Technology Solution for 4G-LTE

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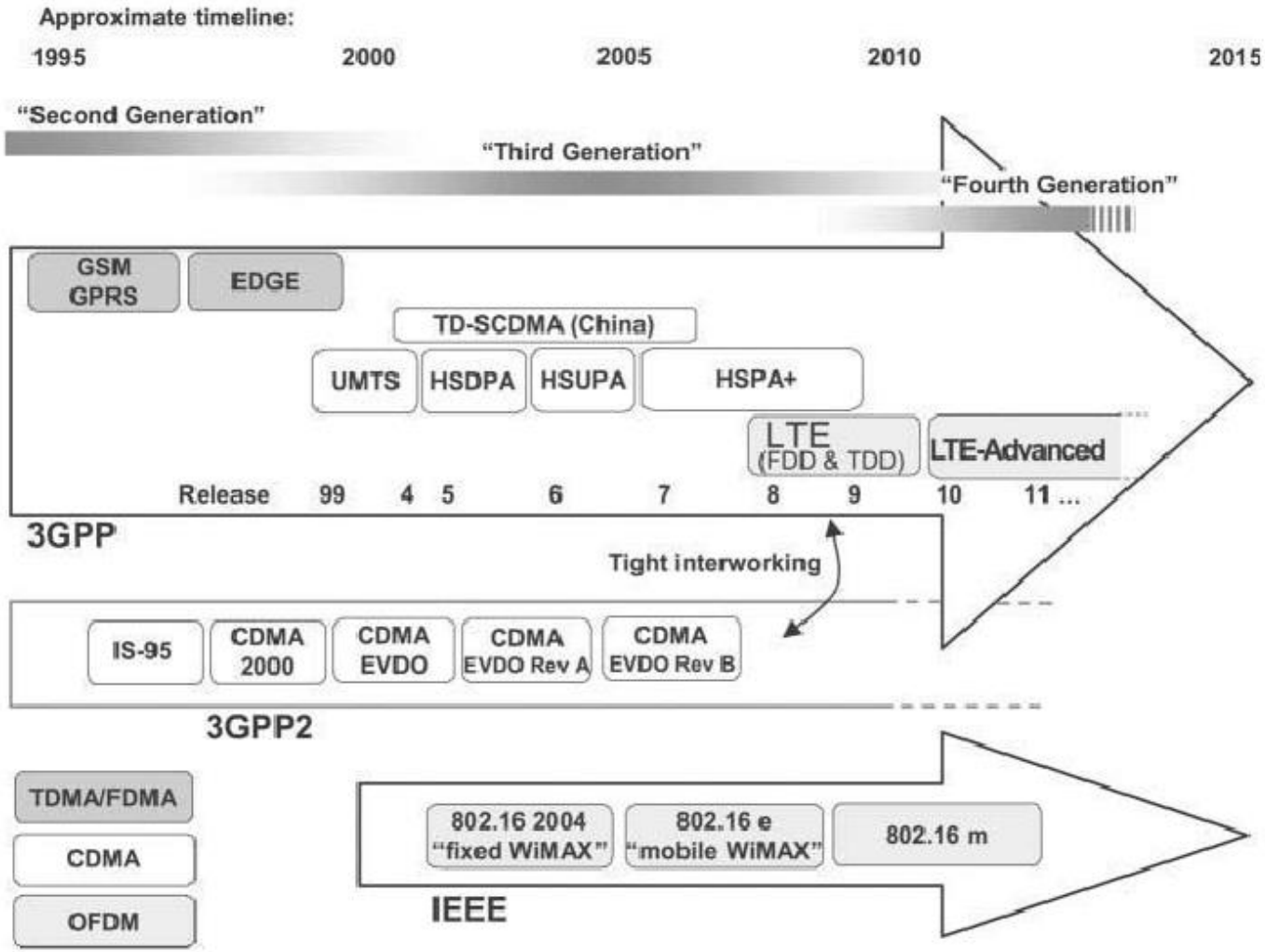
Objectives

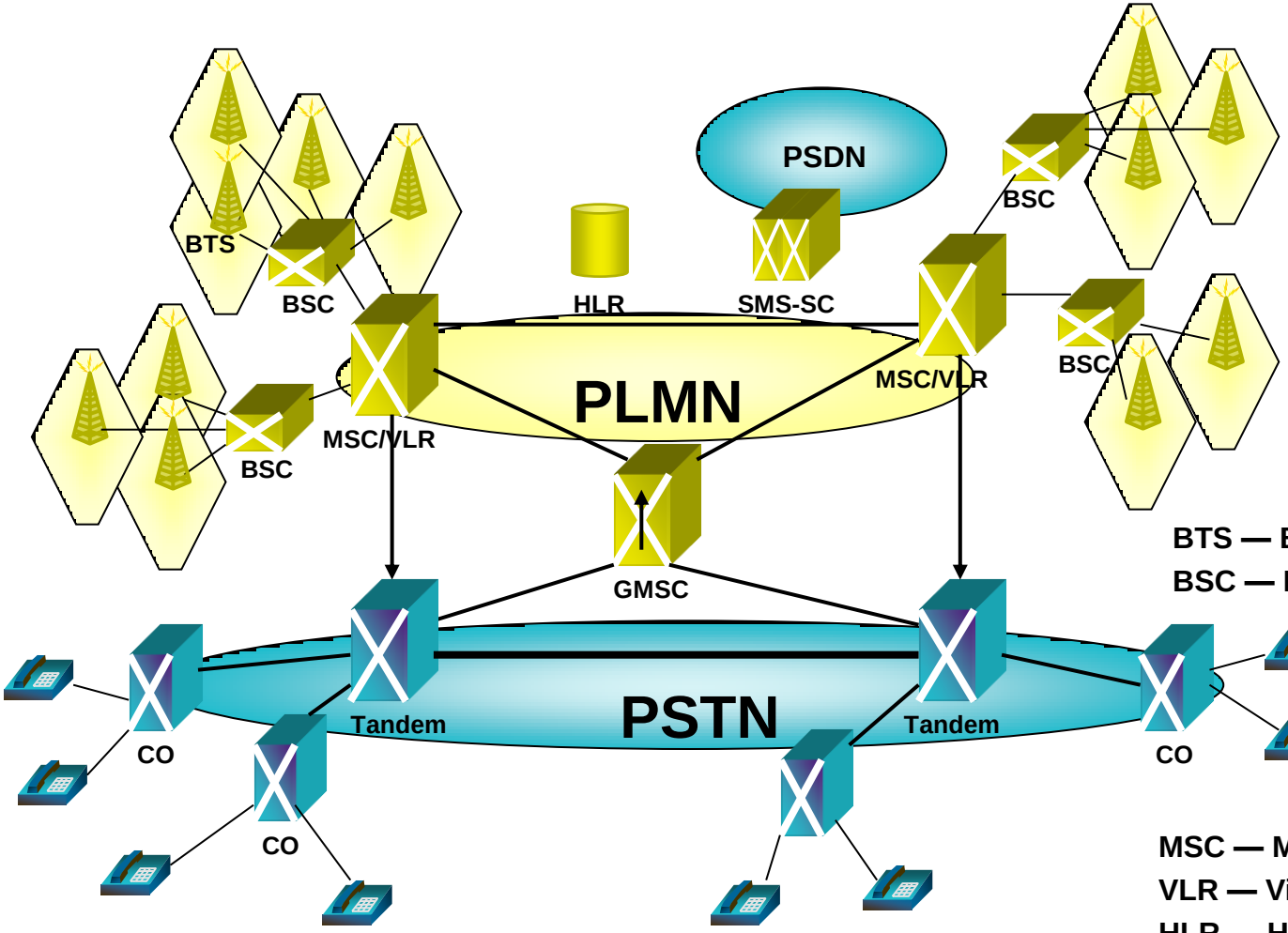
- Technology Evolution
- Requirements of 4G
- LTE-Key Technologies
- LTE-SAE Architecture
- LTE deployments
- Path to 5G

Evolution



- Source : LTE by Stefania Sesia, Issam Toufik, Matthew Baker

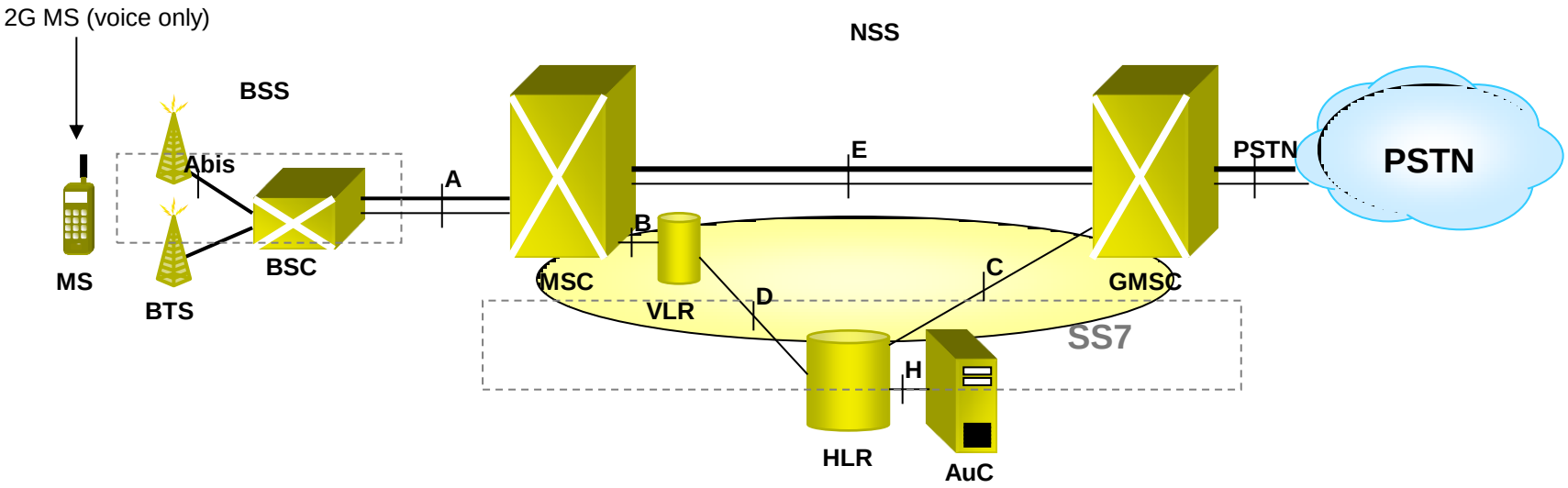
Typical 2G Architecture



BTS — Base Transceiver Station
BSC — Base Station Controller

MSC — Mobile Switching Center
VLR — Visitor Location Register
HLR — Home Location Register

2G Architecture



BSS — Base Station System

BTS — Base Transceiver Station

BSC — Base Station Controller

NSS — Network Sub-System

MSC — Mobile-service Switching Controller

VLR — Visitor Location Register

HLR — Home Location Register

AuC — Authentication Server

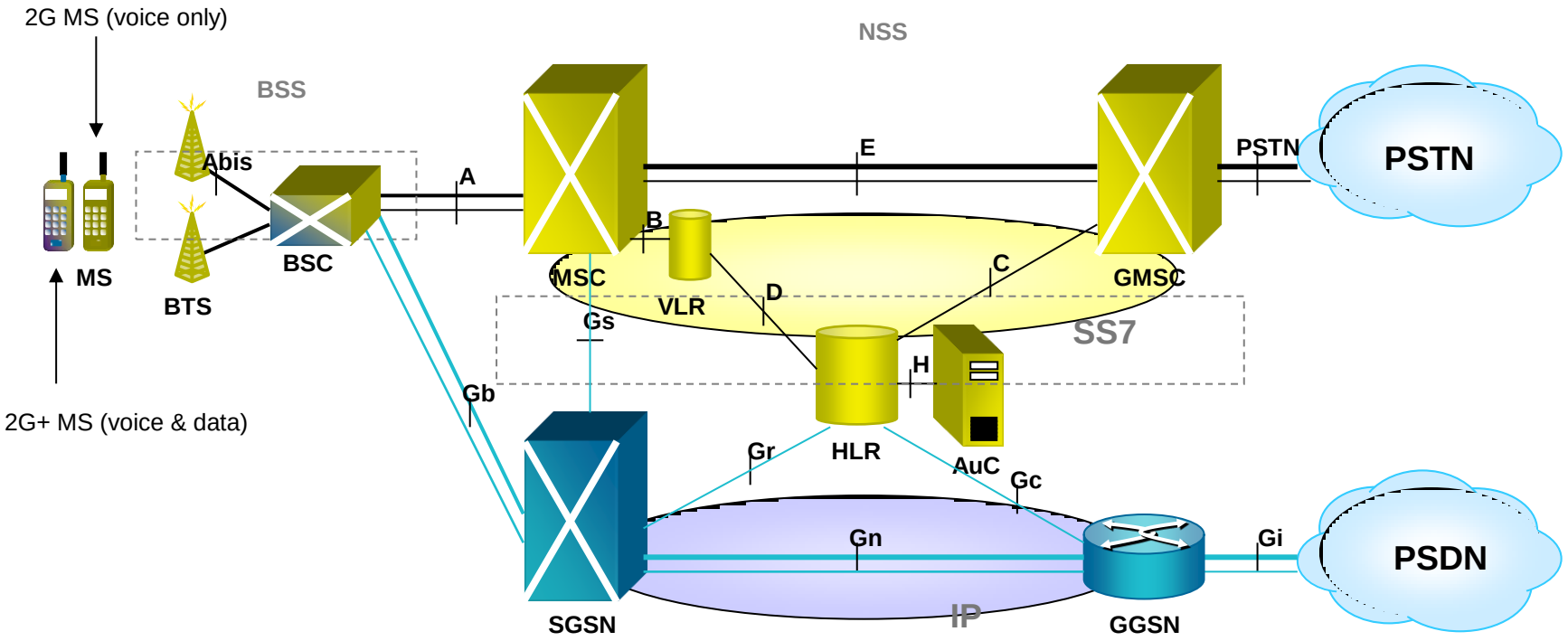
GMSC — Gateway MSC

GPRS — General Packet Radio Service

SGSN — Serving GPRS Support Node

GGSN — Gateway GPRS Support Node

2.5G Architecture



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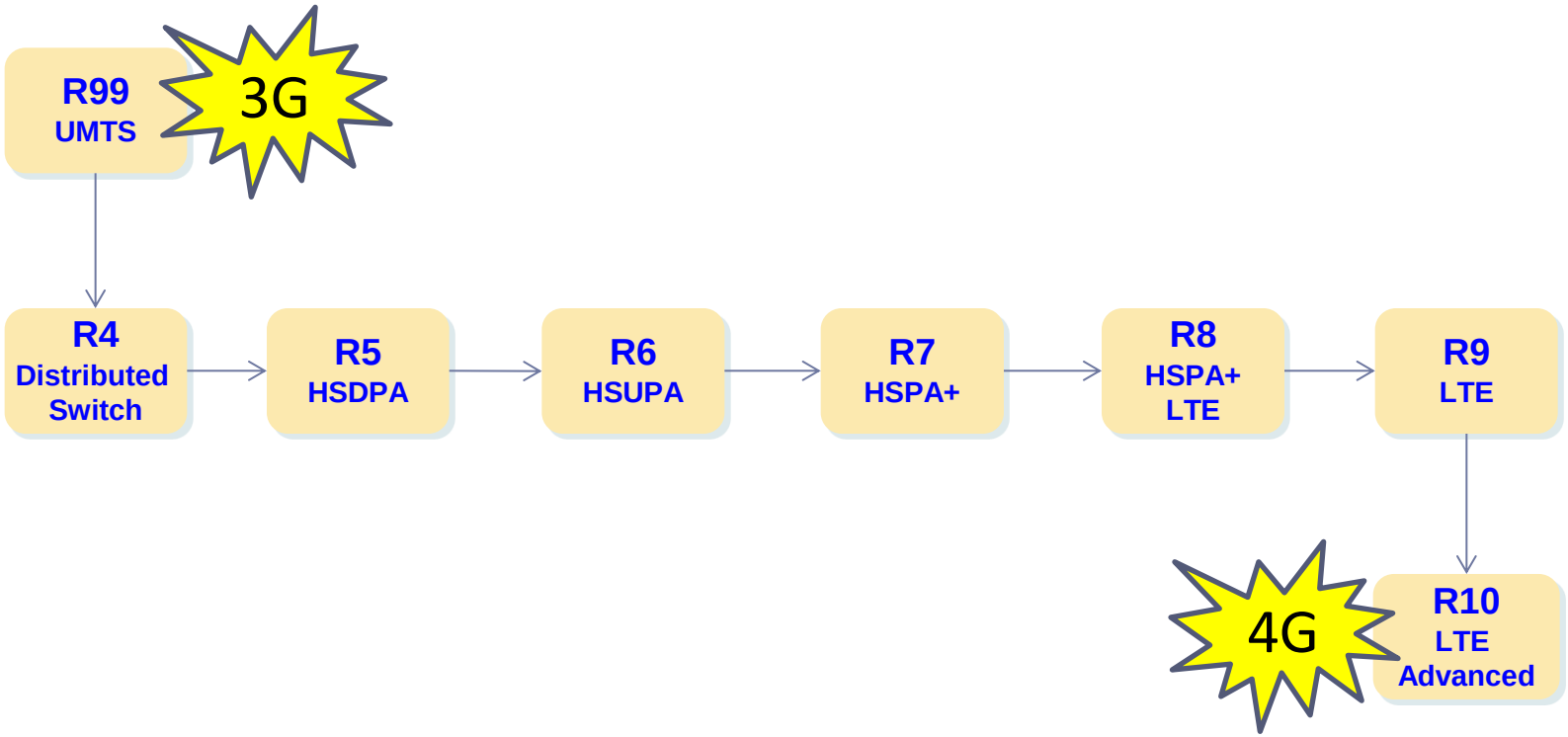
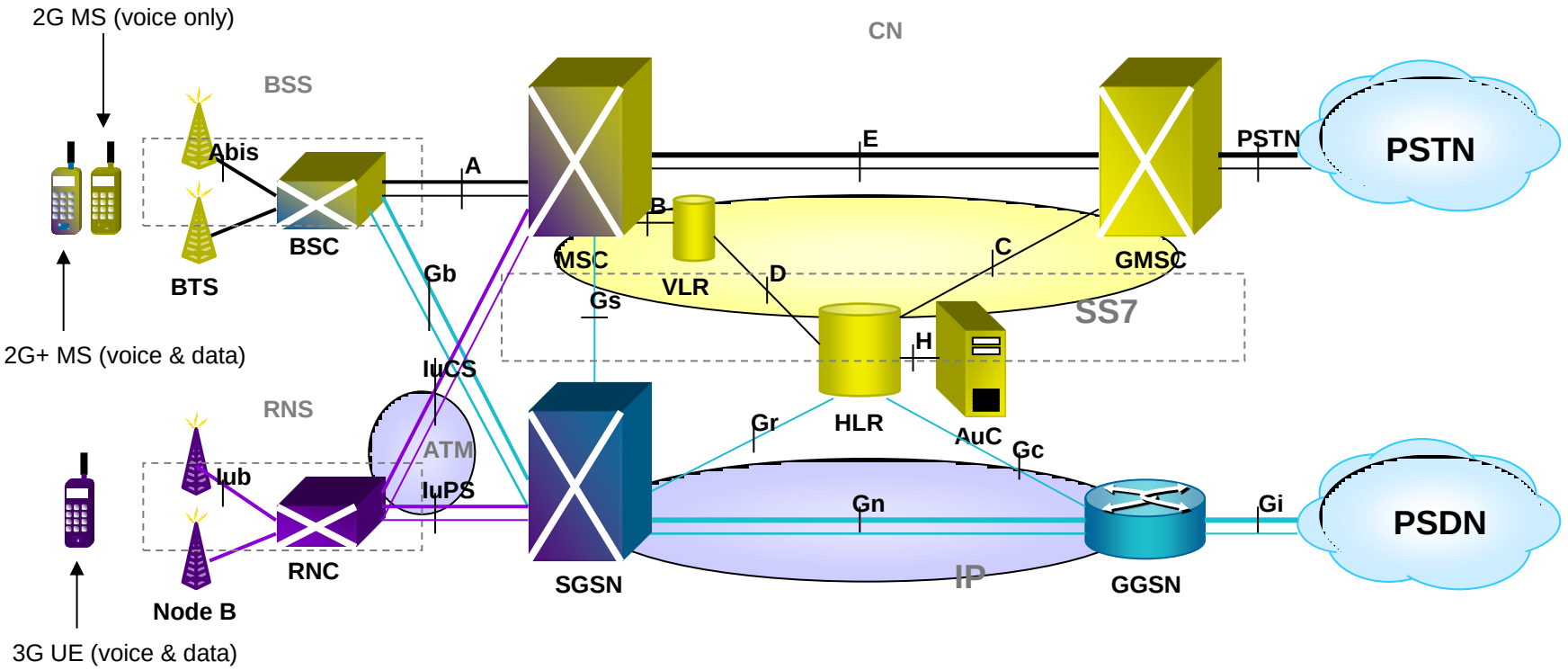
3GPP Migration Path



3GPP

- 3GPP Release 99
  - Adds 3G radios
- 3GPP Release 4
  - Adds **soft switch and Media gateways**
  - Decouple Control and Bearer Plane
- 3GPP Release 5
  - HSDPA
  - First IP Multimedia Services (IMS)
- 3GPP Release 6
  - HSPA
  - MBMS (Multimedia Broadcast Multicast Servides)
  - **IMS**
- 3GPP Release 7
  - HSPA+, (HSPA with higher order modulation)

R99 Architecture



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RNC — Radio Network Controller

CN — Core Network

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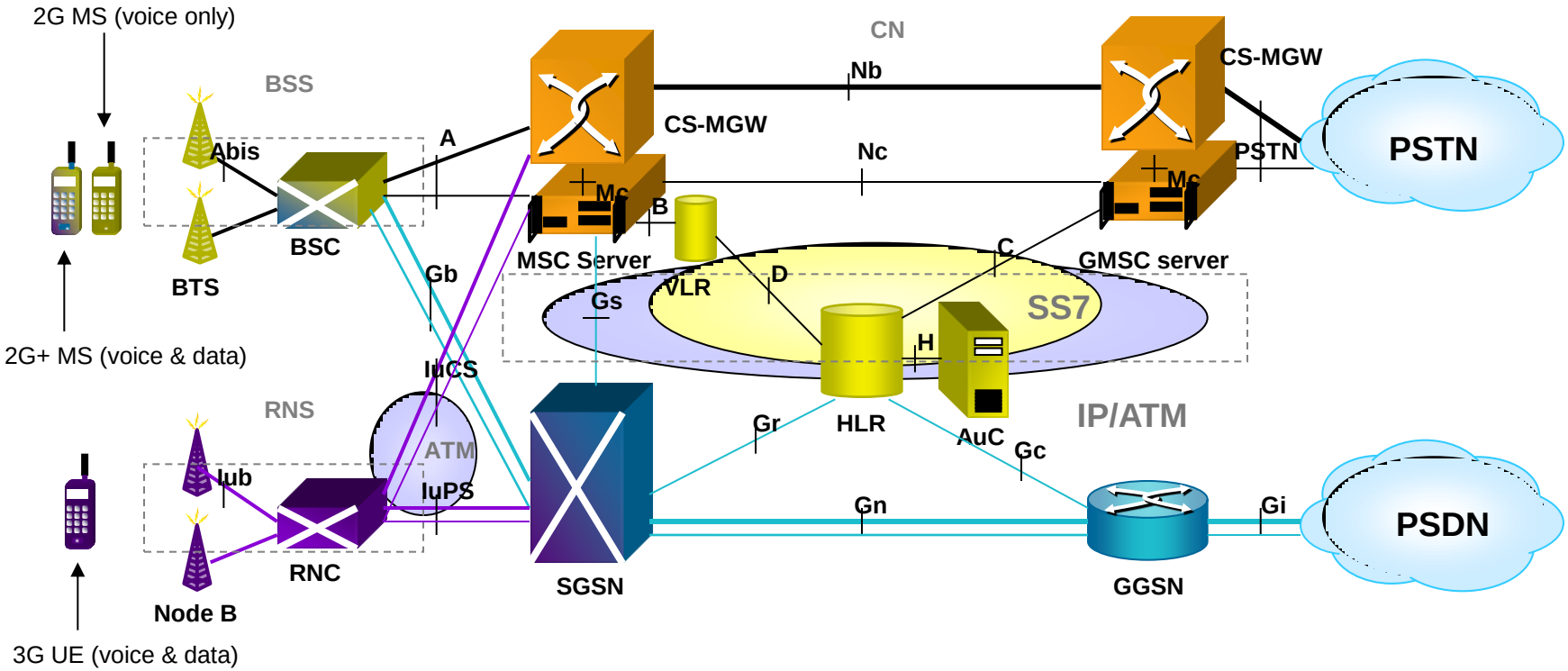
GGSN — Gateway GPRS Support Node

UMTS — Universal Mobile Telecommunication System

R4 Architecture



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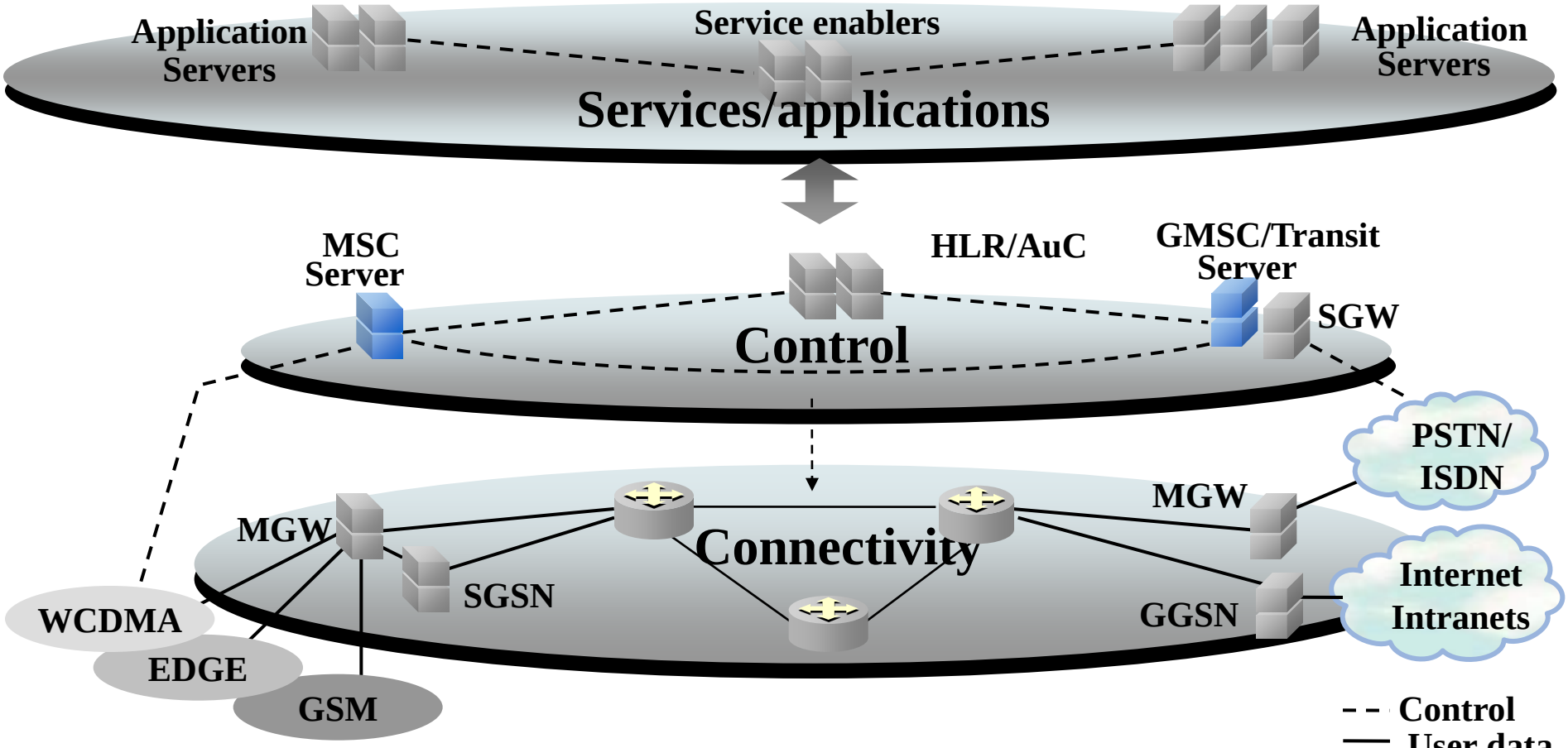
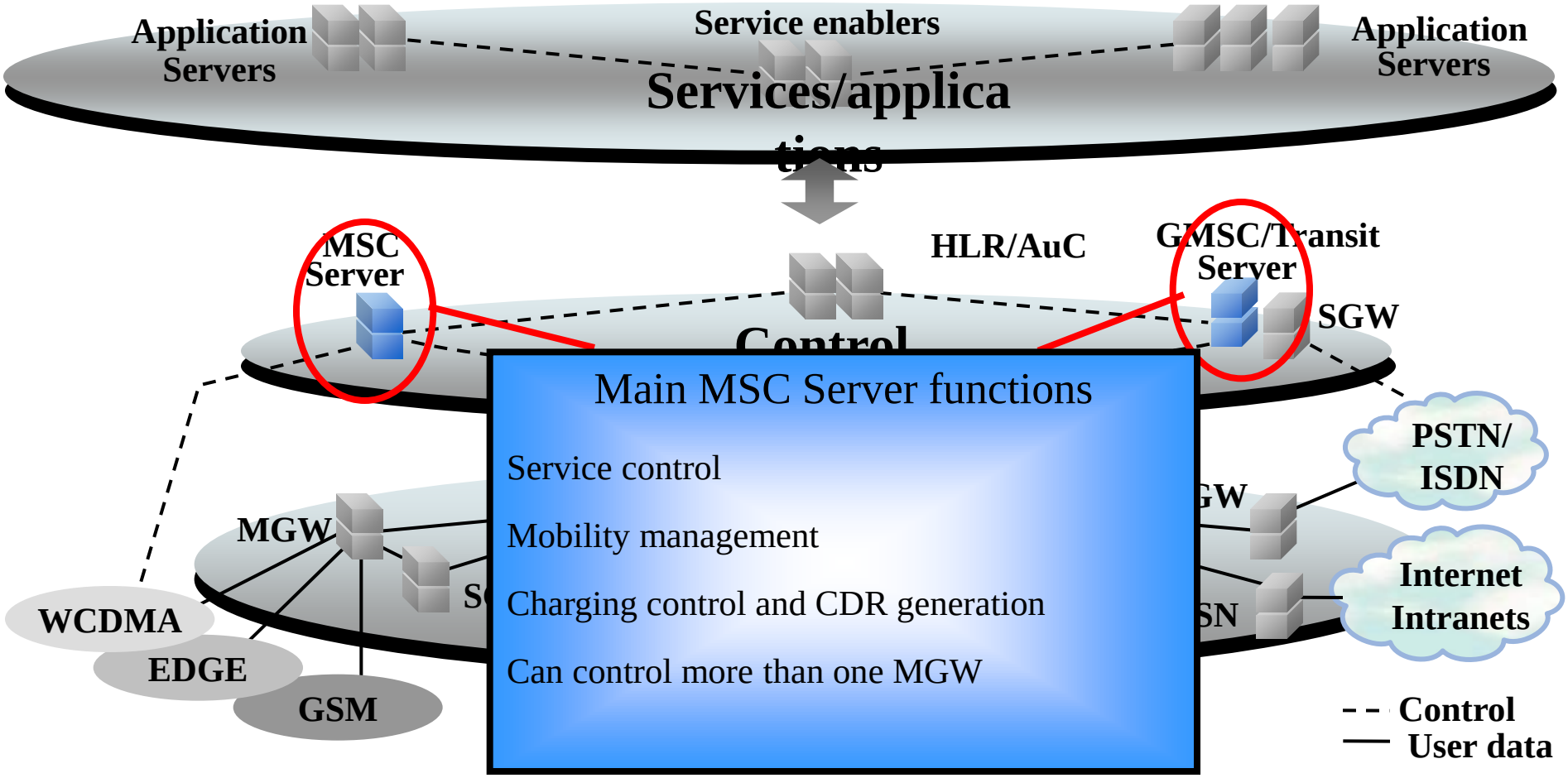
R4 Split Architecture



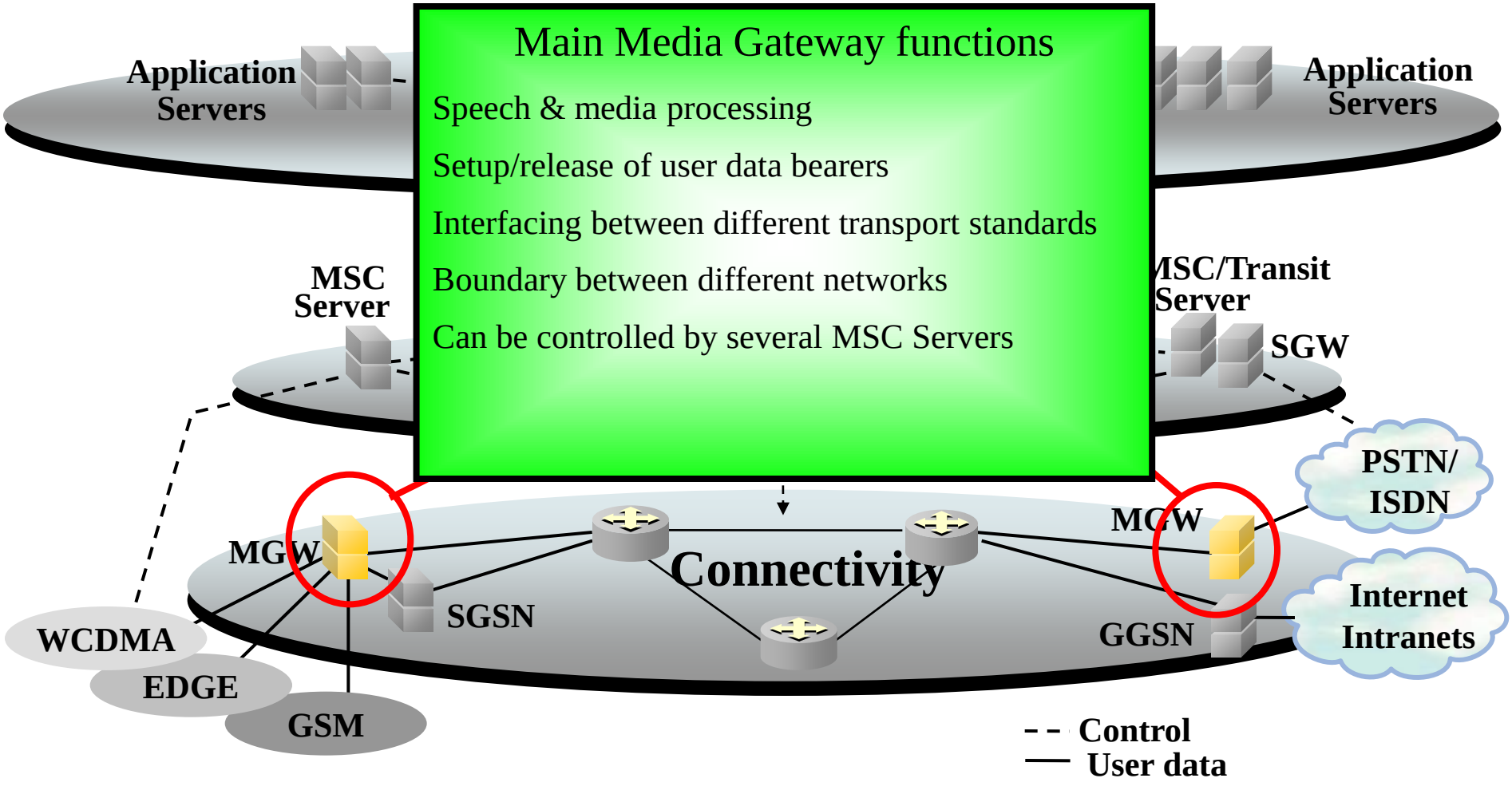
MSC/GMSC Server:



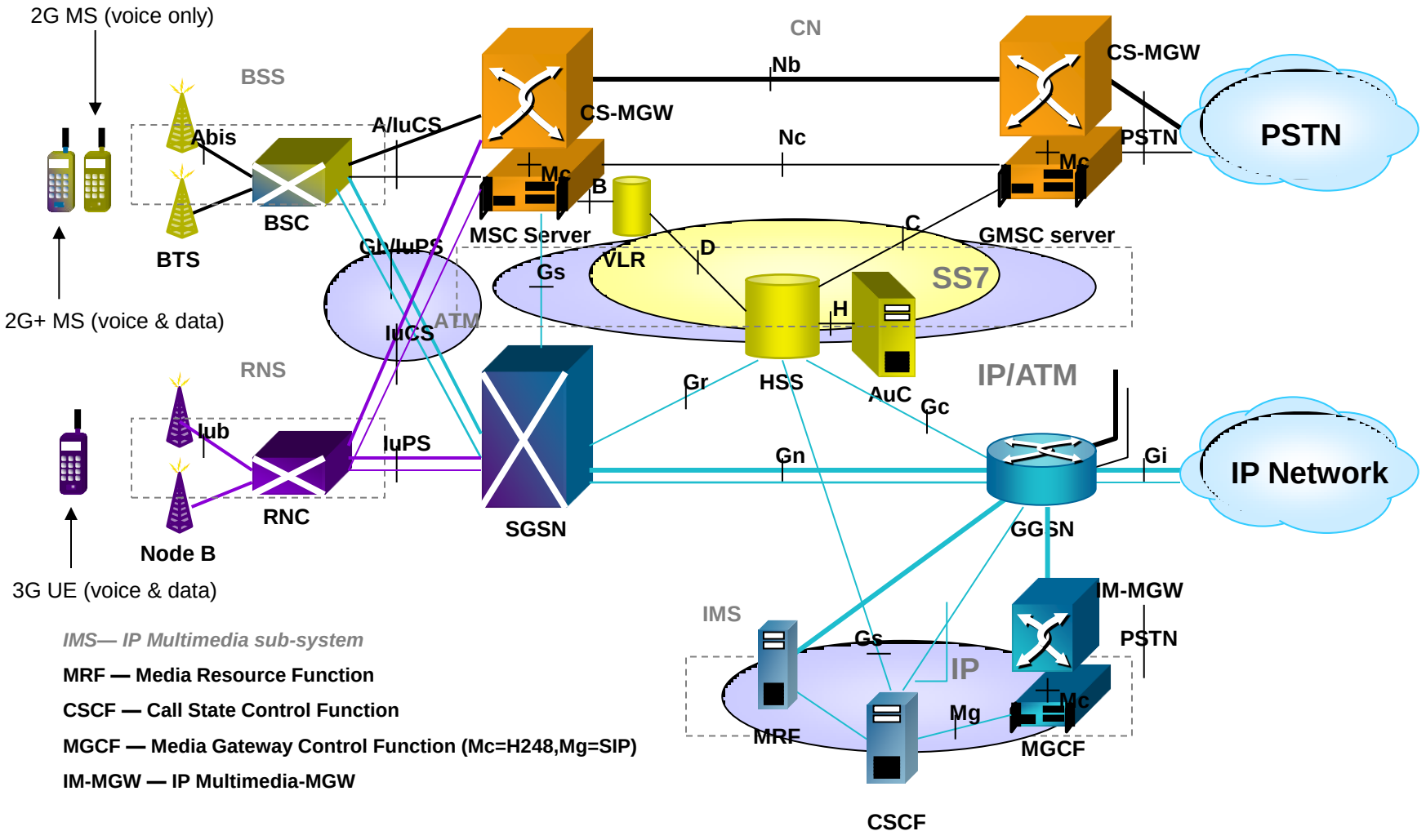
Main MSC Server functions

- Service control
- Mobility management
- Charging control and CDR generation
- Can control more than one MGW

Media Gateway:



R5 Architecture



IMS— IP Multimedia sub-system

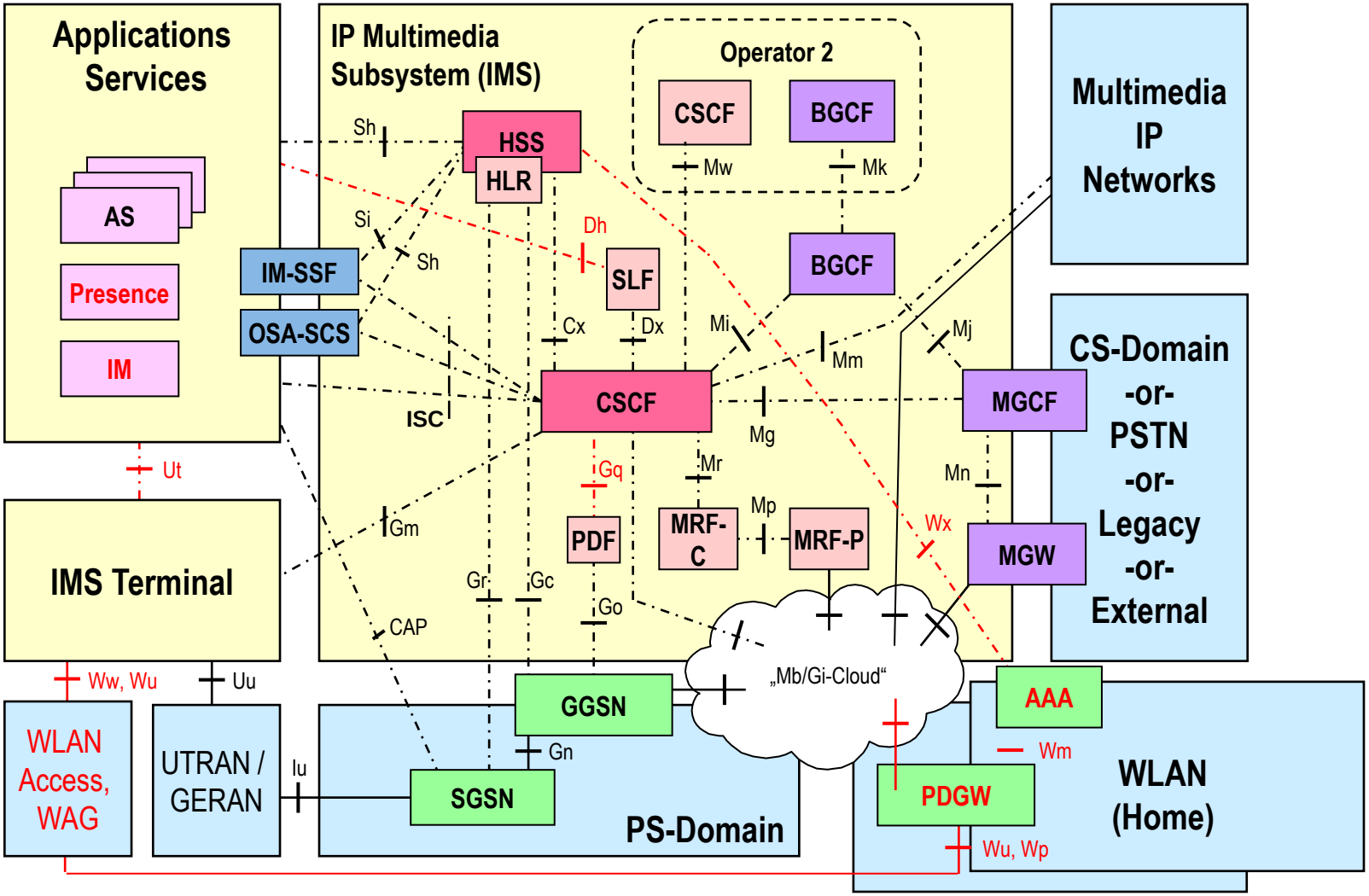
MRF — Media Resource Function

CSCF — Call State Control Function

MGCF — Media Gateway Control Function (Mc=H248,Mg=SIP)

IM-MGW — IP Multimedia-MGW

R6 Architecture



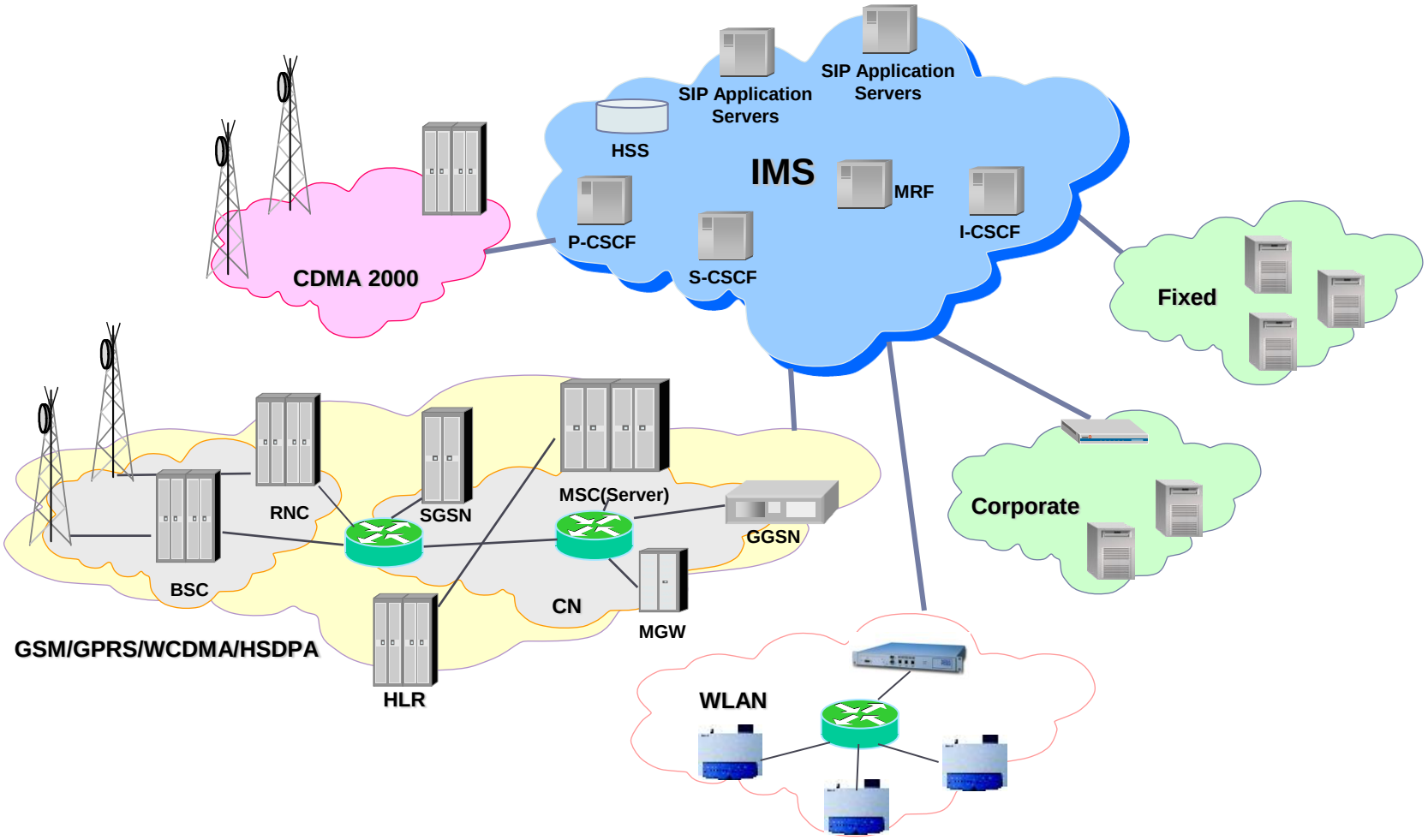
IMS

- IMS is an architecture designed to support the control layer for packet based services, which uses the bearer services of the access network to support the media associated with the service.

- IMS is access agnostic. In a multi-access environment it ensures service availability to all access networks.

- IMS uses SIP capabilities.

IMS : Convergence through an overlay network



IMS – a cornerstone for Convergence

3GPP

- 3GPP Release 8
  - **LTE**
  - “All IP” network.
- 3GPP Release 9
  - LTE Enhancements
  - Increasing LTE’s suitability for different markets and deployments.
- 3GPP Release 10
  - **LTE- Advanced**
  - Carrier Aggregation

Evolution : Outcome

	WCDMA (UMTS)	HDPA	HSPA+	LTE	LTE Advanced
Max downlink speed(bps)	384 k	14 M	28 M	300M	1G
Max uplink speed (bps)	128 k	5.7 M	11 M	75 M	500 M
Latency round trip time (approx)	150 ms	100 ms	50ms (max)	~10 ms	less than 5 ms
3GPP releases	Rel 99/4	Rel 5 / 6	Rel 7	Rel 8	Rel 10
Approx years of initial roll out	2003 / 4	2005 / 6 HSDPA 2007 / 8 HSUPA	2008/ 9	2009/ 10	
Access methodology	CDMA	CDMA	CDMA	OFDMA /SC-FDMA	OFDMA / SC-FDMA

LONG TERM EVOLUTION (LTE)

Key requirements for LTE

- Need for higher data rates
- Greater spectral efficiency
- Greater flexibility of spectrum usage
- Always-on experience (reduce control plane latency)
- Reduce round trip delay (transmission latency)
- Need for Packet Switched optimized system
- Need for high quality of services
- Reasonable power consumption of mobile terminal

Key Technologies of LTE

Three fundamental technologies shaped the LTE design :

- Multi carrier technology
  - **OFDMA** for Downlink
  - SC-FDMA for Uplink
- Multiple Antenna technology
  - **MIMO**
- Packet switched radio Interface
  - **All IP** in RF

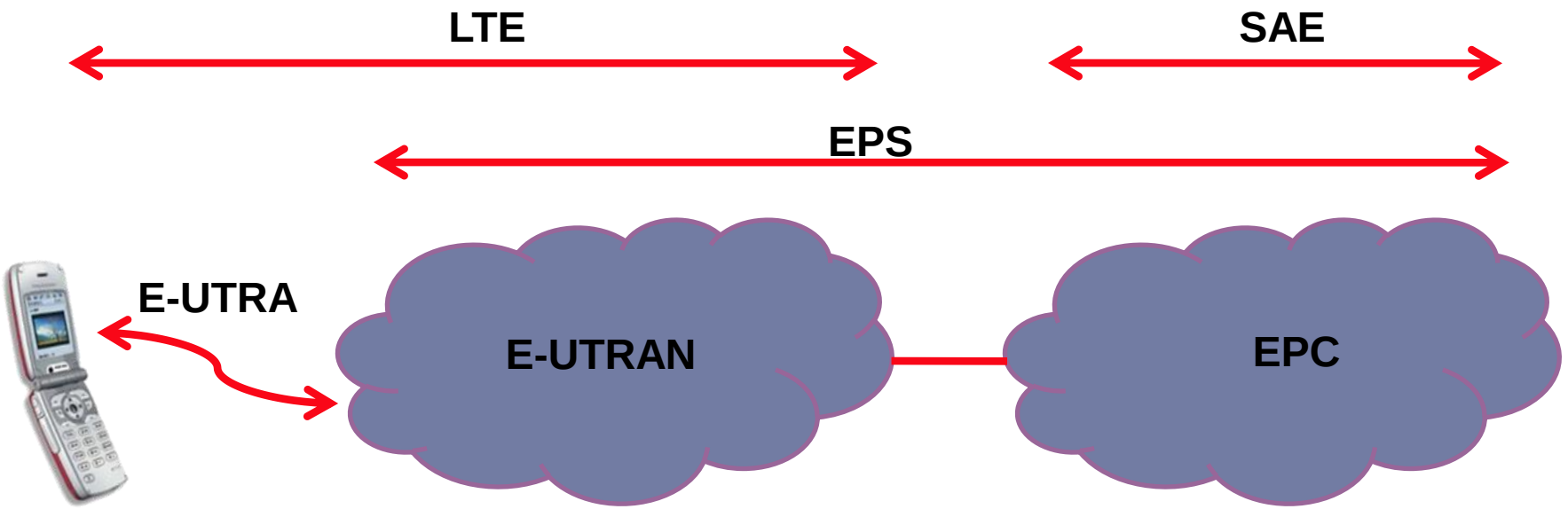
LTE and SAE

Long Term Evolution (LTE) is the term used to describe collectively the evolution of the radio access network into Evolved Universal Terrestrial Radio Access Network (E-UTRAN) and the radio access technology into Evolved Universal Terrestrial Radio Access (E-UTRA).

System Architecture Evolution (SAE) is the term used to describe the evolution of the core network into the Evolved Packet Core (EPC).

There is also a collective term, Evolved packet System (EPS), which refers to the combined E-UTRAN and EPC.

LTE and SAE



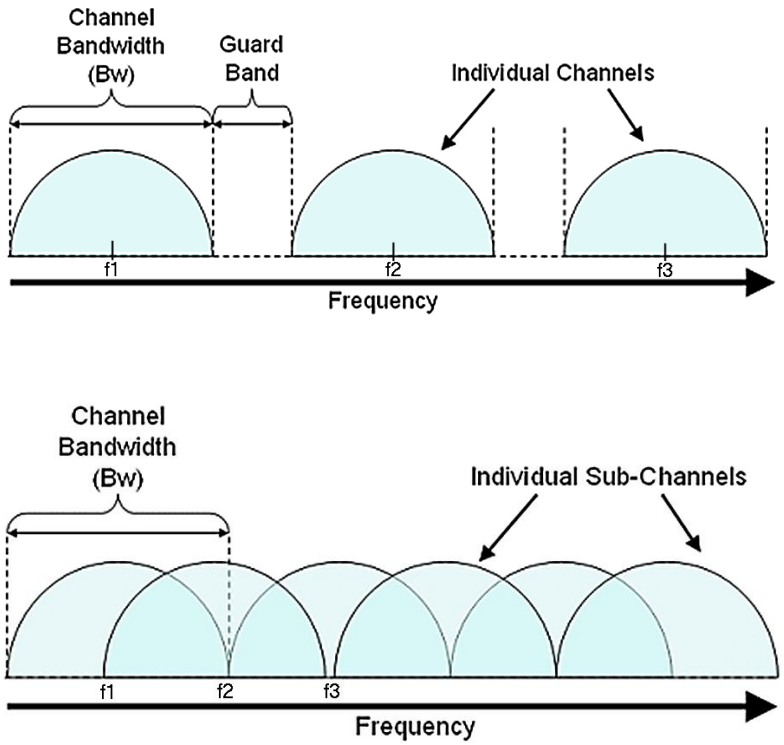
Orthogonal Frequency Division Multiple Access (OFDMA)

OFDM introduction

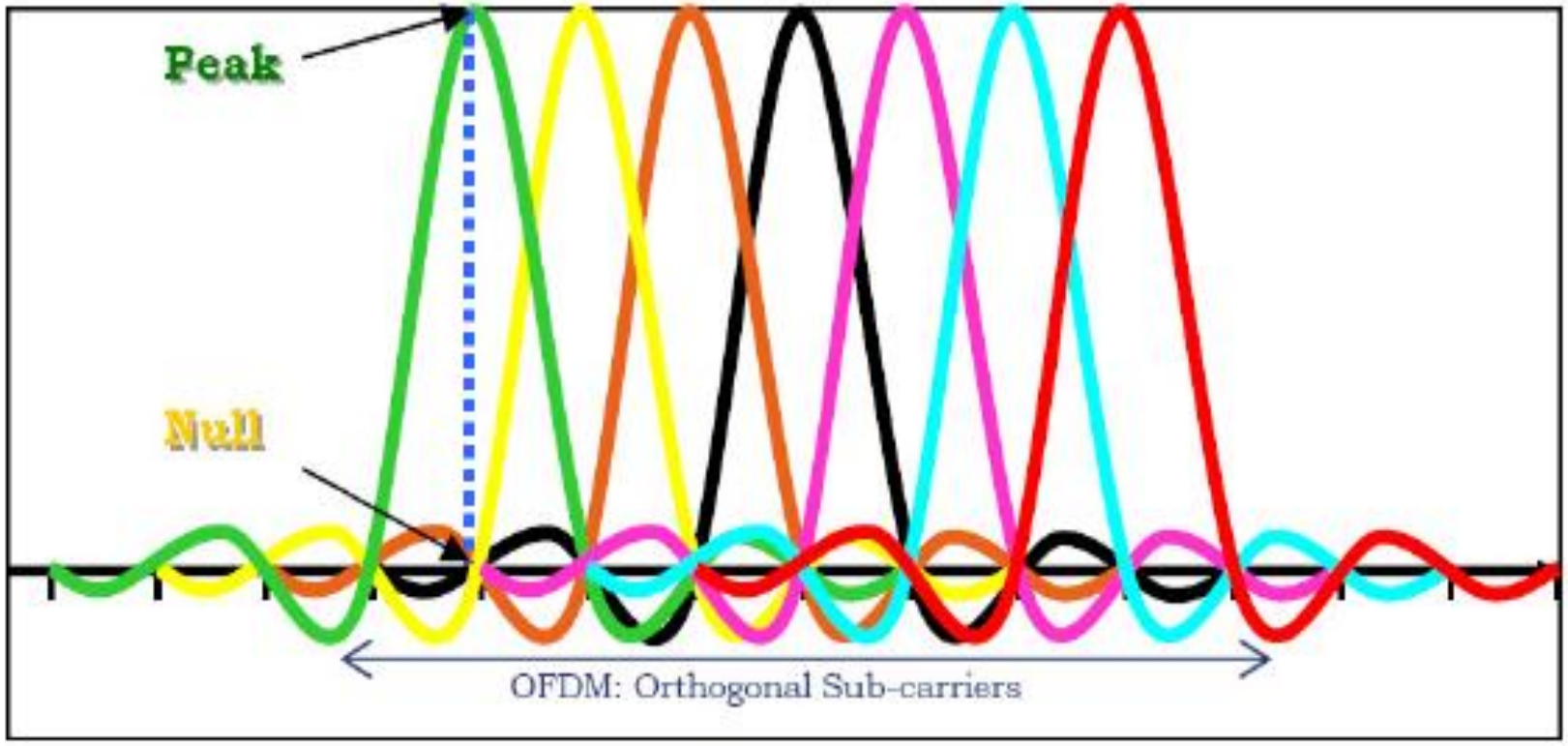
- It is a Digital Multi Carrier modulation Scheme.
- The Available spectrum is divided into several independent sub-carrier to carry data and control information.
- The sub-carriers are selected in a manner so that they are orthogonal to one another. This prevents interference between closely spaced sub-carriers.
- All orthogonal sub-carriers are transmitted simultaneously.
- Orthogonality is achieved by coinciding peak of each sub carrier with null of other sub carriers.
- Independent sub carriers are individually modulated and demodulated with conventional modulation formats.

OFDM Basic Concept

- **OFDM is a special case of Frequency Division Multiplexing (FDM)**
- **For FDM**
  - **No special relationship between the carrier frequencies**
  - **Guard bands have to be inserted to avoid *Adjacent Channel Interference* (ACI)**
- **For OFDM**
  - **Strict relation between carriers**
  - **Carriers are orthogonal to each other and can be packed tight**

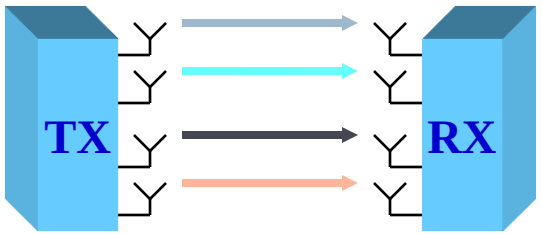


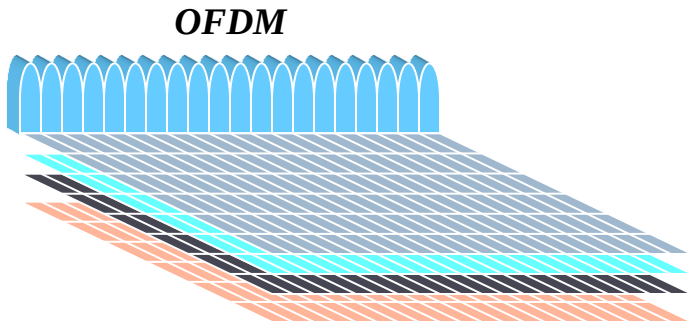
OFDM: orthogonal sub-carriers



Downlink radio access - OFDMA

- Better Coverage and Penetration
- Ultra high spectral efficiency
- High resistance to Multipath /ISI
- Enables Multipath mitigation without using Equalizers and training sequences.
- Useful for Rural, Semi urban, Urban, Dense Urban application.
- Offers Frequency diversity by spreading the carriers all over the used spectrum.





Multi-layered transmission

Uplink Radio Access : SC-FDMA

- Originally two main proposals for LTE uplink radio access
  - OFDMA (basically the same transmission scheme as for the downlink)
  - Single-carrier FDMA (SC-FDMA)

- Main argument for uplink single-carrier transmission:
  - Smaller variations in instantaneous power
    - ➡ Improved PA efficiency or reduced PA back-off
    - ➡ Longer battery life or improved coverage

Uplink radio access– *Single-carrier FDMA*

- Single-carrier ➡ Low peak-to-average power ratio
  - *Improved coverage*
  - *Higher data rates for a given coverage*
  - *Reduced power consumption* ➡ Improved battery life
- Enhanced Inter-user orthogonality by means of FDMA
  - *No Overlap in frequency plane for each user*
  - *No intra-cell interference*
  - *Improved coverage and capacity*

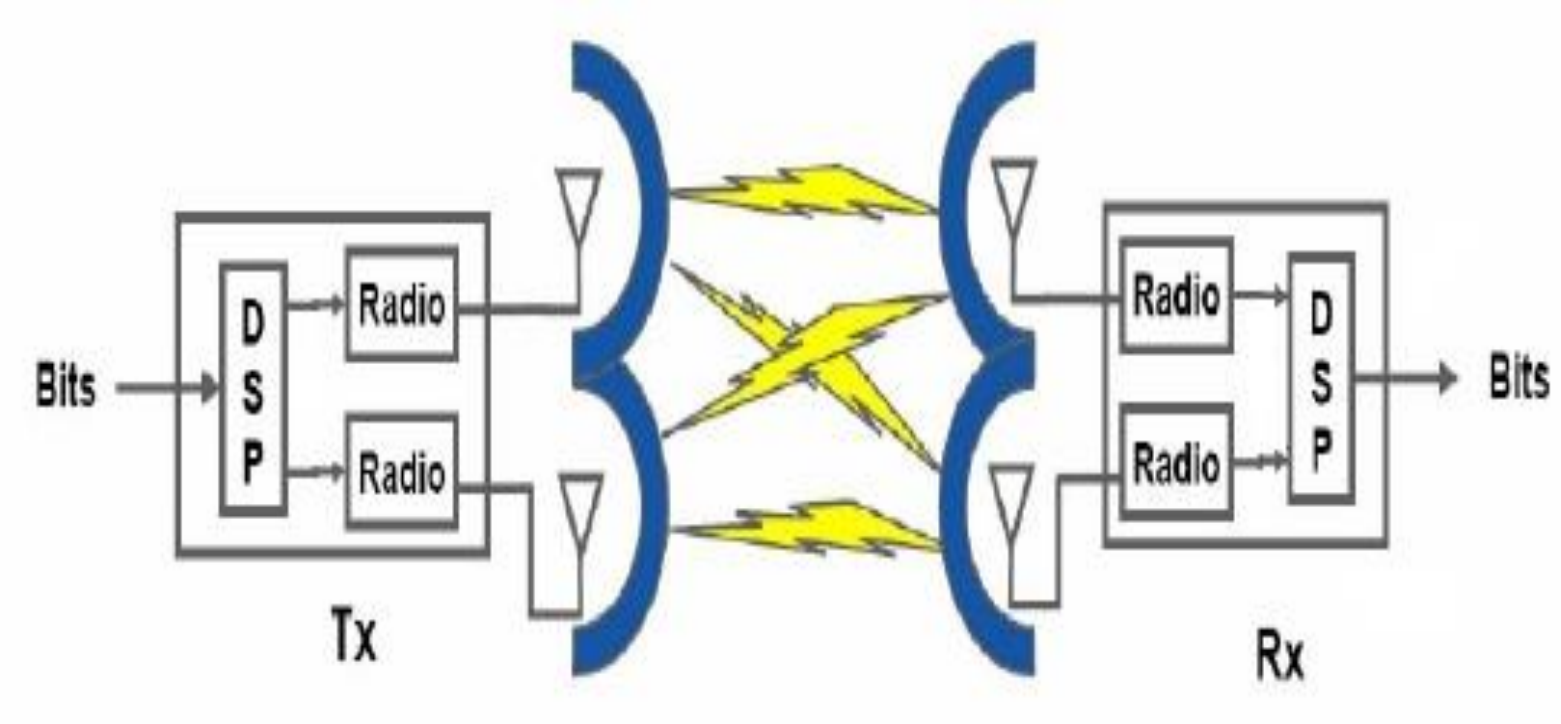
Multiple Input Multiple Output (MIMO)

OVERVIEW OF MIMO

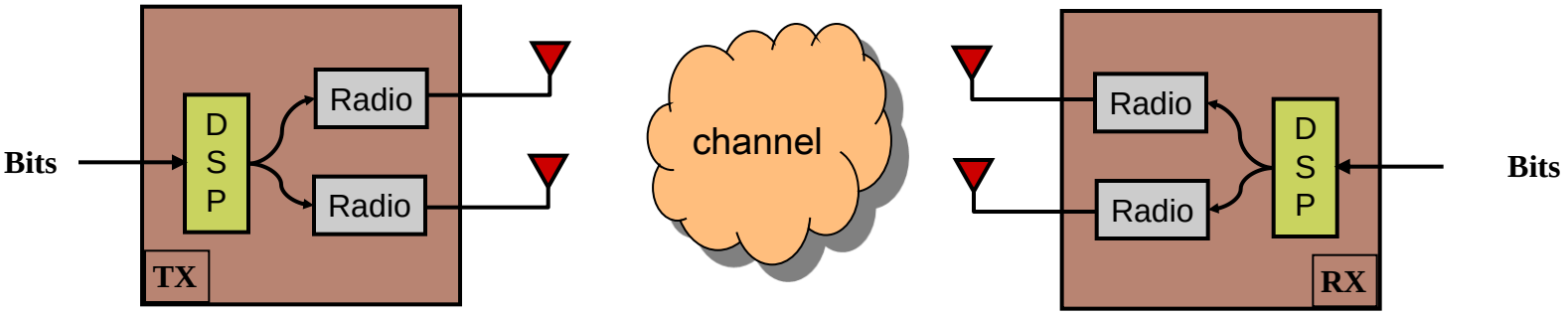
- Multiple-Input Multiple Output (MIMO) has emerged as one of the most promising approaches to achieve higher data rates in cellular systems.
- MIMO systems increase complexity with the use of multiple antennas and associated DSP systems at both the transmitter and the receiver but
- they provide significant benefit by scaling the theoretical achievable spectral efficiency linearly with the number of transmit and receive antenna pairs.

Example of MIMO

2 x 2 MIMO (2 Tx and 2 Rx)



MIMO Wireless Systems



Multiple Input Multiple Output (MIMO) systems with multiple parallel radios improve the following:

- Outages reduced by using information from multiple antennas.
- Transmit power can be increased via multiple power amplifiers.
- Higher throughputs possible.

MIMO : Key fundamentals

Three fundamental principles :

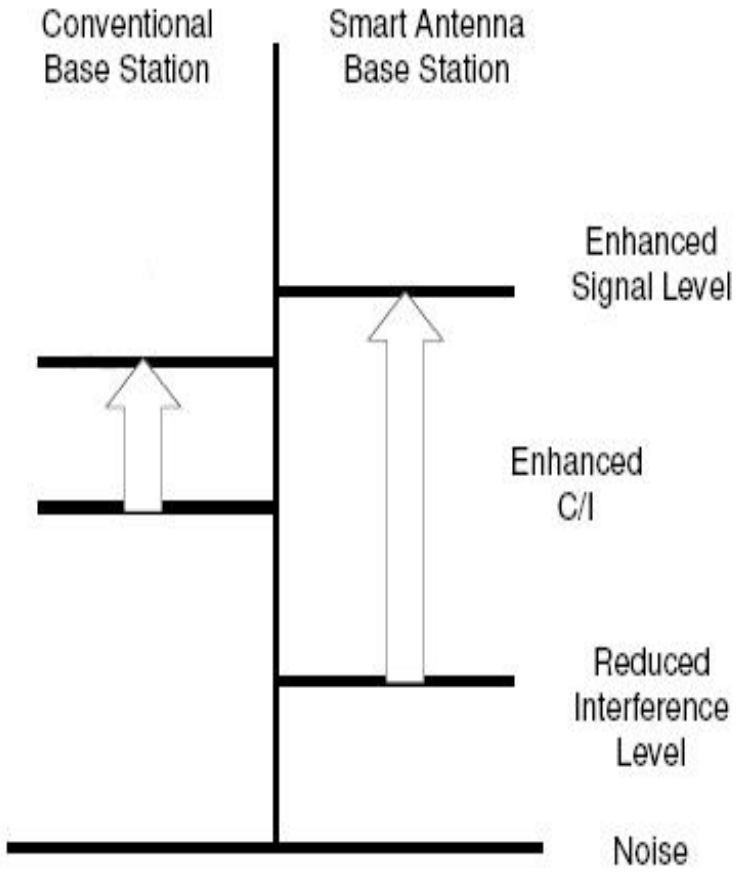
- Diversity gain
  - Use of spatial diversity provided by multiple antennas improved the robustness of transmission against mutipath fading
- Array gain
  - Concentration of energy in one or more given directions via beamforming
- Spatial Multiplexing gain
  - Transmission of multiple signal streams to a single user

MIMO: Diversity Gain

- Multiple antennas are used , on both sides of the link.
- Copies of the same signal, coded differently, are each sent over a different transmit antenna.
- Diversity gain: combats fading effects

MIMO – Beamforming

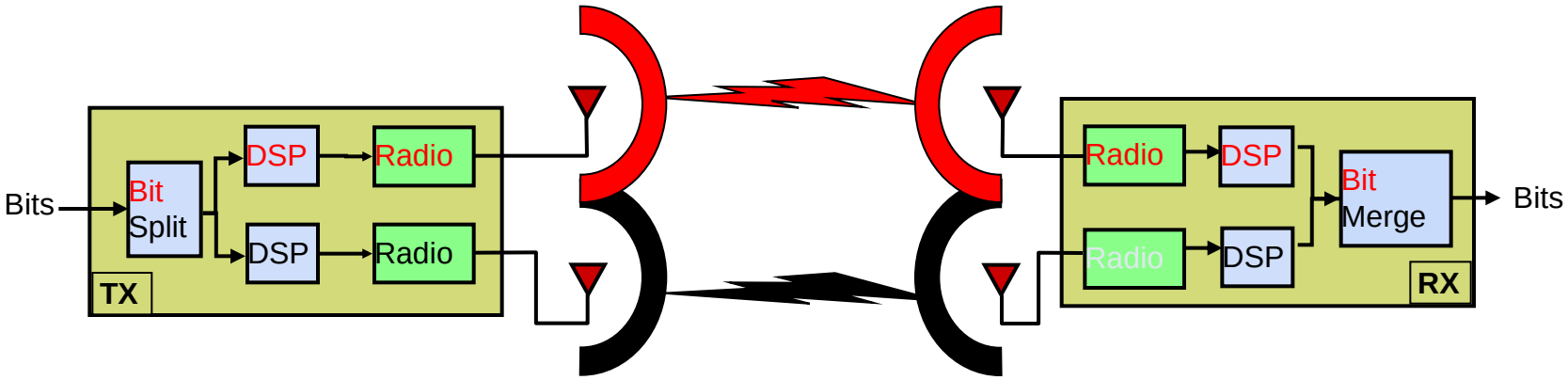
- Enhances signal reception through directional array gain.
- Extends cell coverage
- Suppresses interference in space domain
- Enhances system capacity
- Prolongs battery life



Spatial Multiplexing MIMO Concept

Spatial multiplexing concept:

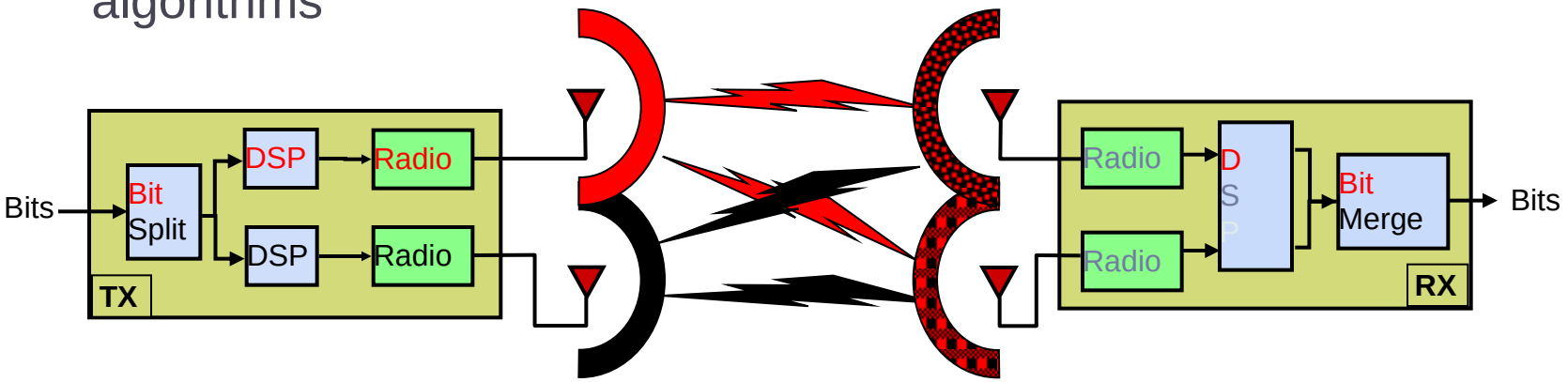
- Form multiple independent links (on same channel) between transmitter and receiver to communicate at higher total data rates



Spatial Multiplexing MIMO Reality

Spatial multiplexing concept:

- Form multiple independent links (on same channel) between transmitter and receiver to communicate at higher total data rates
- However, there are cross-paths between antennas
- The correlation must be decoupled by digital signal processing algorithms



System Architecture Evolution (SAE)

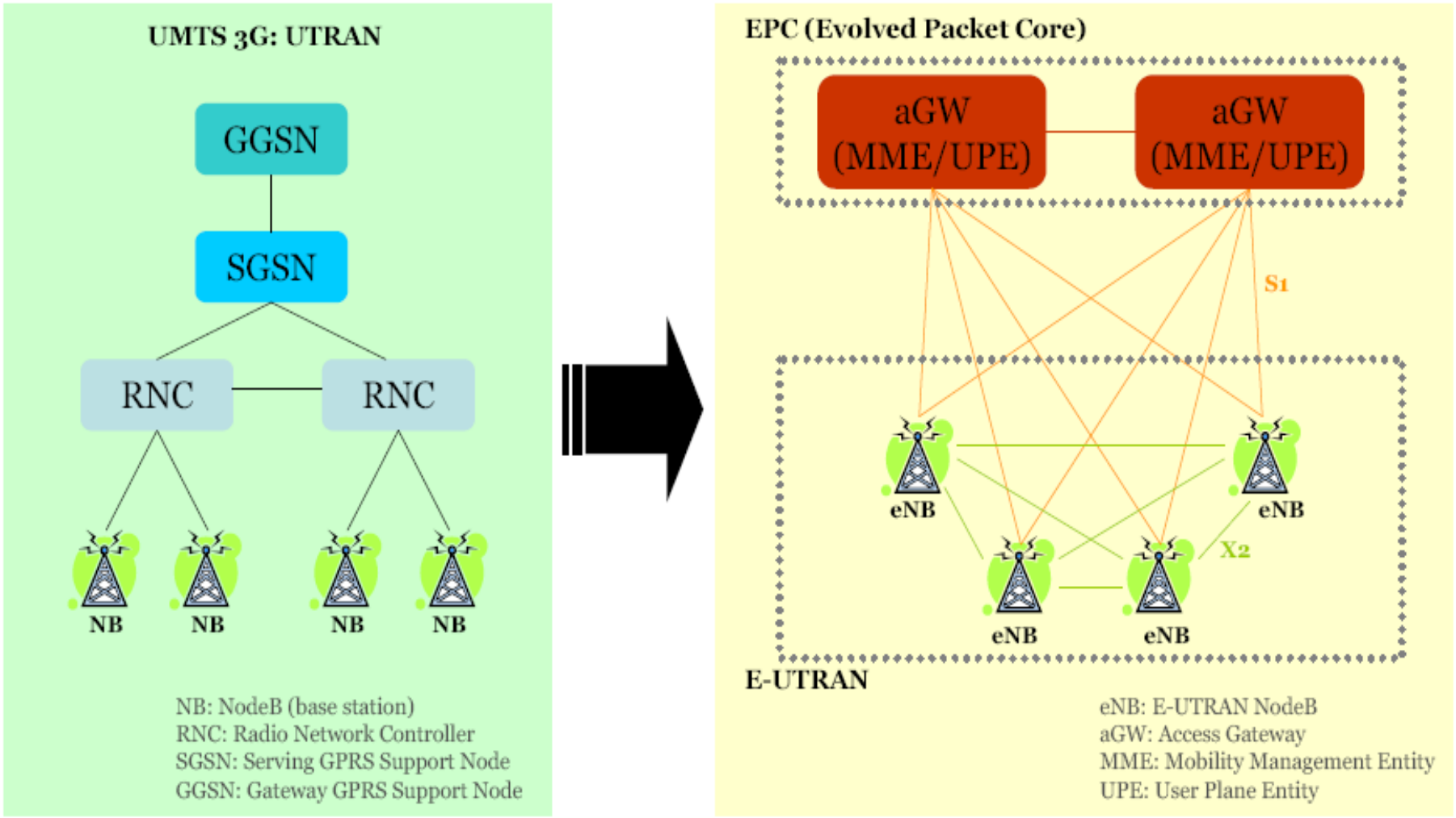
LTE

3GPP defined LTE as an IP-based, flat network architecture.

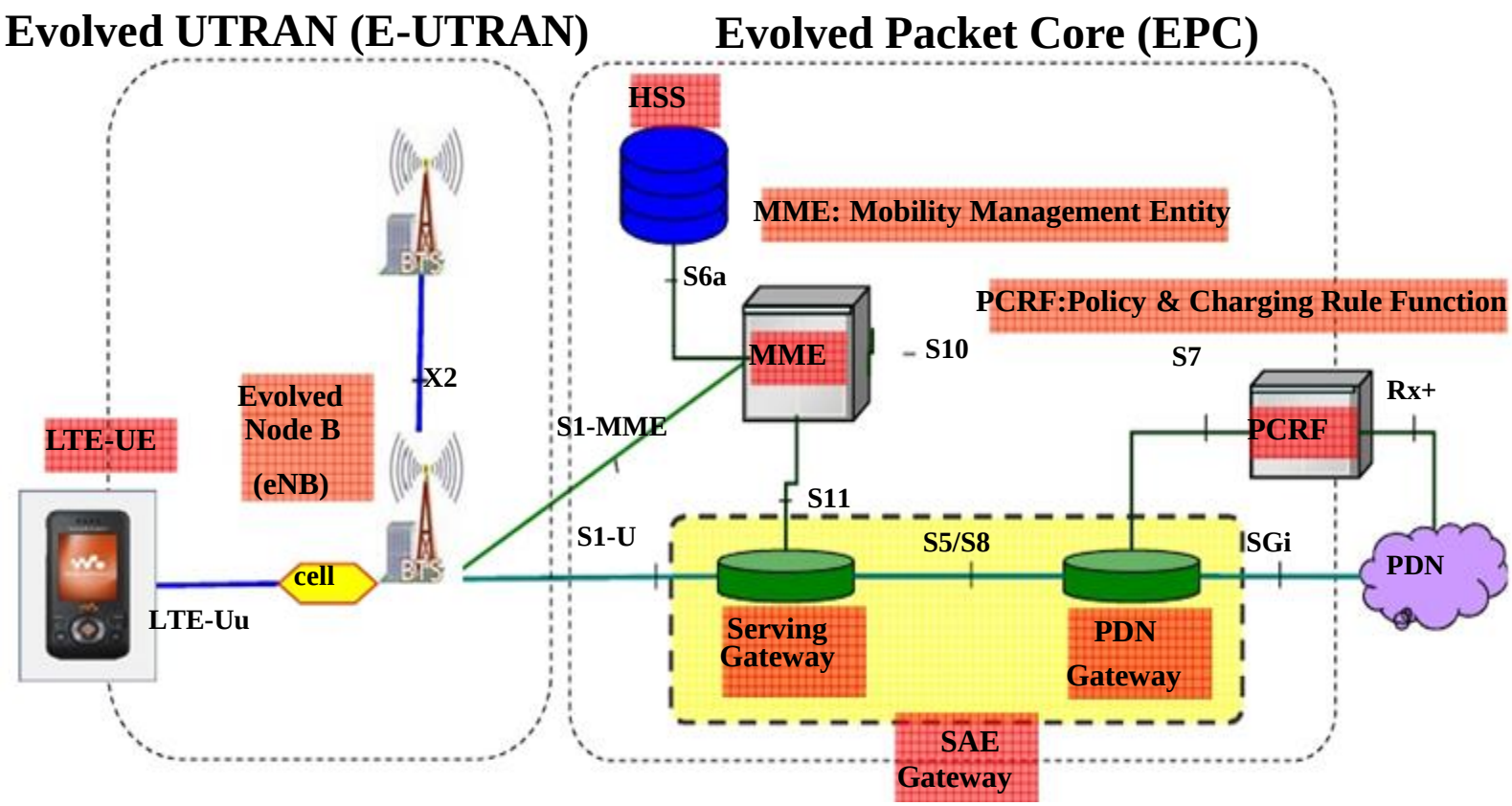
- In the User Plane (UP) of the Evolved Packet System (EPS), there are only two types of nodes (Base Stations and Gateways) while in current hierarchical networks there are four types (Node B, RNC, SGSN, GGSN).

- Flat architecture with less involved nodes reduces latencies and improves performance.

LTE Network Architecture



LTE/SAE Network Elements



LTE-SAE Architecture

Logical network elements for the Basic System Architecture

- User Equipment (UE)
- E-UTRAN Node B (eNodeB)
- Mobility Management Entity (MME)
- Serving Gateway (S-GW)
- PDN Gateway (PDN-GW)
- Policy and Charging Resource Function (PCRF)
- Home Subscription Server (HSS)

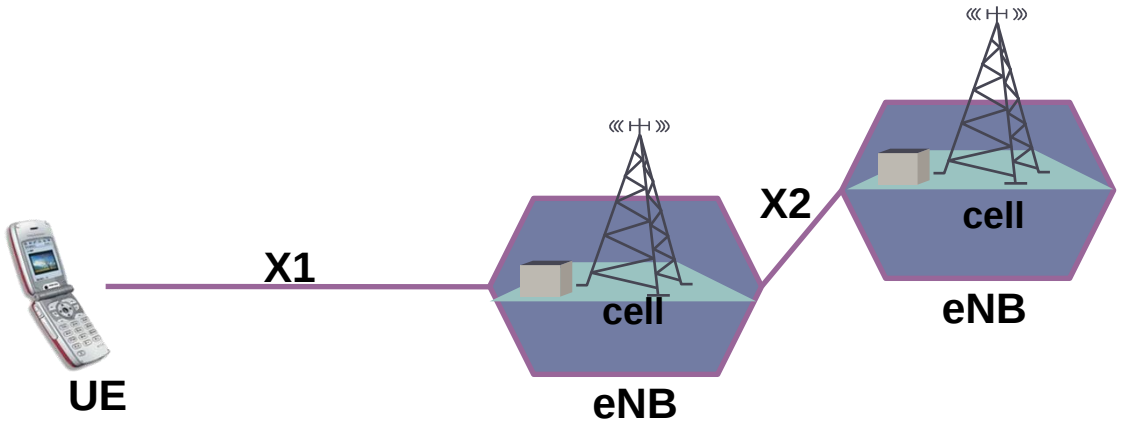
User Equipment (UE)

- UE is the device that the end user applies for communication. Typically it is a hand held device such as a smart phone or a data card such as those used currently in 2G and 3G, or it could be embedded, e.g. to a laptop.

- UE also contains the Universal Subscriber Identity Module (USIM)

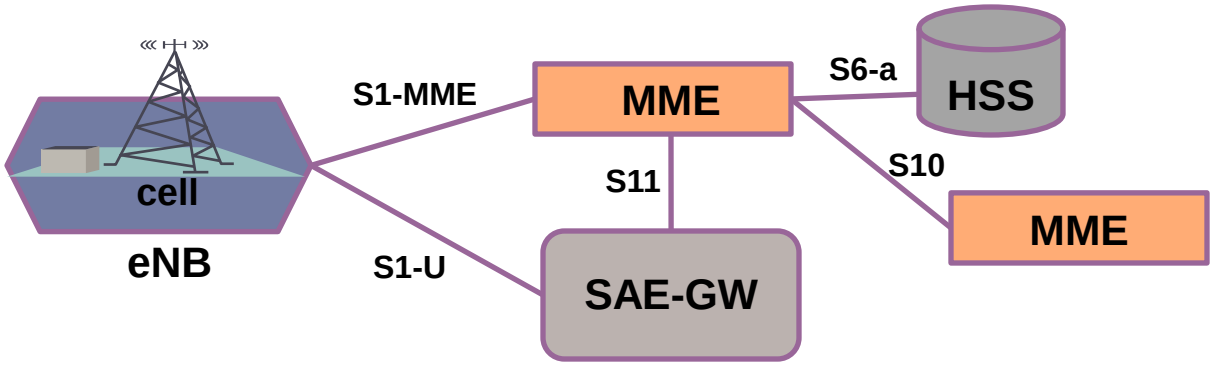
- USIM is used to identify and authenticate the user and to derive security keys for protecting the radio interface transmission.

E-UTRAN Node B (eNodeB)



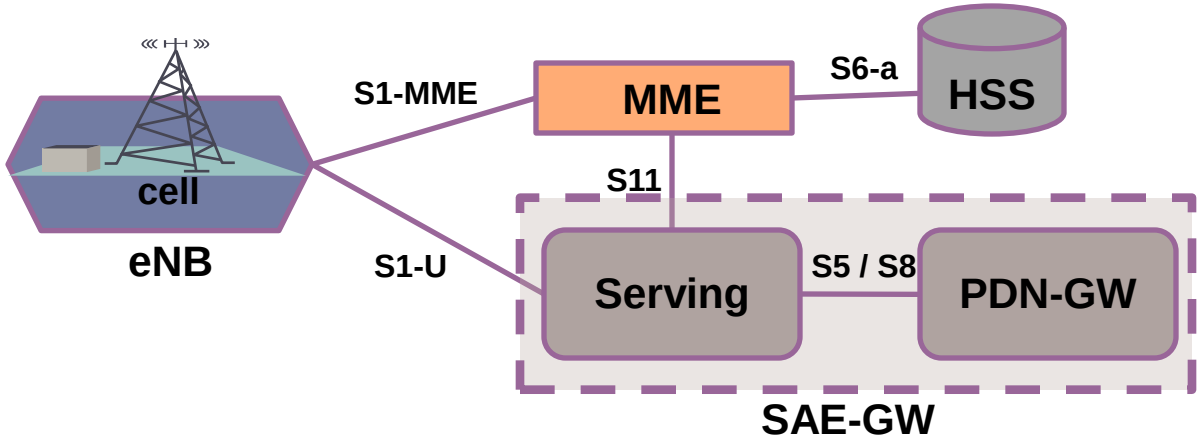
- It replaces the old Node B / RNC combination from 3G. It provides all radio management functions.
- Most of the typical protocols implemented in Radio Network Controller (RNC) are moved to the eNodeB.
- Benefits of the RNC and Node-B merger include reduced latency with fewer hops in the media path, and distribution of the RNC processing load

Mobility Management Entity (MME)



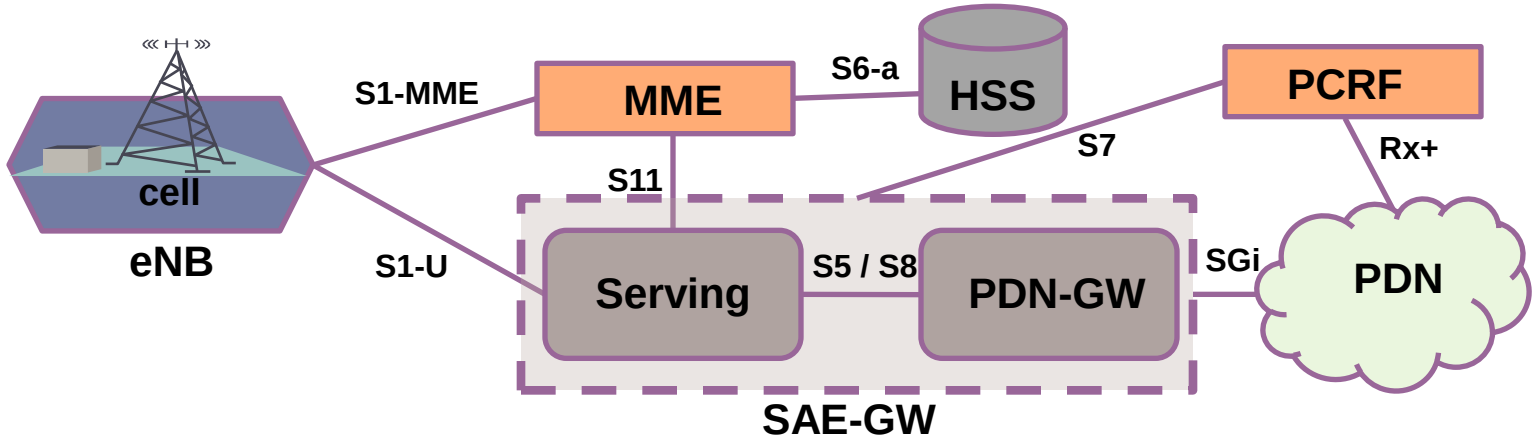
- It is a pure signalling entity inside the EPC.
- Functionality of the MME is signaling coordination to setup transport bearers through the EPC for a UE.
- SAE uses tracking areas to track the position of idle UEs. The basic principle is identical to location or routing areas from 2G/3G.
- MME handles attaches and detaches to the SAE system as well as tracking area updates .Therefore it possesses an interface towards the HSS (home subscriber server) which stores the subscription relevant information and the currently assigned MME in its permanent data base.

Serving SAE Gateway (SAE-GW)



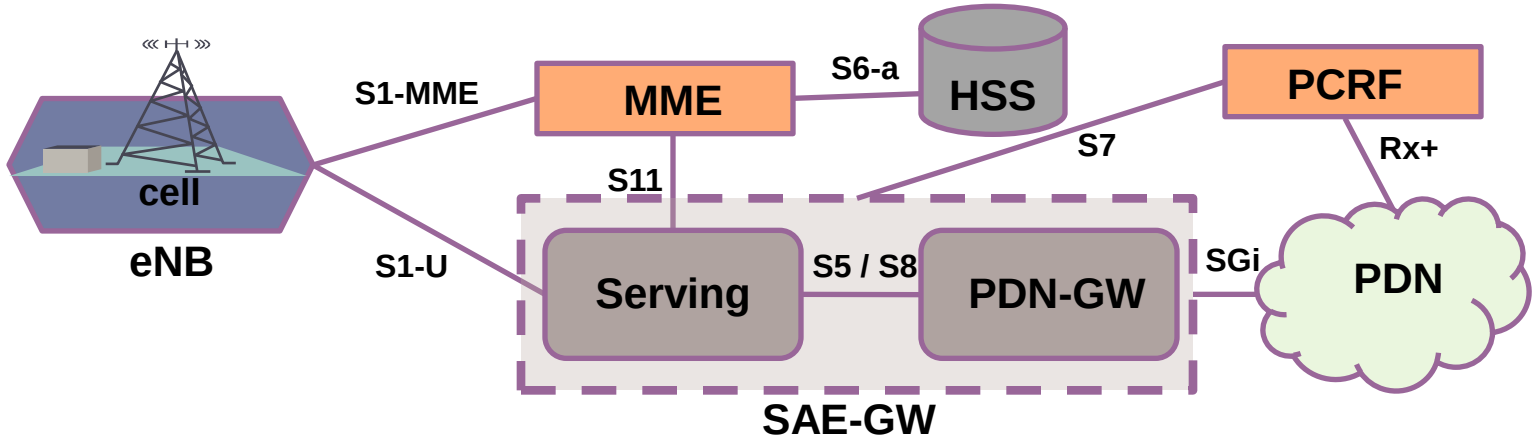
- The serving gateway is a network element that manages the user data path (SAE bearers) within EPC.
- Serving gateway is some kind of distribution and packet data anchoring function within EPC
- It relays the packet data within EPC via the S5/S8 interface to or from the PDN gateway
- Lawful Interception support

PDN SAE Gateway (PDN-GW)



- The PDN gateway provides the connection between EPC and a number of external data networks.
- It is comparable to GGSN in 2G/3G networks.
- Charging support.
- IP Address Allocation for UE.
- Packet Routing/Forwarding between Serving GW and external Data Network and Packet screening (firewall functionality).

Policy and Charging Function (PCRF)



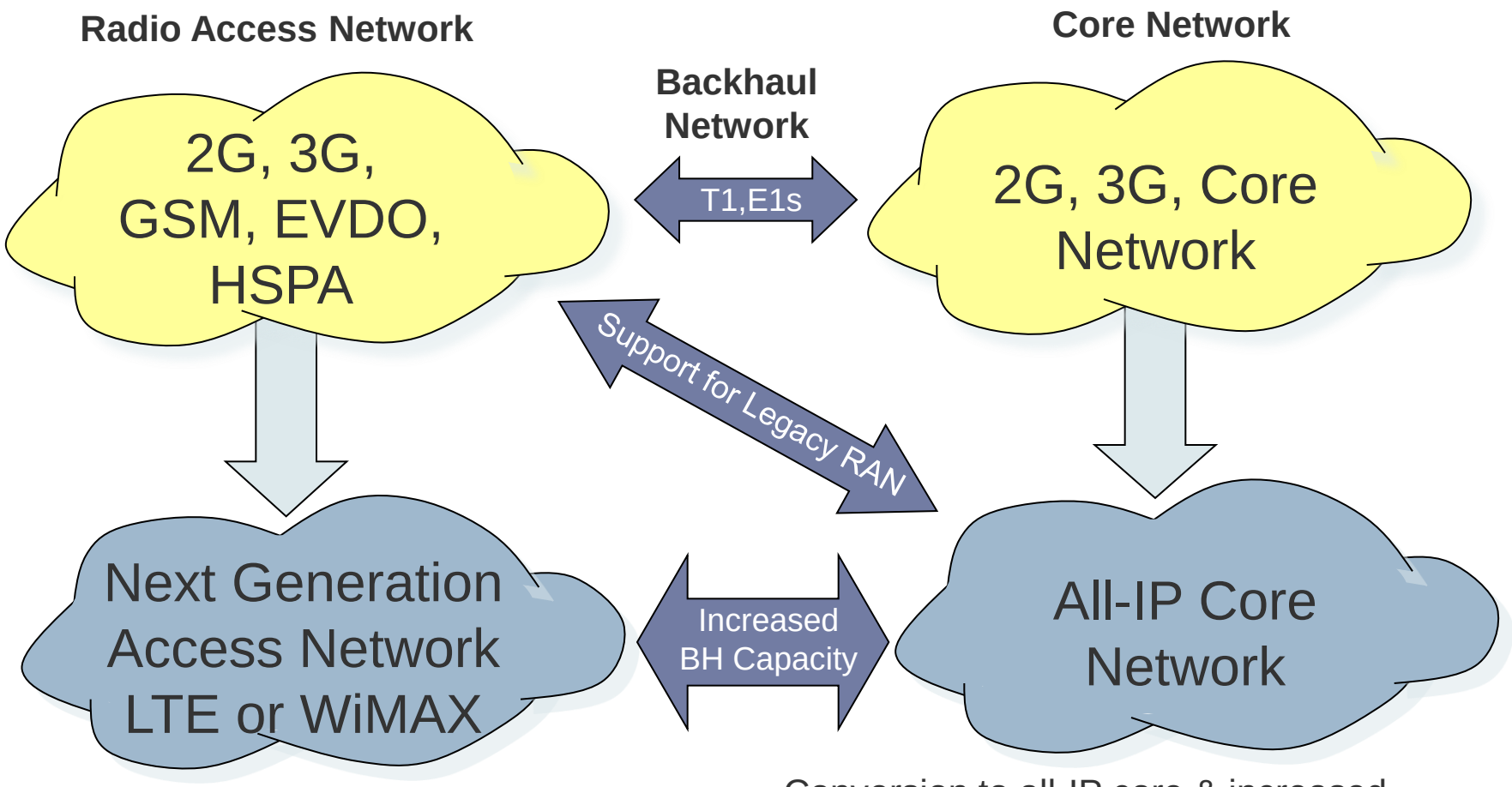
- The PCRF major functionality is the Quality of Service (QoS) coordination between the external PDN and EPC.
- PCRF is connected via Rx+ interface to the external Data network .
- PCRF can be used to check and modify the QoS associated with a SAE bearer setup from SAE or to request the setup of a SAE bearer from the PDN.

Home Subscriber Server (HSS)

- Permanent and central subscriber database maintained centrally by the home operator
- Stores mobility and service data for every subscriber
- The HSS stores the master copy of the subscriber profile, contains information about the services applicable to the user, including information about the allowed packet data connections, and whether roaming to a particular visited network is allowed or not.

LTE Technology Solution Implementation

Upgrade Path for Existing Operators

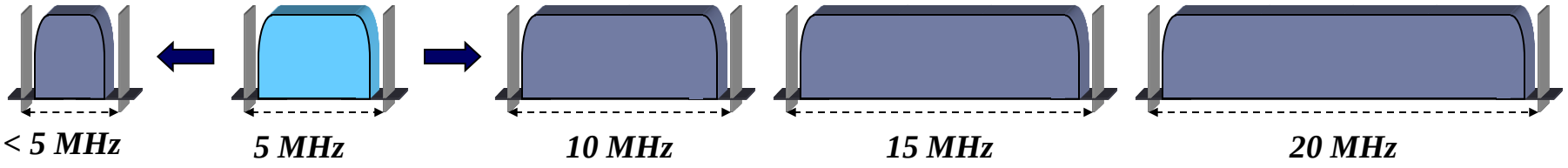


Conversion to all-IP core & increased backhaul capacity required in either case

Long-term evolution – *Spectrum flexibility*

- Operation in a wide range of frequency bands
  - *Current and future 3G spectrum (2 GHz, 2.6 GHz, …)*
  - *Migration of 2G spectrum*
  - *Re-farming of other spectrum*

- Efficient operation in differently-sized spectrum allocations
  - *Up to 20 MHz to enable very high data rates*
  - *Less than 5 MHz to enable smooth spectrum migration*



- Duplex flexibility
  - *Both FDD and TDD mode-of-operations (i.e. operation in Paired as well as Unpaired spectrun)*

Long-term evolution – *Duplex flexibility*

- Possibility for operation in paired *and* unpaired spectrum
  - ➡ *Support for both FDD and TDD operation*

- Maximum commonality between FDD and TDD
  - Strong requirement from some operators

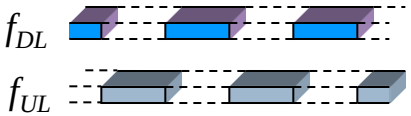
FDD-only

Paired spectrum
Highest data rates for given TX bandwidth and peak power

TDD-only

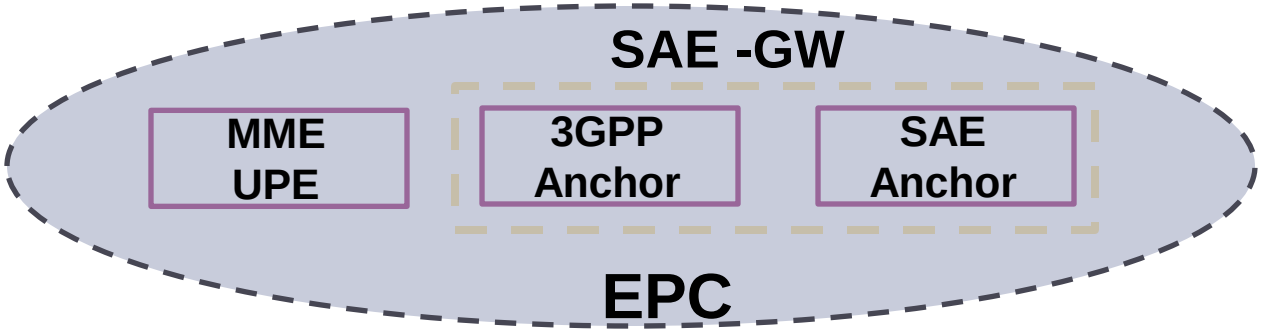
Unpaired spectrum

Combined FDD/TDD



Reduced UE complexity (paired spectrum)

Mobility Support



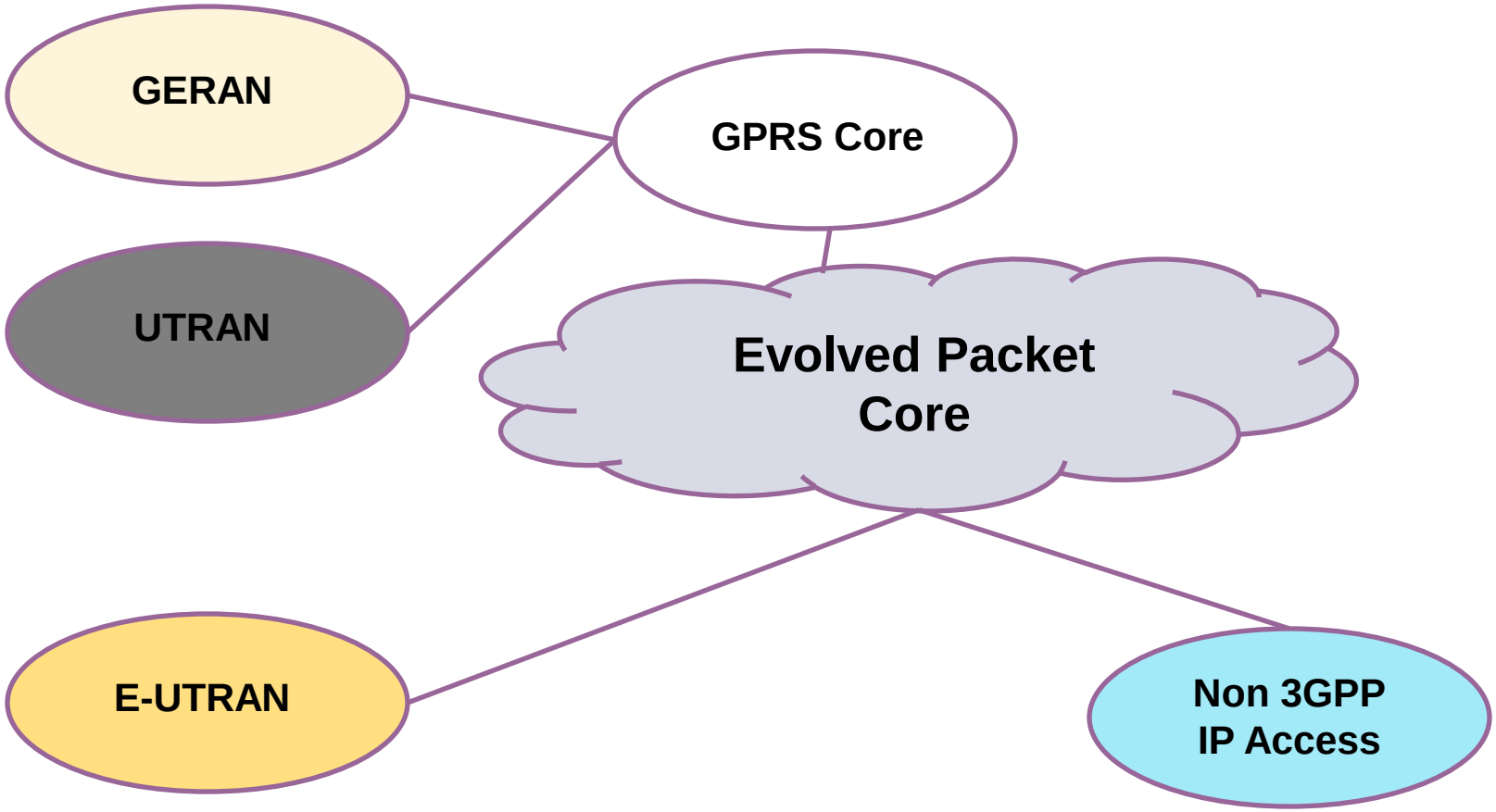
❖ **3GPP anchor:**

- Mobility anchor between 2G/3G and LTE.

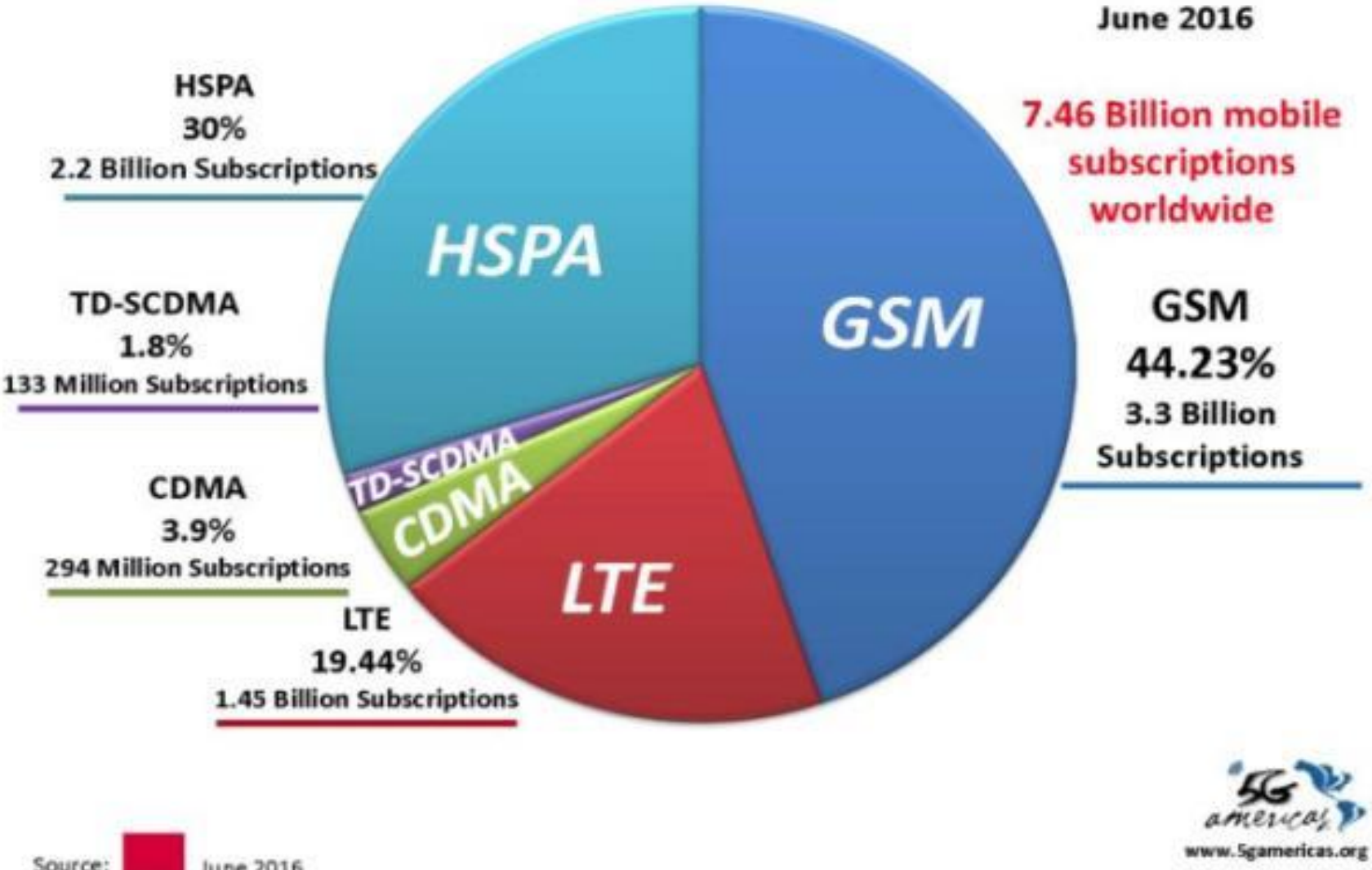
❖ **SAE anchor:**

- Mobility anchor between 3GPP and non 3GPP.

Interworking



Global Mobile Subscribers and Market Share by Technology



LTE deployments in India

- Operators
- Services offered
- Spectrum used for 4G
  - TDD-LTE deployments in 2300 MHz
  - FDD-LTE deployments in 1800 MHz & 850 MHz
  - 700 MHz likely to be used (under auction)

- VoLTE services recently introduced
  - Competition
  - Free voice
  - Data Plans

Path to 5G

- 3GPP Release 11
  - **Self Optimizing Networks**
  - Carrier Aggregation enhancements
- 3GPP Release 12
  - LTE Advance Enhancements
  - Heterogeneous Networks.
- 3GPP Release 13
  - **5G**
  - M2M Communications
  - Active Antenna Systems
  - LTE deployment in unlicensed spectrum

Thank You