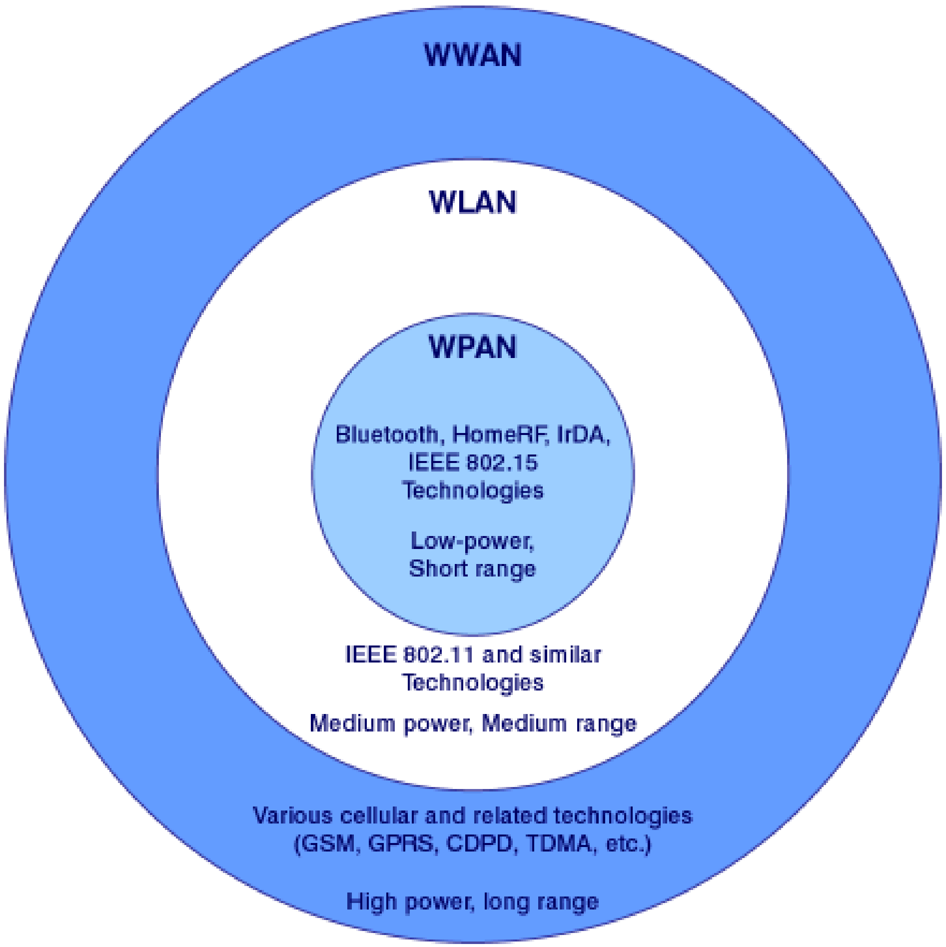
Advanced Communication Networks

Muhammad Taha Jilani

Lecture - 7

Wireless Technologies Hierarchy



WWAN TECHNOLOGIES

Cellular Technologies

GSM Network

- GSM stands for Global System for Mobile communication
  - Defined standards in 1988
  - First testing call – 1991
  - First deployment - 1992

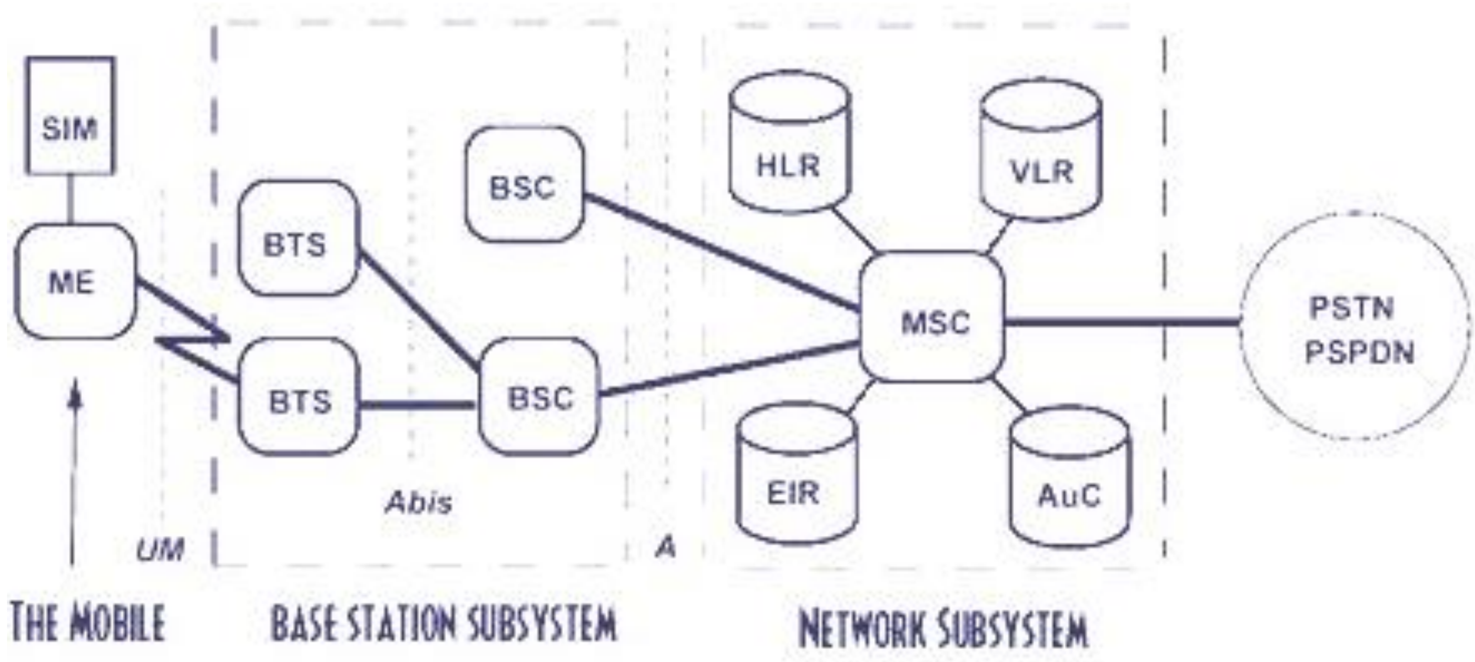
80% Global Mobile market :
5 Billion users (as of 2010)
Australia, Dec 2016 – 1^{st} Shutdown

- The 2^{nd} Generation of Mobile communication system
  - Analog to Digital
  - SMS(Short Message Services)
  - Multi Party Calling, Call holding, Call waiting
  - Call line identity
  - Cell broadcast

GSM Network

- GSM Frequency Range
  - Operates at : 850, 900, 1800 MHz
- Data rate
  - Channel access method : TDMA
  - 270 Kbps (with 8 Channels)

GSM Network Architecture



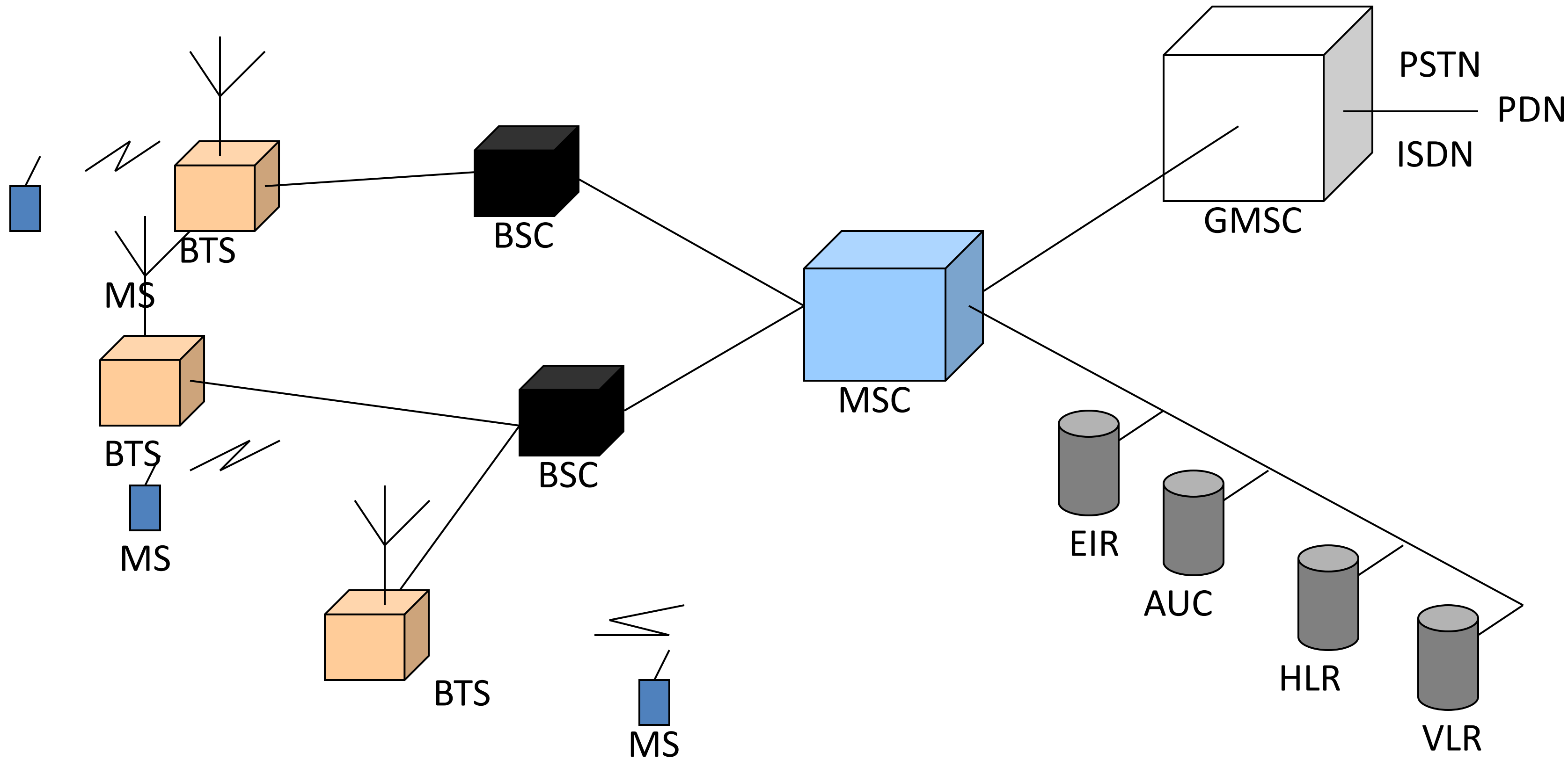
Base Station Subsystem(BSS)
Network Switching Subsystem(NSS) → *Databases/Registers of GSM Network*
Network Management Subsystem(NMS) or Operation and Support Subsystem(OSS)

GSM Network

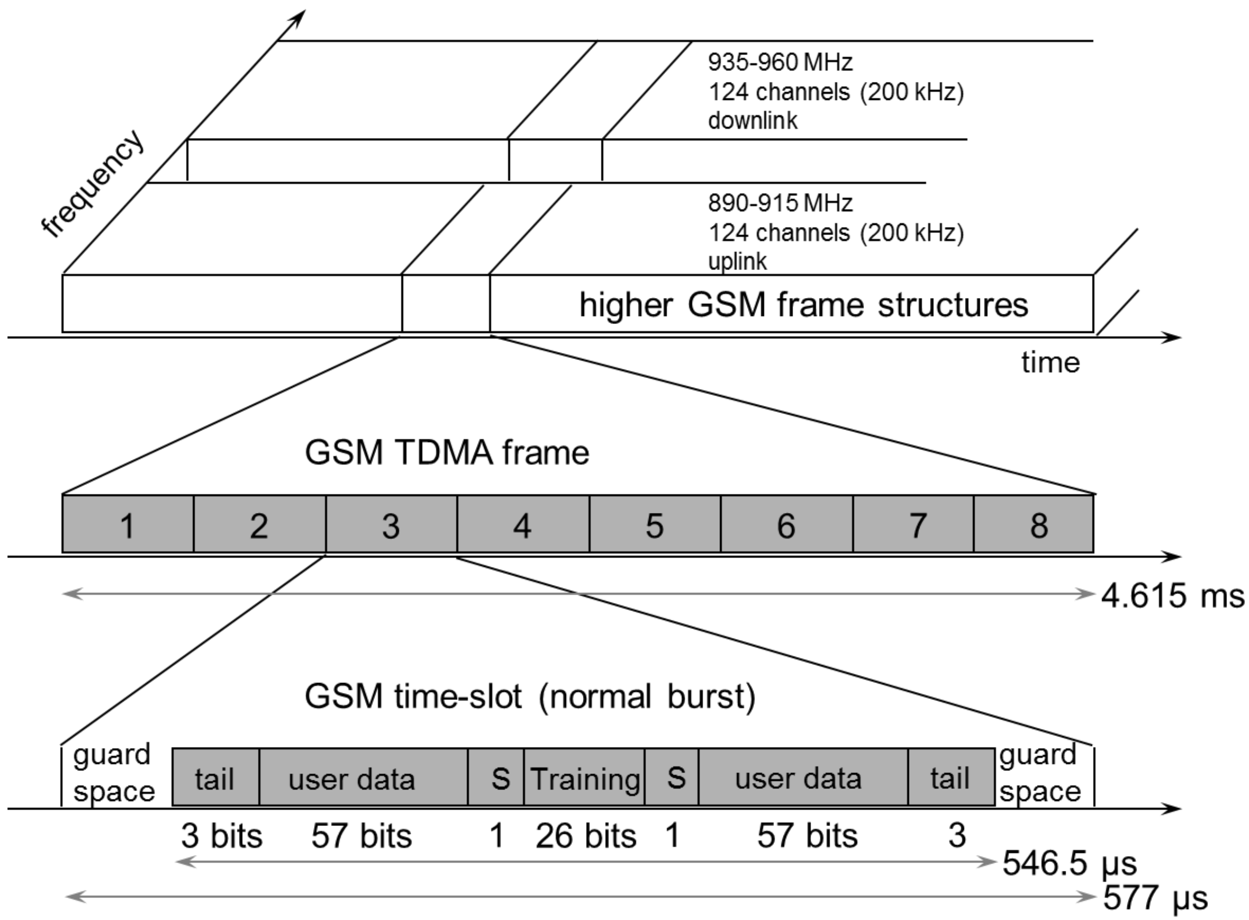
- User Identification in the Network
  - MSISDN = CC + NDC + SN
  - CC : Country Code
  - NDC : National Destination Code
  - SN : Subscriber Number

GSM Architecture

Voice traffic



GSM Frame Format

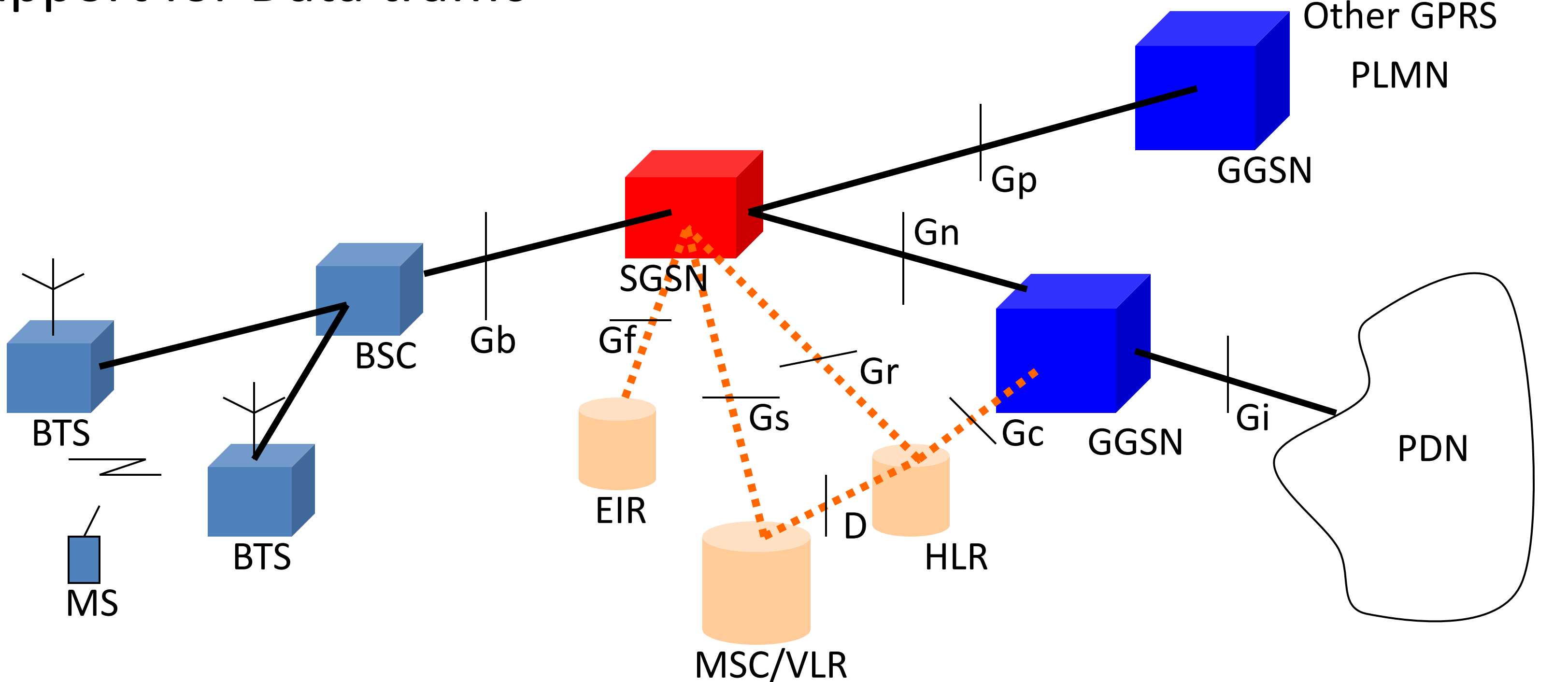


GPRS - General Packet Radio Service

- Data traffic?
- A service for GSM that greatly improves and simplifies wireless access to packet data networks, e.g to the internet.
  - Based on packet switching
  - Data rate in the range of 9-20 kbps initially
  - Then extend up to 115 kbps

GPRS Architecture

Support for Data traffic

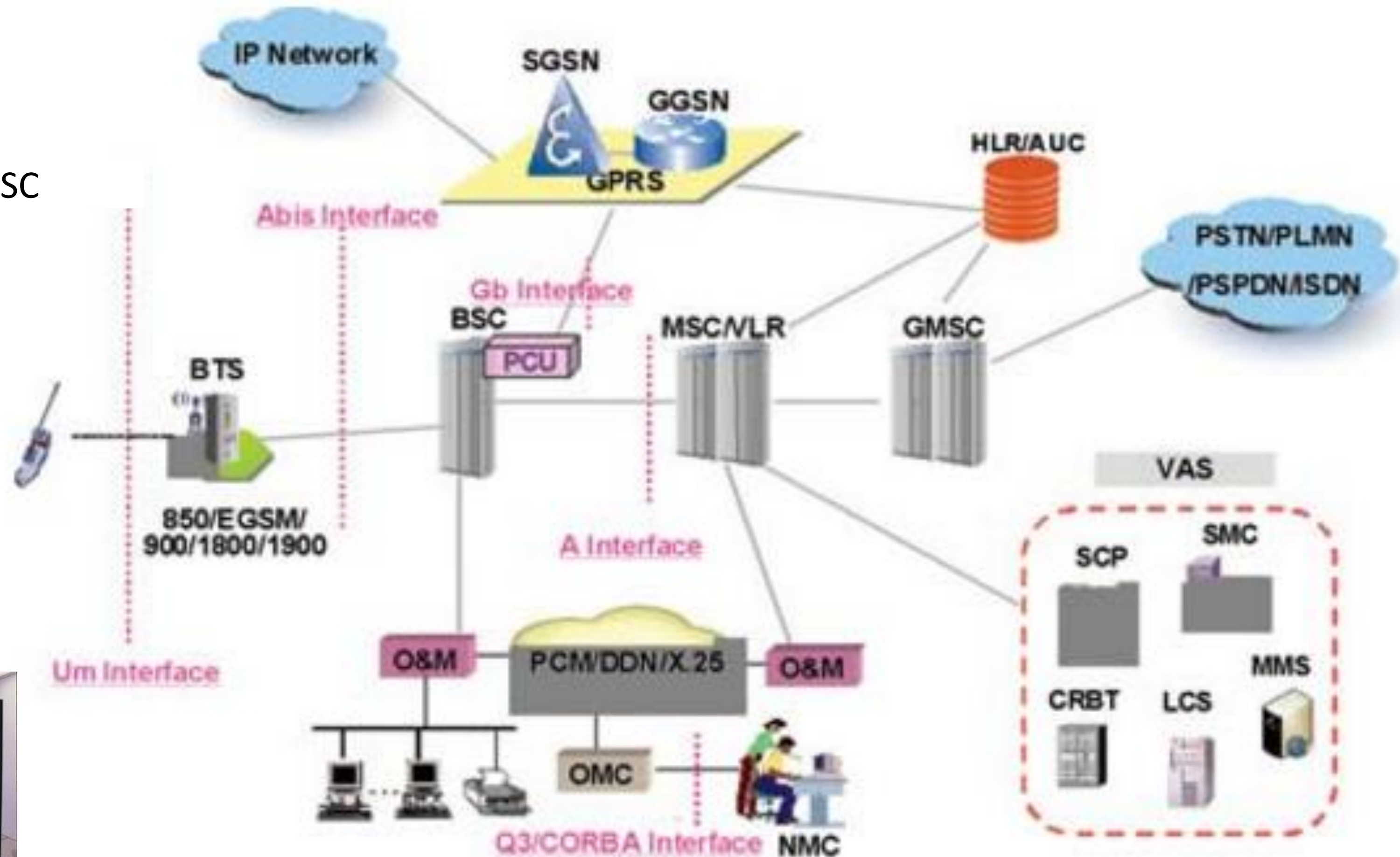


GPRS network elements

- GSN (GPRS Support Nodes): GGSN and SGSN
- GGSN (Gateway GSN)
  - interworking unit between GPRS and PDN (Packet Data Network)
- SGSN (Serving GSN)
  - supports the MS (location, billing, security)
- GR (GPRS Register)
  - user addresses

GSM/GPRS Network Architecture

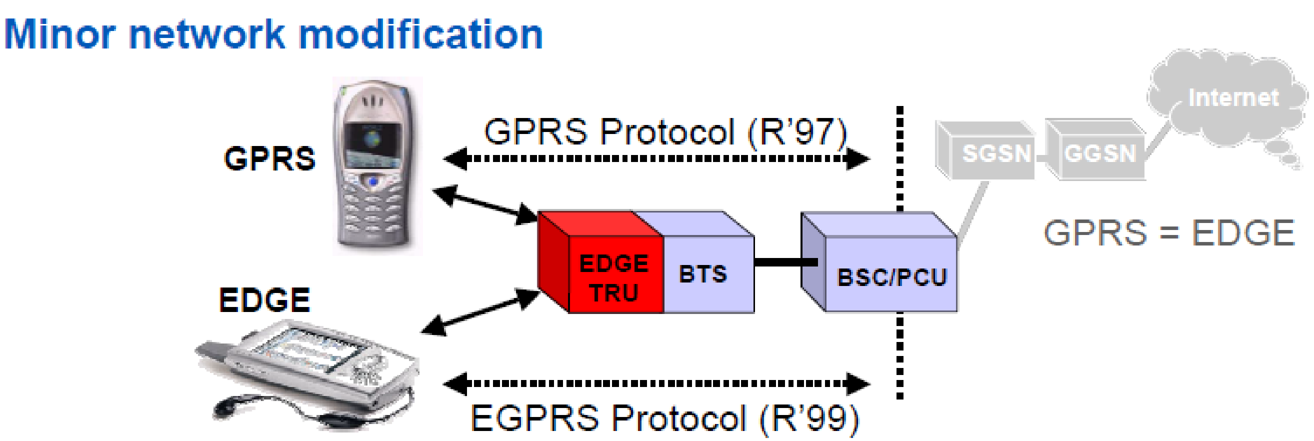
Typical BSC



MSC

EDGE : Enhanced Data rates for Global Evolution

- To provide higher data rate for packet-traffic
  - Data rate: 384 kbps
    - Higher bit rate modulation (8PSK)
    - More robust radio protocol
    - Link Quality Control : Link Adaptation



Network Security

- GSM Security
  - Air-interface: Encryption algorithms : A5/1, A5/2, and A5/3 stream ciphers
    Broken-2007
  - General Packet Radio Service (GPRS) uses GEA/1 and GEA/2 ciphers

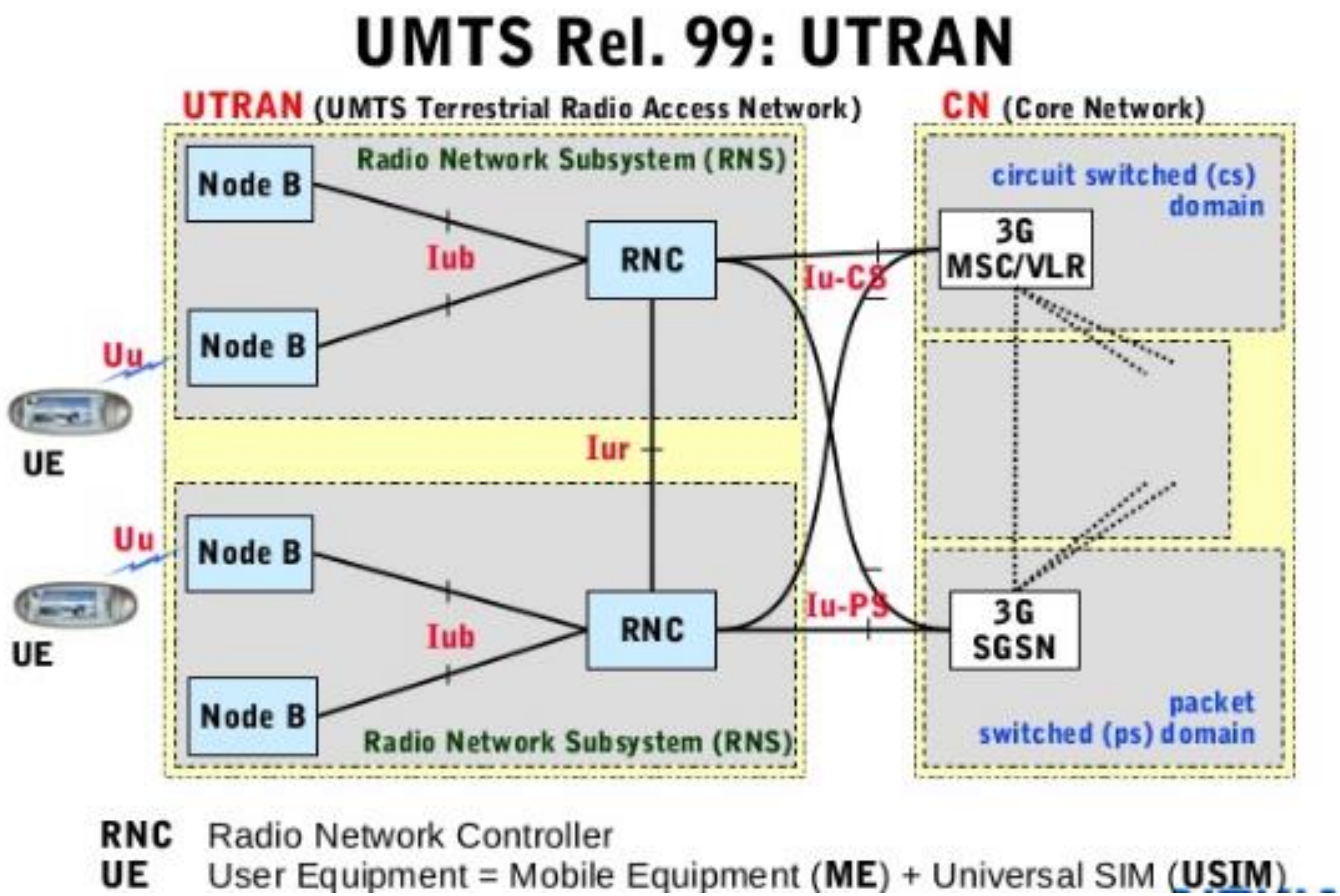
Wideband Code Division Multiple Access (WCDMA) for UMTS

- Need for support to packet data services
  - IP data in the core network
  - IP radio access
  - Convergence of existing networks
- New services in mobile multimedia need higher data rates and flexible utilization of the spectrum
- 3rd Generation Technology –UMTS/CDMA
  - Higher data rates
  - Extensive changes in Access and Core Network

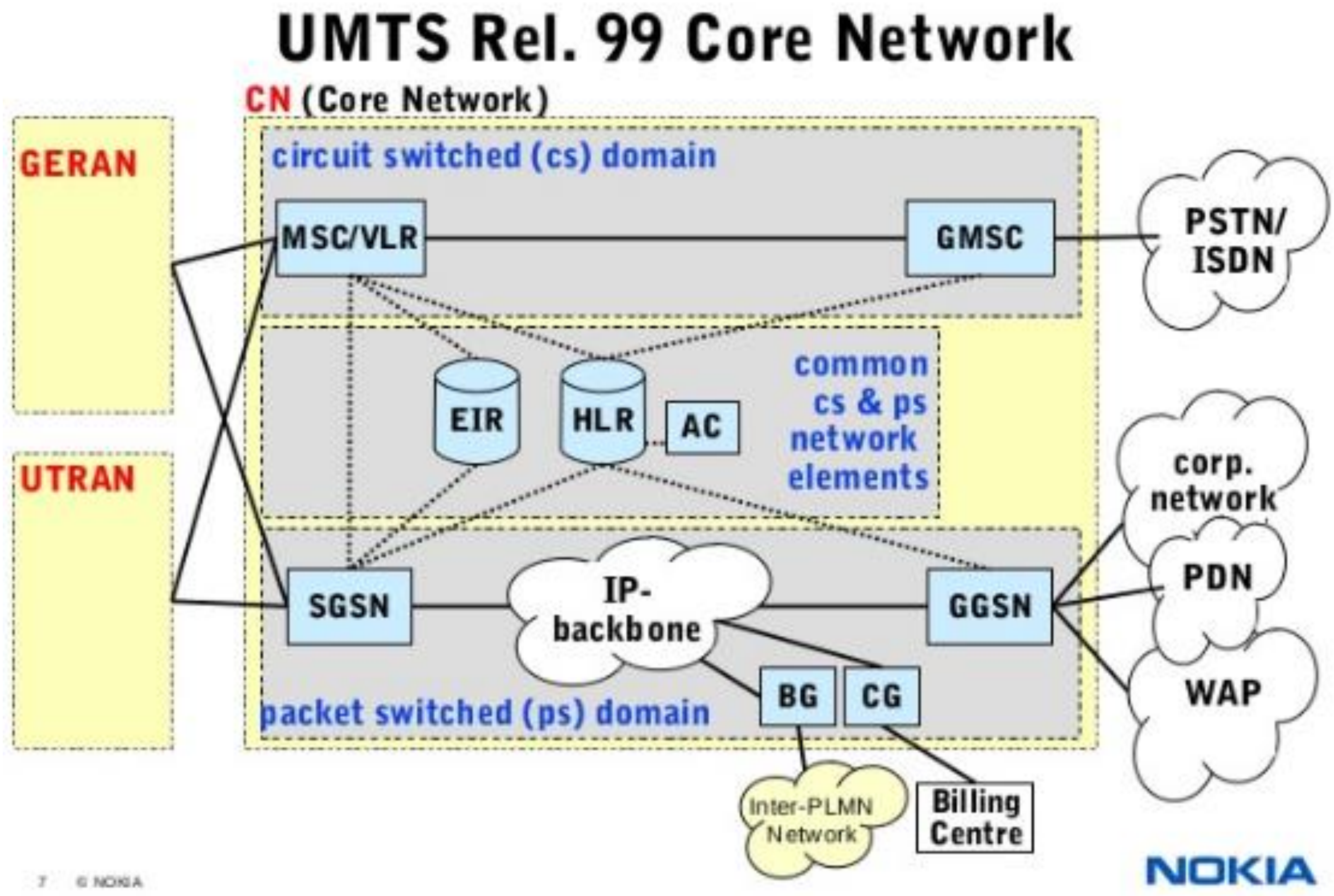
Wideband Code Division Multiple Access (WCDMA) for UMTS

- FDMA and TDMA are not efficient enough
  - TDMA wastes time resources
  - FDMA wastes frequency resource
  - CDMA can exploit the whole bandwidth constantly
- WCDMA was selected for a radio access system for UMTS
- High bit rates
  - With Release '99 theoretically 2 Mbps : Real 384 kbps

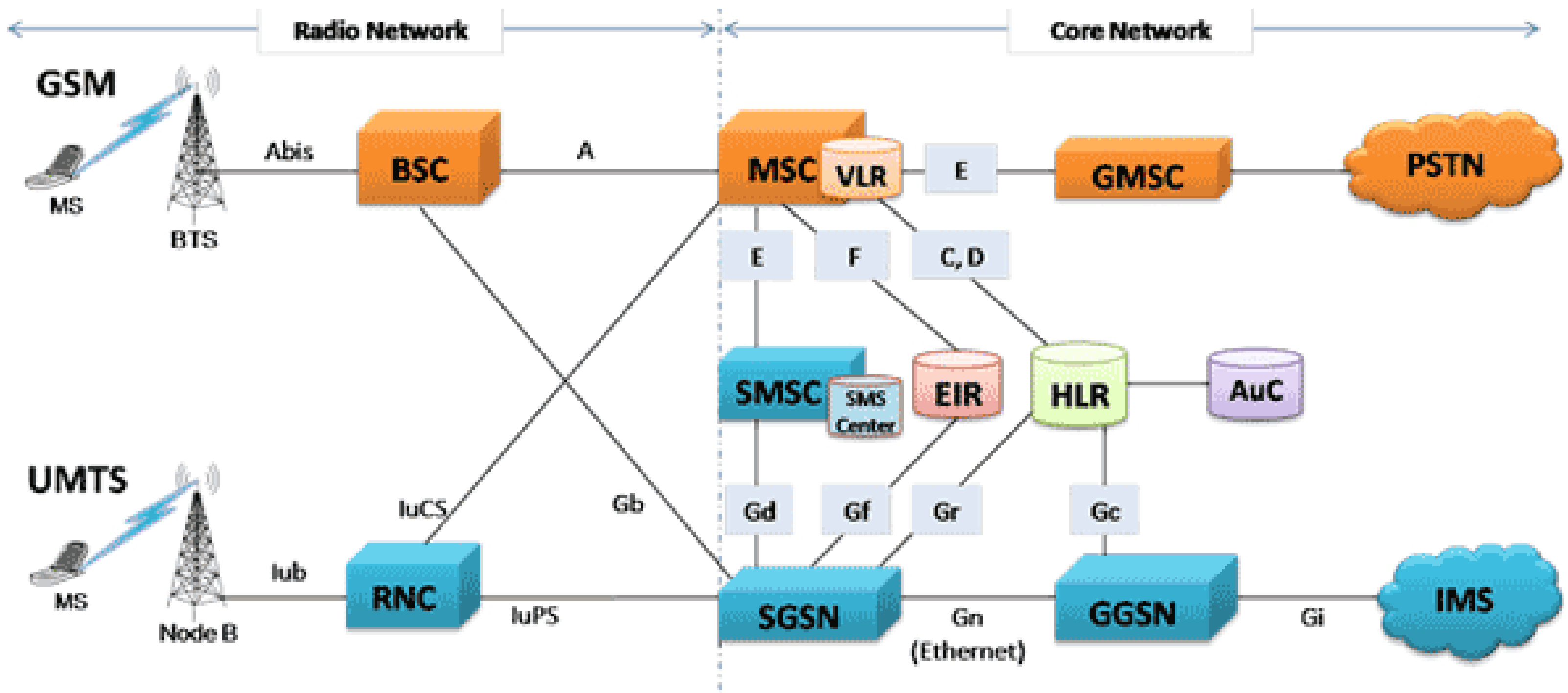
UMTS/WCDMA Network



UMTS/WCDMA Network

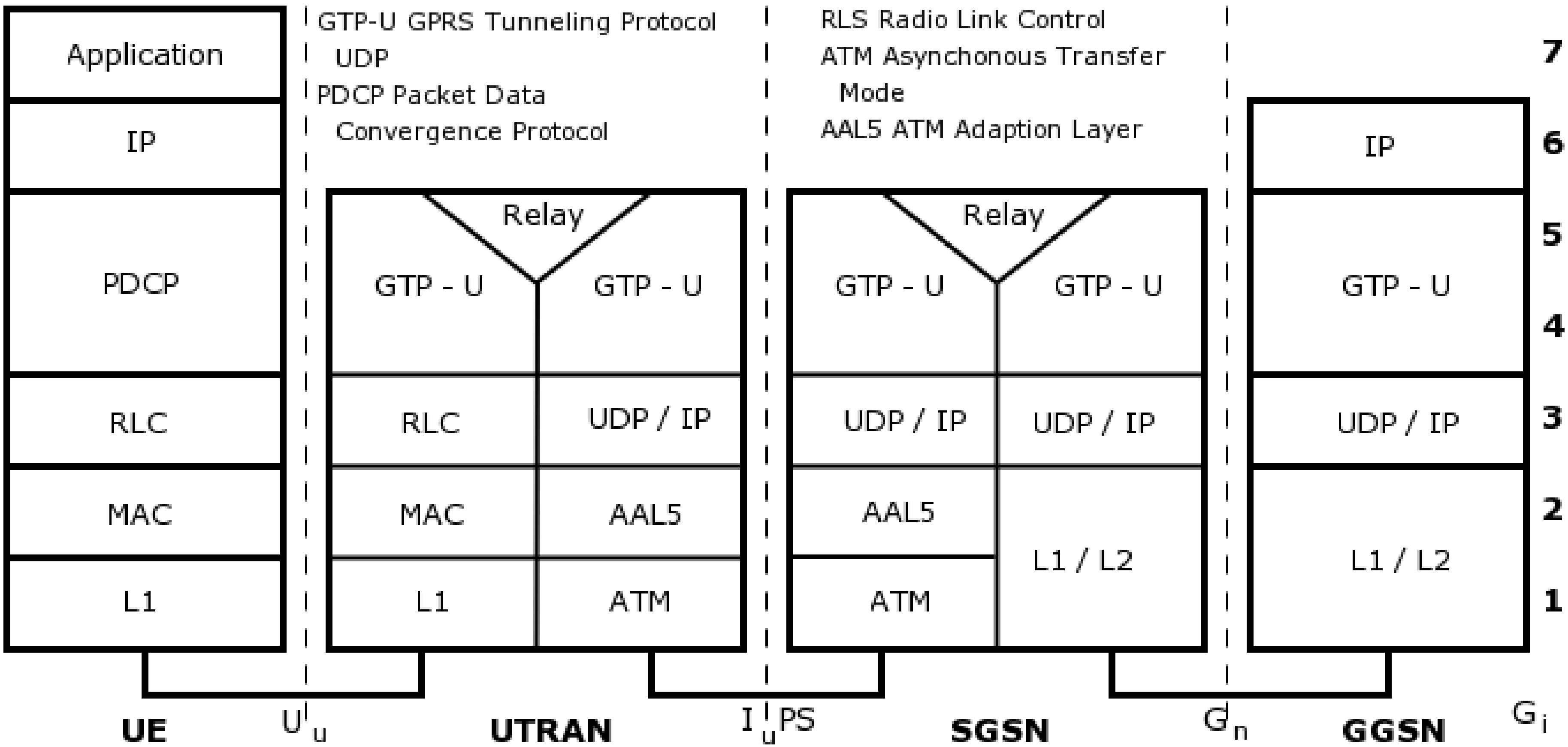


Backward Compatible: GSM & UMTS

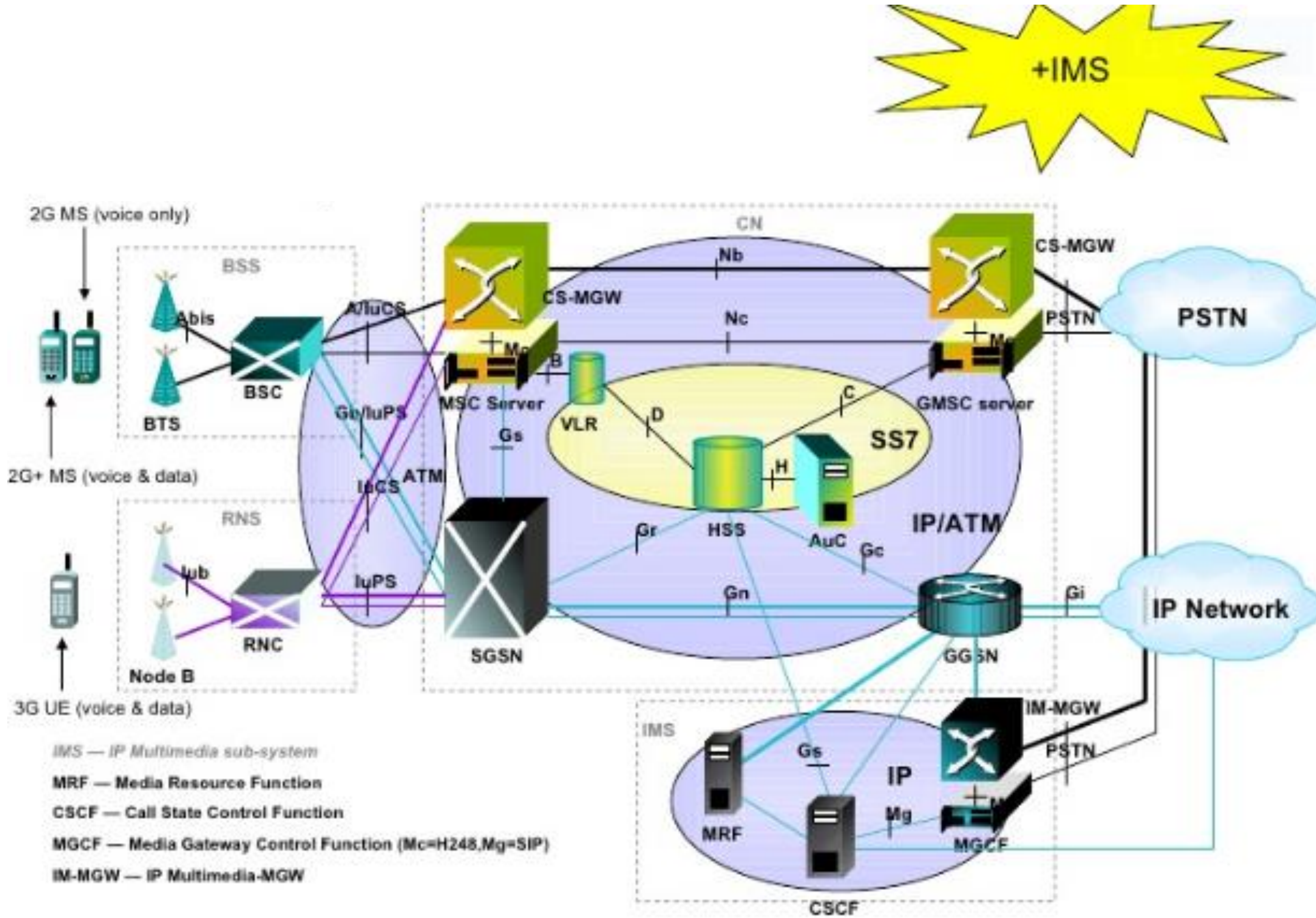


UMTS Protocol Stacks

- The UTMS packet switching domain protocol stack



IP Multimedia Core Network Subsystem (IMS)



IMS Protocol

- In IMS, the Session Initiation Protocol (SIP) is used to
  - initiate, terminate and modify multimedia sessions such as voice calls, video conferences, streaming and chat.
  - SIP is specified by the Internet Engineering Task Force
  - SIP runs on different IP transport protocols such as the User Datagram Protocol (UDP) and the Transmission Control Protocol (TCP).
  - SIP can be used to establish two-party (unicast) or multiparty (multicast) sessions.
  - SIP employs design elements similar to the HTTP request/response transaction mode

Advanced Communication Networks

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Lecture - 8

Before Midterm

- Recap
  - WWAN

HSDPA : High Speed Downlink Packet Access

- Improves System Capacity and User Data Rates in the Downlink Direction to 10Mbps in a 5MHz Channel

- Adaptive Modulation and Coding (AMC)
  - Replaces Fast Power Control :
    User farer from Base Station utilizes a coding and modulation that requires lower Bit Energy to Interference Ratio, leading to a lower throughput

  - Replaces Variable Spreading Factor :
    Use of more robust coding and fast Hybrid Automatic Repeat Request (HARQ, retransmit occurs only between MS and BS)

- Fast Retransmission with Soft Combining and Incremental Redundancy
  - Soft Combining : Identical Retransmissions
  - Incremental Redundancy : Retransmits Parity Bits only

- Fast Scheduling Function
  - which is Controlled in the Base Station rather than by the RNC

HSDPA is max. **14.4 Mbps**,
HSUPA max. data rate of **5.74 Mbps**

Beyond 3G or 3.75G

Long-term Evolution (LTE)

- The ITU-R set standards for 4G connectivity in 2008, as follows:
  - For mobile use, including smartphones and tablets, connection speeds need to have a peak of at least 100 Mbps
  - For more stationary uses such as mobile hotspots, at least 1 Gbps
- Long Term Evolution, and isn’t as much a technology as it is the path followed to achieve 4G speeds.
- Proposed in Release 8, main

Long-term Evolution (LTE)

Motivation for LTE

- Proposed in Release 8, with main motives are
  - Need to ensure the continuity of competitiveness of the 3G system for the future
  - User demand for higher data rates and QoS
  - All IP network & Packet Switch optimised system
  - Continued demand for cost reduction
  - Low complexity

Long-term Evolution (LTE)

LTE in Pakistan

- In Pakistan, since 2014, three telcos are providing 4G services to their subscribers.
- A detailed report released by Open Signal on 4G LTE speeds and coverage around the world, revealed that Pakistan has an average LTE speed of just 4 Mbps; which is slightly above the average for speeds of 3G (3.5 Mbps).
- South Korea and Singapore have set themselves apart by providing the best coverage (97% & 83%) and the best speed, respectively. Singapore provides its citizens the fastest average LTE speed of 37 Mbps
- While, in the World average speed is 13mbps.

Long-term Evolution (LTE)

- Changes at PHY Layer
  - The LTE physical layer is based on Orthogonal Frequency Division Multiplexing scheme OFDM to meet the targets of high data rate and improved spectral efficiency.
  - The spectral resources are allocated/used as a combination of both time (aka slot) and frequency units (aka subcarrier).
  - MIMO options with 2 or 4 Antennas is supported.
  - The modulation schemes supported in the downlink and uplink are QPSK, 16QAM and 64QAM.

Long-term Evolution (LTE)

- Changes at RLC & MAC Layer
  - At Radio Link Control (RLC) Sub Layer, the new functions that are added:
    - Acknowledged, Unacknowledged and Transparent Mode Operation
    - Concatenation, Segmentation and Reassembly of RLC SDUs (AM and UM)
    - Transfer of Upper Layer PDUs to MAC
    - Duplicate detection (UM and AM)
    - RLC re-establishment

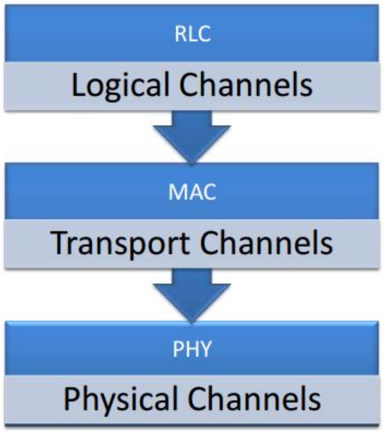
Acknowledged Mode
- SAR & RLC headers
- Reliable in sequence delivery
- Suitable for carrying TCP traffic

Unacknowledged Mode
- SAR & RLC headers
- No delivery guarantees
- Suitable for streaming traffic

Transparent Mode
- No SAR & RLC headers
- No delivery guarantees
- Suitable for carrying voice

Long-term Evolution (LTE)

- Changes at RLC & MAC Layer
  - MAC functions are:
    - Mapping between Transparent and Logical Channels
    - Error Correction Through Hybrid ARQ
    - Priority Handling with Dynamic Scheduling
    - Logical Channel Prioritization



1. RLC layer passes data (PDUs) to the MAC layer as logical channels.
2. The MAC layer formats and sends the logical channel data as transport channel.
3. The physical layer encodes the transport channel data to physical channels.

Long-term Evolution (LTE)

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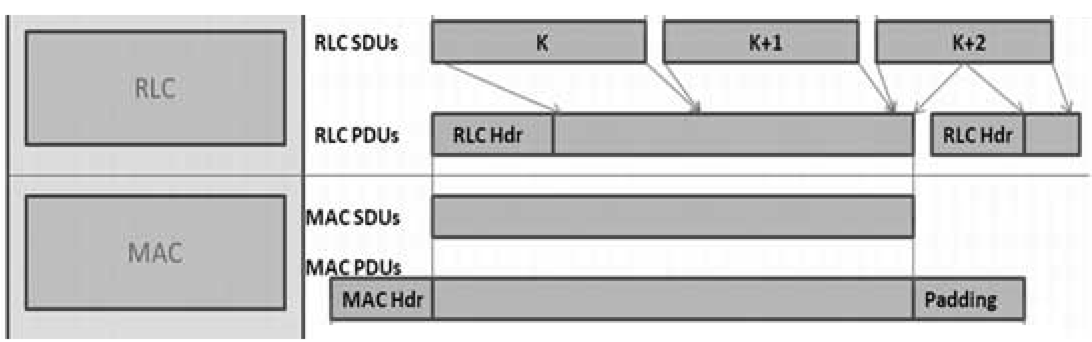
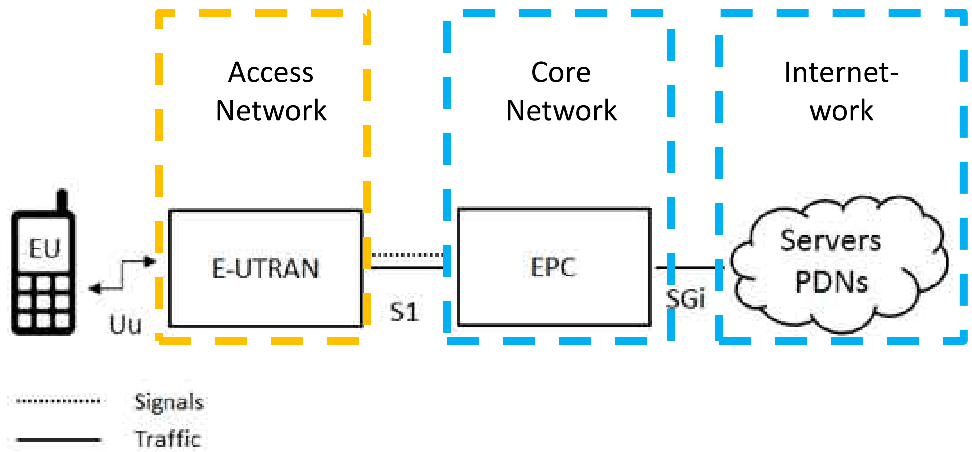


Long-term Evolution (LTE)

- Changes at RLC & MAC Layer
  - The Hybrid-ARQ is suggested at the MAC layer in addition to the ARQ at the RLC layer.
    - Automatic Repeat Query, is used for data error-control that uses acknowledgements and timeouts (specified periods of time allowed to elapse before an acknowledgment is to be received) to achieve reliable data transmission over an unreliable service. Also CRC bits are added to detect error in data.
    - Hybrid ARQ, use the original data that is encoded with a forward error correction (FEC) code, and the parity bits are either immediately sent along with the message or only transmitted upon request when a receiver detects an erroneous message. hybrid ARQ performs better than ARQ in poor signal conditions

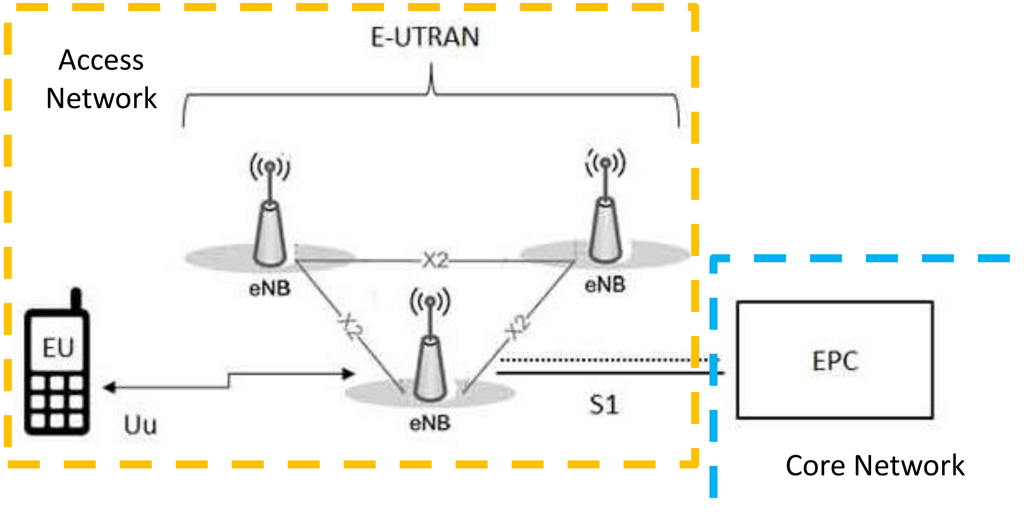
Long-term Evolution (LTE)

- Simple Network Architecture



Long-term Evolution (LTE)

- E-UTRAN - The Access Network Architecture



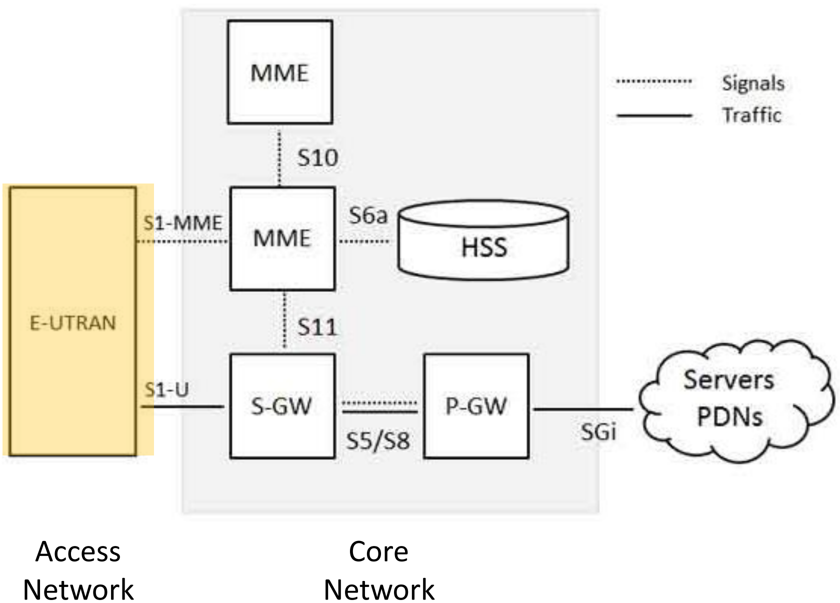
e-NodeB sends and receives radio transmissions to all the mobiles using the analogue and digital signal processing functions of the LTE air interface.

The eNB controls the low-level operation of all its mobiles, by sending them signaling messages such as handover commands.

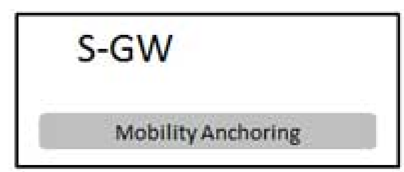
eNBs communicate each other at X2 interface that is based on GTP-U over UDP or IP.

Long-term Evolution (LTE)

- Evolved Packet Core (EPC) - The core network

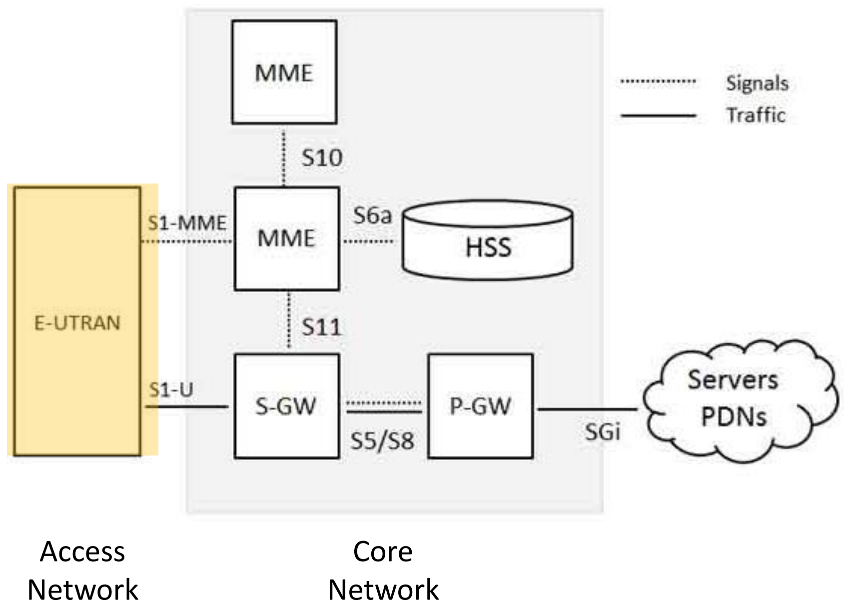


Serving Gateway (S-GW) acts as a router, and forwards data between the base station and the PDN gateway.

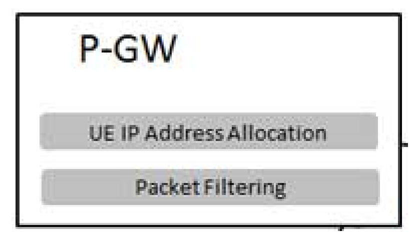


Long-term Evolution (LTE)

- Evolved Packet Core (EPC) - The core network

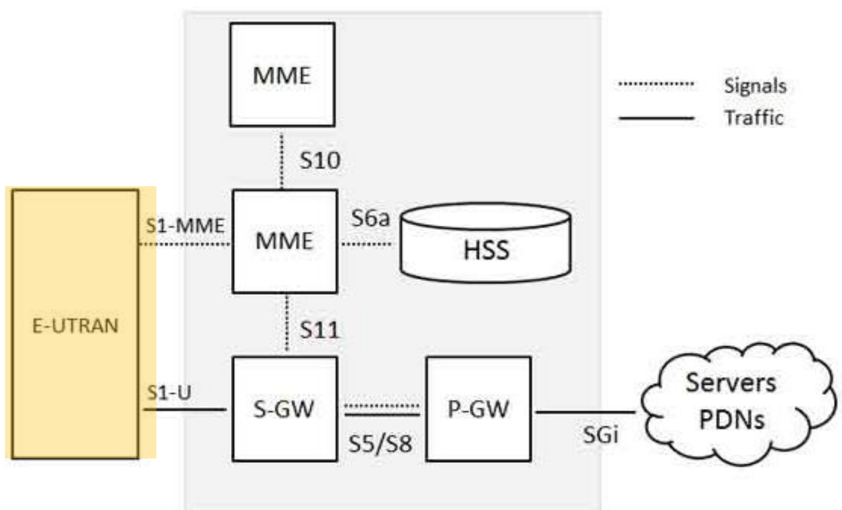


Packet Data Network (PDN) Gateway (P-GW) communicates with the outside world ie. packet data networks PDN. Each packet data network is identified by an access point name (APN). The PDN gateway has the same role as the GPRS support node (GGSN) and the serving GPRS support node (SGSN) with UMTS and GSM.



Long-term Evolution (LTE)

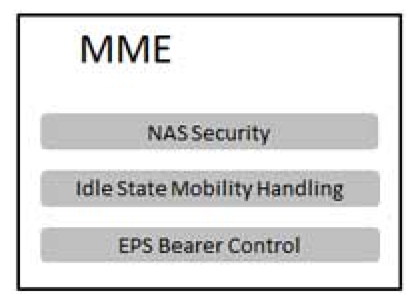
- Evolved Packet Core (EPC) - The core network



Access Network

Core Network

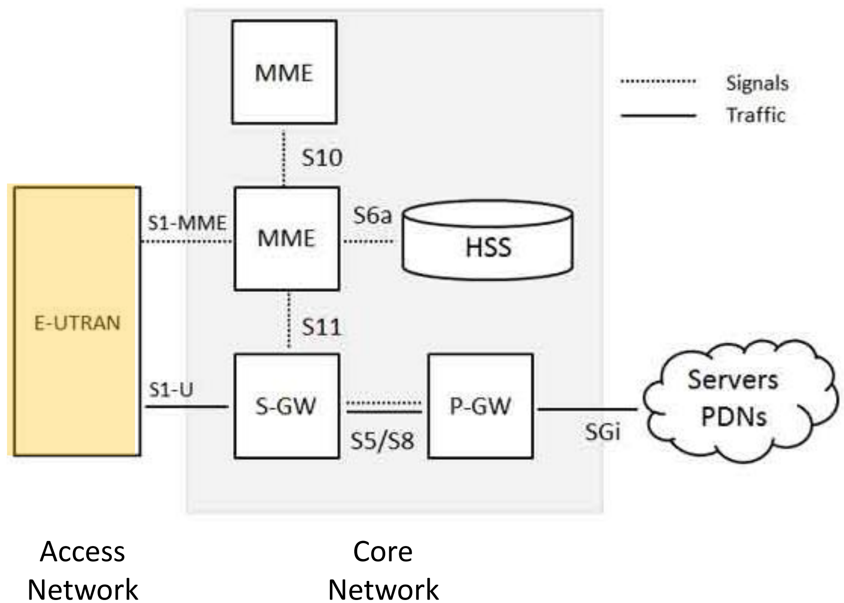
Mobility Management Entity (MME) controls the high-level operation of the mobile by means of signaling messages and Home Subscriber Server (HSS). MME is similar to VLR in GSM



MME connected to E-UTRAN through Stream Control Transmission Protocol (SCTP) over IP a *transport layer protocol*

Long-term Evolution (LTE)

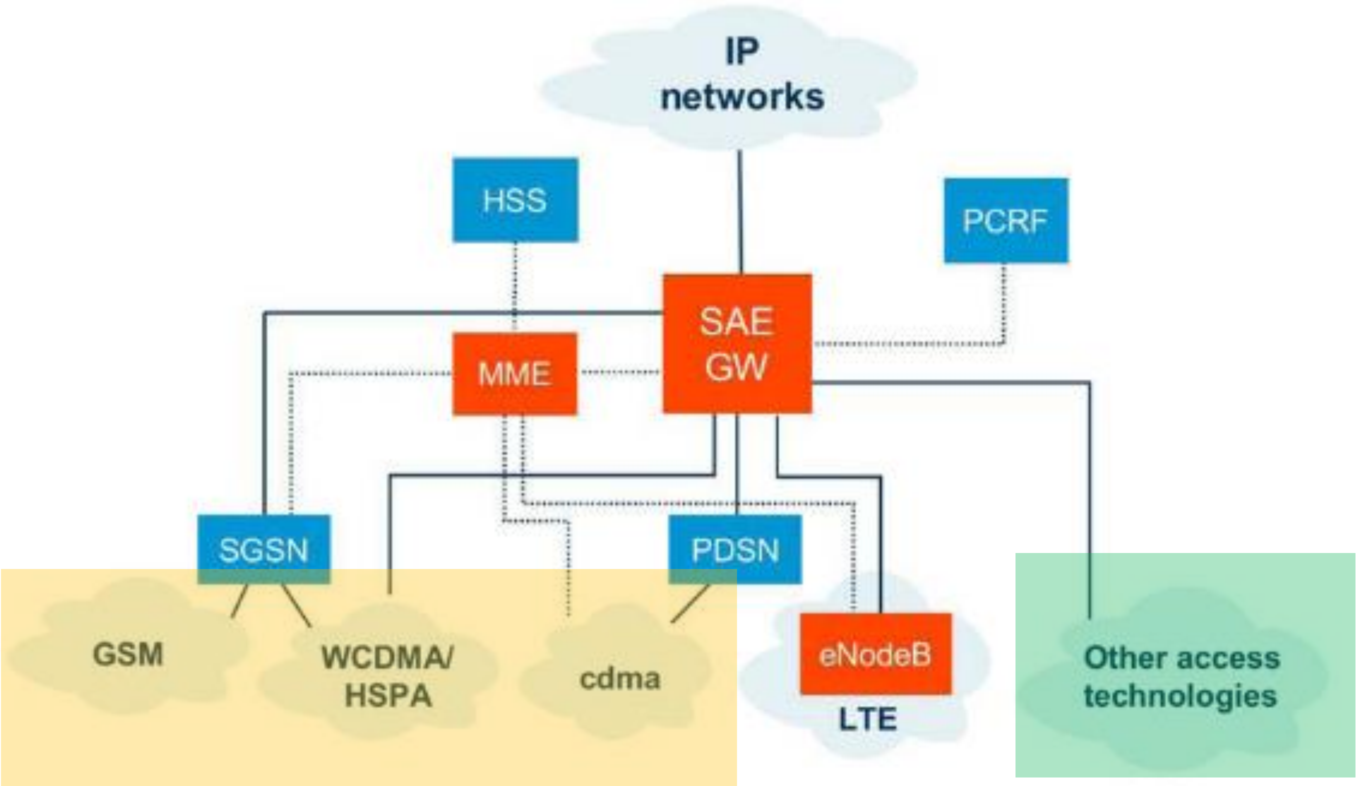
- Evolved Packet Core (EPC) - The core network



Home Subscriber Server (HSS)
Similar to UMTS and GSM, it is a central database that contains information about all the network operator's subscribers. HSS is similar to HLR in GSM

Long-term Evolution (LTE)

LTE Compatibility to Existing Networks

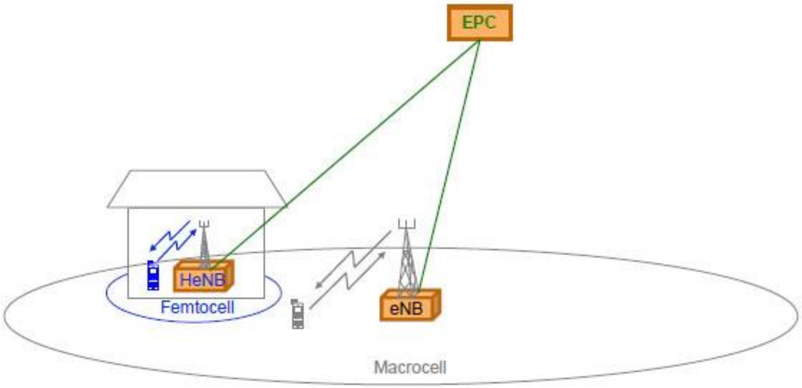


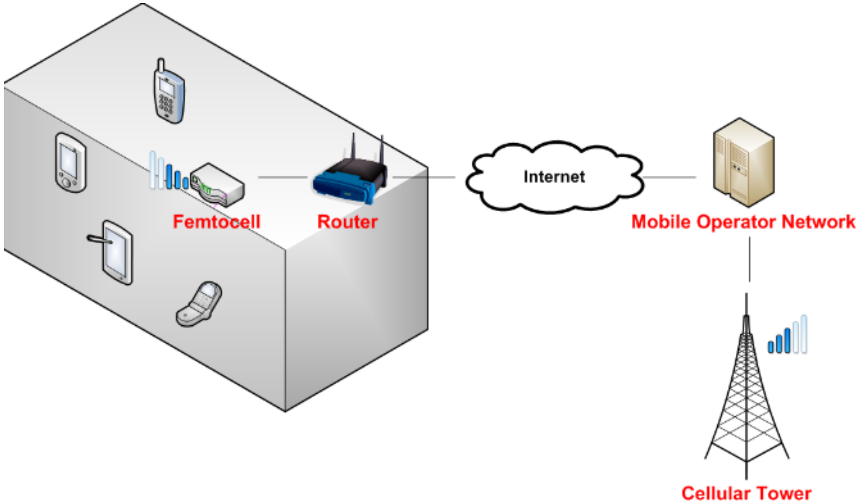
2G/3G Technologies

2G/3G Technologies

Long-term Evolution (LTE)

- Femtocell in LTE network

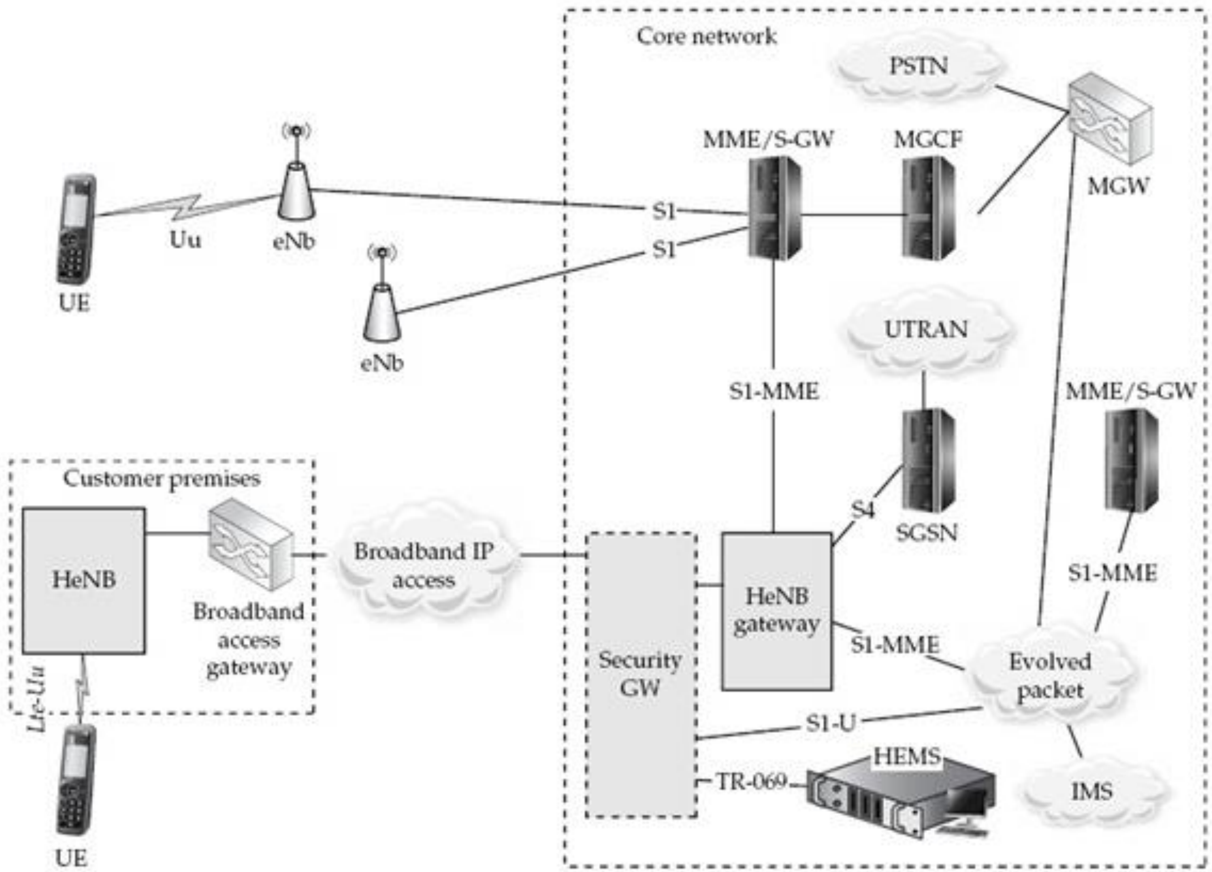




Home e-NodeB is a base station that has been purchased by a user to provide femto-cell coverage within the enterprise or home (in the order of 10 meters). A home eNB belongs to a closed subscriber group (CSG) and can only be accessed by mobiles with a USIM that also belongs to the closed subscriber group.

Long-term Evolution (LTE)

- Femtocell in LTE network



Long-term Evolution (LTE)

- Femtocell Connectivity

Long-term Evolution (LTE)

- Femtocell Application – *enables IoT*