Wireless Technology Applications
Wireless Wide Area Network
Part II

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- GPRS System Architecture
- Spectral efficiency between EDGE and WCDMA
- 3G UMTS system and architecture
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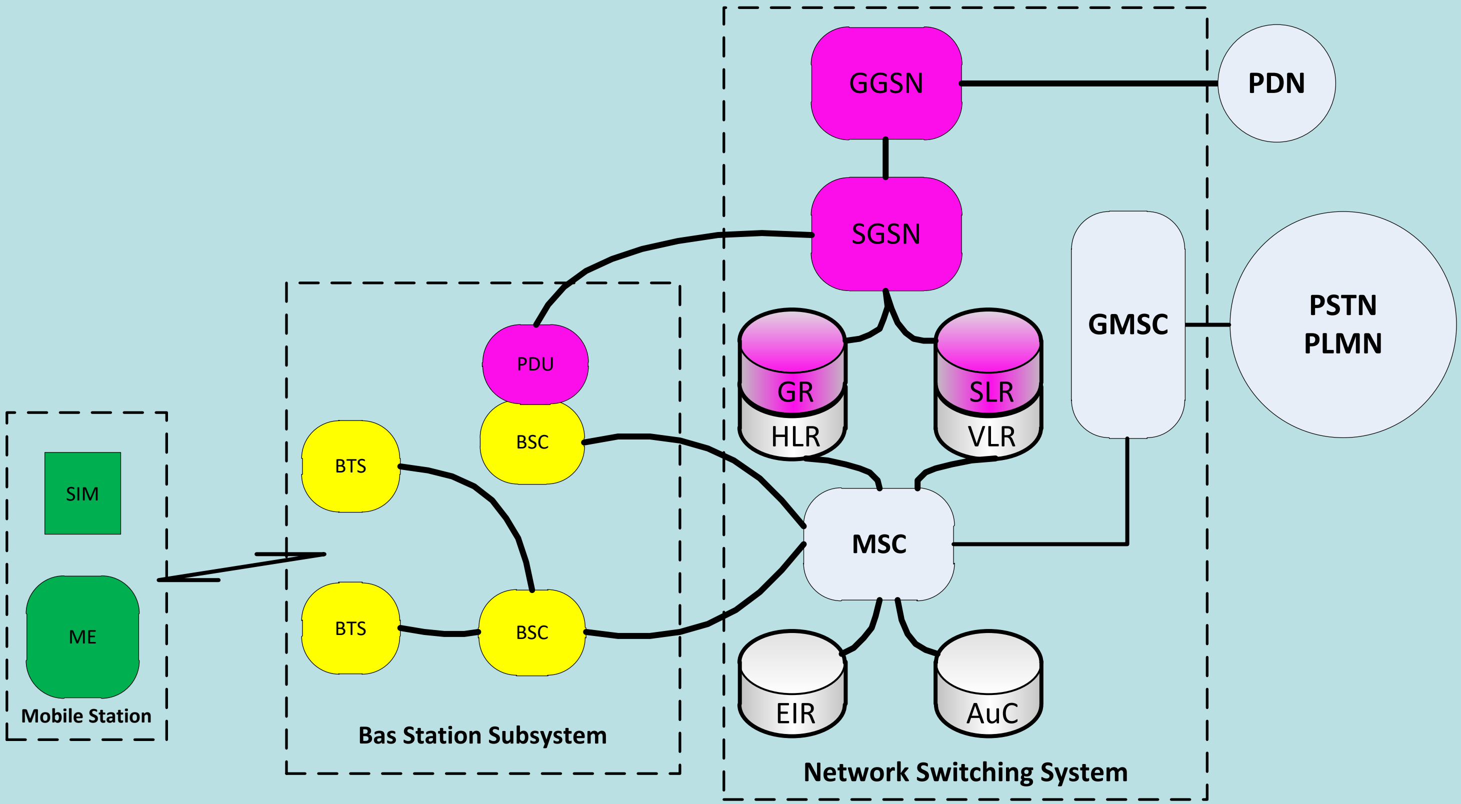
- LTE – Cat M1
- Narrowband IoT (NB-IoT)

GPRS System Architecture, 2.5G

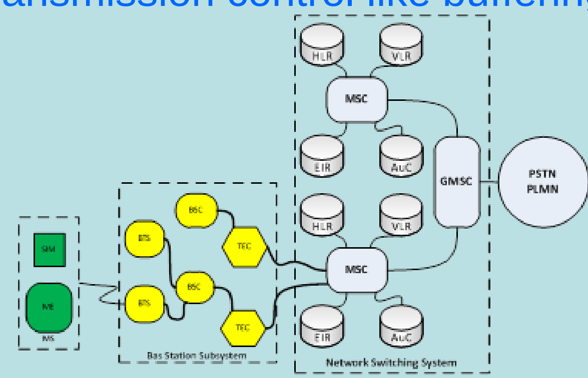
General Packet Radio Service

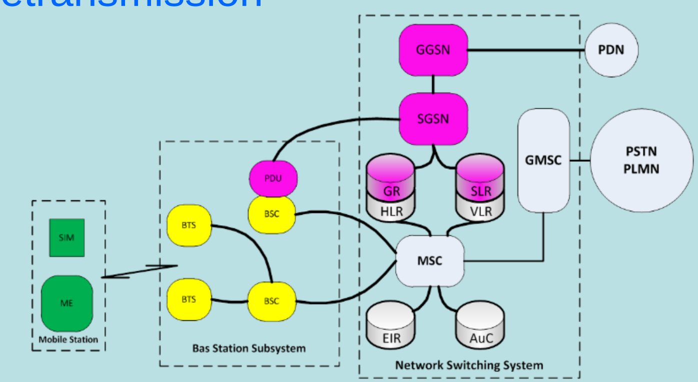


GPRS System Architecture, 2.5G

Additional equipment added to the GSM architecture to support packet switching network

- PCU (Packet Control Unit)
  - to separate the voice information and data information received from the Radio Subsystem
  - data information, routed to the new packet-switching network
  - Functions ➔ packet segmentation and reassembly both on the downlink and uplink
  - scheduling for all active transmissions including radio channel management and transmission control like buffering and retransmission





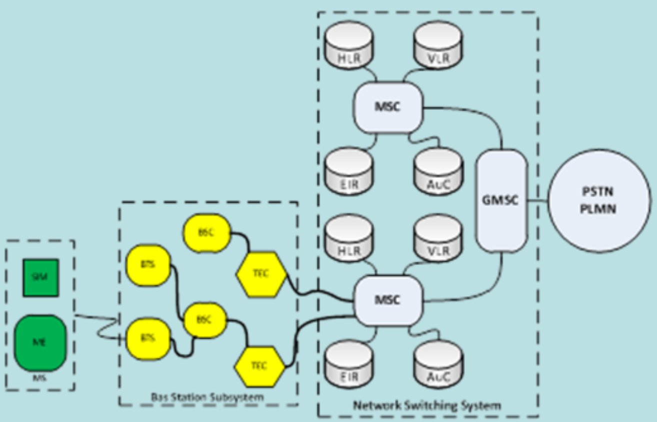
GPRS System Architecture, 2.5G

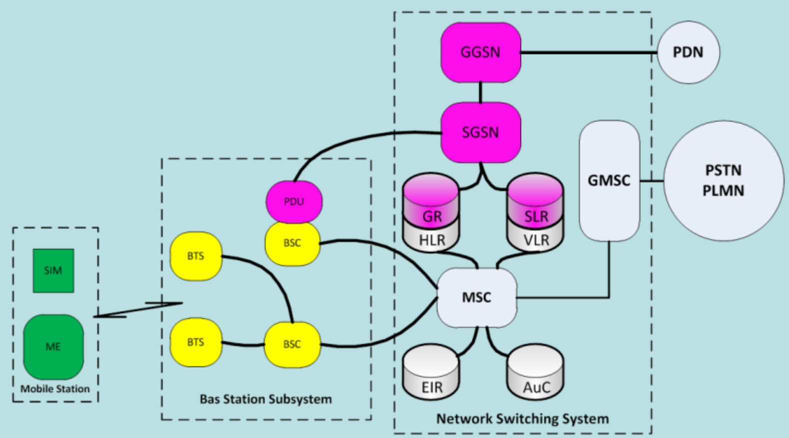
SGSN (Serving GPRS Support Node)

- the equivalent of MSC in the circuit-switching network
- establishes a mobility management context for an attached MS and performs ciphering for packet-oriented traffic

GR is the equivalent of HLR in the circuit-switching network.

SLR is the equivalent of VLR in the circuit-switching network.





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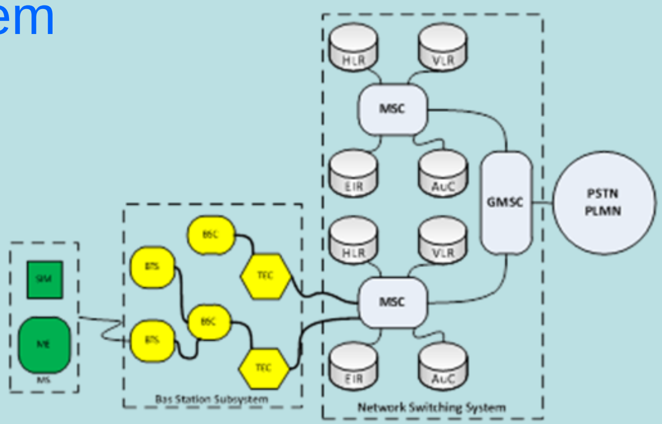
GPRS System Architecture, 2.5G

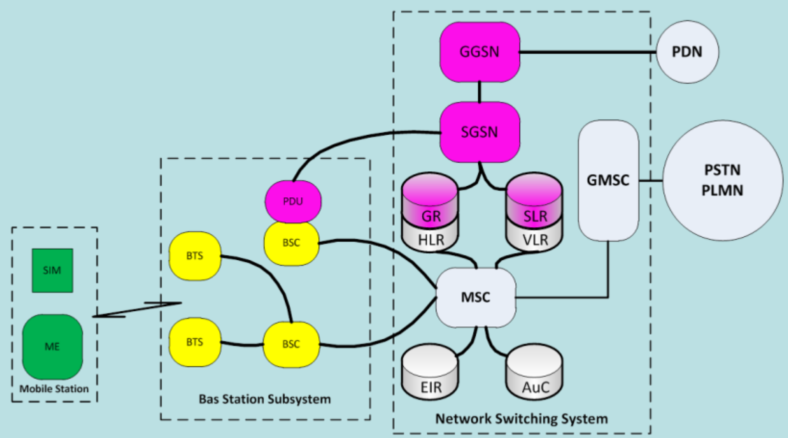
GGSN (Gateway GPRS Support Node)

- the equivalent of GMSC in the circuit-switching network
- the access point for an external data network
- capable of routing packets to the current location of the mobile

Note:

- the use of multi-slots in TDMA frame reduces the capacity of the system





Spectral efficiency between EDGE and WCDMA

3G system

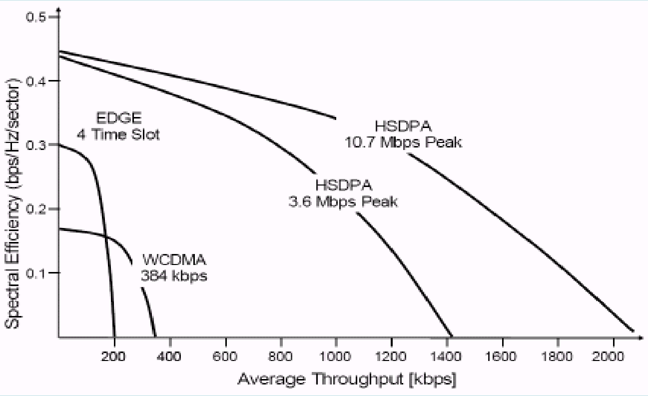
- the air interface uses WCDMA

GSM/GPRS/EDGE

- the air interface FDMA/TDMA

The spectral efficiency for WCDMA at high throughput > the spectral efficiency for FDMA/TDMA

- The capacity for data transmission is increased in 3G



3G UMTS system and architecture

The ITU has defined 384 kbps as the data rate limit required for a service to fulfil the 3rd Generation Mobile Communication System

Three implementations

- UMTS-FDD uses two different frequency bands for duplex communication
- UMTS-TDD uses only one frequency band for duplex communication
- cdma2000 which is an upgrade from IS-95 system used in USA. (In this module, we will not be discussing on cdma2000.)

3G UMTS system and architecture

3G UMTS uses different frequency spectrum compared to GSM.

UMTS-FDD (uplink)	UMTS-FDD (downlink)	UMTS-TDD
1920-1980 MHz	2110-2170 MHz	1900-1920 MHz or 2010-2025 MHz
New frequency bands		
806-960 MHz, 1710-1885 MHz, 2500-2690 MHz		

3G UMTS system and architecture

Requirements for 3rd Generation Mobile Communication System:

- Bit rates up to 2 Mbps for pedestrian speed
- Variable bit rate for bandwidth on demand since different services require different amount of bandwidth
- Multiplexing of services with different quality requirements on a single connection
- Delay requirements from delay-sensitive real time traffic (< 200 ms) to flexible best-effort packet data
- Quality requirements from 10% frame error rate to 10^{-6} bit error rate

3G UMTS system and architecture

- Inter-system handovers (from 2G GSM to 3G UMTS and vice-versa) for coverage enhancements and load balancing
- Support of asymmetric upload and download traffic since the download speed for a user is much more important than the upload speed
- High spectrum efficiency
- Co-existence of 2nd and 3rd generation systems
- Co-existence of FDD and TDD modes

3G UMTS system and architecture

Changes

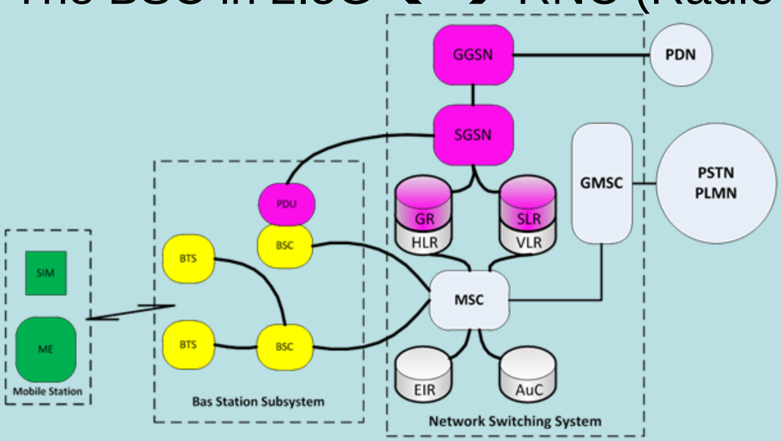
- the Radio Subsystem and the Base Station Subsystem.

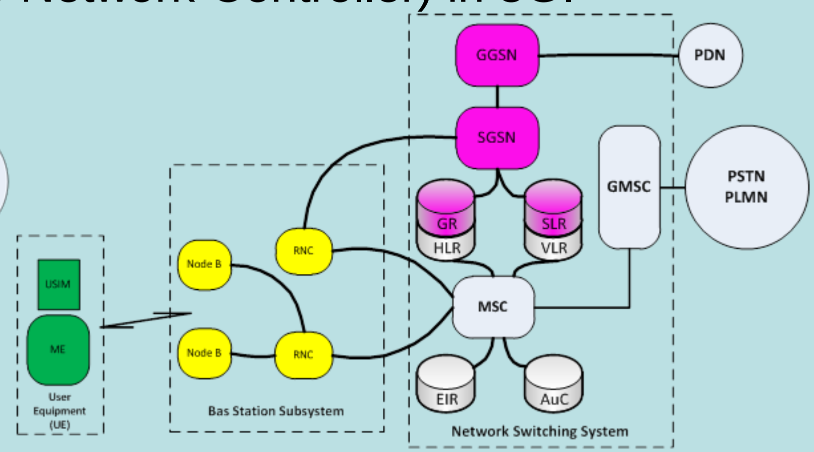
To differentiate the network components

- The MS in 2.5G ← → UE (User Equipment) in 3G
- The SIM in 2.5G ← → USIM in 3G
- The BTS in 2.5G ← → Node-B in 3G

and

- The BSC in 2.5G ← → RNC (Radio Network Controller) in 3G.





3G UMTS system and architecture

In 3G, the UE can have different terminal classes for different services based on the maximum bit rate supported.

- For example, UE can support
  - 32 kbps for basic speech and limited data capabilities
  - 64 kbps for simultaneous speech and data
  - 144 kbps for video telephony
  - 384 kbps, 768 kbps, 2 Mbps for advanced data services

3G UMTS system and architecture

- MS for voice communication using GSM
- MS for data communication using GPRS/EDGE.
- No differentiation in functionalities between different MSs between GSM/GPRS/EDGE and UTMS
- MS and BTS in 2.5G use TDMA/FDMA air interface.
- UE and Node-B in 3G use WCDMA air interface.

3G UMTS system and architecture

- BTS in 2.5G only measures the signal quality and does not decide on handover.
- Node-B in 3G measures the signal quality, perform inner loop power control and decides on soft handover and softer handover.

Hard handover

- all the old radio links in the UE are removed before the new radio links are established.
- In practice, a handover that requires a change of carrier frequency (inter-frequency handover) is always performed as hard handover.

3G UMTS system and architecture

Soft handover

- the radio links are added and removed in a way that the UE always keeps at least one radio link.
- performed by means of macro diversity, which refers to the condition that several radio links are active at the same time.
- can be used when cells operated on the same frequency are changed.

Softer handover

- a special case of soft handover where the radio links that are added and removed belong to the same Node-B, that is the site of co-located base stations from which several sector-cells are served.

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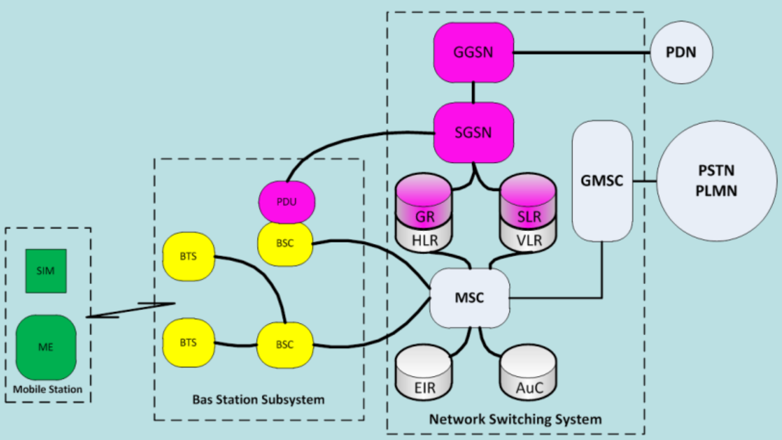
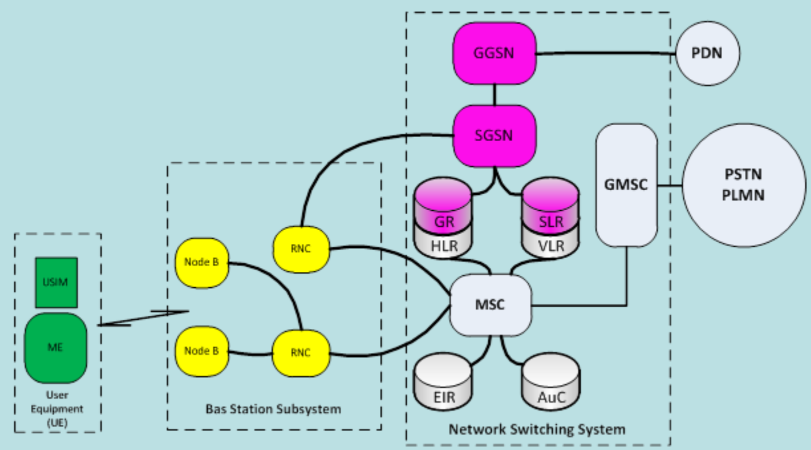
3G UMTS system and architecture

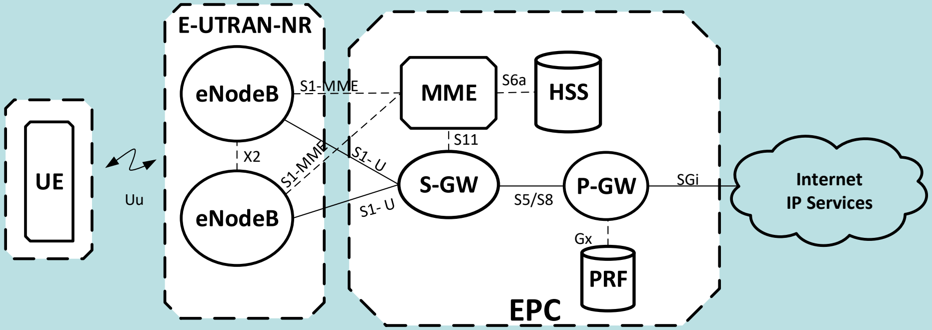
- BSCs in 2.5G do not communicate with one another.
- The RNCs in 3G communicates with one another to manage load control, congestion control and outer loop power control



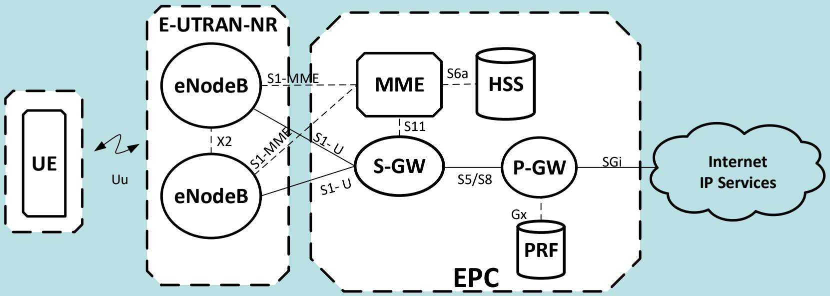


Long Term Evolution, LTE

- What is LTE?
  - LTE is the next generation 3GPP radio access network
  - Based on Evolved Packet System (EPS) which is start with the technology direction of third Generation Partnership Project (3GPP) release 8
- Evolved Packet System (EPS) is comprised of :
  - Evolved Universal Terrestrial Radio Access Network (E-UTRAN)
  - Evolved Packet Core (EPC)



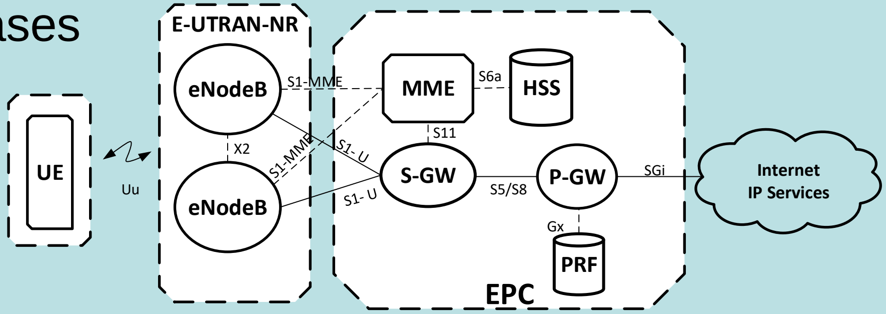
Key Features of LTE



- Radio Side (E-UTRAN)
  - high spectral efficiency
  - very low latency
  - support of variable bandwidth
  - simplification of radio network and
  - Support of packet based services: Multicast, VoIP, etc
- Network Side (Evolved Packet Core – EPC)
  - Simple protocol architecture
  - Improvement in latency, capacity, throughput, idle to active transitions
  - Optimization for IP traffic and services and
  - Simplified support and handover to non-3GPP access technologies

Key Features of LTE

- E-UTRAN
  - consists of the physical element, the Evolved NodeB (eNodeB)
  - absence of a network controller
  - a flat architecture
  - reduces system complexity and cost
  - allows better performance over the radio interface
- Evolved Packet Core (EPC)
  - handles non-radio related tasks such as all mobility and routing to support heterogeneous access networks
  - authentication and billing databases



LTE Air Interface

- LTE Downlink Transmission Scheme
  - the Orthogonal Frequency Division Multiple Access (OFDMA)
  - allow the access of multiple users on the available bandwidth
  - assigned a specific time-frequency resource to each user
- LTE Uplink Transmission Scheme
  - SC-FDMA (Single Carrier Frequency Division Multiple Access)) with cyclic prefix
  - better peak-to-average power ratio (PAPR) properties
- LTE bandwidths
  - 1.4, 3, 5, 10, 15 and 20 MHz
- Peak data rates
  - target 100 Mbps (downlink) and 50 Mbps (uplink) for 20 MHz spectrum allocation, assuming 2 receive antennas and 1 transmit antenna at the terminal

LTE Air Interface

Description	Specifications
Duplex	FDD and TDD
Multiple Access Technique	DL: OFDMA, UL: SCFDMA
Channel Bandwidth	1.4, 3, 5, 10, 15 and 20 MHz
Advanced Antenna Techniques	MIMO 2x2, 4x4
Modulation Type	QPSK, 16-QAM, 64-QAM
Sub-carrier Spacing	15 kHz
Number of symbols per frame	140
Symbol Duration	66.7 us
Forward Error Correction	1/3 Convolutional and Turbo

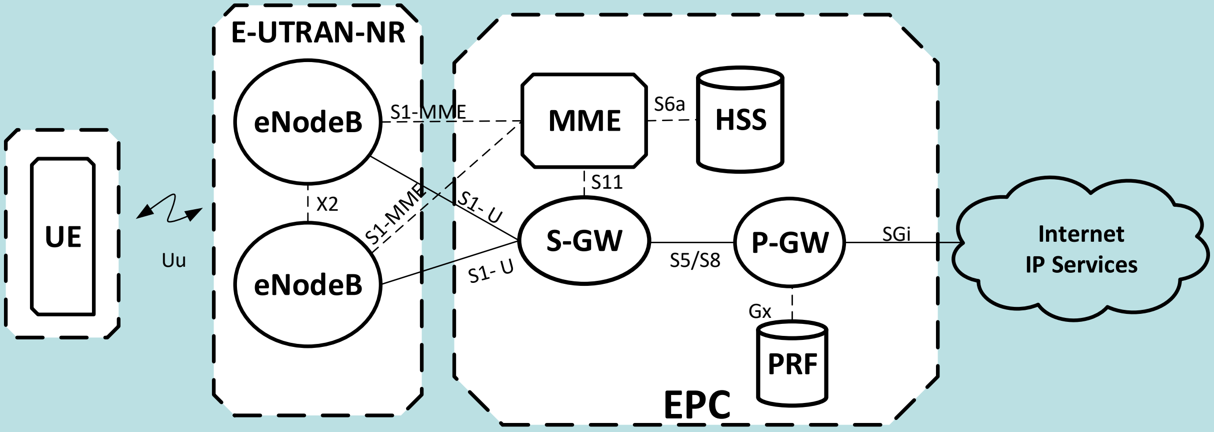
LTE Frequency Bands

- LTE Frequency Bands Covered by different Mobile Operators in Singapore

Frequency Band	**LTE Uplink, FDD**	**LTE Downlink, FDD**	**LTE TDD**
1800 MHz	1710 MHz – 1785 MHz	1805 MHz – 1880 MHz	
2600 MHz	2500 MHz – 2560 MHz	2620 MHz – 2680 MHz	2570 MHz – 2615 MHz

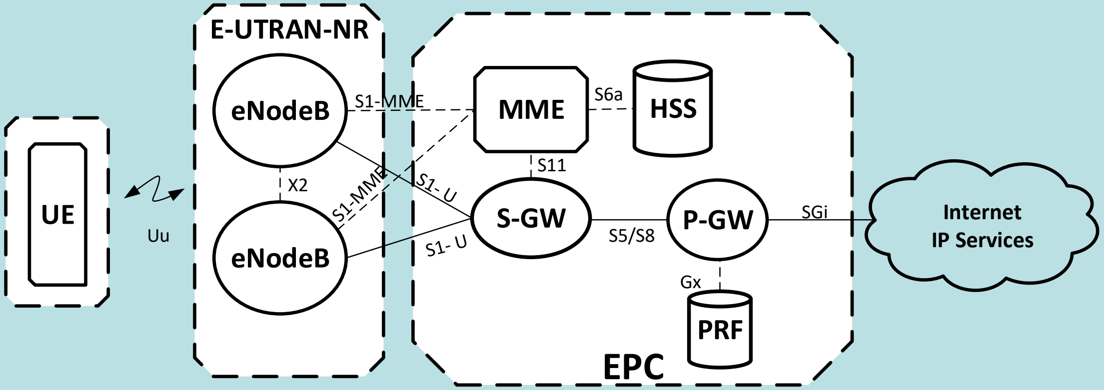
LTE System Architecture

- LTE system architecture consists of
  - user equipment (UE),
  - E-UTRAN and
  - EPC



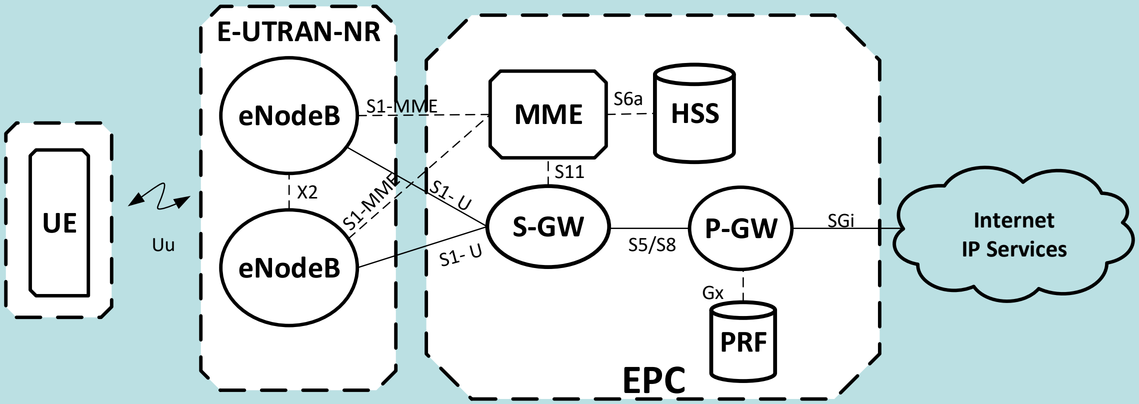
LTE System Architecture

- User Equipment (UE)
  - consists of mico-USIM and radio equipment
  - five LTE user equipment categories depending on maximum peak data rate and MIMO capabilities
- Example, UE with two transmit antennas but only one transmitter chain
  - choose the antenna that provides the best channel to the eNodeB decided by feedback of eNodeB
  - keep the UE cost low



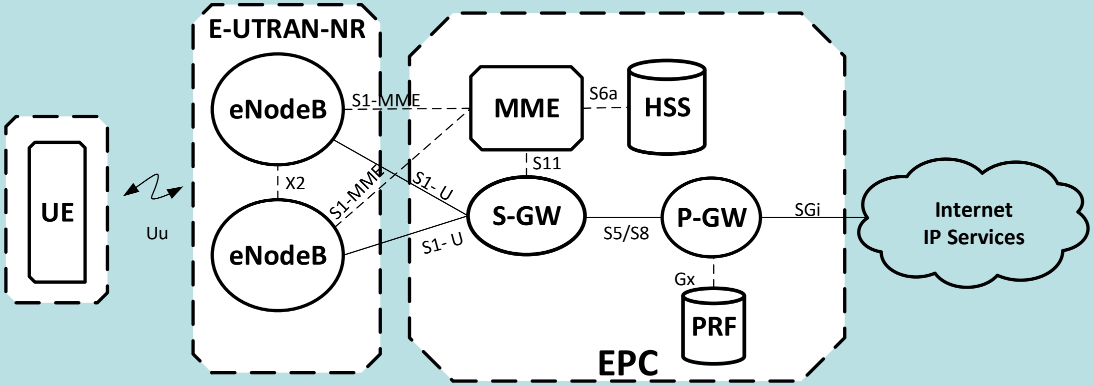
LTE System Architecture

- Enhanced Node-B (eNodeB)
- handle tasks that related to radio functionality of EPS such as
- coding, multi-antenna techniques, radio-resource management, fast retransmission, scheduling and adaption control to improve latency and throughput of the network
  - Scheduling and dynamic allocation of resources to UEs in both uplink and downlink direction
  - Controlling mobility of the UE in connected mode
  - State transition from IDLE to connected mode and vice versa
  - Admission control and congestion control
  - Buffer of the data during handover



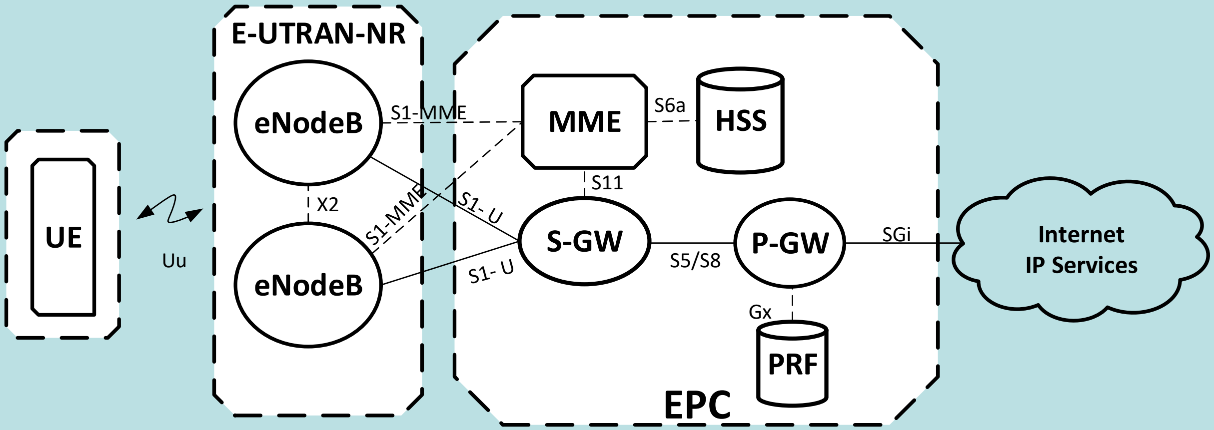
LTE System Architecture

- Mobility Management Entity (MME)
- MME is responsible for Control Plane signalling and its functions:
  - Interacts with HSS for user authentication, profile download, etc.
  - Interacts with eNodeB and S-GW for S-GW selection, tunnel control, paging, handovers, etc.
  - Handle mobility management in Idle mode
  - Maintain US context during IDLE mode of UE
  - Responsible for NSA signalling and NAS signalling security
  - Does bearer management for the UE



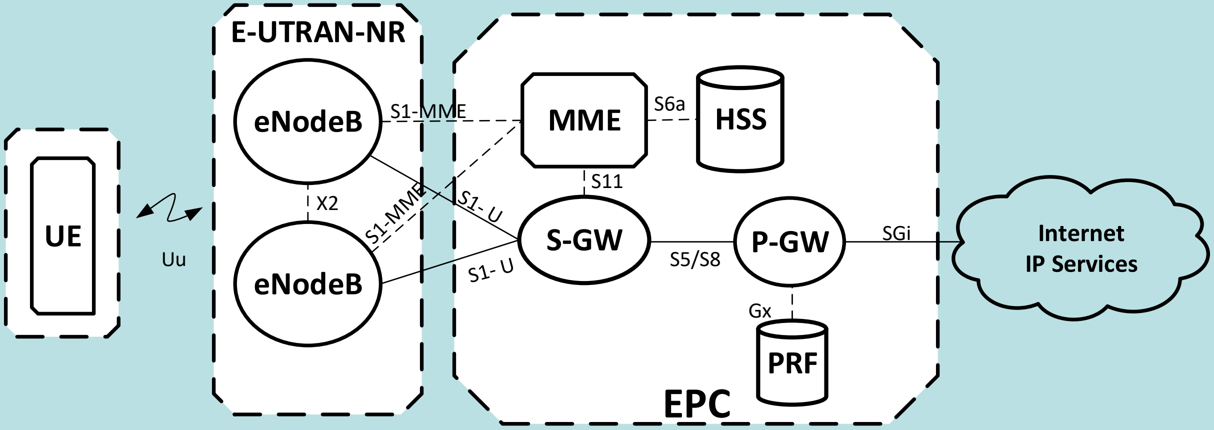
LTE System Architecture

- Serving Gateway (S-GW)
- S-GW is responsible for user plane or data plane anchoring for 3GPP access and 2G/3G bearer plane interworking. It functions:
  - Act as mobility anchor for the data bearers
  - Buffers the downlink data when UE is in IDLE mode
  - Processes all IP packets to/from UE (QoS control, LQI)



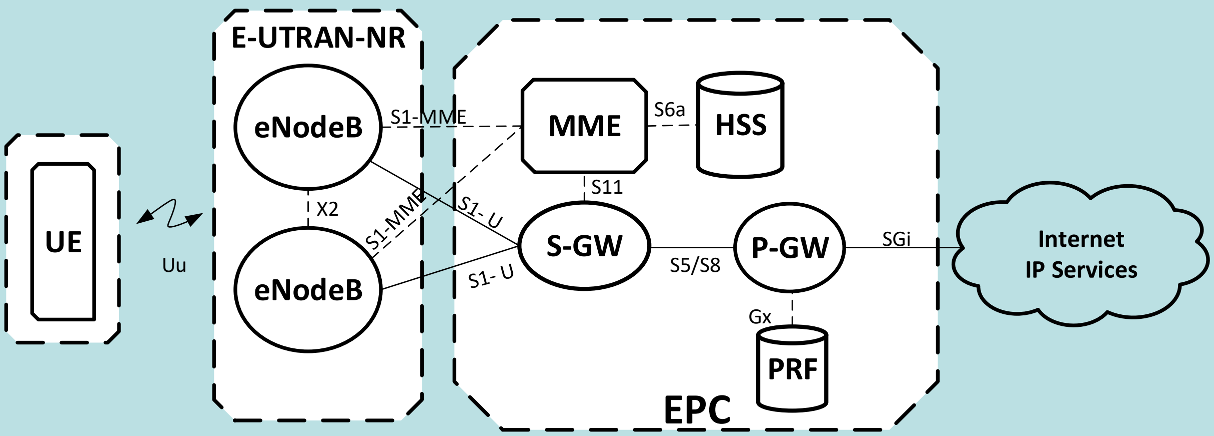
LTE System Architecture

- Home Subscriber Server (HSS)
- HSS carried forward from UMTS and GSM and centralised database holding user profile. It functions:
  - Interacts with MME for user authentication and profile download
  - Stores current location information (e.g. assigned MME, Serving SGW)
  - One or more subscription profiles containing IMSI, QoS, Services, etc.



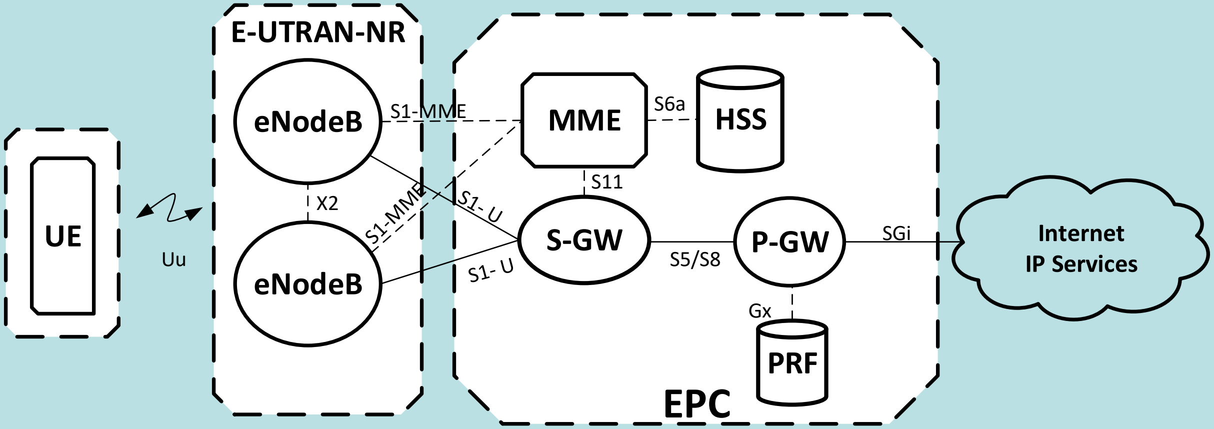
LTE System Architecture

- Packet Data Network Gateway (PDN-GW)
- Subscriber-aware data plane anchoring for all access networks. It functions:
  - Anchor point in home or visited network for all IP-based access (3GPP or not)
  - Session-based user authentication and IP address allocation (IPv4/v6)
  - Processes all IP packets to/from UE (QoS control, PCEF, LI)



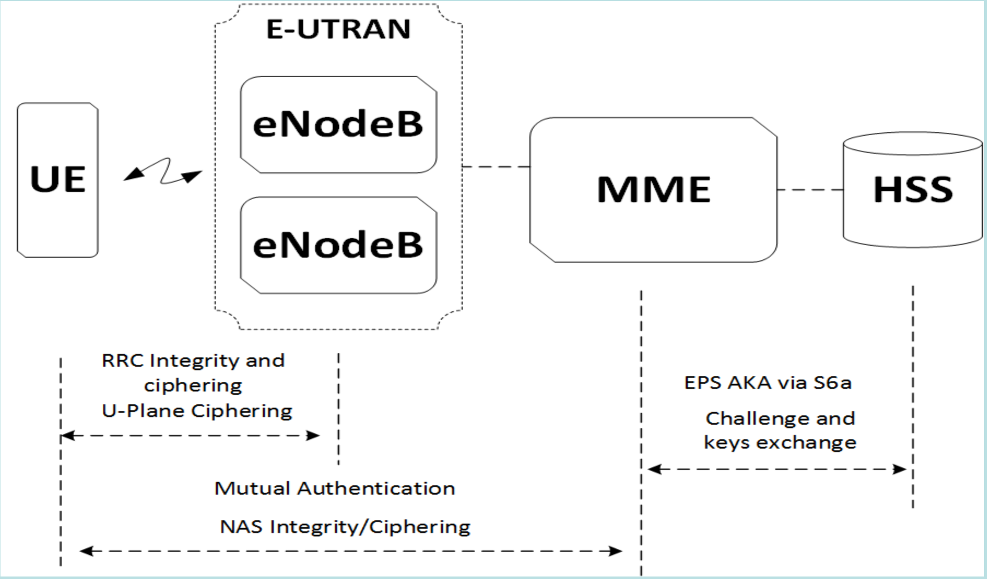
LTE System Architecture

- Policy & Charging Rule Function (PCRF)
- User and application-aware policy decision point. It functions:
  - Interacts with PGW to enforce per session or per flow policies
  - Gets event notification from PGW (mobility and/or traffic related)
  - Interacts with application for admission control and policy definition
  - Supports roaming capabilities



Evolved Packet System Security (EPS Security)

- USIM and HSS are required to be used for security in LTE.
  - There are different set of keys used for ciphering, derived from the same original K stored in the USIM/HSS



LTE Advanced, 4G

- LTE Advanced is the next milestone in the evolution of LTE, starting from 3GPP Rel. 10.
- The goals of LTE-A:
  - Increased data throughput
  - Improved flexibility of spectrum allocation
  - Decrease latency
  - Increase reliability data transmission
  - Increase in communication efficiency

- LTE-A can provide as much as 10x the speed (both uplink and downlink) of LTE. In addition, latency is also lower than 5 msec.

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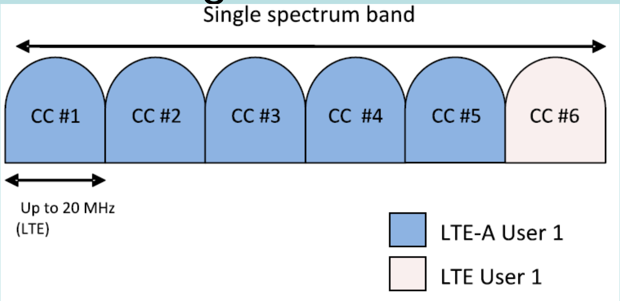
LTE Advanced, 4G

- Three major categories of enhancements
  - Carrier aggregation to leverage more spectrum and increase data rates (bps)
  - Enhanced MIMO technique to increase spectral efficiency (bps/Hz)
  - Relay Node to improve data communication especially cell boundary to increase coverage
- increase capacity and improve the user experience, the most gain comes from optimizing HetNets.

Carrier aggregation

- Carrier aggregation technique
  - boost transmission capacity, achieve higher peak data rates
  - the maximum channel bandwidth as 100MHz
- For medium data rates
  - the use of lower orders of modulation and lower code rates
  - reduce the required link budget, transmission power, and interference
  - better coverage
- Example
  - Carrier aggregation in contiguous bandwidth

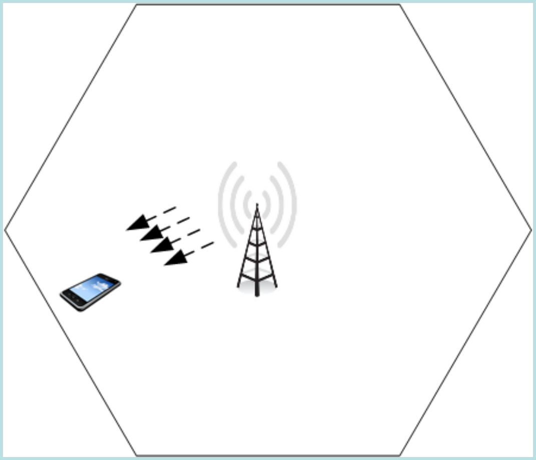


Enhanced MIMO technique for higher spectral efficiency

- based on an adaptive multi-mode framework
- demand of higher data rates and wider coverage
- selecting the appropriate MIMO scheme
- adaptation strategy is chosen based on all the different channel measurements that are gathered at the base station through a low rate feedback mechanism
- three operating modes
  - Single-User MIMO (SU-MIMO)
  - Multi-User MIMO (MU-MIMO)
  - Cooperative Multipoint (CoMP) MIMO

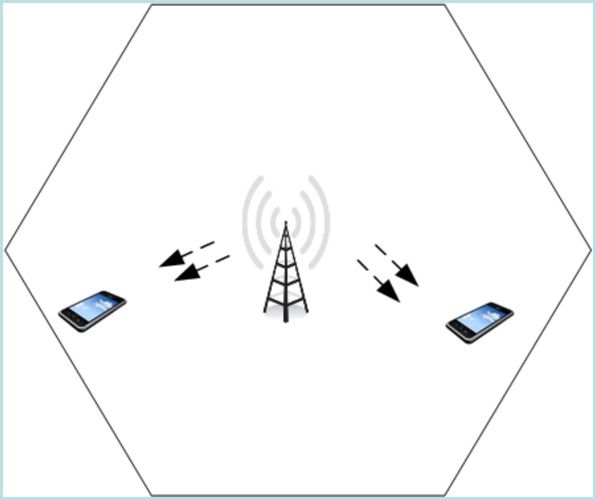
Single-User MIMO (SU-MIMO)

- transmit diversity and spatial multiplexing techniques using beamforming
- higher-order MIMO to substantial increase in the peak user data rates



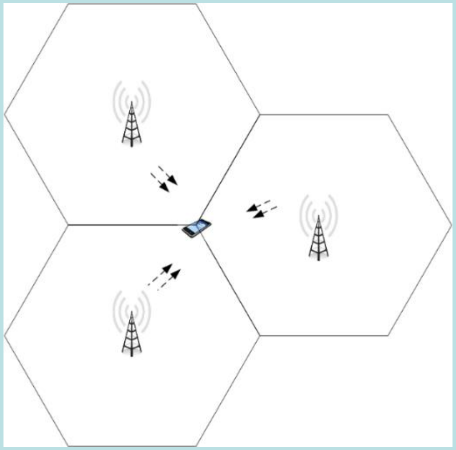
Multi-User MIMO (MU-MIMO)

- flexibility of SDMA
- a different number of streams to reach each user in order to increase the cell average data rate



Cooperative Multipoint (CoMP) MIMO

- boosted by enabling techniques that use coordination in transmission and reception of signals among different base stations, which also helps reducing inter-cell interference
- increase capacity and improve the user experience
- processing and scheduling is centralized
- needs low-latency fibre connections between the processing/scheduling facility and the cells



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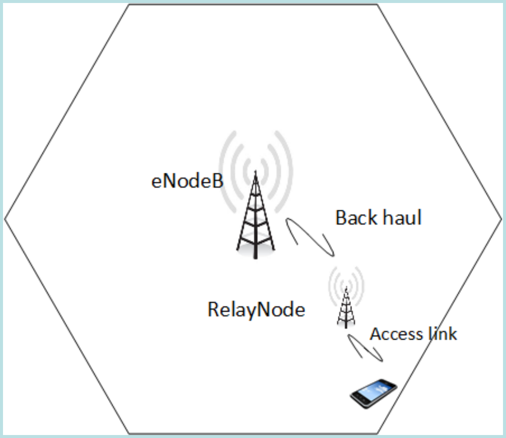
Relay Node

- Improve coverage and throughput
- Provide coverage in new areas
- Temporary network deployment
- Cell-edge throughput
- Coverage of high data rate
- Group mobility



LTE – Cat M1

- LTE Cat M1, suitable for the IoT
- LTE-MTC low power wide area (LPWA) technology standard published by 3GPP in the Release 13 specification
- supports IoT through lower device complexity and provides extended coverage, while allowing the reuse of the LTE installed base
- battery lifetime as long as 10 years
- a wide range of use cases
- modem costs reduced to 20-25% of the current EGPRS modems

Narrowband IoT (NB-IoT)

- LTE Cat NB1, Low Power Wide Area (LPWA) technology
- many more devices to the Internet of Things
- optimized for applications that need to communicate small amounts of data over long periods of time
- operates in licensed spectrum and existing established mobile networks, it is able to provide security, reliability, and guaranteed quality of service
  - low device price
  - Optimized for very low power consumption +10 year of battery life
  - excellent extended long range coverage and deep penetration indoors and underground
  - integrated into the cellular system, therefore easy deployment into existing cellular network architecture
  - network security & reliability (industry standard based)
  - lower component cost

Summary

- The architecture of GSM with a brief description of the functions performed by each equipment.
- An understanding of GMSK modulation
- The frame structure of GSM
- Two stages of architecture evolution from 2G GSM to 3G UMTS
- Changes made from 2G GSM to 2.5G GPRS
- GPRS System Architecture
- Changes made in 3G UMTS
- LTE
- LTE-A
- LTE – Cat M1
- Narrowband IoT (NB-IoT)