Architecture

1. LTE UE uses MIMO technology which is connected to RAN via air or Uu interface.
2. RAN part is known as EUTRAN (evolved universal terrestrial radio access network).



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Architecture

3. E-UTRAN contains only one separate controller that is E-Node B which is attached to core network.
4. Core network of 2G as well as 3G contains MSC and its databases for voice transmission and SGSN, GGSN and all its databases for data transmission.
5. While for 4G new core network is evolved which is named as EPC.
6. This evolution of new core network is termed as SAE.

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Architecture

7. Entities attached to EPC are:
    a. MME (Mobility Management Equipment)
    b. HSS (Home Station Subsystem)
    c. SGW (Serving Gateway)
    d. PGW (Paging Gateway)
    e. PDN (Public Data Network)
    f. PCRF (Policy Control Radio Function)
8. Interface between UE and E-UTRAN is Uu and between 2 E-Node Bs is X2.

(contd...)

Architecture

9. Interface between E-UTRAN and EPC is S1 interface that is for signalling part S1-C interface is used and for data part S1-U interface is used.
10. MME provides information regarding changing locations, authentication and handovers.
11. HSS provides the functions same as that of HLR.
12. SGW functions same as SGSN and provides routing of all data packets .
13. PGW functions same as SGSN and allocates different IP addresses.
14. PCRF provides handover from one generation to another generation.

Network Description

1. UE
    a. Must have USIM (Universal Subscriber Identity Module) which is an electronic chip having an electrical interface with handset.
    b. Handset is different from that of 2G/3G because it requires high data rates transmission.
    c. This handset uses MIMO technology that has number of configurations i.e. 4 X 4, 4 X 2, 2 X 4, 2 X 2.
    d. A transreceiver.

(contd...)

Network Description

2. E Node B
    a. Its main function is Radio resource management.
        i. Resource allocation.
        ii. Handover control.
    b. Radio resource parameter check
    c. Closed loop power control

(contd...)

Network Description

3. MME
    a. Its main function is Mobility resource management.
        i. Handovers.
        ii. Security control:
            1. Security in RAN is Access Stratum (AS)
            2. Security in CN is Non Access Stratum (NAS).

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Network Description

4. HSS
   a. It functions same as HLR.
   b. It is the permanent database that contains user related information.
5. SGW
   a. Its main function is routing of data.
6. PGW
   a. IP allocation and routing
   b. Has DNS (Domain Name Server) connectivity to connect to different servers.

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LTE Key Points

Key Points

1. Number of users:
   a. The 1st key point of 4G LTE is having more number of users and accommodate all users with high internet speed.
2. Access scheme:
   a. There are 3 main access schemes i.e. TDMA, FDMA, CDMA.
   b. In 4G OFDMA access technique is used.
3. Hardware
   a. For 4G a new and smarter hardware is required for faster processing.

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Key Points

4. UE Categories
   a. For downlink, 64 QAM modulation technique is used for all categories.
   b. For uplink, 16 QAM modulation is used for UE categories 1-4 and 64 QAM modulation for UE category 5.

UE categories	1	2	3	4	5
UL speed	10 Mbps	50 Mbps	100 Mbps	150 Mbps	300 Mbps
DL Speed	5 Mbps	25 Mbps	50 Mbps	50 Mbps	75 Mbps

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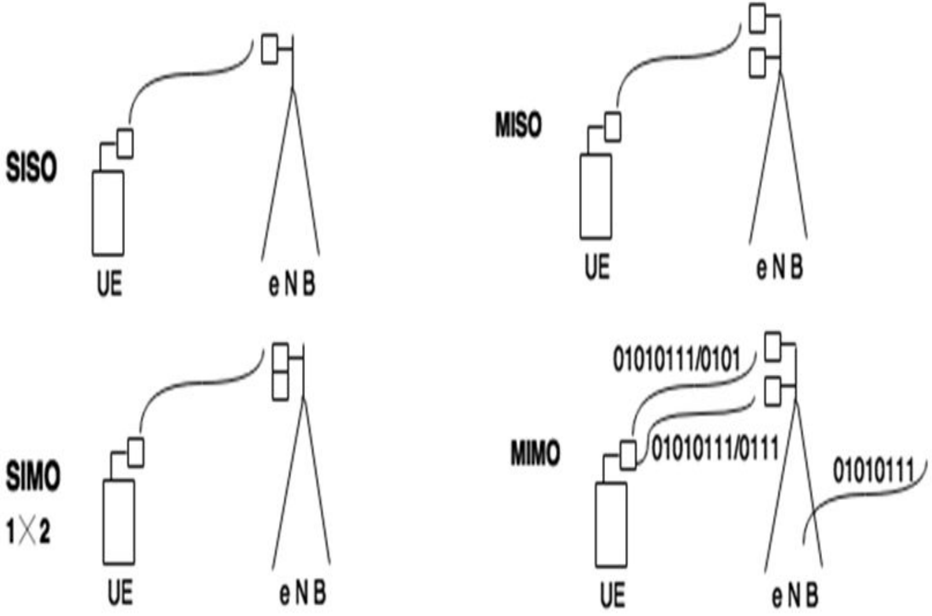
Transmission Techniques

1. MIMO stands for multiple inputs and multiple outputs
2. SISO is having only 1 transmitter and 1 receiver.
3. SIMO is having only 1 transmitter and multiple receivers. This is known as receiver diversity.



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Transmission Techniques

4. MISO is having multiple/number of transmitters and only 1 receiver. This is known as transmitter diversity.
5. While in 4G MIMO (Multiple Inputs and Multiple Outputs) technique is used which uses both transmitter as well as receiver diversities.
6. For instance, if we have to send 01010111, there are 2 methods to send this information, either we will send 01010111 on both the channels or else 0101 on 1 channel and 0111 on the other. This is known as spatial diversity.
7. The highest configuration in MIMO technology is 4 X 4 configuration.

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Transmission Techniques

8. In this case e N B has 4 TRXs, and practically, there is a need of 4 TRXs at UE also.
9. As network has some limited capacity where multiple TRx can be added but for UE which is a portable device, more the number of TRx can made the system bulky and configuration becomes very tough.
10. So, 4 X 2 configuration is mostly used.
11. MIMO technology is used in antenna configuration to increase the transmission and reception levels of the network.

Modulation

1. Superimposing weak signal on a strong signal so that it can carried at long distance.
2. In GSM and GPRS, GMSK modulation is used in which 1 bit is modulated at a time. IN EDGE, 8PSK modulation is used in which 3 bits are modulated at a time.
3. In 3G UMTS, modulation techniques used are BPSK for uplink in which 2bits are modulated and QPSK that modulates 4 bits at a time.

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Modulation

4. In 4G, modulation techniques used are 16QAM that modulates 4 bits at a time at an angle of 90 degrees and 64QAM that modulates 6 bits at a time each at an angle of 90 degrees.

LTE Resource Blocks

Introduction

1. To accommodate large number of users, more bandwidth is required.
2. All these BWs are divided into a group/blocks of 12 subcarriers.
3. Therefore, 20MHz band can have 100 groups or also called scheduling blocks.
4. Similarly for 15 MHz band there are 60 scheduling blocks, 10 MHz band has 50 scheduling blocks, 5MHz band has 25, 3 MHz has 15 and 1.4MHz has 6 scheduling blocks.

(contd...)

Introduction

5. In 4G, for 20 MHz band, there are 100 scheduling blocks i.e. 10 blocks of 10 msec each.
6. LTE frame has 10 blocks having duration of 10 msec. Each block is known as scheduling block or subframe.
7. Therefore, in 1 LTE frame there are 10 subframes.
8. 1 subframe is divided into 2 slots.
9. Hence, 1 frame has 20 slots. These slots are called resource blocks (RB).

(contd...)

Introduction

10. Each RB is divided into frequency domain as well as in time domain.
11. So there are 12 OFDMA symbols/subcarriers in 1 RB.
12. These subcarriers are divided in time by cyclic prefix method.

Cyclic Prefix and OFDM

1. Prefixing of the symbol with repetition of the end.
2. OFDM uses cyclic prefixes to combat multipath by making channel estimation easy.
3. 2 methods are used Normal Cyclic Prefix (NCP/7 symbols) and Extended Cyclic Prefix (ECP/6 symbols).
4. 12 subcarriers are divided into 7 blocks each. Hence, there are 84 resource elements when using NCP method.

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Cyclic Prefix and OFDM

5. In RB, some of the REs are RS (Reference Signals) that are LTE channels.
6. For ECP, 12 subcarriers are divided into 6 blocks each. Hence, there are 72 REs.
7. In normal cyclic prefix, seven symbols are used, the time duration of the symbol using at that time is more than that of the previous symbols because it represents the start of the symbol.
8. In OFDMA, the function of orthogonality is used in which each symbol is at an angle of 90 degrees. So, these symbols can never interfere.

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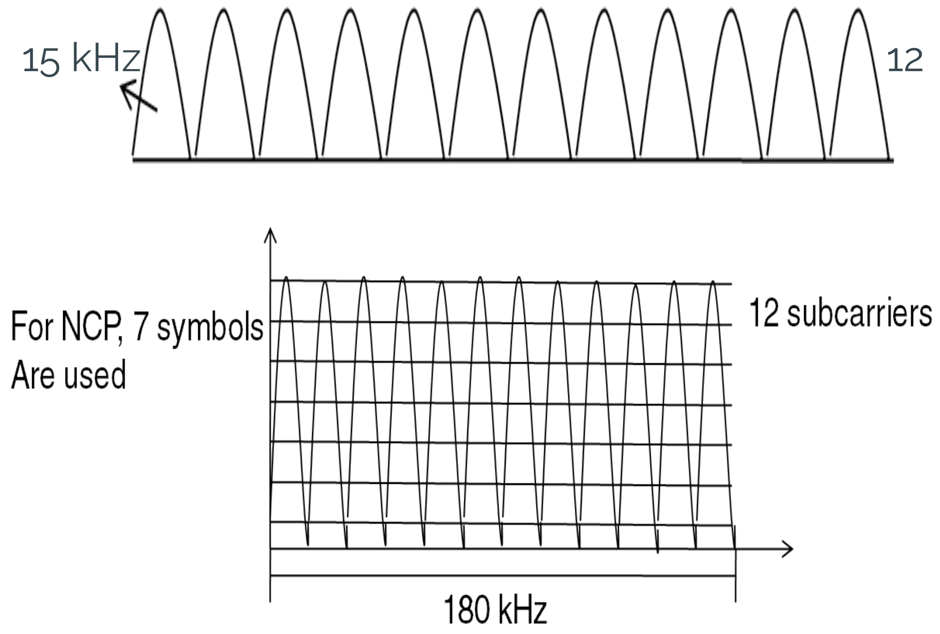
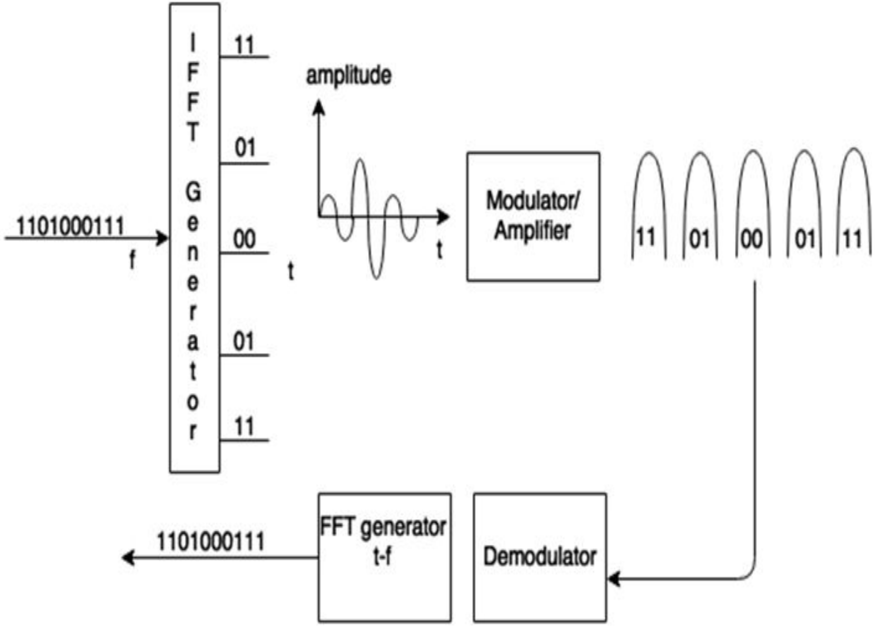
Cyclic Prefix and OFDM

9. Hence, all the subcarriers are orthogonal to each other like walsh codes in CDMA.
10. Each carrier of LTE=15 kHz
11. Hence, each RB is of 180 kHz.
12. Each RE can carry different data or same data.
13. For downlink, OFDMA is used
14. For uplink, SCFDMA is used.



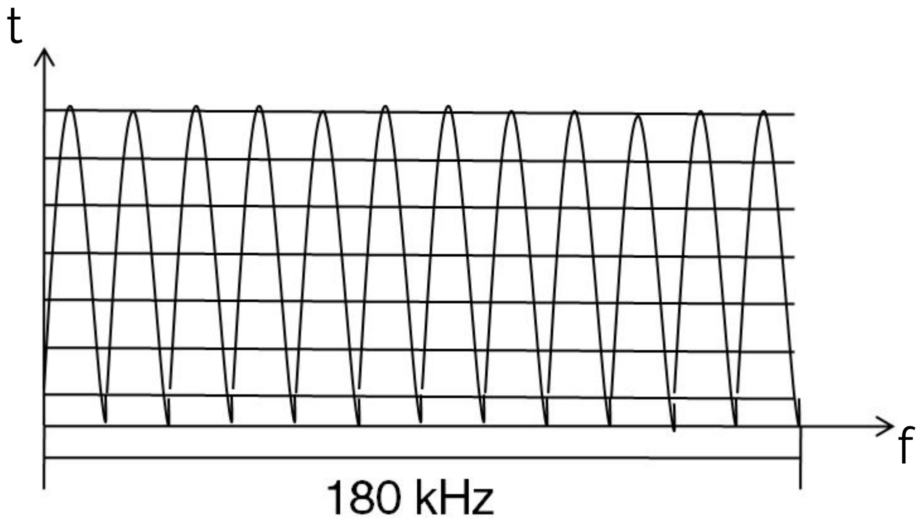
OFDM Generation

1. 2 transform techniques are used: IFFT and FFT.
2. Fourier transform is used to convert frequency to time domain and vice-versa.
3. For converting time to frequency domain, IFFT is used and for inverse process FFT is used.



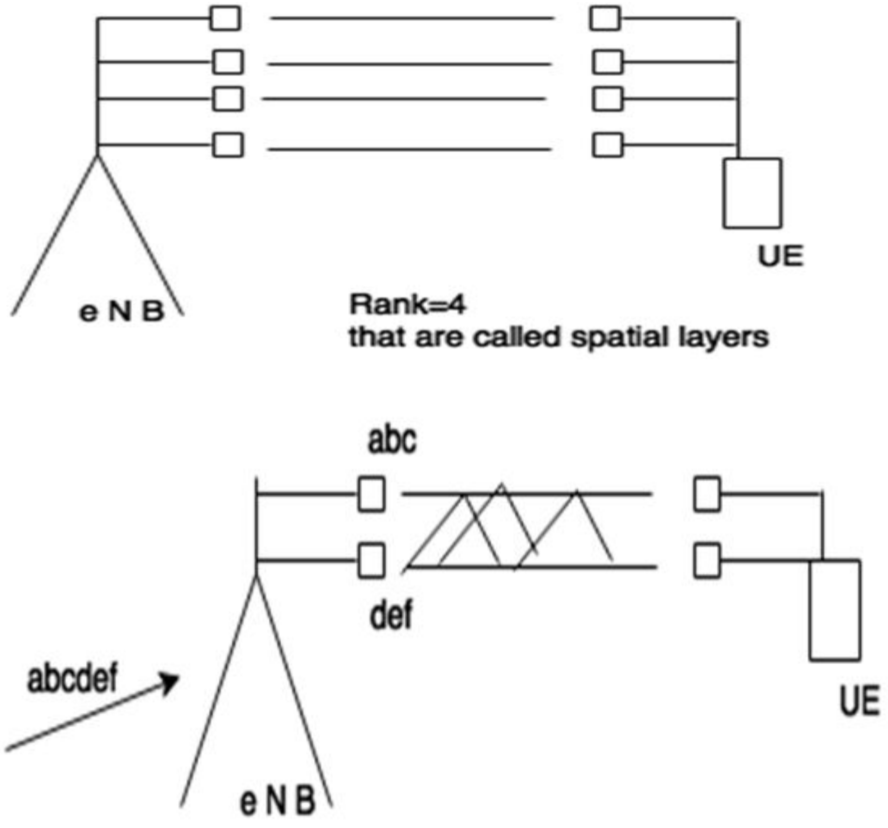
SCFDMA

1. Same data on different subcarriers.
2. In UE power amplifiers are used to reduce the peak to average power ratio.
3. To reduce peak to average power ratio, SCFDMA scheme is used.



Spatial Multiplexing

1. In 4G multiple antennas are used and number of antennas represent number of layers which is called Rank.
2. Different data can be transmitted through different path in shorter period of time. This will increase capacity and reduces the range.
3. But if same data is sent through every transmitter, the coverage will increase and speed is reduced.



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LTE Channels

Introduction

1. A channel may be defined as a medium or path through which a user is interconnected to the network.
2. It is used to send information signal from one or several transmitters to one or several receivers.
3. Channel may be uplink, downlink or bidirectional.
4. Channels use two types of media:
   a. Cables (twisted pair wire, copper wire, or fiber-optic cable)
   b. Broadcast (microwave, satellite, radio, or infra red)

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Protocol Model Layers

1. There is a 3 layer model i.e. physical, data link and network layer.
2. In GSM there in not any mapping of channels. In 3G, all the channels are mapped.
3. Three different channels are: logical channels, physical channels and transport channels.
4. Physical channel: user is in direct contact with this channel to send/receive uplink or downlink information and works in physical layer.

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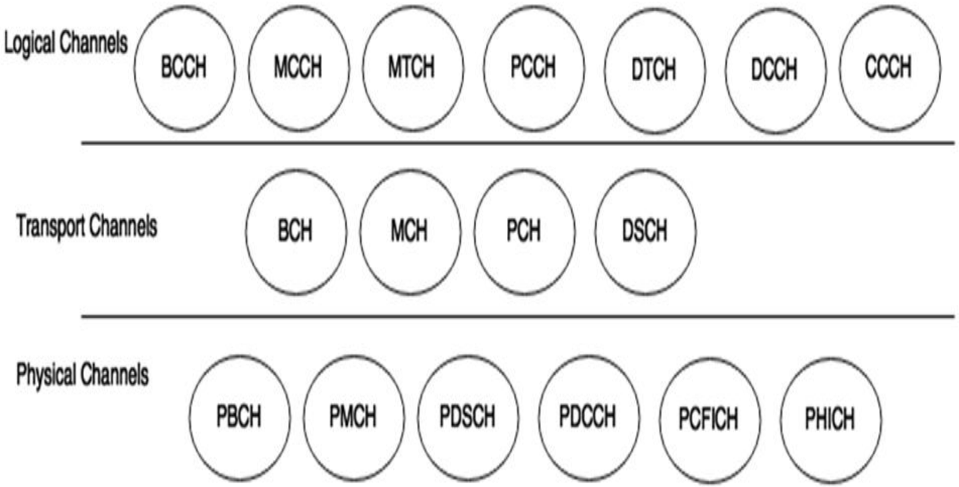
Protocol Model Layers

5. Logical Channels: Network will communicate with the user with the help of logical channels and works in network layer.
6. Transport channels: Provides a medium for physical channels to communicate with logical channels and vice-versa.

Downlink Channels

1. Information is transmitted from eNodeB to UE.



Broadcast Control Channel (BCCH)

1. Sends information from one to all
2. Includes information common to all like cell information, etc.
3. Has MIB (Master Information Block) & SIB (System Information Block)
4. MIB radiates static information (like frequency) and SIB is dynamic (like HO parameters, RF parameter, Power parameters).
5. BCCH of logical layer is mapped on BCH of transport layer which is further mapped on PBCH (Physical Broadcast Channel) of physical layer.

Multicast Channel (MCH)

1. Transmission from one end to a specified group.
2. Includes MCCH (Multicast Control Channel) for signaling & MTCH (Multicast Traffic Channel) for data.
3. Used for promotional services (offers/videos)
4. MCCH & MTCH are mapped on MCH and PMCH of transport and physical layers, respectively.

Paging Control Channel (PCCH)

1. Includes continuous location updates.
2. Mapped on PCH (Paging Channel) and PDSCH (Physical Downlink Shared Channel) of transport and physical channels, respectively.
3. Paging channels have 2 types: Paging Type I for idle users (no location updates) and Paging Type II for dedicated users (location updates).

Dedicated Channels (DCH)

1. Includes DTCH (Dedicated Traffic Channel) & DCCH (Dedicated Control Channel).
2. These are dedicated to a particular user shared multiple tasks.
3. DTCH & DCCH are mapped on DSCH (Data Shared Channel) of Transport channel and PDSCH of physical channel.

Common Control Channel (CCCH)

1. Used for continuous location changes.
2. Mapped on DSCH (Data Shared Channel) of Transport channel and PDSCH of physical channel.

Physical Data Control Channel (PDCCH)

1. Radiates information related to paging and HARQ (Hybrid Automatic Repeat Request).
2. PCIFCH & PDCCH work in collaboration.
3. 1 symbol represents only paging, 2 symbols represent paging and HARQ both and 3 symbols represent handover parameters are also received.

Physical Control Format Indication Channel (PCFICH)

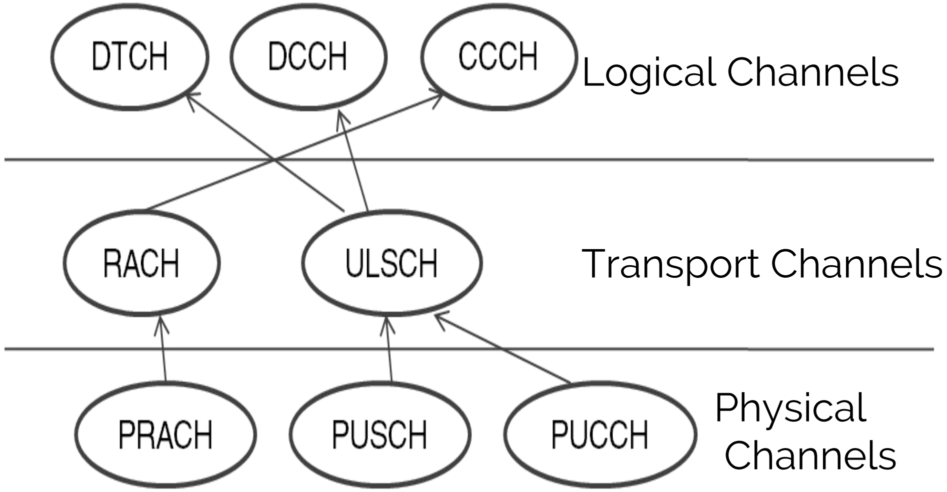
1. Indicates information in PDCCH (Physical Data Control Channel).
2. Has 2 bits. If 00, there is no symbol in PDCCH.
3. 01 represents one symbol, 10 represents 2 symbols and 11 represents 3 symbols.

Physical Hybrid Indication Channel (PHICH)

1. Indicates NACK (Negative Acknowledgement) i.e. data is not received and ACK (Acknowledgement) i.e. data is received.
2. If NACK is received, HARQ is requested.

Uplink Channels

1. In this case also same protocol structure is used as that of downlink channels.
2. User will contact with physical layer.
3. All channels of physical layer are mapped on channels of transport layer which are further mapped on channels of network layer.

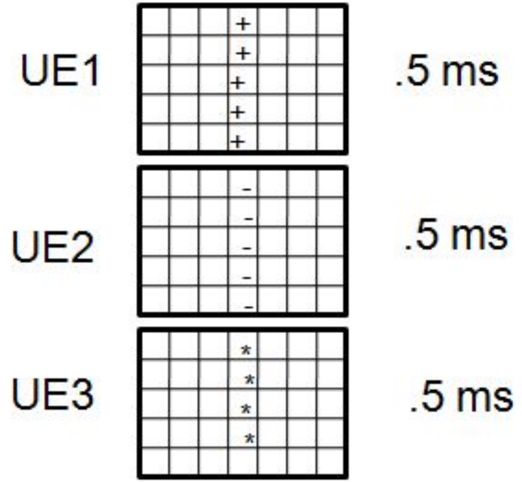


Uplink Signals

1. Uplink channels are required by UE to communicate with eNodeB.
2. Modulation used may be 16-QAM or 64-QAM.
3. SCFDMA multiple access scheme is used in uplink channels.
4. For uplink process number of signals are required.
5. There are two types of signals: DM-RS and SRS

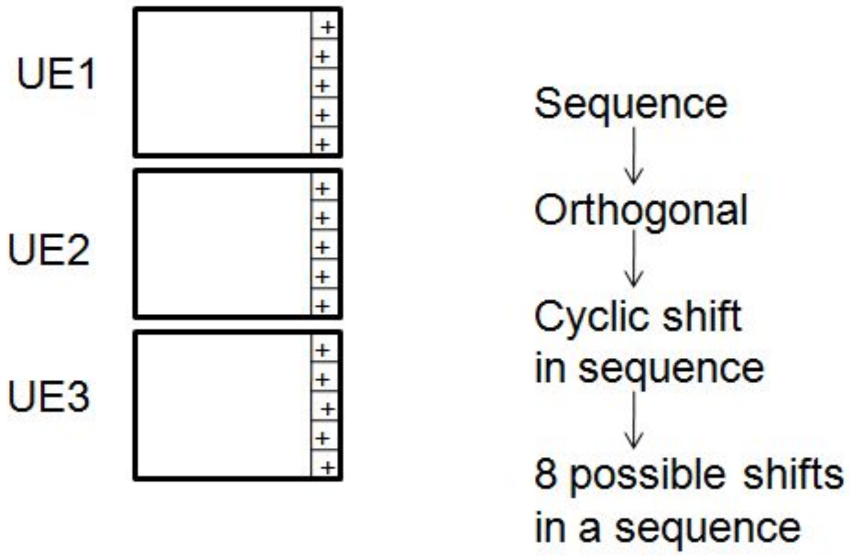
Data deModulation Reference Signal

1. UE sends a data modulated on some carrier to increase the signal strength.
2. These signals are added in modulated signal so that it can be demodulated at eNB end.
3. DMRS is located at the center of SCFDMA.
4. As, in figure, there are different modulated signals in case of 3 UEs so eNB demodulates the signal accordingly.



Sounding Reference Signals

1. Used to have estimation of channel quality by eNB uplink scheduler.
2. Transmitted over entire bandwidth with periodicity of 2,5,10,20,40,80,160,320 msec.
3. PUSCH is used for transmission in uplink process to carry SRS.
4. PUCCH is used to carry information regarding CQI levels and for scheduling request and uses the concept of ACK and NACK.
5. Only one channel can transmit at a time.

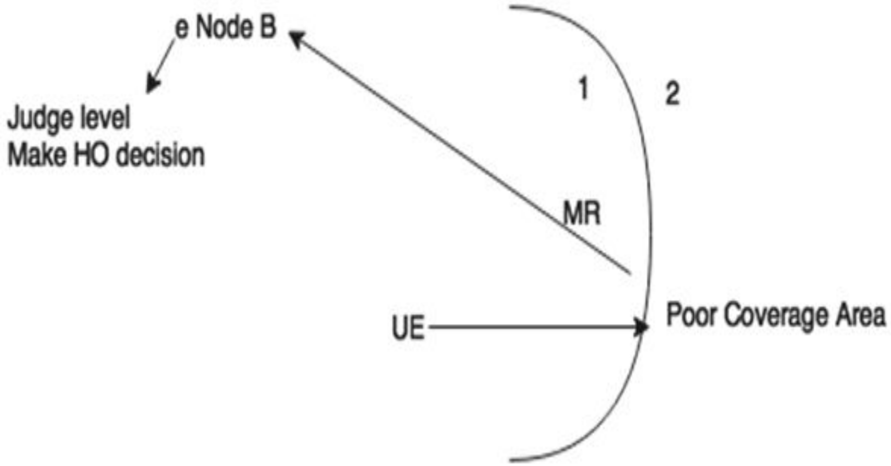


Power Class of UE

1. Some power classes are defined according to which it can transmit or consume a power.
2. Four power classes are defined.
3. Power for PC1 is 23 dBm, for PC2 27 dBm, for PC3 30 dBm and for PC4 33dBm.
4. Number of power classes are used to transmit desired power to e NodeB.

Handovers in LTE

1. Hard handovers: break before make (GSM).
2. Soft handovers: make before break (W-CDMA).
3. LTE adopts hard handover scenario.



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Handovers in LTE

4. HO criteria
   a. MR
   b. Analysis
   c. HO decision
   d. HO failure/success
5. HO Categories
   a. X2 based HOs
   b. S1 based HOs

(contd...)

Handovers in LTE

6. HO related to frequency
   a. Interfrequency Hos: when frequency bands are different
   b. Intrafrequency Hos: within a same frequency band
7. IRAT (Inter Radio Access Technology) HO
   a. From one generation to another generation i.e. from 4G to 3G and so on.

Spatial Multiplexing

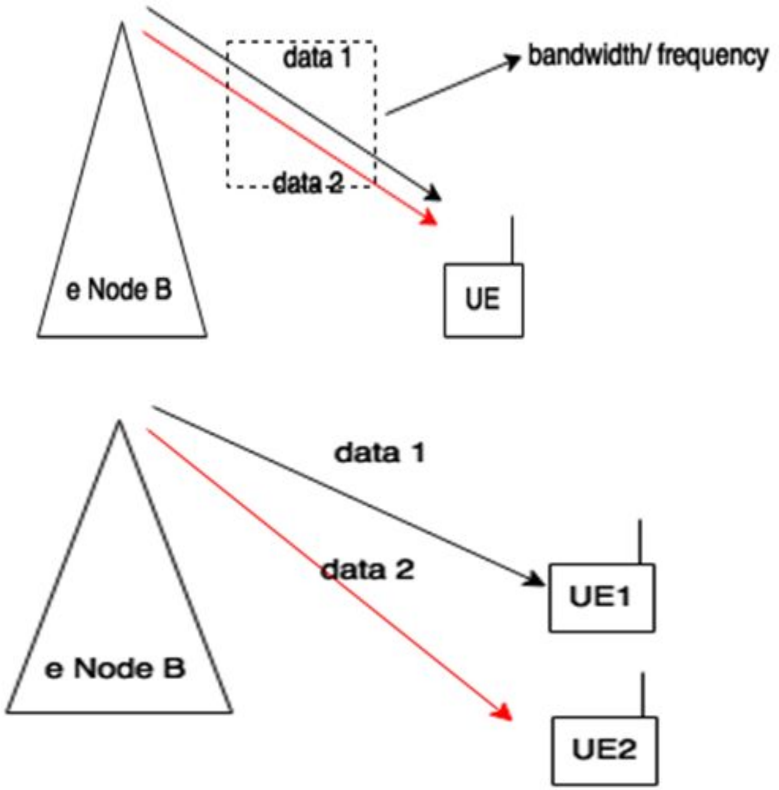
Introduction

1. UE and eNodeB can communicate with each other using air interface.
2. UE can send number of data streams for uploading and e Node B can send number of streams for downloading in air interface.
3. To control this transmission over air interface spatial multiplexing is used.
4. In spatial multiplexing, different data is transmitted to single user on a same resource.

(contd...)

Introduction

5. It improves cell edge performance.
6. SDMA (Space Division Multiple Access):
   a. Multiple users can use same e Node B.
   b. Different data is sent to different users.



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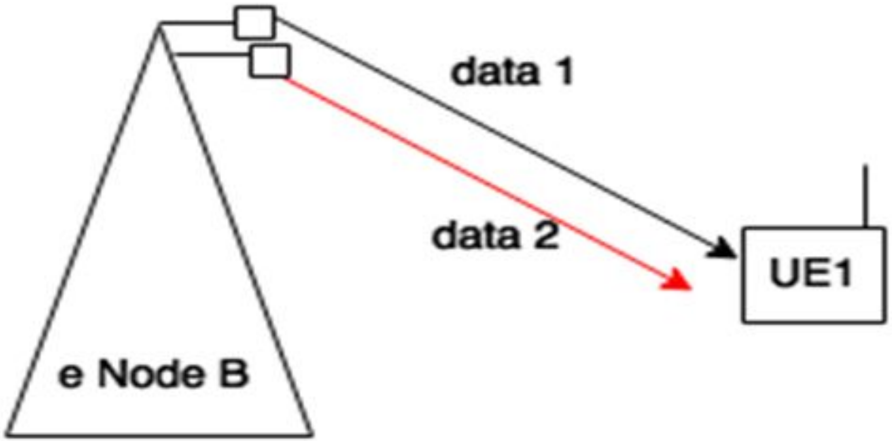
Introduction

7. Transmitter Diversity
   a. Multiple transmitters to send data.
   b. Spatial Multiplexing concept is used.
8. Uplink MIMO follows spatial multiplexing and SDMA.
9. Downlink MIMO follows spatial multiplexing, SDMA and transmitter diversity.



Spatial division multiplexing modes

1. Open loop modes: No feedback is there so data can't be retransmitted.
2. Closed loop modes: feedback is there so data can be retransmitted.
3. Parameters are: CQI(Channel Quality Index), RI (Rank Indicator), PMI (Pre-coding Matrix Indication).
   a. CQI(Channel Quality Index) includes RSRP, RSRQ, RSRP
   b. RI (Rank Indicator) includes number of antennas used.
   c. PMI (Pre-coding Matrix Indication) includes indication about data; whether same data is sent or different data is sent.

(contd...)

Spatial division multiplexing modes

4. Codewords are sent from transmitter to receiver to provide security to the data.
5. Maximum allowed codes used in LTE are 2.

LTE Synchronization

Precoding Techniques

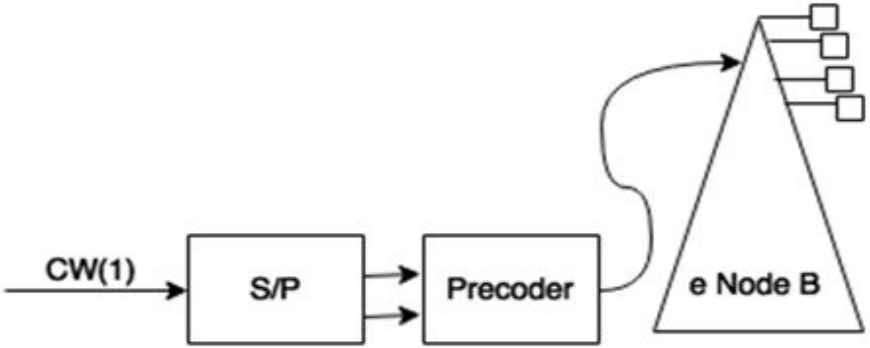
1. LTE use maximum of 2 codewords.
2. 1 X 4 precoding:
   a. I codeword is precoded and sent through 4 antennas.
3. 2 X 4 precoding:
   a. 2 codewords are precoded and sent through 4 antennas
   b. One is sent through first 2 antennas and second code by other 2 antennas.

(contd...)

Precoding Techniques

c. Retransmission is done by using serial to parallel converters.

d. In this case single code is divided into two parts when 2 X 4 precoding is used.



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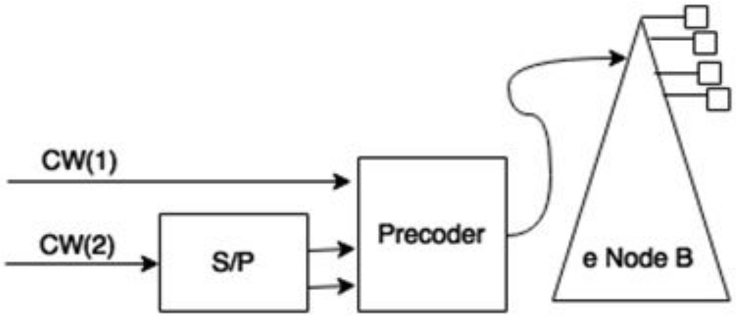
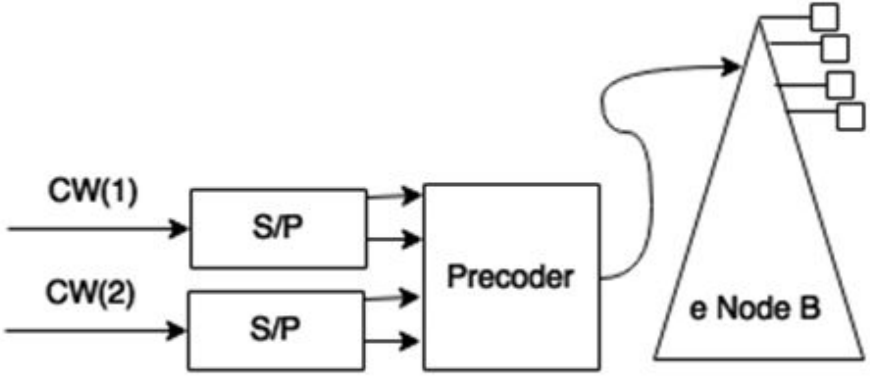
Precoding Techniques

1. 3 X 4 precoding:



2. 4 X 4 precoding:



Key Points

1. Multi User MIMO :
    a. MIMO is provided for multiple users.
    b. Throughput will be increased by generating more codewords and precoding techniques.
2. Single User MIMO:
    a. MIMO is provided for only a single user.

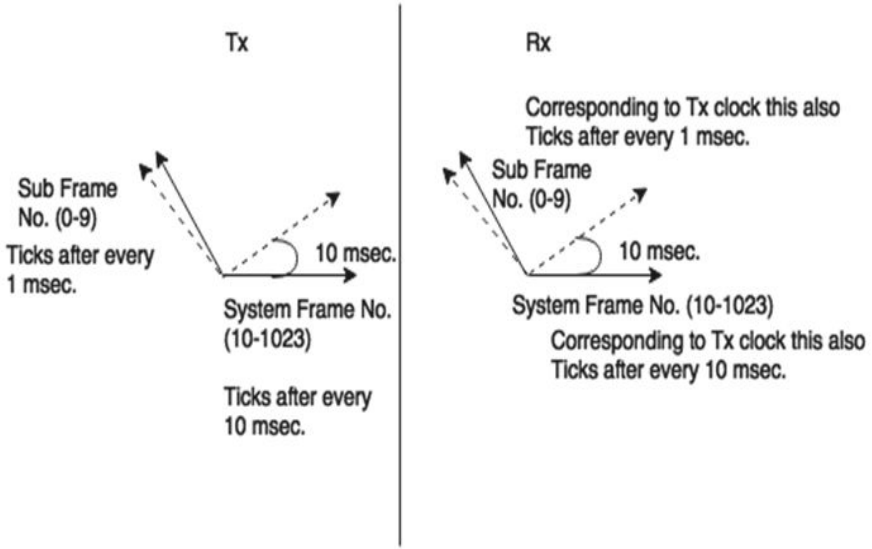
LTE Synchronization

1. For proper data transfer without any delay, synchronization is required.
2. Delay will result in redundancy or network failures.
3. Whole system can be synchronized with the help of clocks.
4. Every network should be timely synchronized so that there will not be any lag.
5. If there is any lag, there is a probability of collisions.

(contd...)

LTE Synchronization

6. Let us suppose that receiver clock has 3 pm time and it must be synchronized with the transmitter.
7. If transmitter transmits at 3 pm then receiver will receive at 3 pm only without any lag.
8. For synchronization, clocks will be accurate.



Synchronization Procedure During Initial Request

1. When UE is initiated, the procedure required to synchronize with e NodeB is called synchronization step.
2. Both UE and eNodeB has system frame numbers and sub frame numbers to remain in synchronization.

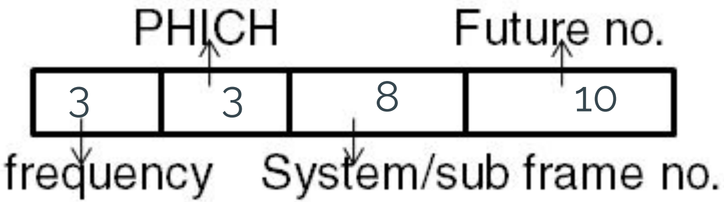
Synchronization Channels

1. PSCH (Primary Synchronization Channel): synchronizes System Frame No.
2. SSCH (Secondary Synchronization Channel): synchronizes Sub Frame No.
3. Physical broadcast channel is used to radiate information (MIB, SIB) to all the subscribers.
4. eNodeB radiates MIB after every 40 msec that contains either same information data or different data.

(contd...)

LTE Synchronization

5. MIB has 24 bits.



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LTE Cell Search

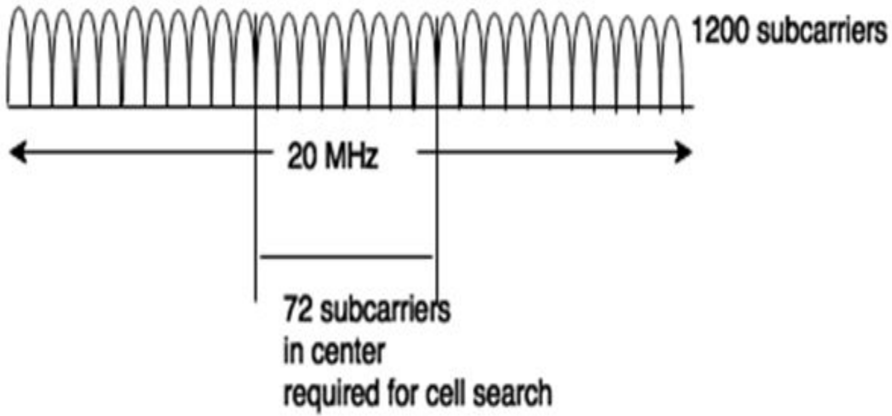
Basis of Cell Search

1. There are number of cell and we have to identify each n every cell.
2. In order to search each and every cell, identification is required which is termed as Physical Cell ID (PCI).
3. Each sector has a different ID (PCI).
4. To get access to the network, user has to find the PCI and this process is referred to as cell search.
5. Purpose of cell search is to connect to a nearby cell.

(contd...)

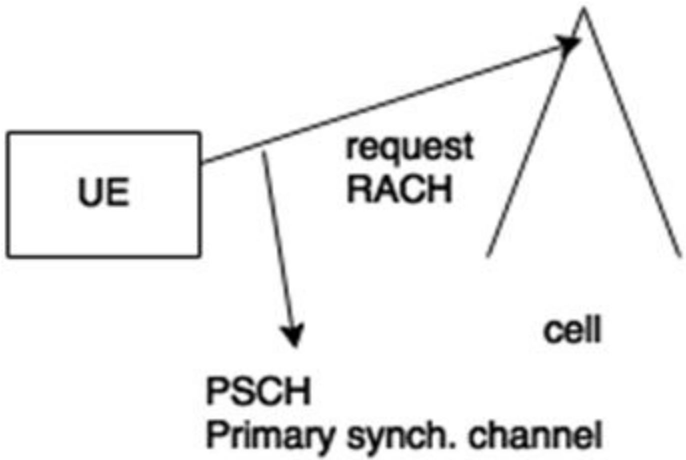
Basis of Cell Search

1. Total available PCI in LTE = 504
2. This whole PCI must be divided in a group of 3.
3. UE sends one group to search for a nearby cell.
4. Hence, total groups are = 168.
5. One can acquire 3 subcarriers at a time.



Primary Synchronization Channel

1. To acquire PSCH, there is a duration of 5 msec.
2. Function of PSCH is to latch the timing and frequency synchronization.
3. It tells the location of user in frequency and time.

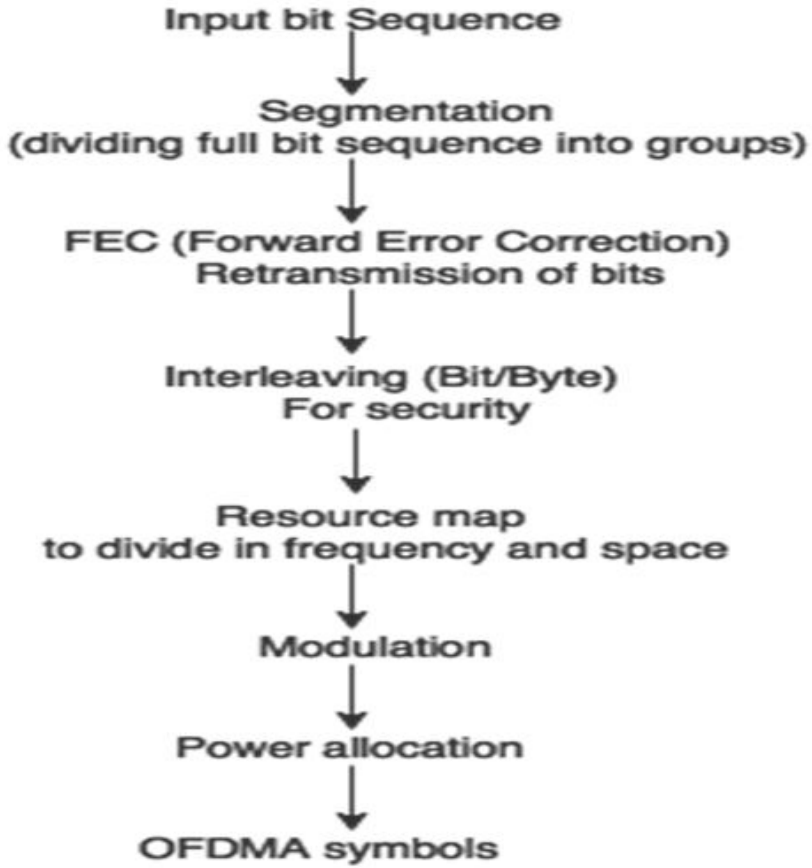


Secondary Synchronization Channel

1. It is acquired within 10 msec.
2. Helps to allocate with one group ID.
3. After allocation of PSCH & SSCH, user is allocated a physical cell ID that contains timing consideration which is Downlink reference symbol and Pseudo random sequence helps to latch to a particular network.
4. Hence, the user can decode Physical broadcast channel (PBCH) that contains cell related information.

(contd...)

Signal Transmission



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Multimedia Broadcast Multicast Services

Introduction

1. Offered by R-10 LTE and LTE-A
2. Broadcast is from one to all and multimedia is from one to many.
3. In multicast, there are several number of registered users to whom services are provided.
4. In broadcast, there is an open concept.
5. Promotional offers are sent by using multicast scheme.

(contd...)

Introduction

6. Advertisements are sent using broadcast scheme.
7. To access these services frequencies are required.
8. Main concern should be there on Inter-cell Interference Mitigation.
9. If 2 cells are radiating same message, there are chances of interference.
10. So to mitigate interference power should be controlled.
11. For Inter-cell Interference Mitigation, coordination should be there, for which static and semi-static coordination are used.

(contd...)

Coordination Methods

1. Coordination between two cells is static coordination.
2. When S1 and X2 interfaces are involved, semi-static coordination is used.
3. Coordination methods are:
    a. Inter-cell Interference Mitigation cancellation/suppression
    b. Inter-cell Interference Mitigation by intelligent scheduling: in which specific subcarriers carry the messages of power control.
    c. Inter-cell Interference Mitigation by open loop power control.

(contd...)

Coordination Methods

1. MBMS services are provided on single frequency
2. To broadcast, same set of subcarriers are used to carry messages in all the cells.
3. To multicast, unregistered user cannot decode the messages sent by the network.

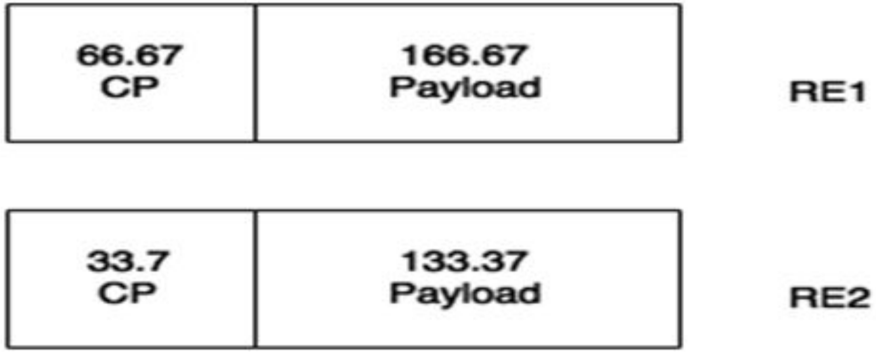
(contd...)

EMBMS

1. Same scenario as that of MBMS.
2. Focuses on television transmission.
3. Unicast and Multicast REs
   a. Unicast is from one to one
   b. Multicast is one to many.

Unicast RE

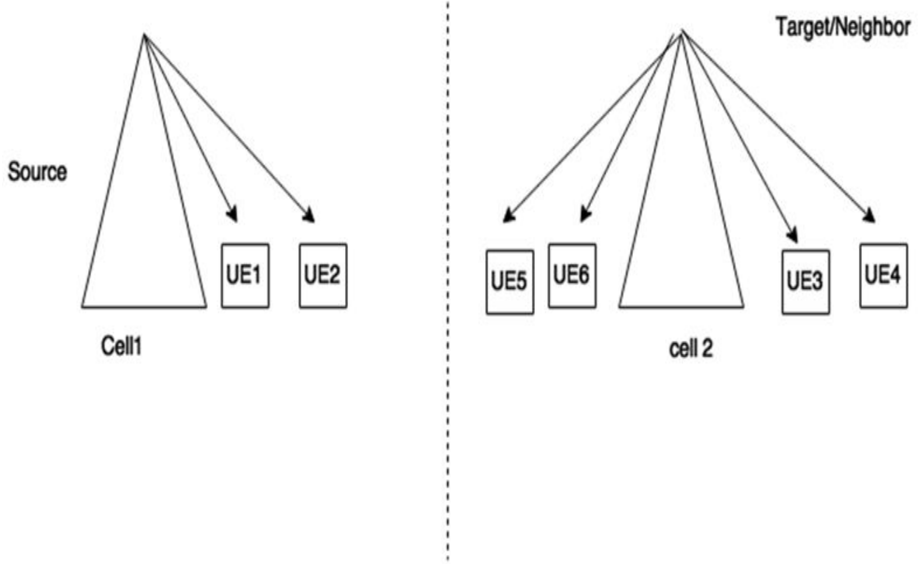
Multicast RE



LTE Power Control

Introduction

1. LTE network radiates the power that must be regulated or controlled.
2. Parameters that are radiated are called power control parameters.



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Introduction

3. The power radiated by UE 5 or UE6 can interfere with that of the source network and that of UE1 and UE2 interfere with target network regarding the signal strength may be less.
4. Every UE has a source as well as target SINR values that is what level of interference is received as compared to the source signal.
5. When interference is more, overload indication value is passed to the interfering cell.
6. Based on this overload indication the interfering cell adjust its PC parameters or target SINR values.

Power Control Methods

1. Static power control
   a. In GSM and CDMA, this type of PC method is used in which no adjusting parameters are there.
2. Fractional power control
   a. In LTE, this type of PC method is used in which PC parameters are adjusted according to SINR values.

LTE scheduling

1. Heavy load on U/L and D/L shared channels as both carry data, signaling etc.
2. Data is managed in both frequency and time.
3. This is called scheduling.Scheduler manages radio qualities, power control, QoS management, and users.
4. For U/L scheduling processes, UE has to contact eNB to send U/L scheduling request includes buffer status report, and SRS (Sounding Reference Signal).

(contd...)

LTE scheduling

5. After that eNB grants U/L scheduling using HARQ on PUCCH/PRACH.
6. In D/L scheduling process, eNB will pass D/L scheduling to UE.
7. In return UE sends CQI, RI, PC Parameters so that adjustments are done accordingly.
8. Hence, PRB (Primary Resource Block) is assigned to carry data and signaling.

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LTE Frequency Reuse

Introduction

1. Frequency is a limited resource.
2. It is not practically possible to have large number of frequencies.
3. Operators purchase these frequencies according to their needs.
4. So fully spectrum efficiency the same frequency has been used again and again at different locations at a same time and at a particular distance.
5. Frequency reuse concept is different in all the technologies
6. In GSM, in same cell all the three sectors are provided with different frequencies so that there is not a possibility of co-channel or adjacent channel interference.

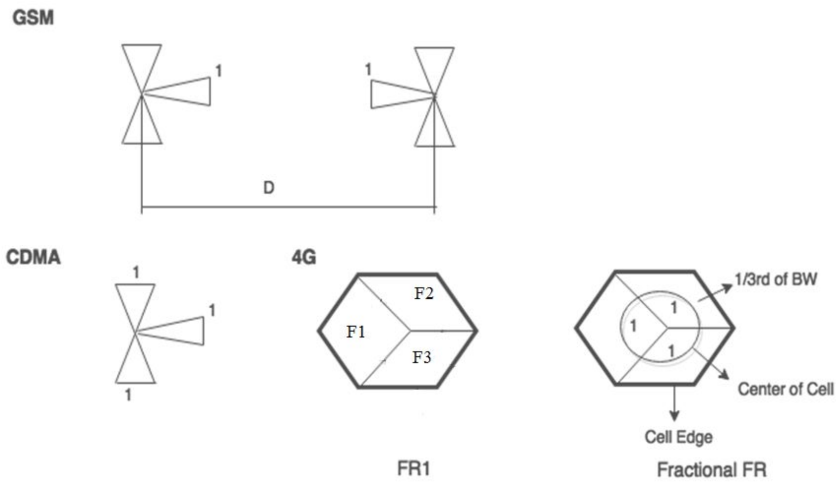
(contd...)

Introduction

7. So the same frequency is used at a particular distance called frequency reuse distance so that there is not any interference.
8. Similarly in CDMA, frequency reuse is one that is in all the three sectors same frequency is used as users are provided with different codes.
9. In 4G there are number of bands and according to those bands frequency can be purchased.
10. For instance, if 1920-1980 and 2110-2170 FDD band is purchased having BW of 20 MHz, same frequency is allocated to all the sectors of the cell.

Frequency Reuse Types

1. FR1: same frequency to entire cell i.e. to the cell edge as well as to the centre of the cell.
2. Fractional frequency reuse: both the center and edges of cell are given different frequencies i.e. cell edges has given 1/3rd of the entire bandwidth.
3. Hence, throughput increases in 4G and also spectrum efficiency is improved.



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Frequency Reuse Types

4. Bandwidths provided are 1.4, 3, 5, 10, 15, 20 MHz
5. 20 MHz is the maximum bandwidth.
6. Number of carriers are aggregated if frequency has to be increased from 20 MHz.
7. This process is called carrier aggregation.
8. For each and every carrier, there is space in between which is called channel raster.
9. In 4G LTE, channel raster is 100 kHz.

(contd...)

Frequency Reuse Types

10. Modulation in 4G is MCS (Modulation Coding Scheme)
11. MCS has 30 codes for modulation.
12. Codes from 0-9 uses QPSK, 10-17 uses 16-QAM and from 18-24 uses 64-QAM.

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LTE Protocols

Introduction

1. Rules and regulations to run a system effectively.
2. Each generation requires protocols for communication between entities.
3. Wireless protocol stack has only three layers as:
   a. Physical layer
   b. Data link layer
   c. Network layer
4. In each and every layer there are protocols which help in functioning of the system.

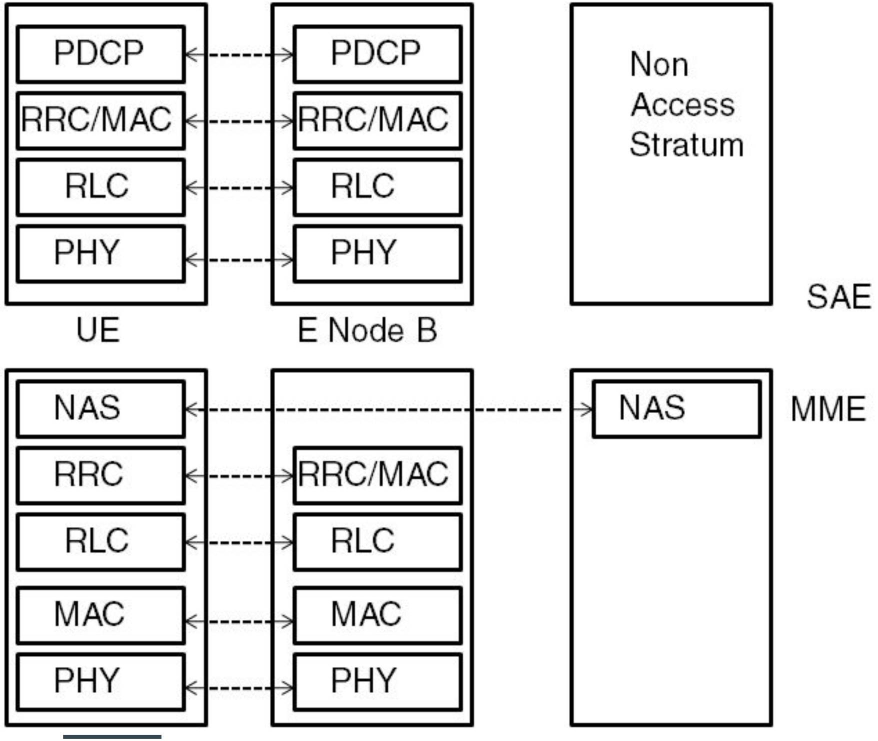
(contd...)

Introduction

5. Physical layer has a contact with user plane and network layer with control plane.
6. Physical layer helps to communicate with user and network layer is used to communicate with the network.
7. In uplink, UE can send the message through physical layer and eNode B receives the message through network layer.
8. In downlink, e Node B sends the message with the help of network layer and UE receives the message with the help of physical layer.

Protocol Parameters

1. RLC
   a. Served as layer three.
   b. Scheduling
   c. ARQ and HARQ
   d. Error correction through ARQ
   e. Protocol error check
   f. Flow control
   g. Segmentation



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Protocol Parameters

2. PDCP:
    a. Transfer of user data
    b. Sequence delivery of data
    c. Header compression
    d. Ciphering
3. HARQ: ACK when data is received and NACK when data is not received.
4. Synchronous transmission is there when there is an ACK and NACK in a circular process.

(contd...)

Protocol Parameters

5. The time between Tx and reTx should be 8 msec.
6. RRC:
   a. UE and eNB air interface is controlled by RRC.
   b. Broadcast
   c. Paging
   d. RB control
   e. UE measurements

(contd...)

Protocol Parameters

7. RRC idle mode:
    a. Broadcast cell information.
    b. UE ID in UE tracking area.
    c. Cell reselection.
8. RRC connected mode:
    a. UE connection so that network can trans-receive information.
    b. Neighbor information for HO.

RRC States

1. It is a radio resource control protocol which is used between UE and eNB.
2. 2 states of RRC: RRC Idle and RRC connected.
3. LTE work on DRx (Discontinuous Reception) cycles to save power of UE.
4. UE continuously scans for PDCCH to know about data.
5. In DRx cycle, UE can awake for some time scans for PDCCH and then sleep and so on.
6. In RRC Idle state, UE will have continuous reception of channels required for broadcasting and synchronization.

(contd...)

RRC States

7. There is a mobility management in RRC Idle state also.
8. Tracking Area Update (TAU): when UE is moving it will continuously updating its tracking area.
9. So, in RRC Idle state TAI (Tracking Area Identity) is provided to each UE so that we can easily track their location.
10. In idle state, there are cell reselection and paging processes.
11. User can move from RRC Idle to RRC Connection state.

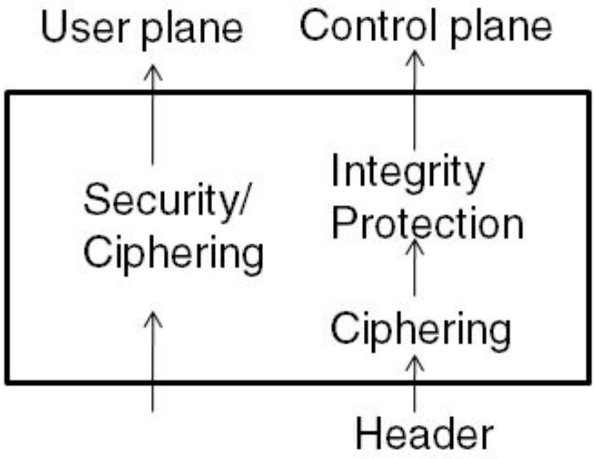
(contd...)

RRC States

12. EUTRAN knows the location of UE.
13. In RRC Connection state, there is a transmission and reception of data between 2 ends.
14. Handovers are also required so that connection cannot break down.
15. UE works in both states, sometimes in RRC Idle and sometimes in RRC Connected.

Packet Data Convergence Protocol Services

1. Responsible for header compression
2. In sequence delivery of data packets
3. Security/ Integrity protection for NAS signaling.

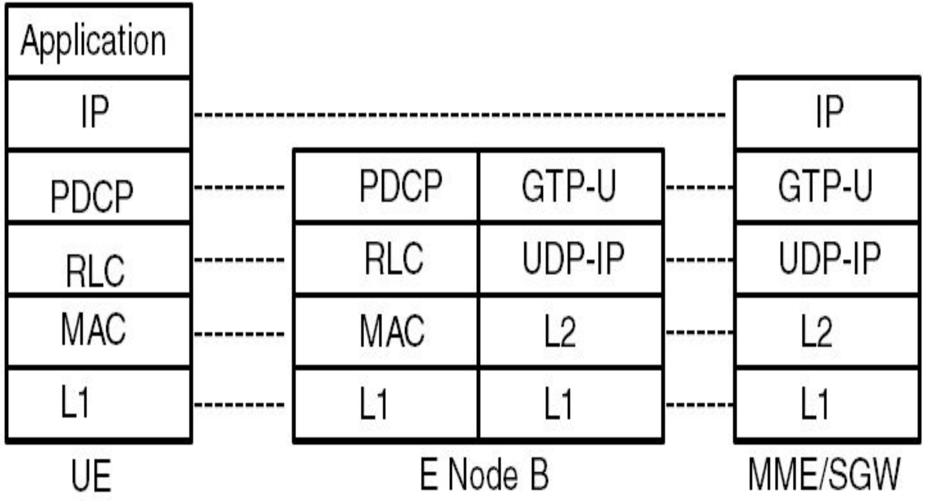


Hybrid Automatic Repeat Request

1. Works on stop and wait procedures.
2. For downlink, it uses asynchronous transmission whereas for uplink, it uses synchronous transmission.
3. Time between transmission and retransmission is only 8 msec.

NAS Protocols

1. NAS is Non Access Stratum protocols.
2. The part between UE and EUTRAN is AS while between EUTRAN and CN is NAS.
3. NAS protocols are called highest stratum because these are used by EPC.



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NAS Protocols

4. These are required for mobility of UE.
5. For mobility UE has to communicate with MME for all location changes.
6. These are also used for session management.
7. IP connectivity is required to send packets from SGW to UE for which IP address is required.
8. In every protocol stack, first layer is physical layer and second layer is data link layer.

(contd...)

NAS Protocols

9. GTP-U (GPRS Tunneling Protocol-User plane)
   a. Tunneling is a process used to control the packets.
   b. Distribution of packets according to destination is called tunneling.
   c. Protocol used is GTP-U.

LTE Security

Requirements of LTE

1. High level of security
2. Smooth transition from 3G to 4G
3. Allowed use of USIM
4. Same level of security in 3G/4G

Changes in LTE security

1. Hierarchy security systems

MME key pool

↓

eNB key

↓

UE

2. Separation of security in AS and NAS

Cryptography

1. AKA and IKE
2. AKA is Authentication Key Agreement
3. IKE is Internet Key Exchange
4. NDS is Network Domain Service in IP layer.
5. Cryptography: conversion of signal into codes.
6. For cryptography ciphers are used which are the codes.
7. There are two types of ciphers: Substitutional and Transpositional Ciphers.

(contd...)

Cryptography

8. Substitutional Cipher converts numbers, symbols and alphabets.
9. Transpositional Cipher converts position of a message.
10. For example: message is: HI, HOW ARE YOU and the ciphered text is: HO, IHE YRA WUO as key is 45321.

1	2	3	4	5
H	I	,	H	O
W	A	R	E	Y
O	U			

4	5	3	2	1
H	O	,	I	H
E	Y	R	A	W
			U	O

(contd...)

Cryptography

11. Cryptography has two types
    a. Symmetric Cryptography:
        i. Only one secret key
        ii. Sender sends the data using encrypt key and same key is used to decrypt the data at receiver.
    b. Asymmetric cryptography
        i. Two secret keys: public and private secret keys.
        ii. Sender sends the encrypted data using public key and receiver can decrypt the data using private key.

LTE Security

1. MME is a functional database that has a pool of keys.
2. Any key, say K1, produced at MME is used to generate keys at various eNBs.
3. If, in any case, the key of a single eNB is hacked, even then data can't be decoded.
4. Regular key exchange is there whenever there requires any access or signaling.
5. Hence, high data security is there.
6. GSM is not compatible with this high level of security due to which GSM SIMs are not used in 4G LTE.

(contd...)

LTE Security

7. UE is communicating to eNB for RRC (Radio Resource Control).
8. UE is communication to the core network for authentication, mobility and session management.
9. Hence, there is a need to provide security to both the AS and NAS parts.
10. So, the data and control signaling in AS and NAS parts should be protected.
11. For UE-eNB connection, security is needed in air interface.
12. Communication between UE and eNB is for RRC.

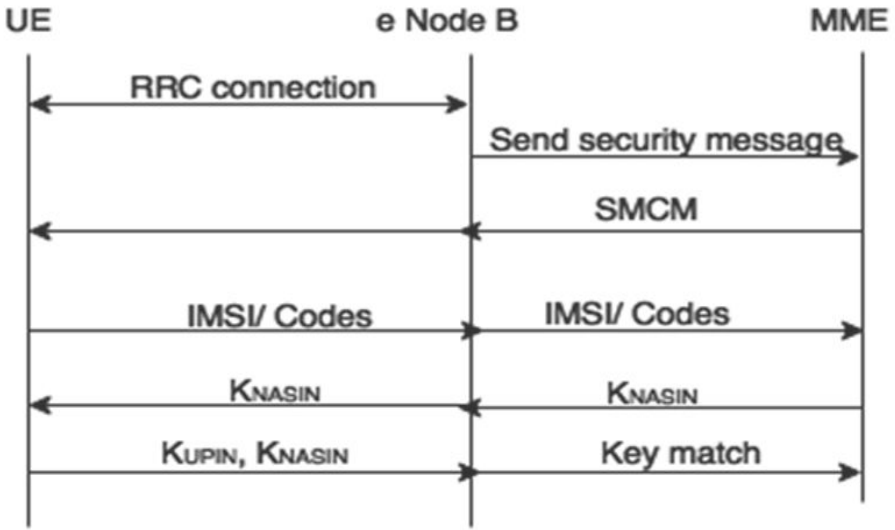
Security Keys

1. Keys used are:
    a. KRRCIN (Integrity Key):
    b. KRRCEN (Encryption Key)
    c. KUPEN (User Plane Encryption)
2. All of these keys are derived from KeNB(e Node B Key)
3. If the keys can recognize each other only then the data can be decrypted.
4. So, these are the keys for AS part.
5. All keys are derived from KNASME (Non Access Stratum Mobility Key).
6. Keys derived from KNASME are KNASIN, KNASEN

(contd...)

Security Keys

7. Like GSM, LTE also validate its user by using Security Mode Command Message.
8. SMCM is initiated by MME for user authentication.
9. MME sends this message to UE in return UE sends IMSI number.
10. For every signaling in LTE, there is a key exchange.



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LTE Sampling and Cell Hierarchy

Cell Hierarchy

1. Cell is the smallest coverage area.
2. Cell hierarchy is the arrangement of number of cells.
3. There are number of cells so these are divided into number of categories.
4. Hence, cells can have a different hierarchy.
5. Femto cells are the smallest cells of LTE network, ranges upto 10 m.
6. Femto cells are used in houses, small offices or buildings i.e area with less number of users.
7. This cell has a low power eNodeB.

(contd...)

Cell Hierarchy

8. The next category is Pico cell, range greater than 10m and are used in offices, buildings and aircrafts.
9. Next we have small cells having a range of 1-2 kms.
10. As the size of cell increases, BTS power can also be increased.
11. Then there are microcells, range of upto 35 Kms.
12. The number of cells are combined to cover the area of 35 Kms.
13. Macrocell is combination of microcells to provide large coverage.
14. The combination of clusters form superclusters.

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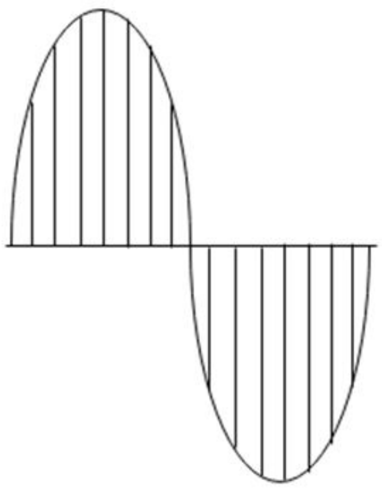
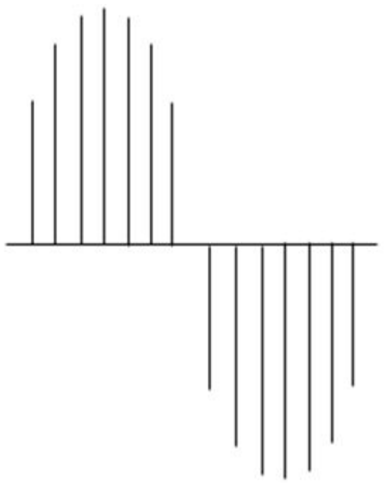
Sampling

1. Breaking of signal into number of parts.
2. Continuous signal is converted into discrete form.
3. Sampling frequency/ sampling rate is the rate with which the signal is divided.





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Sampling

4. It is defined as average number of samples per second.
5. fs= 1/Ts
6. At transmitter, frequency is divided to time and vice-versa at receiver. This is a concept of FFT.
7. FFT is used to change time to frequency and IFFT is used to change frequency to time.
8. Hence, IFFT is required at transmitter and FFT at receiver.

(contd...)

Sampling

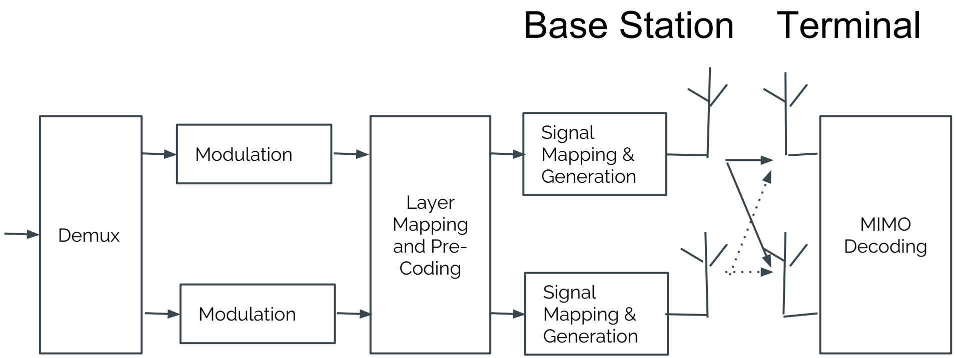
9. So, practically OFDMA and SCFDMA are possible with sampling.

Bandwidth	1.4	3	5	10	15	20
Resource Block (Subcarriers)	72 (6)	180 (15)	300 (25)	600 (50)	900 (75)	1200 (100)
Samples per slot	960	1920	3840	7680	11520	15360
Sample Rate	1.92	3.84	7.68	15.36	23.04	30.72

Transmission Modes

Introduction

1. To achieve high data rates in downlink, LTE uses MIMO technology.
2. It also offers fallback technologies like transmit diversity or SISO.
3. It also supports Beamforming.



TM1-Single Transmit Antenna

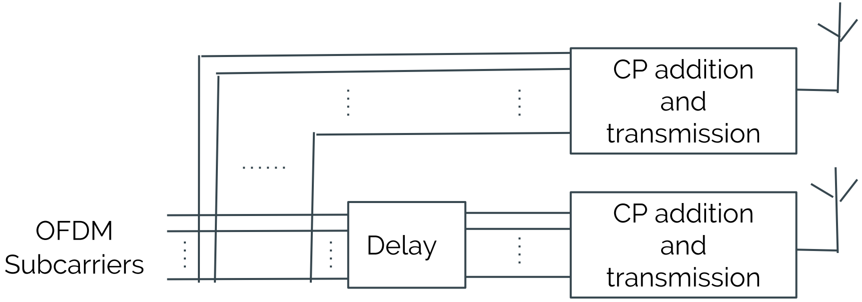
1. This mode uses only one transmit antenna.

TM2- Transmit Diversity

1. It is the default MIMO mode.
2. It sends the same information via various antennas.
3. Each antenna stream uses different coding and different frequency resources.
4. This improves SNR and makes transmission robust.
5. It is used as a fallback option for some transmission modes.
6. Used to transmit PBCH and PDCCH.

TM3- Open Loop Spatial Multiplexing with CDD

1. Supports spatial multiplexing of two to four layers that are multiplexed to two to four antennas to achieve higher data rates.

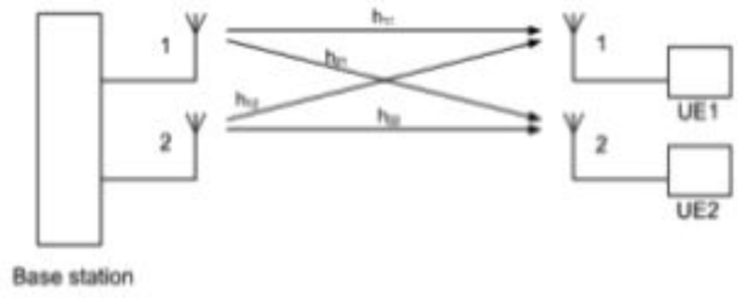


TM4- Closed Loop Spatial Multiplexing

1. Supports spatial multiplexing with up to four layers that are multiplexed to up to four antennas to achieve higher data rates.
2. The BS transmits cell-specific RS, distributed over various RE and over various TS, to permit channel estimation at the receiver.
3. A response regarding the channel situation is sent by UE that includes information regarding the preferred precoding from the defined codebook.

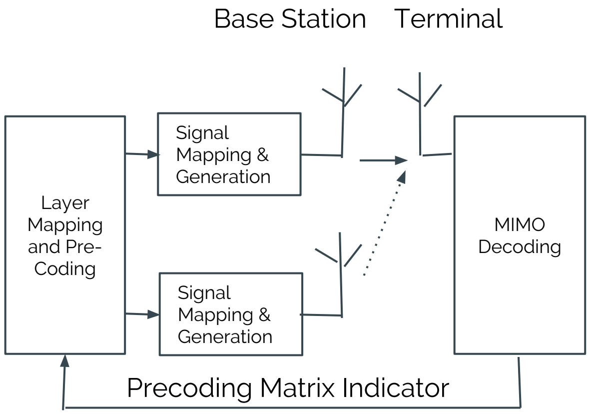
TM5-Multi User MIMO

1. It is similar to mode 4.
2. Uses codebook based closed loop spatial multiplexing.
3. One layer is dedicated for one UE.



TM6-Closed Loop Spatial Multiplexing using a Single Transmission Layer

1. It is a special case of mode 4.
2. Only one layer is used.
3. The UE estimates the channel and sends the index of the most suitable precoding matrix back to the BS.
4. BS sends the precoded signal via all antenna ports.

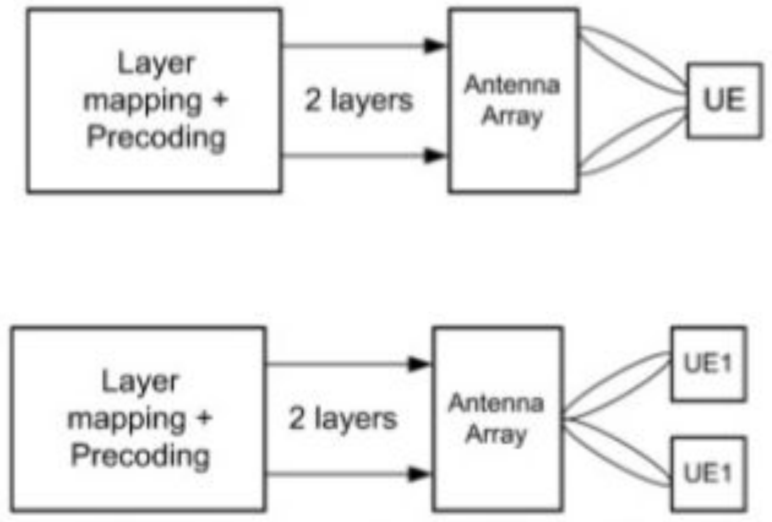


TM7- Beamforming

1. UE-specific RSs are used.
2. Both the data and the RS are transmitted using the same antenna weightings.
3. This transmission mode is called single antenna port 5.
4. The optimum beamforming weighting can be determined from the channel estimation.

TM8- Dual Layer Beamforming

1. This will permit the BS to weight two layers individually at the antennas so that beamforming can be combined with spatial multiplexing for one or more UEs.



LTE Antennas and Identifiers

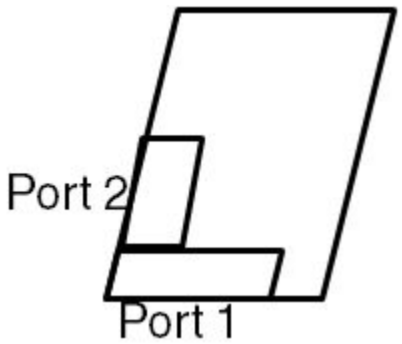
Introduction to Antennas

1. As mobile devices are small in size, so the antennas must be of comparable size.
2. UE antenna configuration:
   a. As eNB sends a signal at a high speed, UE must receive signal at high speed also.
   b. So antenna of UE must be upgraded so that it can have maximum throughput values and bit rate.

(contd...)

Introduction to Antennas

c. UE works on dual port configuration in which two ports are used to receive or transmit.
d. Thickness should be 1 cm or 0.5 cm.
e. Width should be equivalent to 6 cm and length should be approximately equal to 12 cm.



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Introduction to Antennas

f. 2 ports are orthogonal radiating elements to have pattern diversity (more data rates).
g. These ports have zero separation so that there will be size reduction.
h. When both ports are excited, MIMO technology is used in that case.
i. Port 1 is excited which is transmitting and receiving and port 2 is terminated.
j. Third case is port 1 is excited which is transmitting and receiving and port 2 is open circuited which is receiving but one at a time.

Specific Absorption Rate

1. SAR is defined as the energy absorbed by the user body tissues should be less than certain values so that it can't damage the tissues.
2. It limits the energy dissipation
3. It's units are Watts/kg tissues.
4. All the devices are manufactured by taking into account the energy dissipation concept so that radiations can't penetrate into the human body in large extent.
5. Otherwise the body cells or tissues get damaged.

(contd...)

Specific Absorption Rate

6. There are two standards of SAR: European and American.
7. According to European standard, SAR should be less than 2 watt per kg tissue and use 10 g cube localized peak.
8. According to the American standard, SAR should be less than 1 watt per kg tissue and use 1 g cube localized peak.
9. Localized peak defines the amount of energy dissipated per tissue.
10. Before manufacturing the device, we must take into concern the amount of energy dissipated, specifications like length, width and height.

Antenna Selection Parameters

1. Antenna is a deciding factor for beamforming and coverage areas.
2. Antenna selection parameters:
   a. Beam width/ beam pattern:
      i. Every antenna forms its own beam.
      ii. The area upto which the beam of antenna provides coverage at different angles is beam width.
   b. Bandwidth:
      i. In LTE, there are FDD and TDD modes and the antenna should follow the bandwidth criteria.

(contd…)

Antenna Selection Parameters

c. Power handling capacity:
    i. Transmission of signal depends on the radiating power.
d. Gain:
    i. In air interface there are large number of losses so gain is provided so that signal can boost up.
e. Manufacturer
f. Cost effective

(contd...)

Antenna Selection Parameters

3. There are directional and omni-directional antennas.
4. Patch antennas are used because of its handling capacity and can be of any shape which can be connected in both series and parallel modes.
5. There are 2 parameters to adjust angles at which beam is formed.
6. Etheta=0 to 90 degrees and Ephie=0 to 180 degrees.
7. To have a beam in one particular direction there must be given an appropriate values of theta and phie.
8. Full beam is a combination of Etheta and Ephie.

(contd...)

Antenna Selection Parameters

9. There are both the major beam and sidelobes.
10. MIMO technology requires Agile antennas because these antennas can cross highly concentrated concrete walls.
11. eNB provides data to multiple users crossing all the hindrances in between.

(contd...)

Introduction to Identifiers

1. Identifiers are the identification numbers used to identify the user and the network.
2. Various identifiers are:
   a. MSISDN (Mobile Subscriber Integrated Service Digital Number)
   b. IMSI (International Mobile Subscriber Identity)
   c. TIN (Temporary Identification Number)
   d. GUTI (Globally Unique UE Temporary Identity)
   e. S-TMSI(SAE-Temporary Mobile Subscriber Identity)
   f. IMEI (International Mobile Equipment Identity)

Identifiers

1. MSISDN (Mobile Subscriber Integrated Service Digital Number):
   a. Contact number which is user specific with specified country code.
2. IMSI (International Mobile Subscriber Identity)
   a. Used for security
   b. Secure number corresponding to MSISDN
3. TIN (Temporary Identification Number)
   a. UE has MM context saved in its memory and MM contains TIN parameters.
   b. TIN parameters contains different GUTIs.

(contd...)

Identifiers

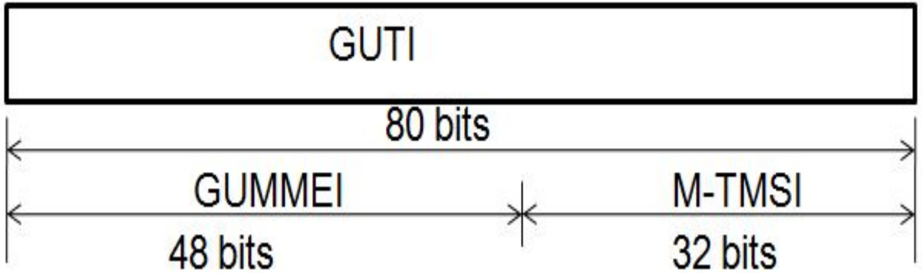
4. GUTI (Globally Unique UE Temporary Identity)
   a. Contains temporary identification of UE which is unique globally.
   b. When UE wants to contact to the network it will send GUTI, which is allocated to the user, to the eNB.
   c. GUTI has address of MME which helps to locate the particular MME in the core network.
   d. GUTI is user identification according to MME which has 2 categories as: GUMME-I (Globally Unique Mobility Management Identifier) and M-TMSI (MME-TMSI).

(contd...)

Identifiers

e. Whole GUTI is of 80 bits.

f. GUMMEI composed of MCC, MNC, MME group ID and MME Code; where MCC is Mobile Country Code and MNC is Mobile Network Code and MME group ID combined with MME code is MME ID.



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Key Points

1. When UE fallbacks from LTE to 3G, then it will send M-TMSI to the core network to get access to the circuit switched network.
2. S-TMSI is used to locate the SGW in the core network.
3. IMEI is used to identify the UE by the LTE network.

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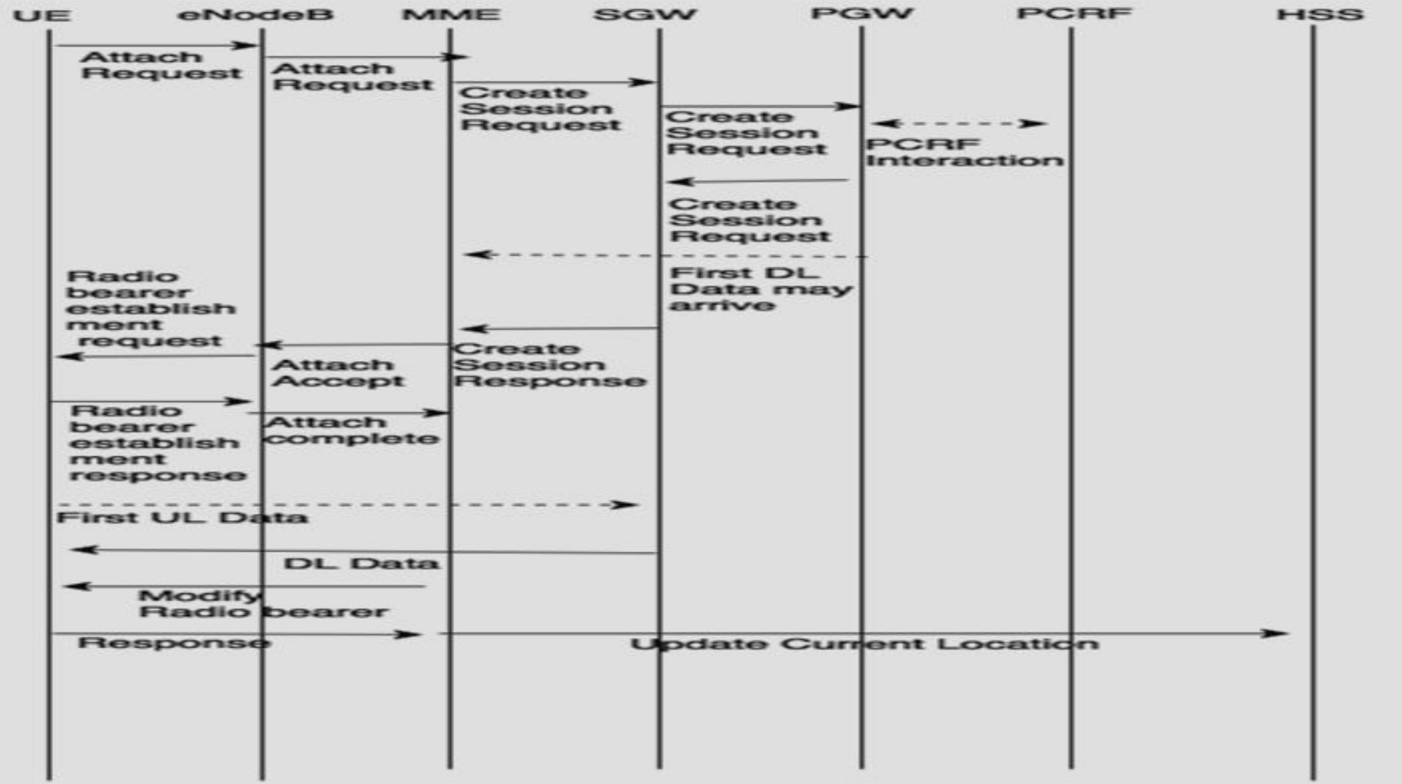
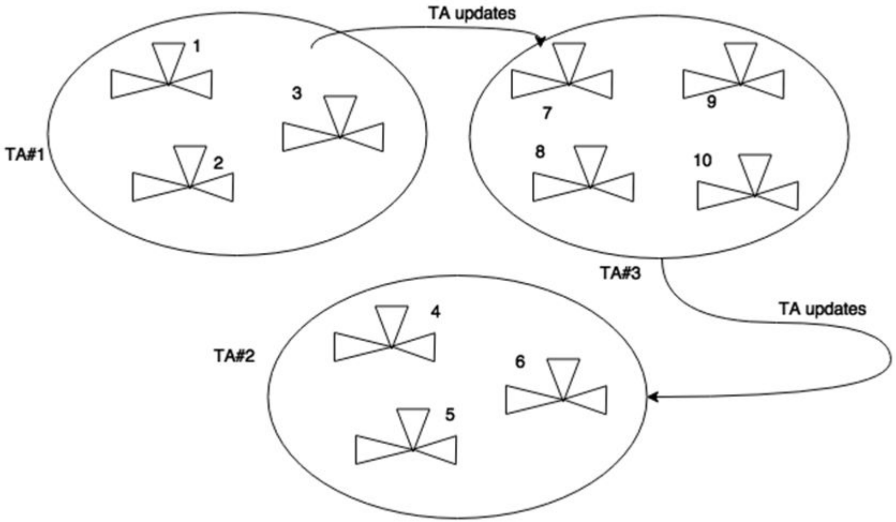
LTE Attach Process and Data Flow

Initial Call/Data Flow Process



Attach Process

1. MME is regularly updating Tracking Areas with the help of HSS.
2. If user is moving within a cell, TA can't be updated but when user is moving from one cell to another TA will be updated.
3. In case of high mobility users, TAU (Tracking Area Update) is used to update the tracking area.



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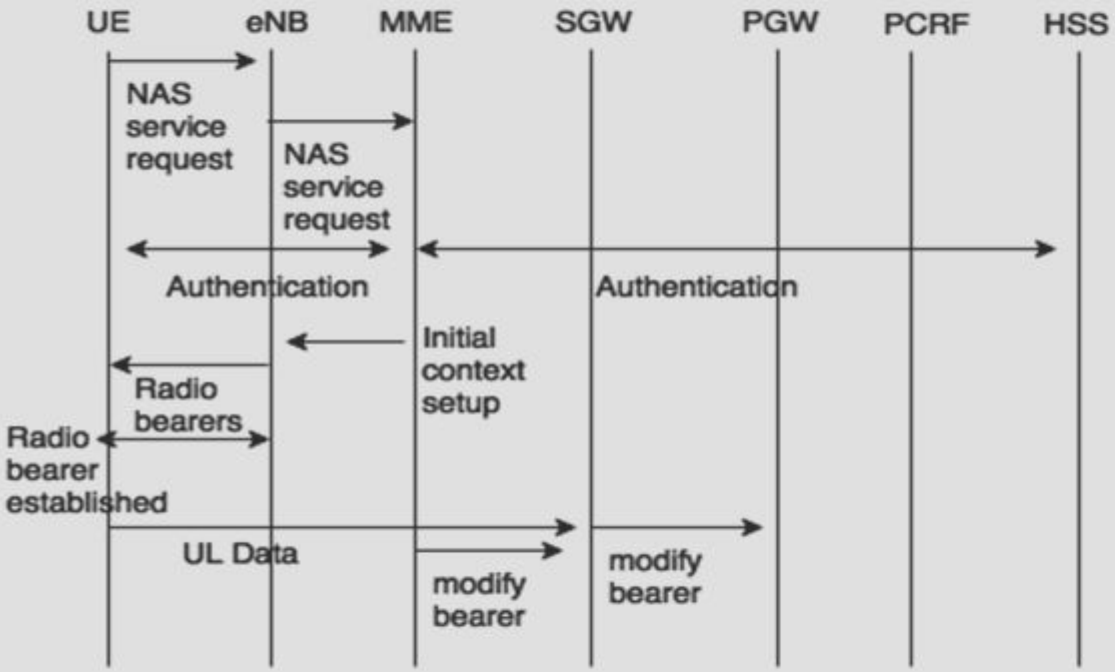
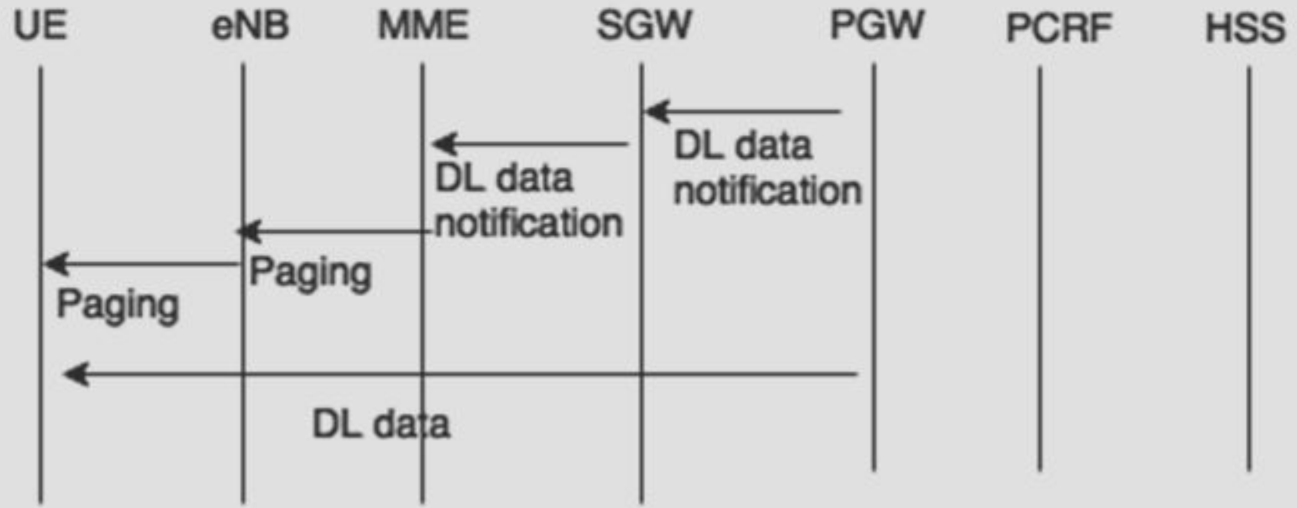
Tracking Area Update

UE Triggered Service Request



Network Triggered Service Request



LTE Voice Solutions

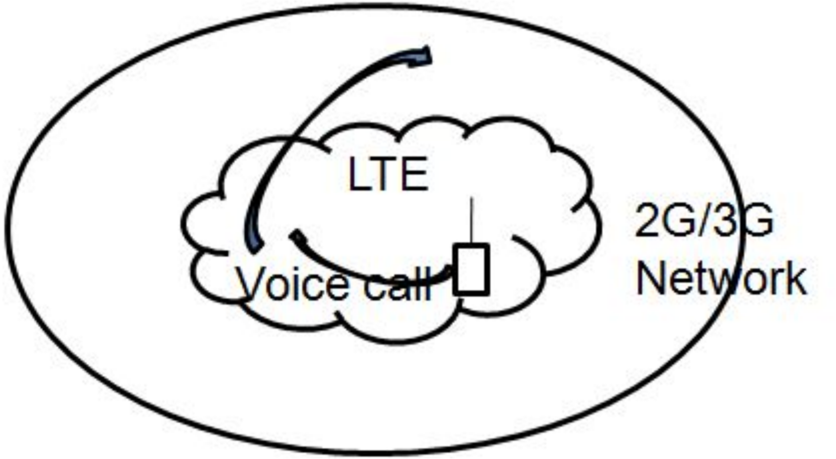
Introduction

1. As LTE is fully packet switched network that provides extremely high data rates.
2. But there is a need for voice transmission also.
3. There are 2 solutions to carry voice: voice over IMS or CSFB.
4. In case of CSFB, we have to fall back from 4G to 2G/3G networks for voice transmission.
5. In case of voice over IMS (IP Multimedia System), voice is transmitted over IP (VoIP), which is a feature of LTE-A.

(contd...)

CSFB

1. In CSFB, there is a delay in connection while in VOIP connection is faster and has rich voice experience.
2. It has simple architecture while VoIP has complex architecture.
3. As 2G/3G network is PS & CS while 4G is fully PS and for calls we need to fall back to 2G/3G.



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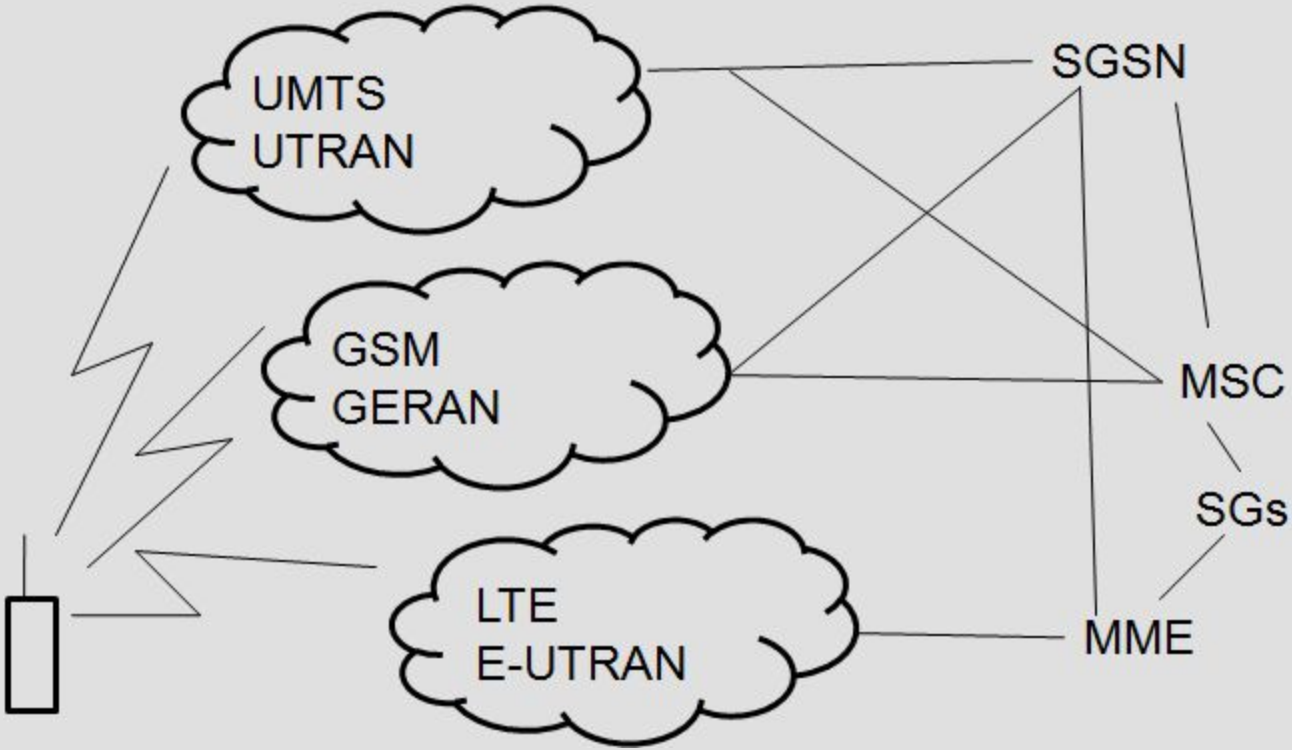
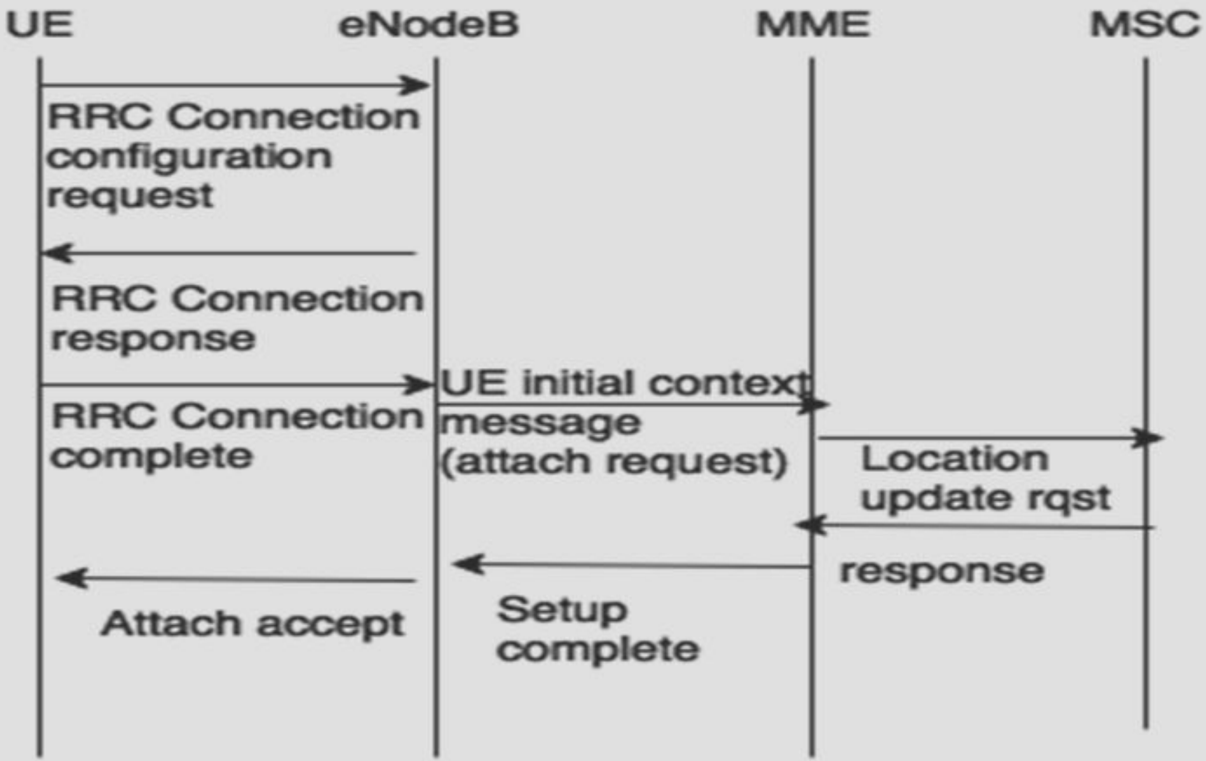
CSFB Architecture



Location Update Process



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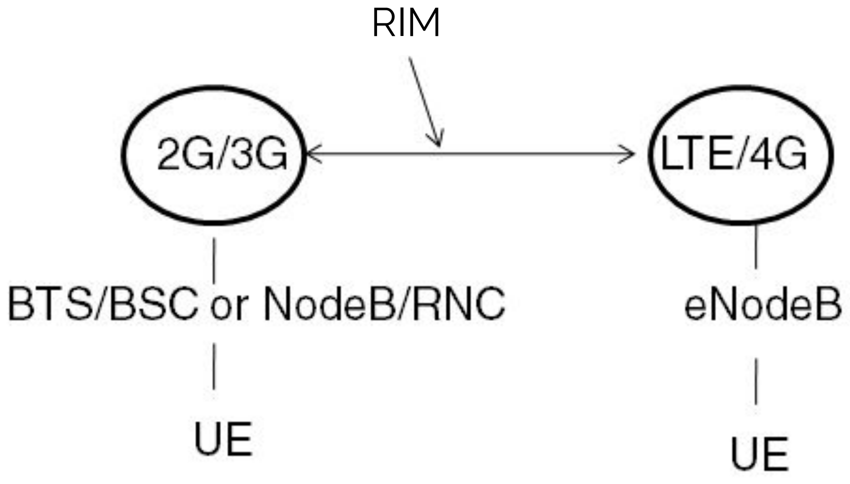
Location Update Process

1. For eNodeB Handover switch parameter, blind HO switch is required.
2. If blind HO switch is OFF, UE can have RAT HO/ measurements i.e. eNodeB has an information of the radio frequencies of the required network.
3. If blind HO switch is ON, UE can't measure inter RAT.



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Location Update Process

4. To disconnect, RRC release message is sent that contains reports i.e. single reports at only one interval of time and multiple reports are received after intervals.
5. To fall back from one network to another, information is required to latch to the network i.e. the codes and the frequencies, but the blind HO switch remains OFF.

CSFB Phases

1. Triggering Phase: for CSFB request.
2. Measuring Phase: to which MSC has to connect.
3. Decision Phase: contains routing parameters.

LTE VOLTE/VILTE

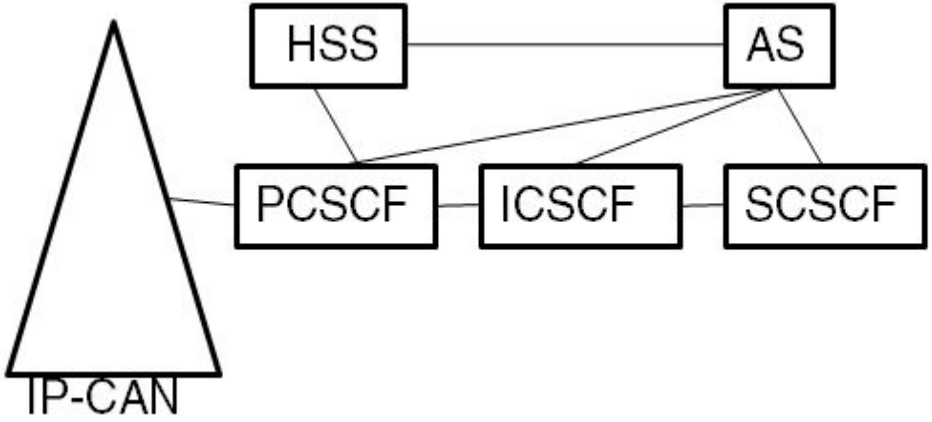
Introduction

1. Video over LTE and Voice over LTE are features of LTE-A .
2. Video and voice are transmitted simultaneously through IMS network.
3. CSFB has been discussed earlier which is a feature of LTE.
4. In IP Multimedia Services, voice is transmitted after converting in IP.
5. In VOLTE, voice is transmitted over LTE network.
6. As LTE is fully packet switched network, so voice will be latched on IP and transmitted.
7. It is said that voice will be treated as a packet data for transmission through IMS.

(contd...)

Network Architecture

1. IPCAN (IP Connectivity Access Network): It is RAN and MME of LTE. UE is connected to IPCAN.
2. PCSCF (Proxy Call State Control Function)
3. ICSCF (Interrogating Call State Control Function)
4. SCSCF (Serving Call State Control Function)
5. AS (Application Server)



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Processing

1. For transmission of voice over LTE network, UE can call IP-CAN network (eNB/MME).
2. IP-CAN calls PCSCF which deals with security and its functions include authentication and activate PDCP (Packet Data Convergence Protocol) which helps to transfer packets.
3. ICSCF will allocate a proper DNS (Domain Name Server).
4. SCSCF will validate IP address of the user.
5. AS is the main unit which is used for controlling all the IP addresses and codec.

(contd...)

Processing

6. AS is used for IPv4 to IPv6 conversion and as voice codecs.
7. Voice codec in LTE is same as used in GSM/UMTS.
8. AMR (Adaptive Multi Rate) codec is used to code the voice which is to be transmitted.
9. IMS uses IETF protocols and the protocol which is used is SIP (Session Initiation Protocol).
10. AS has a function of transmitting SIP also which can control the entire voice transmission process.

(contd...)

Processing

11. SIP controls the voice in IMS network.
12. SRVCC (Single Radio Voice Call Continuity) is used for the continuity of voice call whether it is CS or PS so that the risk of call drop can be reduced.
13. Hence, SRVCC is used to handover from PS to CS voice call so that voice can be transmitted continuously without any breakage or drop.

VILTE

1. Video over LTE or Video calling in LTE has high quality and less latency.
2. Video over LTE uses the same IMS network and protocols but different codec is used.
3. Codec for video is 324 M codec in 3G and in LTE, H.264 codec is used.
4. By using this codec, LTE provides better performance as compared to 3G.

Self Optimizing Network

Introduction

1. In SON, there is a concept of automatic planning, configuration, optimization of networks.
2. If concept of SON is used, it will get automatically planned, configured and optimized.
3. It has various categories:
   a. Distributed SON: main focus is on radio part (eNB SO)
   b. Centralized SON: main focus on CN
   c. Hybrid SON: combination of both Distributed and Centralized SON.

(contd...)

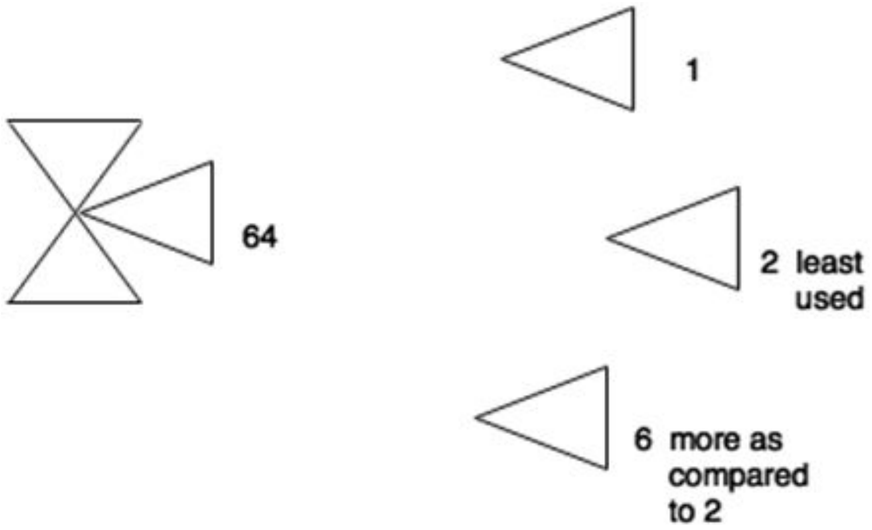
Features of SON

1. In order to heal RAN, concept of SON is introduced.
2. In SON, E Node B's are smarter to adjust the parameters and configure automatically.
3. Automatic configuration and optimization is directly related to the software.
4. Network of LTE has some plug & play paradigm which can automatically adjust various parameters.
5. Automatic Neighbor Relation is a feature of SON. As each cell of LTE has 64 neighbors which are defined for that particular cell.

(contd...)

Features of SON

6. Configure all the neighbors and all neighbors are defined for that particular cell.
7. For instance, let cell has neighbors 1&2 and not six. But number 2 is less used and number 6 is used more as compared to 2 than eNB adds the most used cell and deletes the less used cells.



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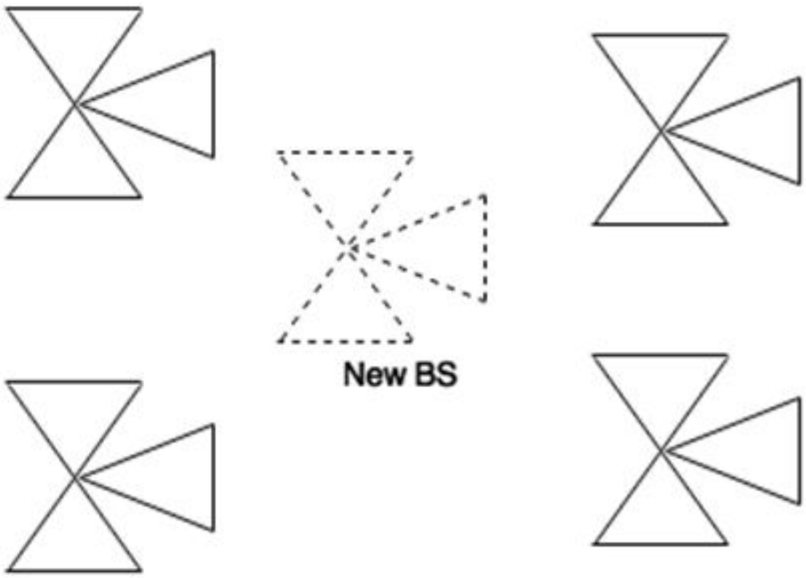
Features of SON

8. SON is providing facilities if new base station has to be installed.
9. When new BS has to be installed, and when it is just powered ON, it will be automatically configured and integrated.



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Features of SON

10. Also, each and every nearby BSs come to know about the new BS and will automatically adjust their coverage, tilts and power to accommodate the new BS.
11. Neighboring BSs adjust their parameters and also controls the interference which is the main feature.
12. The main feature of SON is energy saving.
13. During night hours when there is low traffic the network will sleep i.e. BTS is automatically switched OFF and neighboring cells will be automatically re-configured to cover the area.

(contd...)

Features of SON

14. If one eNB has no traffic and its neighboring eNB has low traffic then the eNB with no traffic will sleep and the eNB with low traffic will adjust its coverage.
15. But if there is a sudden traffic that the neighbor eNB doesn’t handle it, the serving eNB wakes up.
16. Hence, energy can be saved by using the concept of SON.

LTE Advanced

Deployment History

1. In 2008 3GPP held two workshops on IMT Advanced, where the "Requirements for Further Advancements for E-UTRA" were gathered.
2. The resulting Technical Report was then published in June 2008
3. The report was submitted to the ITU-R defining the LTE-Advanced system as their proposal for IMT-Advanced.

(contd...)

Key Features

1. Peak data rates: downlink - 1 Gbps; uplink - 500 Mbps.
2. Spectrum efficiency: 3 times greater than LTE.
3. Peak spectrum efficiency: downlink - 30 bps/Hz; uplink - 15 bps/Hz.
4. Spectrum use: the ability to support scalable bandwidth use and spectrum aggregation where non-contiguous spectrum needs to be used.
5. Latency: from Idle to Connected in less than 50 ms and then shorter than 5 ms one way for individual packet transmission.

(contd...)

Key Features

6. Cell edge user throughput to be twice that of LTE.
7. Average user throughput to be 3 times that of LTE.
8. Mobility: Same as that in LTE
9. Compatibility: LTE Advanced shall be capable of interworking with LTE and 3GPP legacy systems.

(contd...)

LTE-A Technologies

1. Orthogonal Frequency Division Multiplex, OFDM
    a. OFDM forms the basis of the radio bearer.
    b. There is OFDMA along with SC-FDMA.
    c. These will be used in a hybrid format.

(contd...)

LTE-A Technologies

2. Multiple Input Multiple Output, MIMO:
   a. MIMO enables the data rates achieved to be increased beyond what the basic radio bearer would normally allow.
   b. For LTE Advanced, the use of MIMO involves the use of additional antennas in the matrix.
   c. As the number of antennas increases, the overhead increases and the return per additional path is less.

(contd...)

LTE-A Technologies

3. Carrier Aggregation, CA:
    a. As many operators do not have sufficient contiguous spectrum to provide the required bandwidths for the very high data rates, a scheme known as carrier aggregation has been developed.
    b. Using this technology operators are able to utilise multiple channels either in the same bands or different areas of the spectrum to provide the required bandwidth.

(contd…)

LTE-A Technologies

4. Coordinated Multipoint :
   a. One of the key issues with many cellular systems is that of poor performance at the cell edges.
   b. Interference from adjacent cells along with poor signal quality lead to a reduction in data rates.
   c. For LTE-Advanced a scheme known as coordinated multipoint has been introduced.

(contd...)

LTE-A Technologies

5. LTE Relaying:
   a. LTE relaying is a scheme that enables signals to be forwarded by remote stations from a main base station to improve coverage.
6. Device to Device, D2D:
   a. LTE D2D is a facility that has been requested by a number of users, in particular the emergency services.
   b. It enables fast swift access via direct communication - a facility that is essential for the emergency services when they may be on the scene of an incident.

(contd...)

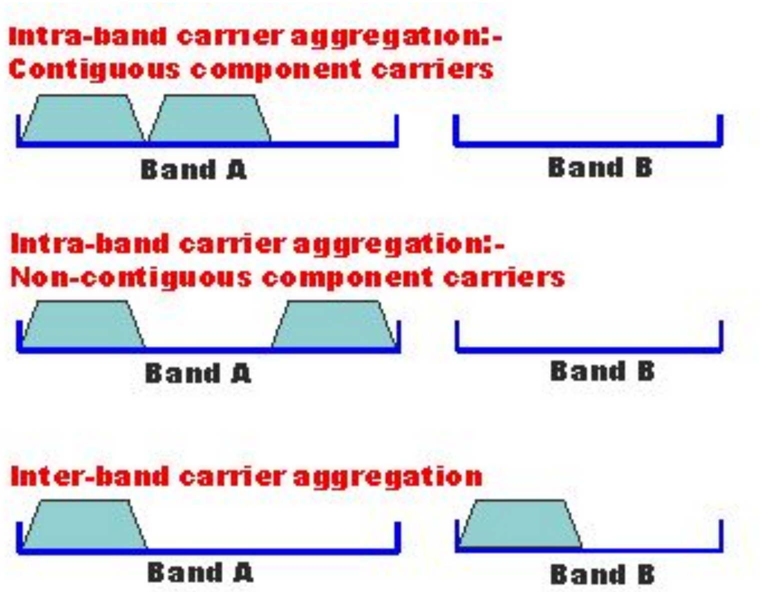
Carrier Aggregation

1. Using LTE Advanced carrier aggregation, it is possible to utilise more than one carrier and in this way increase the overall transmission bandwidth.
2. LTE Advanced offers considerably higher data rates.
3. To achieve these very high data rates it is necessary to increase the transmission bandwidths over those that can be supported by a single carrier or channel.
4. The method being proposed is termed carrier aggregation, CA, or sometimes channel aggregation.

(contd...)

Carrier Aggregation

5. RF aspects of carrier aggregation
   a. Intra-band
      i. Contiguous
      ii. Non-contiguous
   b. Inter-band non-contiguous



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Carrier Aggregation

6. When carriers are aggregated, each carrier is referred to as a component carrier.
7. There are two categories:
   a. Primary component carrier
   b. Secondary component carrier

(contd...)

LTE CoMP

1. LTE Coordinated Multipoint is essentially a range of different techniques that enable the dynamic coordination of transmission and reception over a variety of different base stations.
2. The aim is to improve overall quality for the user as well as improving the utilisation of the network.
3. LTE Advanced CoMP turns the inter-cell interference into useful signal.

(contd...)

LTE CoMP

4. Advantages
    a. Makes better utilisation of network
    b. Provides enhanced reception performance
    c. Multiple site reception increases received power
    d. Interference reduction

(contd...)

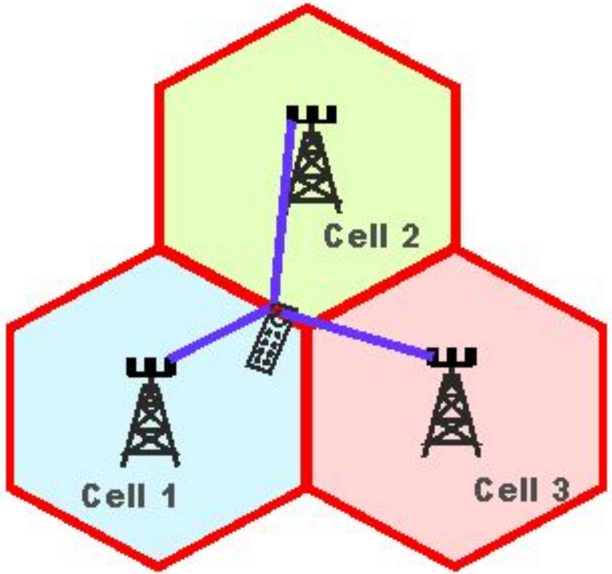
LTE CoMP

5. CoMP transmission and reception actually refers to a wide range of techniques that enable dynamic coordination or transmission and reception with multiple geographically separated eNBs.
6. It enhances the overall system performance, utilise the resources more effectively and improve the end user service quality.
7. 4G LTE CoMP, Coordinated Multipoint requires close coordination between a number of geographically separated eNBs.

(contd...)

LTE CoMP

8. They dynamically coordinate to provide joint scheduling and transmissions as well as proving joint processing of the received signals.
9. In this way a UE at the edge of a cell is able to be served by two or more eNBs to improve signals reception / transmission.



(contd...)

LTE CoMP

10. LTE CoMP has two major categories:
    a. Joint processing
    b. Coordinated scheduling or beamforming
11. Downlink LTE CoMP
    a. Joint processing schemes for transmitting in the downlink
    b. Coordinated scheduling and or beamforming

(contd...)

LTE CoMP

12. Uplink LTE CoMP
    a. Joint reception and processing
    b. Coordinated scheduling
13. One of the key requirements for LTE is that it should be able to provide a very low level of latency.
14. The additional processing required for multiple site reception and transmission could add significantly to any delays.

(contd...)

LTE Relay

1. LTE relaying enhances both coverage and capacity.
2. Need for LTE relay technology
   a. The use of technologies such as MIMO, OFDM and advanced error correction techniques improve throughput under many conditions, but do not fully mitigate the problems experienced at the cell edge.
   b. So, it is necessary to look at solutions that will enhance performance at the cell edge for a comparatively low cost.
   c. Hence, LTE relays is one solution.

(contd...)

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(contd...)

LTE Relay

3. A relay will actually receive, demodulates and decodes the data, apply any error correction, etc to it and then re-transmitting a new signal.
4. In this way, the signal quality is enhanced with an LTE relay, rather than suffering degradation from a reduced signal to noise ratio when using a repeater.
5. LTE relay advantages
    a. Increase network density
    b. Network coverage extension
    c. Rapid network roll-out

(contd...)

LTE Relay

6. LTE relay nodes can operate in one of two scenarios:
   a. Half-Duplex
   b. Full Duplex
7. LTE relay types
   a. Inband
   b. Outband

(contd...)

LTE Relay

8. For the LTE relay nodes themselves there are two basic types that are being proposed, although there are subdivisions within these basic types:
   a. Type 1 LTE relay nodes
      i. Type 1.a
      ii. Type 1.b
   b. Type 2 LTE relay nodes

(contd...)

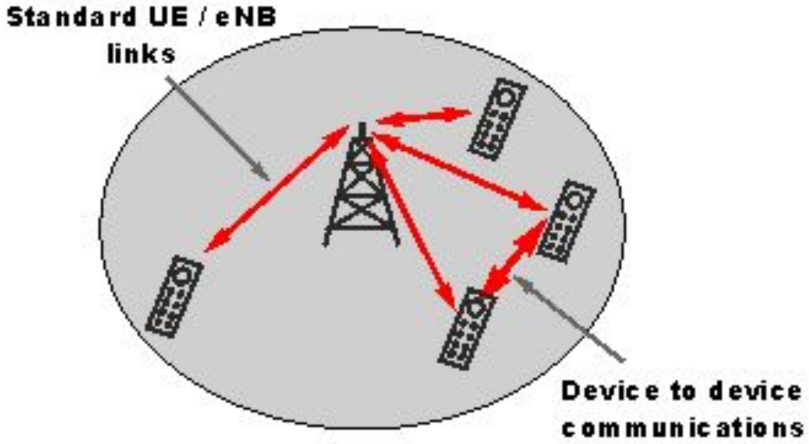
LTE D2D

1. D2D communication using the LTE system is used where direct communications are needed within a small area.
2. It enables LTE based devices to communicate directly with one another when they are in close proximity.
3. This could allow large volumes of media or other data to be transferred from one device to another over short distances and using a direct connection.

(contd...)

LTE D2D

4. This form of device to device transfer would enable the data to be transferred without the need to run it via the cellular network itself, thereby avoiding problems with overloading the network.



LTE D2D

5. Benefits of D2D
    a. Data rates
    b. Reliable communications
    c. Instant communications
    d. Use of licensed spectrum
    e. Interference reduction
    f. Power saving

(contd...)