LTE Network Architecture

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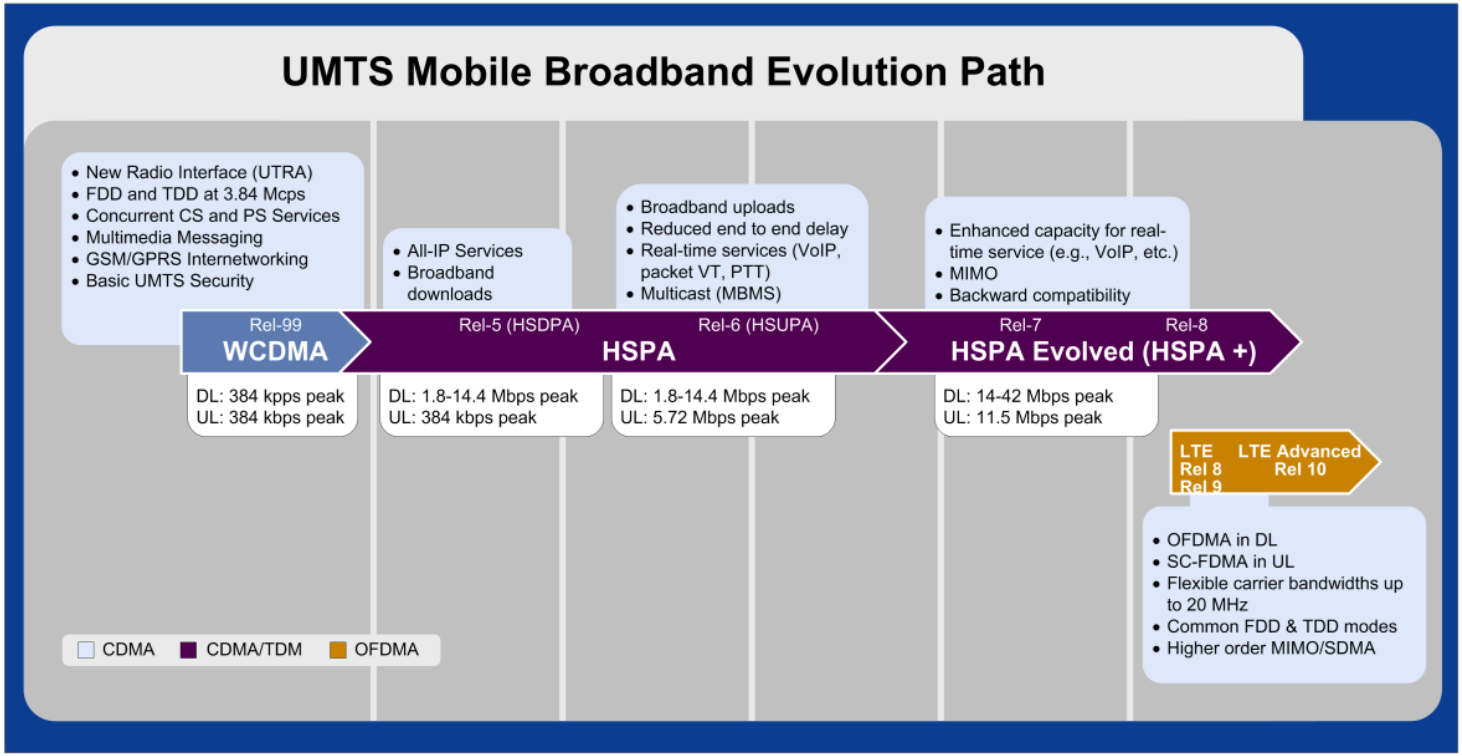
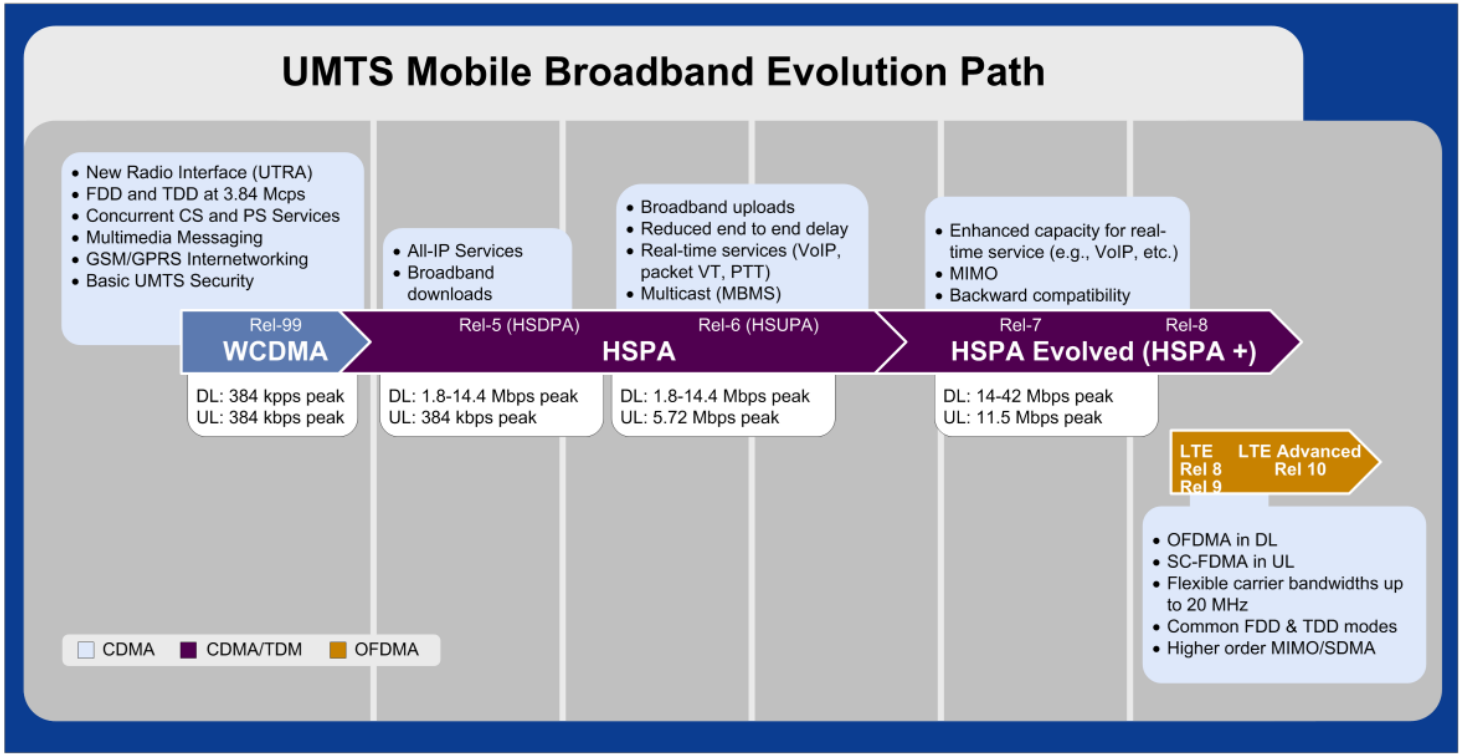
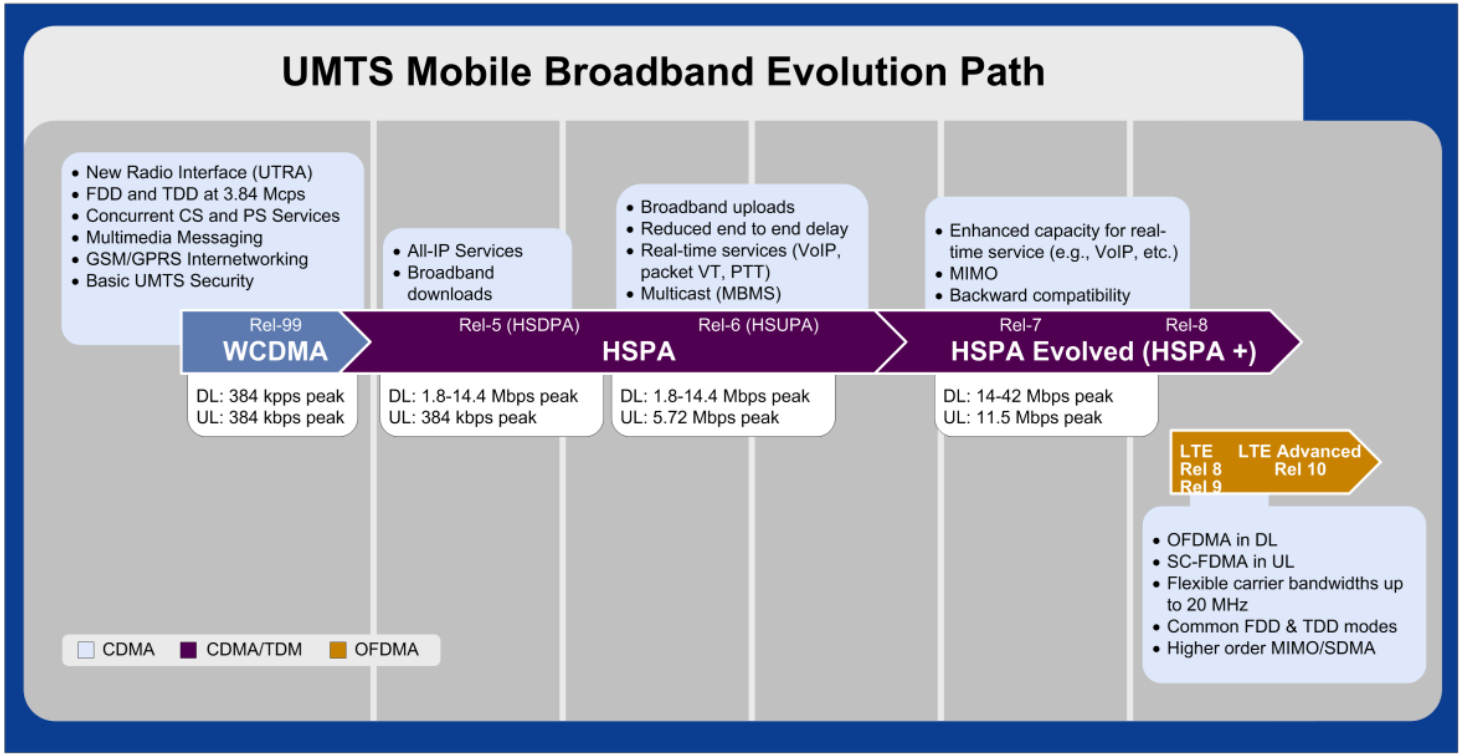


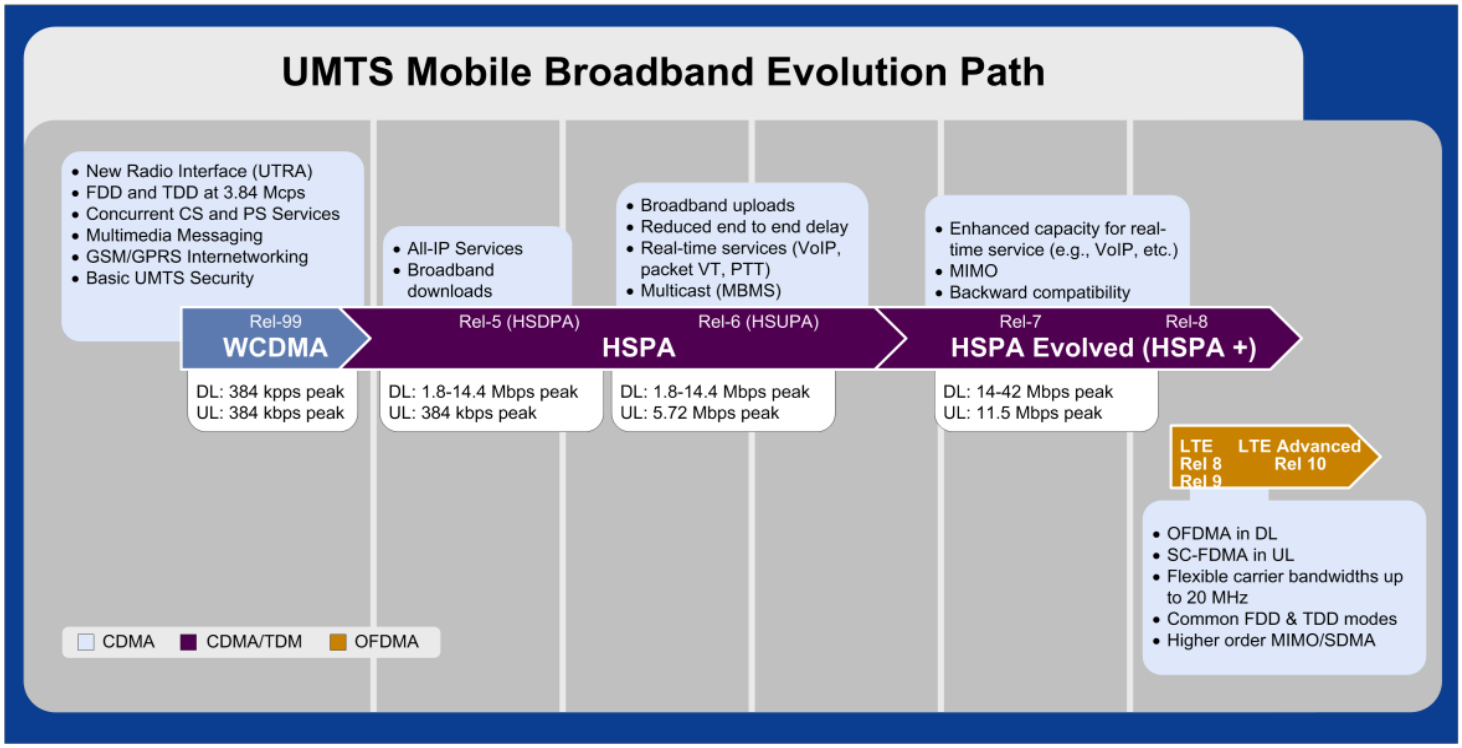
- Release 99 – Specified the first UMTS 3G networks, incorporating a CDMA air interface



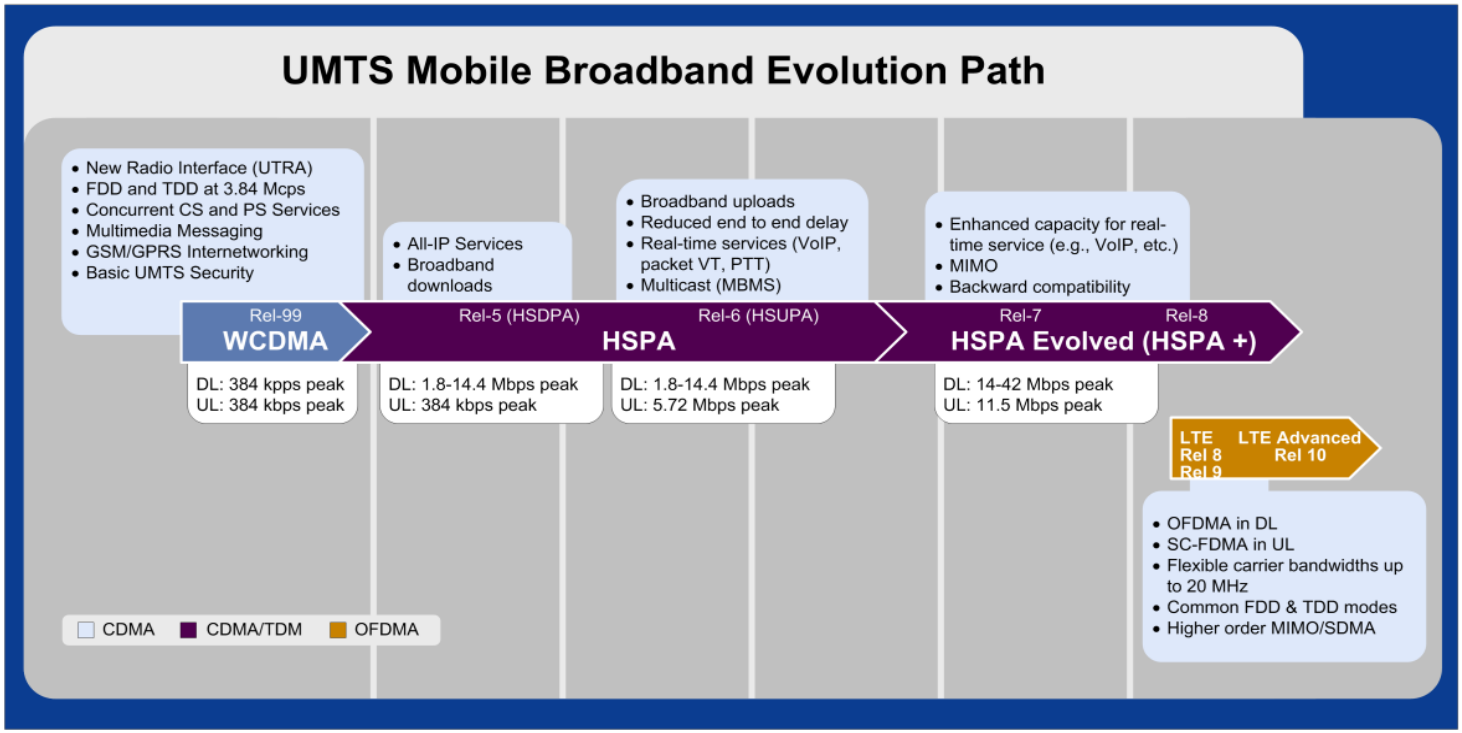
- Release 5 – Introduced mainly IMS, HSDPA (allowing broadband services on the Downlink), and other minor enhancements



- Release 6 – Integrated operation with Wireless LAN networks and added HSUPA (enables broadband uploads and services), MBMS, and enhancements to IMS such as Push-to-Talk over Cellular (PoC), video conferencing, messaging, etc.



- Release 7 – Significant progress made in 2006 and 2007 toward completion of this release. Most documents are under revision control. Introduced, among other features, enhancements to High-Speed Packet Access (HSPA+), QoS, and improvements to real-time applications like VoIP



- Release 8 – In progress (expected 2009). Introducing, among others, E-UTRA (also called LTE, based on OFDMA), All-IP Network (also called SAE), and Femto cells operation. Release 8 constitutes a refactoring of UMTS as an entirely IP based fourth-generation network. 3GPP RAN approved the LTE Physical Layer specifications in September 2007.

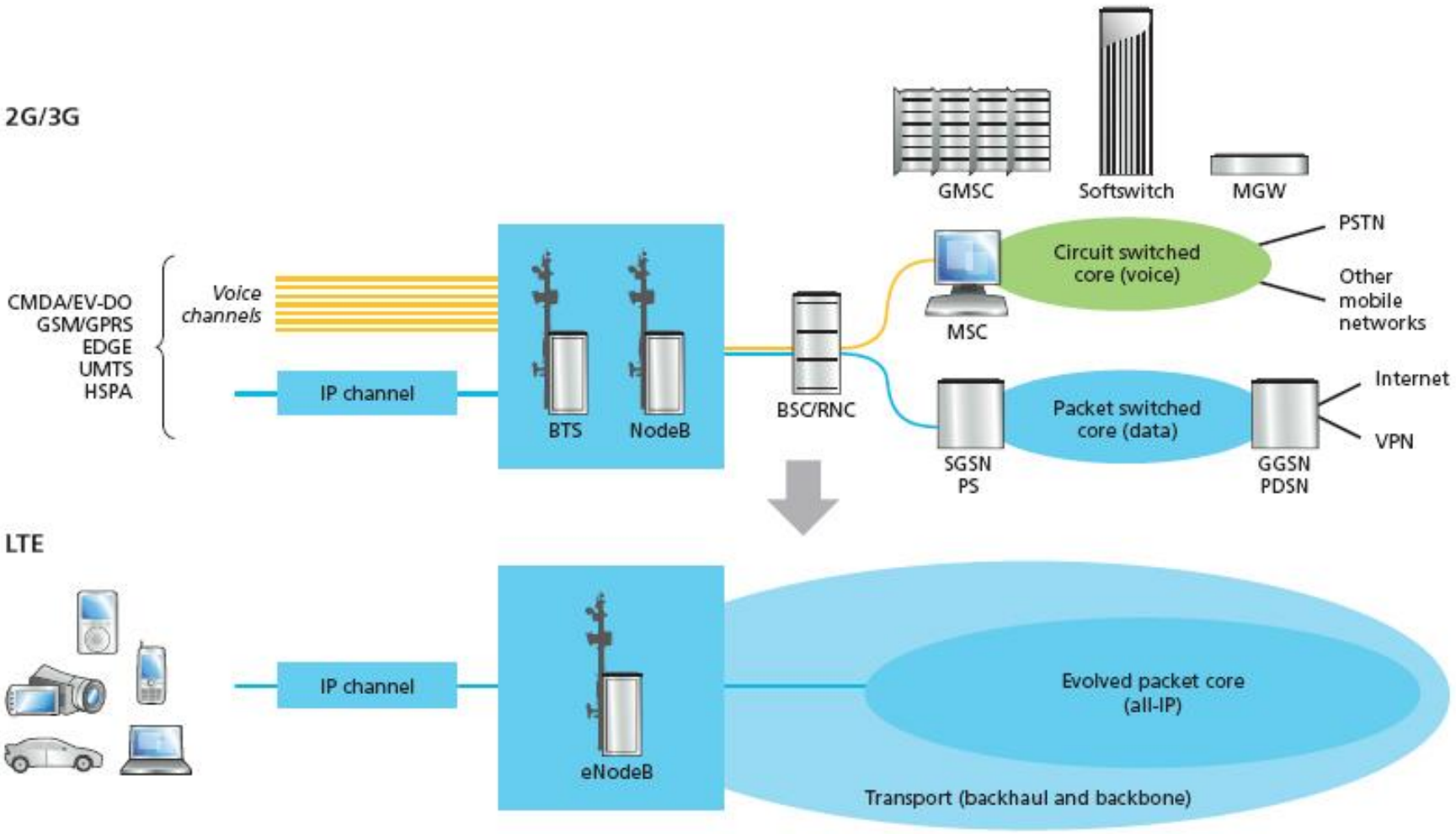
eUTRAN and EPC

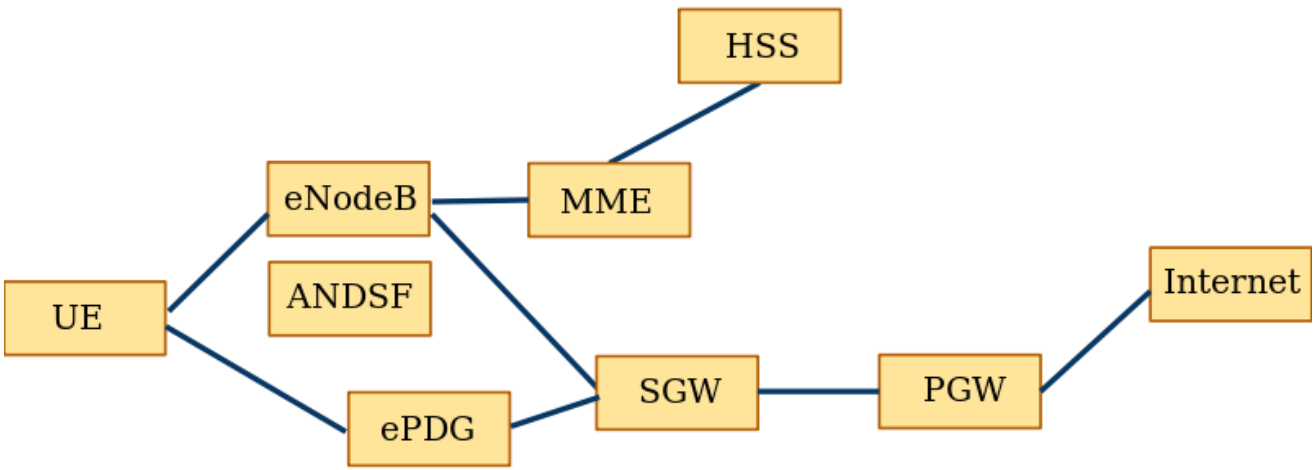
- Long Term Evolution (LTE) : Evolution of 3GPP UMTS Terrestrial Radio Access (E-UTRA technology)
  - UMTS(Universal Mobile Telecommunications System): The radio access network connects to the core network which is an evolution from the GSM core

- Evolved Package System (EPS): Evolution of the complete 3GPP UMTS Radio Access, Package Core and its integration into legacy 3GPP/non-3GPP networks. Includes;
  - Radio Access Network: Evolved UTRA Network (E-UTRAN)
  - System Architecture: Evolved Package Core (EPC)
  - http://www.youtube.com/watch?v=lNQcSgKVhSk

- E-UTRA:
  - Air Interface of 3GPP's LTE upgrade path for mobile networks
  - Radio Access Network standard meant to be a replacement of the UMTS, HSDPA and HSUPA technologies specified in 3GPP releases 5 and beyond
  - Provides higher data rates, lower latency and is optimized for packet data
  - Responsible for radio resource management, header compression, security and connectivity to evolved package core
  - Simply a connection of eNodeBs networked together
  - The E-NodeB performs tasks similar to those performed by the NodeBs and RNC (Radio Network Controller) together in UTRAN
  - Contains the radio and antenna equipment to link the UE and the LTE core network via the RF air interface
  - E-NodeB is the hardware that is connected to the mobile phone network that communicates directly with mobile handsets, like a Base Transceiver Station (BTS) in GSM networks
  - E-NodeB vs NodeB and RNC ->lower response time

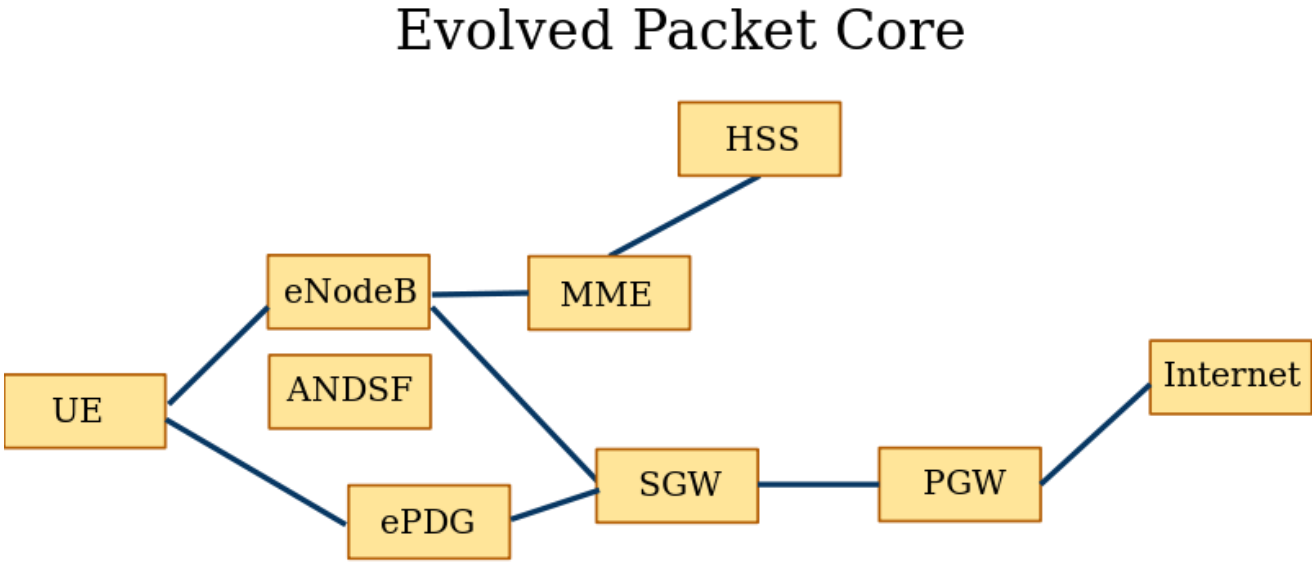
Figure 1. LTE: Evolution from separate CS and PS core sub-domains (3GPP case shown) to one common IP core





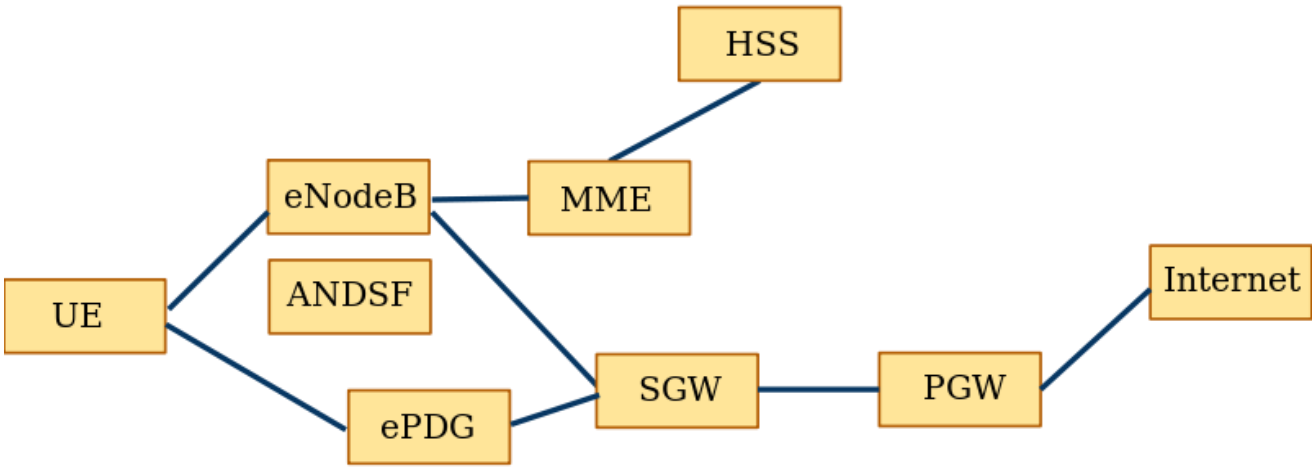
- MME (Mobility Management Entity)
  - Controls the signaling between UE and core network
  - Establishment,maintenance and release of radio bearer service
  - Responsible for paging and tracking the UE between calls and selecting of proper S-GW upon connection
  - Act the termination point for ciphering protection, and therefore is the point of lawful inception of signaling

EPC – System Architecture Evolution



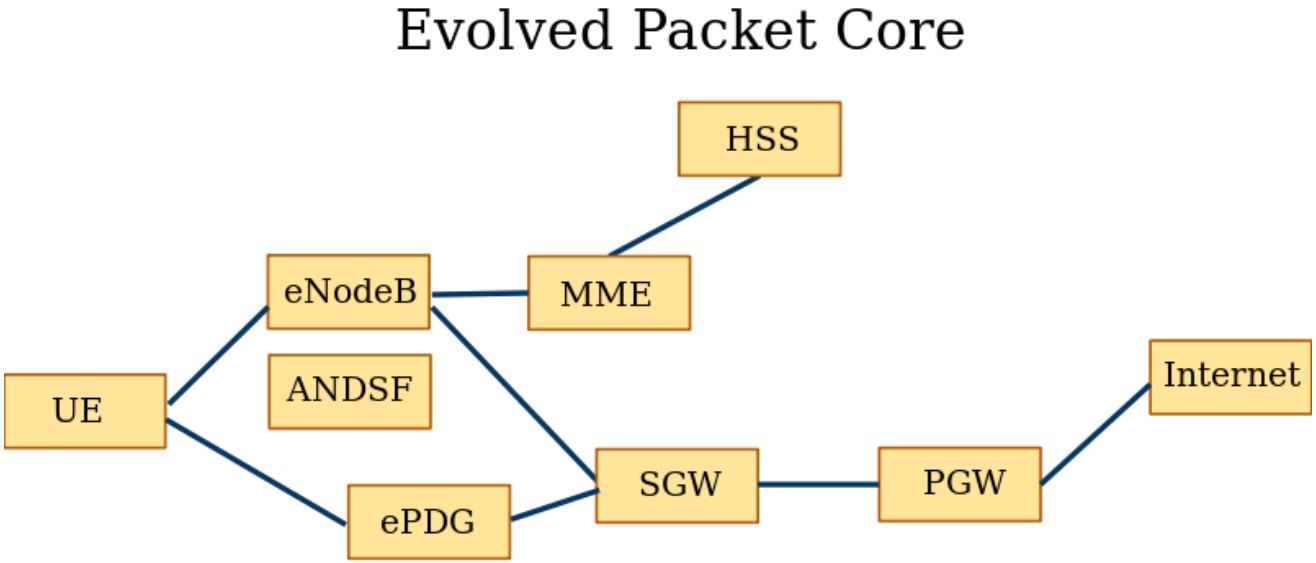
- SGW (Serving Gateway)
  - Routes data packets, maintains the data connection for inter-eNodeB and intersystem handovers between LTE and GSM/UMTS.
  - Stores UE context, for example bearer service parameters and routing information
  - Is the main junction between the redio Access network and the core network

EPC – System Architecture Evolution



- PGW (Package Switched Data Gateway)
  - Provides connectivity for the EU to external packet data networks
  - Allocates IP addresses for UE and QoS enforcement
  - Maintains mobility Connection between LTE/UMTS/GSM systems and non-3GPP systems like WiMAX and

EPC – System Architecture Evolution



- HSS (Home Subscriber Server)
  - Database similar to the HLR in GSM/WCDMA core network that contains subscriber-related information supporting call control session management
  - Primarily involved in authentication, authorization, security ciphering and can provide user location details

EPC – System Architecture Evolution

LTE GAINS

- LTE benefits Include
  - High Data Rates
  - Reduced Latency
  - Improved end-user throughputs
- LTE gains are realized by
  - Increased Radio Frequenct Deployement bandwidth
    - Flexible deployments in 1.4,3,5,10,15,20 MHz
  - MIMO (Multiple Antennas)
    - Using 2 antennas on Based Station and mobile device can provide up to 2x improvement
    - A second receiver is required in the mobile device raising costs
    - Same gain is available in 3G in HSPA+
  - Flatter all IP network with fewer network elements

Benefits of an all-IP Network

- Lower equipment costs than circuit switched 2G and 3G wireless infrastructure
- Increased interoperability between equipment from different vendors
- Flexibility to handle voice, data and future traffic requirements
- Open interfaces offer an easier path for development, future improvements and support

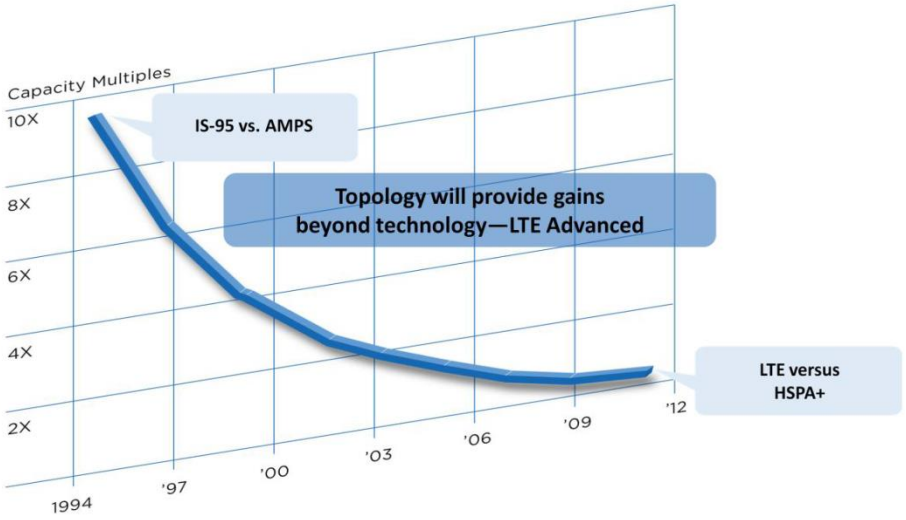
Shannon's Curve

- Tells the maximum rate at which information can be transmitted over a communications channel of a specified bandwidth in the presence of noise
- Advanced 3G systems have low signal-to-noise ratio requirements – very little improvement available for this term
- Bandwidth is what LTE manipulates
  - For MIMO Systems, capacity increases nearly with min (M,N)
    - M: number of transmit antennas
    - N: number of received antennas

Shannon's Curve

- Shannon's Capacity Theorem :
  - Capacity (bits/sec) = Bandwidth x $\log_2$ (1+S/N)

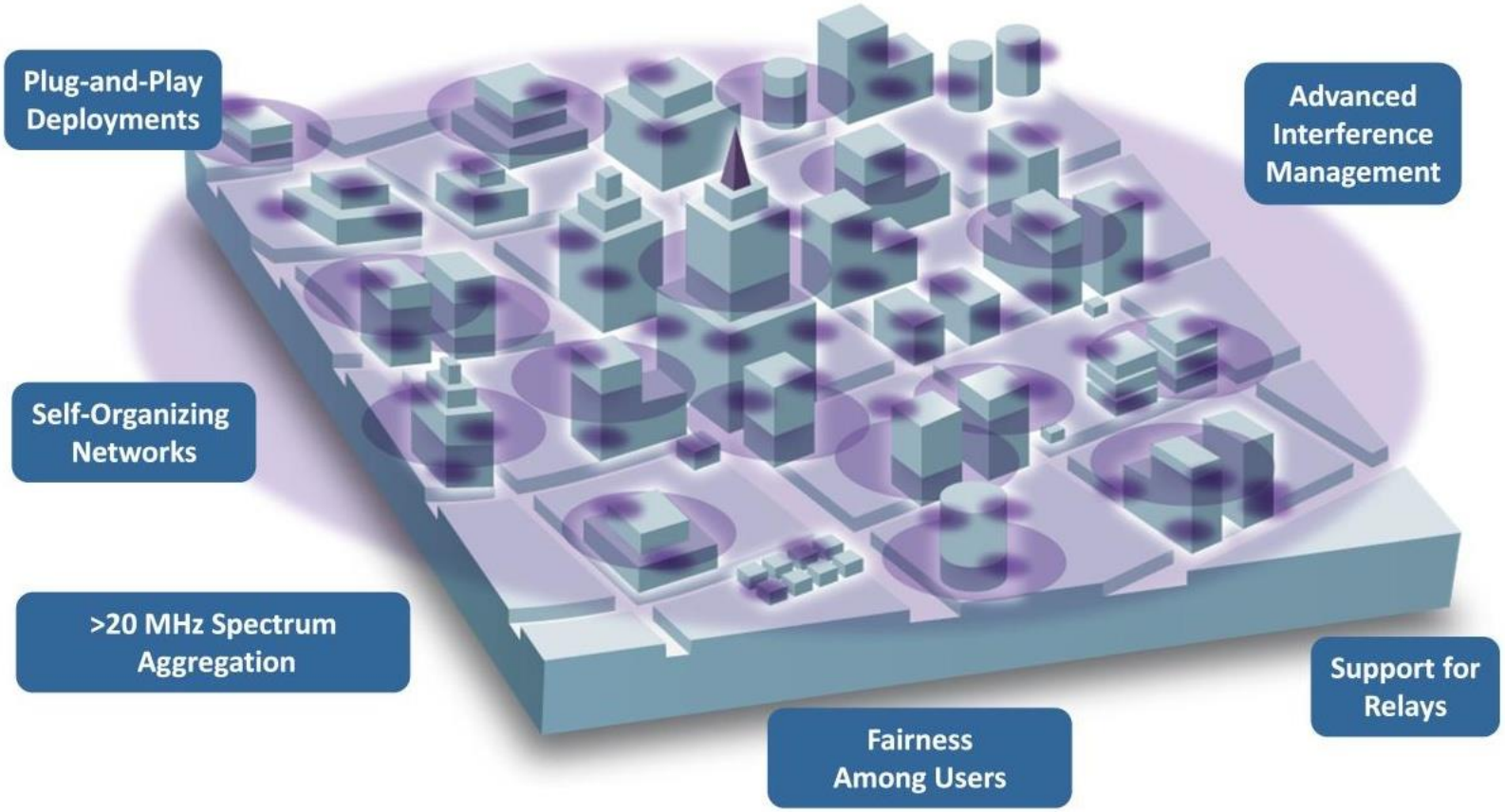
    - Capacity is the channel capacity in bits per second
    - Bandwidth is the bandwidth of the channel, in hertz
    - S is the total received signal power over the bandwidth, measured in watt or volt
    - N is the total noise or interference power over the bandwidth, measured in watt or volt
    - S/N is the signal-to-noise ratio (SNR) or the carrier-to-noise ratio (CNR) of the communication signal to the Gaussian noise interference expressed as a linear power ratio (not as logarithmic decibels).



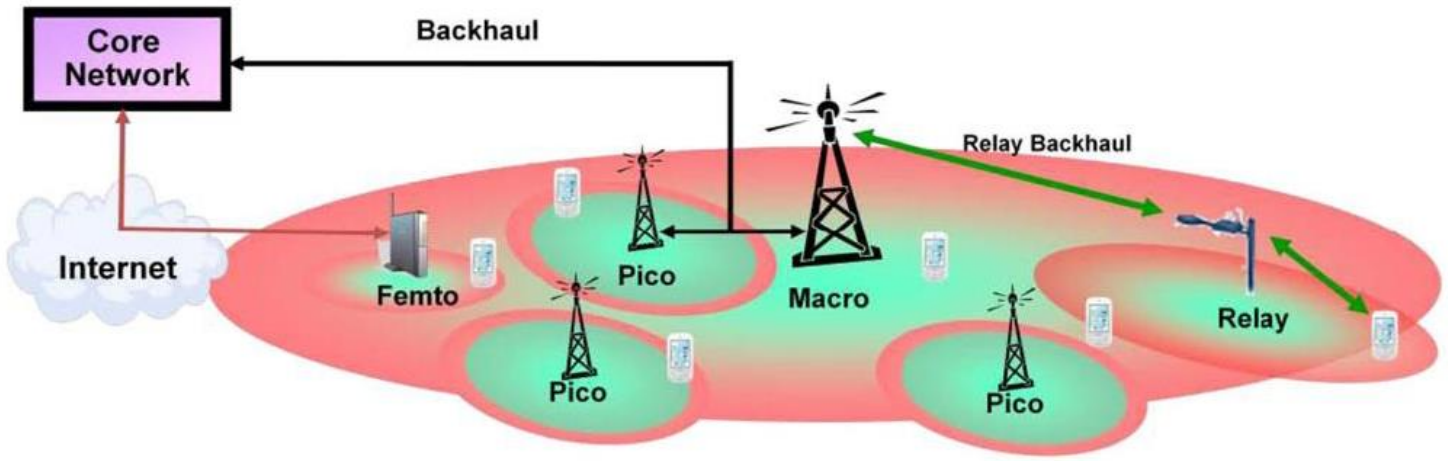
- Early cellular systems (AMPS) -> Signal to noise Ratio (SNR) : 17 dB
- GSM introduced improvements -> SNR : 12-14 dB
- IS-95 With better coding and spread spectrum techniques-> 5 -7 db
- Current 3G systems reduced SNRs a few dB better than IS-95 same as LTE Performance
  - approaching the theoretical limit expressed by Shannon's capacity theorem
  - Since gains practically exhausted, further advances in capacitywill come from topology changes in network deployment

Radio Link Improvement is Slowing – What is next

Improved Performance for Advanced Topology Networks with LTE Advanced



- **Improved Performance for Advanced Topology Networks with LTE Advanced**
- There is growing evidence that femtocells are essential to deliver further improvements in mobile network design and, in the case of LTE, to ensure more subscribers receive peak data rates. LTE is approaching the theoretical maximum information transfer rate (Shannon's limit) and further improvements will only be possible by rolling out more, smaller cells.
- In fact, an analysis of Cooper's law - which holds that wireless capacity doubles every 30 months – shows that the dominant factor in improvements to date has been the use of smaller cells as opposed to other methods such as revised modulation techniques, better coding, or the use of more frequencies.



- Heterogeneous networks are comprised of Macro, Pico and Femto Cells
- Having lots of cells provides more opportunities for the user to connect to a cell with low pass loss
- Low path loss between cell and user increases capacity and data rates
- More sophisticated interference management and cancelation techniques also increase capacity and data rates

Heterogeneous Networks

Heterogeneous Networks

- Heterogeneous networks provide a path to greatly increased performance. Current networks are often limited by the path loss (radio signal attenuation) between the serving cell and the user.
- Decreasing this path loss improves the signal to noise ratio, which leads to increased data rates for the user and higher capacity for the serving cell.
- Managing the interference of other users and cells also can improve the signal to noise ratio.
- New techniques have been developed for canceling interference at the cell and at the user device. These techniques will be deployed soon.

LTE Summary

- LTE Provides a path to 4G performance
- Waveform processing (modulation/demodulation) has reached a mature status in 3G and shows little room for improvement
- LTE achieves increased performance over 3G by using wider RF bandwidth
- New network topologies are required to increase performance
- Heterogeneous networks will be the new norm