

# Evolved UMTS Overview

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# UMTS

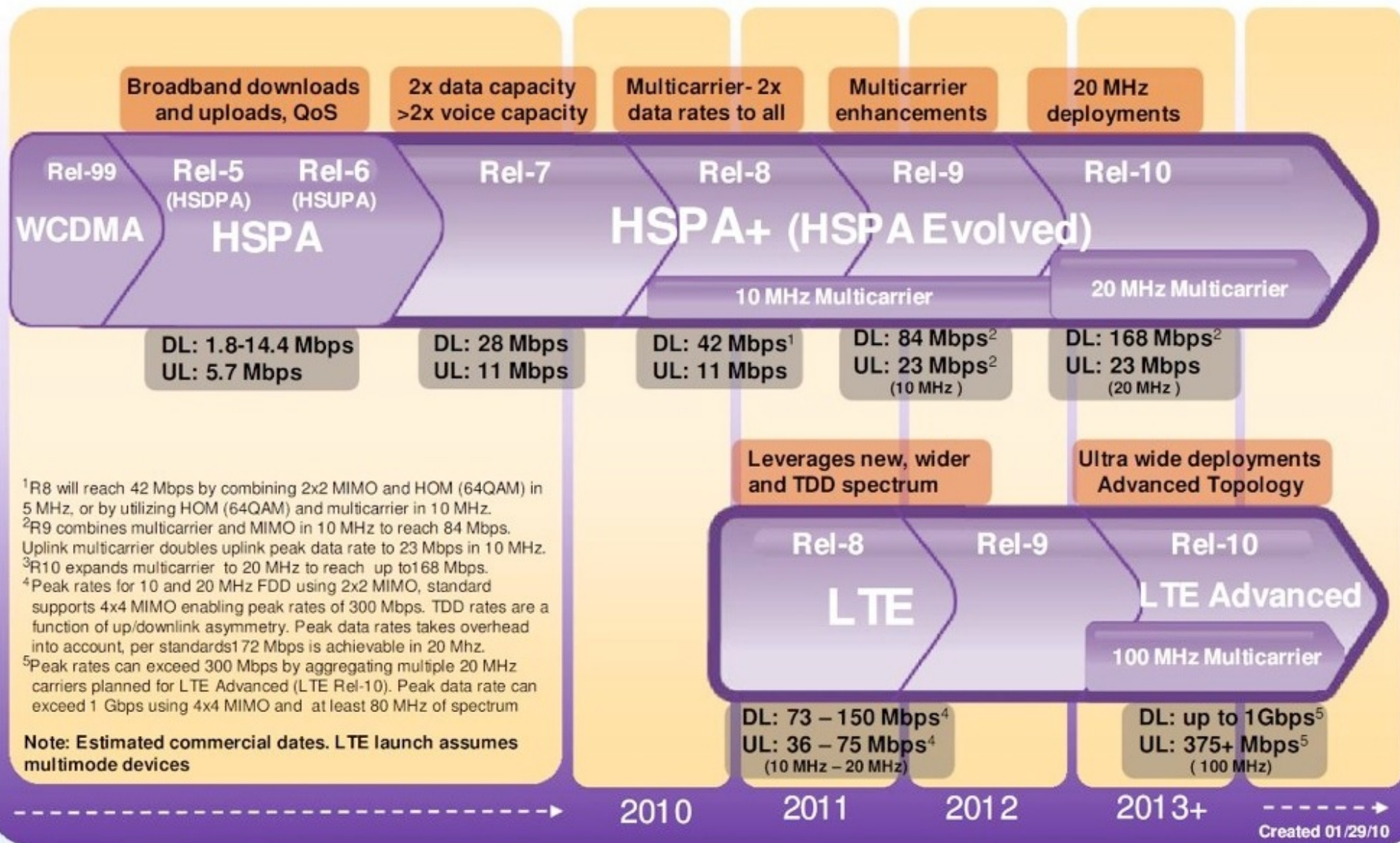
- Universal Mobile Telecommunications System (UMTS)
  - ✓ A third generation mobile cellular system for networks based on GSM standard
  - ✓ Developed and maintained by the 3GPP (3rd Generation Partnership Project)
  - ✓ UMTS is a component of the International Telecommunications Union IMT-2000 standard set and compares with the CDMA2000 standard set for networks based on the competing cdmaOne technology

- UMTS uses Wideband Code Division Multiple Access (W-CDMA) radio access technology to offer greater spectral efficiency and bandwidth to mobile network operators
- UMTS specifies a complete network system
  - ✓ Radio access network (UMTS Terrestrial Radio Access Network, UTRAN)
  - ✓ Core network (Mobile Application Part, MAP)
  - ✓ Authentication of users via SIM (Subscriber Identity Module) cards

# 3GPP Standards

Version <sup>[5]</sup>	Released <sup>[6]</sup>	Info
Phase 1	1992	GSM Features
Phase 2	1995	GSM Features, EFR Codec,
Release 96	1997 Q1	GSM Features, 14.4 kbit/s User Data Rate,
Release 97	1998 Q1	GSM Features, GPRS
Release 98	1999 Q1	GSM Features, AMR, EDGE, GPRS for PCS1900
Release 99	2000 Q1	Specified the first <b>UMTS</b> 3G networks, incorporating a <b>CDMA</b> air interface <sup>[7]</sup>
Release 4	2001 Q2	Originally called the <b>Release 2000</b> - added features including an <b>all-IP</b> Core Network <sup>[8]</sup>
Release 5	2002 Q1	Introduced <b>IMS</b> and <b>HSDPA</b> <sup>[9]</sup>
Release 6	2004 Q4	Integrated operation with <b>Wireless LAN</b> networks and adds <b>HSUPA</b> , <b>MBMS</b> , enhancements to <b>IMS</b> such as <b>Push to Talk over Cellular (PoC)</b> , <b>GAN</b> <sup>[10]</sup>
Release 7	2007 Q4	Focuses on decreasing latency, improvements to <b>QoS</b> and real-time applications such as <b>VoIP</b> . <sup>[11]</sup> This specification also focus on <b>HSPA+</b> (High Speed Packet Access Evolution), <b>SIM</b> high-speed protocol and contactless front-end interface ( <b>Near Field Communication</b> enabling operators to deliver contactless services like <b>Mobile Payments</b> ), <b>EDGE Evolution</b> .
Release 8	2008 Q4	First <b>LTE</b> release. All-IP Network (SAE). New <b>OFDMA</b> , <b>FDE</b> and <b>MIMO</b> based radio interface, not backwards compatible with previous CDMA interfaces. <b>Dual-Cell HSDPA</b> .
Release 9	2009 Q4	SAES Enhancements, <b>WiMAX</b> and LTE/UMTS Interoperability. Dual-Cell HSDPA with <b>MIMO</b> , <b>Dual-Cell HSUPA</b> .
Release 10	2011 Q1	<b>LTE Advanced</b> fulfilling <b>IMT Advanced 4G</b> requirements. Backwards compatible with release 8 (LTE). Multi-Cell HSDPA (4 carriers).
Release 11	2012 Q3	Advanced IP <b>Interconnection</b> of Services. <b>Service layer</b> interconnection between national operators/carriers as well as third party application providers.
Release 12	Planned to 2014 Q2	Content still open (as of October 2012).

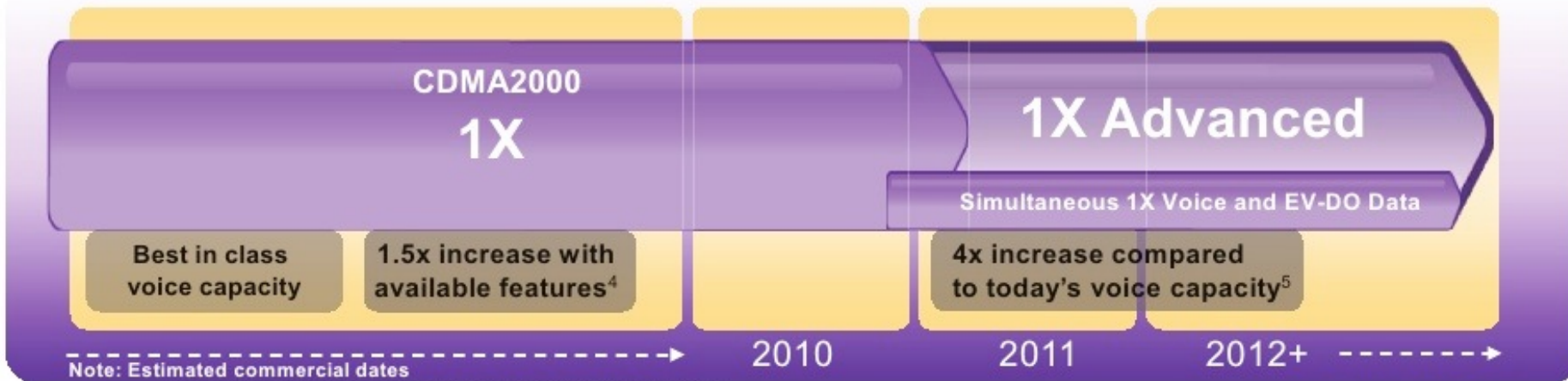
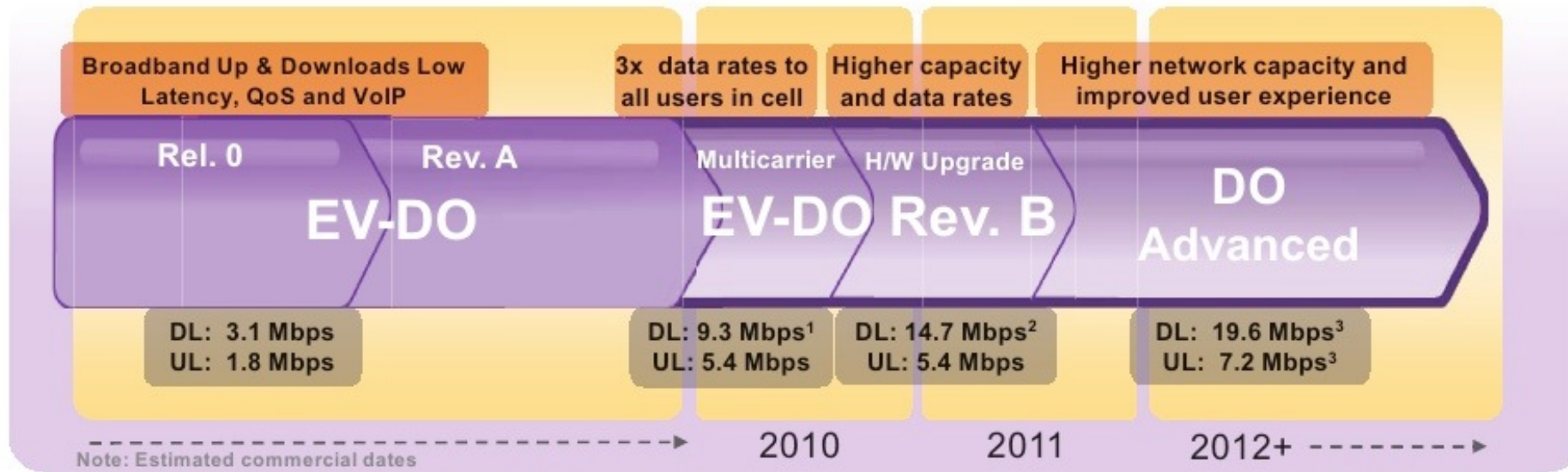
# LTE Advanced: A Parallel Evolution Path to HSPA+



# 3GPP2 Standards

V · T · E		Cellular network standards	[hide]
<b>0G (radio telephones)</b>	MTS · MTA * MTB * MTC · IMTS · MTD · AMTS · OLT · Autoradiopuhelin · B-Netz		
1G	<b>AMPS family</b>	AMPS (TIA/EIA/IS-3, ANSI/TIA/EIA-553) · N-AMPS (TIA/EIA/IS-91) · TACS · ETACS	
	<b>Other</b>	NMT · C-450 · Hicap · Mobitex · DataTAC	
2G	<b>GSM/3GPP family</b>	GSM · CSD	
	<b>3GPP2 family</b>	cdmaOne (TIA/EIA/IS-95 and ANSI-J-STD 008)	
	<b>AMPS family</b>	D-AMPS (IS-54 and IS-136)	
2G transitional (2.5G, 2.75G)	<b>Other</b>	CDPD · iDEN · PDC · PHS	
	<b>GSM/3GPP family</b>	HSCSD · GPRS · EDGE/EGPRS (UWC-136)	
	<b>3GPP2 family</b>	CDMA2000 1X (TIA/EIA/IS-2000) · 1X Advanced	
3G (IMT-2000)	<b>Other</b>	WiDEN	
	<b>3GPP family</b>	UMTS (UTRAN) · WCDMA-FDD · WCDMA-TDD · UTRA-TDD LCR (TD-SCDMA)	
3G transitional (3.5G, 3.75G, 3.9G)	<b>3GPP2 family</b>	CDMA2000 1xEV-DO Release 0 (TIA/IS-856)	
	<b>3GPP family</b>	HSPA · HSPA+ · LTE (E-UTRA)	
	<b>3GPP2 family</b>	CDMA2000 1xEV-DO Revision A (TIA/EIA/IS-856-A) EV-DO Revision B (TIA/EIA/IS-856-B) · DO Advanced	
4G (IMT Advanced)	<b>IEEE family</b>	Mobile WiMAX (IEEE 802.16e) · Flash-OFDM · IEEE 802.20	
	<b>3GPP family</b>	LTE Advanced (E-UTRA)	
5G	<b>IEEE family</b>	WiMAX-Advanced (IEEE 802.16m)	
	Research concept, not under formal development		
Links	<b>Related articles</b>	Cellular networks · Mobile telephony · History · List of standards · Comparison of standards · Channel access methods · Spectral efficiency comparison table · Cellular frequencies · GSM frequency bands · UMTS frequency bands · Mobile broadband · NGMN Alliance · MIMO	
	<b>External links</b>	3rd Generation Partnership Project (3GPP) <span><span>↗</span></span> · Third Generation Partnership Project 2 (3GPP2) <span><span>↗</span></span> · IMT-2000/IMT-Advanced Portal <span><span>↗</span></span> · Institute of Electrical and Electronics Engineers Inc. (IEEE) <span><span>↗</span></span> · International Telecommunication Union (ITU) <span><span>↗</span></span> · Telecommunications Industry Association (TIA) <span><span>↗</span></span>	

# 1X and EV-DO Have Strong Evolution Paths



<sup>1</sup>Peak rate for 3 EV-DO carriers supported by initial implementation.

<sup>2</sup>Peak rate for 3 EV-DO carriers with 64QAM in the DL. Rev. B standard supports up to 15 aggregated Rev. A carriers.

<sup>3</sup>DO Advanced peak rate for 4 Rev. B carriers; Assumes 64QAM in the DL.

<sup>4</sup>Capacity increase possible with new codec (EVRC-B) and handset interference cancellation (QLIC). <sup>5</sup>4x increase with receive diversity; 3x without

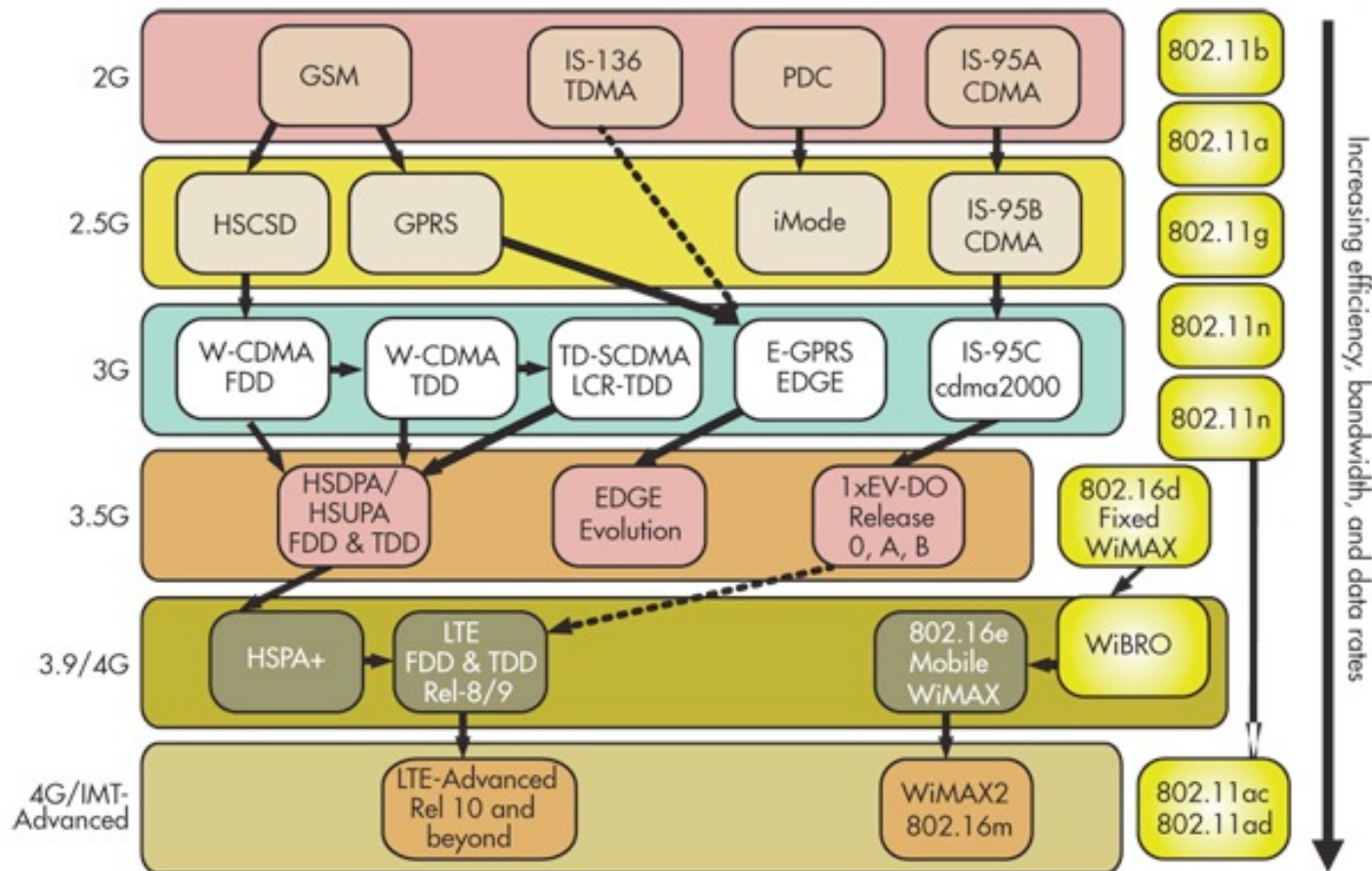


Fig1. In the evolution of wireless cellular standards, all paths eventually lead to some form of LTE or a WiMAX alternative. (courtesy of Agilent Technologies)

### 802.11 n/ac/ad Comparison

	802.11n	802.11ac	802.11ad
<b>Throughput</b>	600 Mbps	3.2 Gbps	Up to 7 Gbps
<b>Coverage</b>	Home, 70 m	Home, 30 m	Room, <5m
<b>Freq. Band</b>	2.4/5 GHz	5 GHz	2.4/5/60 GHz
<b>Antennas</b>	4 x 4 MIMO	8 x 8 MIMO	>10 x 10 MIMO
<b>Applications</b>	Data, Video	Video	Uncompressed Video

- 802.11ac 在單一空間流(spatial streams)中使用不同頻寬 bandwidth與不同調變 modulation 之理論傳輸速率 Mbps

Modulation	Coding rate	20 MHz channels		40 MHz channels		80 MHz channels		160 MHz channels	
		800 ns GI	400 ns GI	800 ns GI	400 ns GI	800 ns GI	400 ns GI	800 ns GI	400 ns GI
BPSK	1/2	6.5	7.2	13.5	15	29.3	32.5	58.5	65
QPSK	1/2	13	14.4	27	30	58.5	65	117	130
QPSK	3/4	19.5	21.7	40.5	45	87.8	97.5	175.5	195
16-QAM	1/2	26	28.9	54	60	117	130	234	260
16-QAM	3/4	39	43.3	81	90	175.5	195	351	390
64-QAM	2/3	52	57.8	108	120	234	260	468	520
64-QAM	3/4	58.5	65	121.5	135	263.3	292.5	526.5	585
64-QAM	5/6	65	72.2	135	150	292.5	325	585	650
256-QAM	3/4	78	86.7	162	180	351	390	702	780
256-QAM	5/6	N/A	N/A	180	200	390	433.3	780	866.7

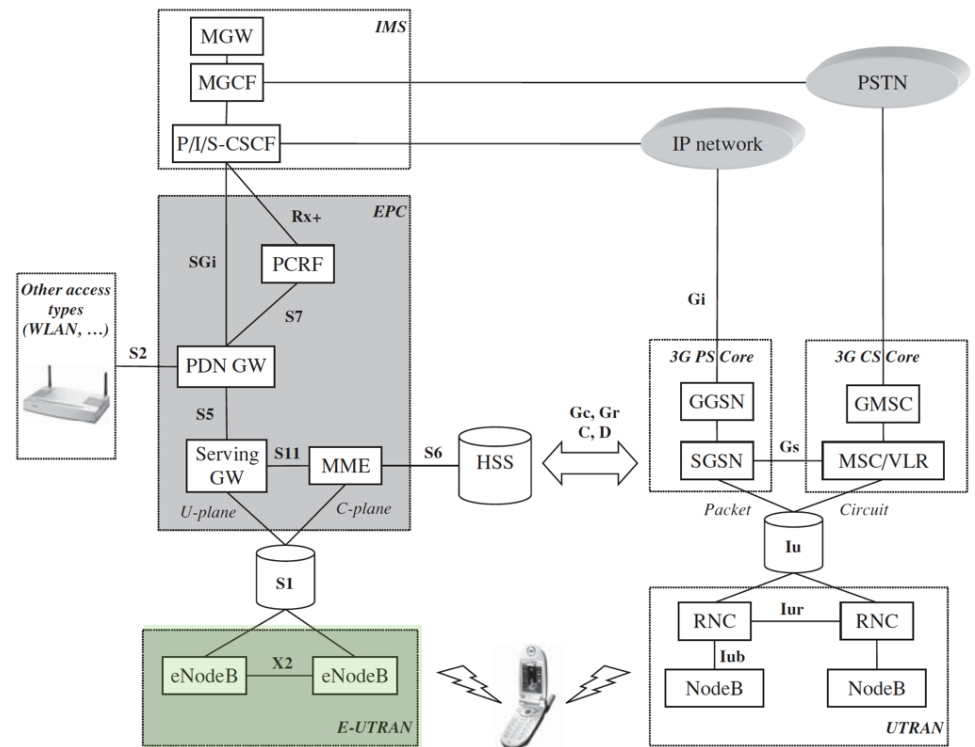
GI: Guard Interval (timing between wireless frames)

- 若802.11ac 使用最高 **160 MHz bandwidth**，與最佳之調變 **256-QAM**，在**8**個空間流(spatial streams)之情況下，最高可達 **6.93 Gbps (=8 x 866.7 Mbps)**之理論傳輸速率

# 1. The Access Network Requirements

- The associated requirements of the new Radio Access Network (RAN) of Evolved UMTS system
  - ✓ Radio interface throughput
  - ✓ Data transmission latency
  - ✓ Terminal state transition requirements
  - ✓ Mobility requirements
  - ✓ Flexibility in spectrum usage
  - ✓ Mobility requirements between systems

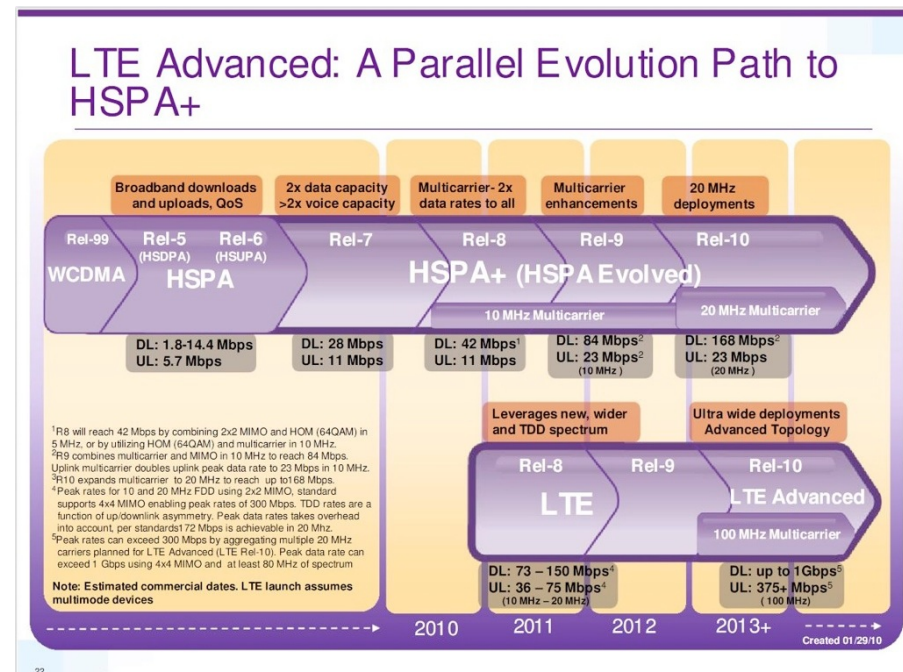
- E-UTRAN (Evolved Universal Terrestrial Radio Access Network)
  - ✓ The access network of Evolved UMTS (or EPS for Evolved Packet System)
  - ✓ Not only includes the radio interface, but also the network nodes and terrestrial interfaces supporting the radio-related features



# 1.1 Radio Interface Throughput

- UMTS / WCDMA expected throughput
  - ✓ 144 Kbps in rural [鄉村] outdoor radio environments
  - ✓ 384 Kbps in urban [城市] or suburban [郊區] outdoor radio environments
  - ✓ 2,048 Kbps in indoor or low range outdoor radio environment
- UMTS / WCDMA expected spectrum efficiency
  - ✓ Assumes a theoretical maximum of **2 Mbps** within a 5MHz spectrum allocation for dedicated channels
  - ✓ The corresponding spectrum efficiencies
    - ➔ **0.4** bits/s/Hz for WCDMA downlink

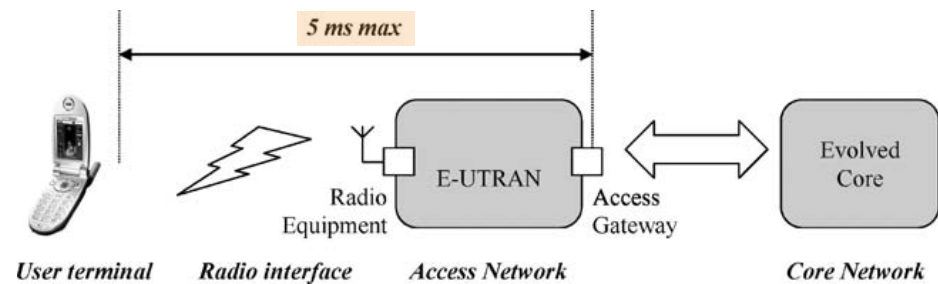
- UMTS / HSDPA (High Speed Downlink Packet Access) expected throughput
  - ✓ More than 2Mbps in urban or low-range outdoor radio environments
- UMTS / HSDPA expected spectrum efficiency
  - ✓ Assumes a theoretical maximum of **14.4 Mbps** within a 5 MHz spectrum allocation when using HSDPA shared channel techniques
  - ✓ The corresponding spectrum efficiency
    - ➔ **2.9** bits/s/Hz for HSDPA downlink



- E-UTRAN radio interface shall be able to support
  - ✓ Throughput
    - ➔ An instantaneous downlink (from network to terminal) peak data rate of 100 Mbps within a 20MHz downlink spectrum allocation
    - ➔ An instantaneous uplink (from terminal to network) peak data rate of 50 Mbps within a 20MHz uplink spectrum allocation
  - ✓ Spectrum efficiency
    - ➔ 5 bits/s/Hz for downlink
    - ➔ 2.5 bits/s/Hz for uplink

# 1.2 Data Transmission Latency

- E-UTRAN shall enable a user data latency of less than 5 ms in a non-loaded condition



- This value corresponds to the maximum transfer delay between the E-UTRAN access gateway and the user terminal, including
  - ✓ The transfer delay between nodes within the Access Network, and
  - ✓ The transmission over the radio interface

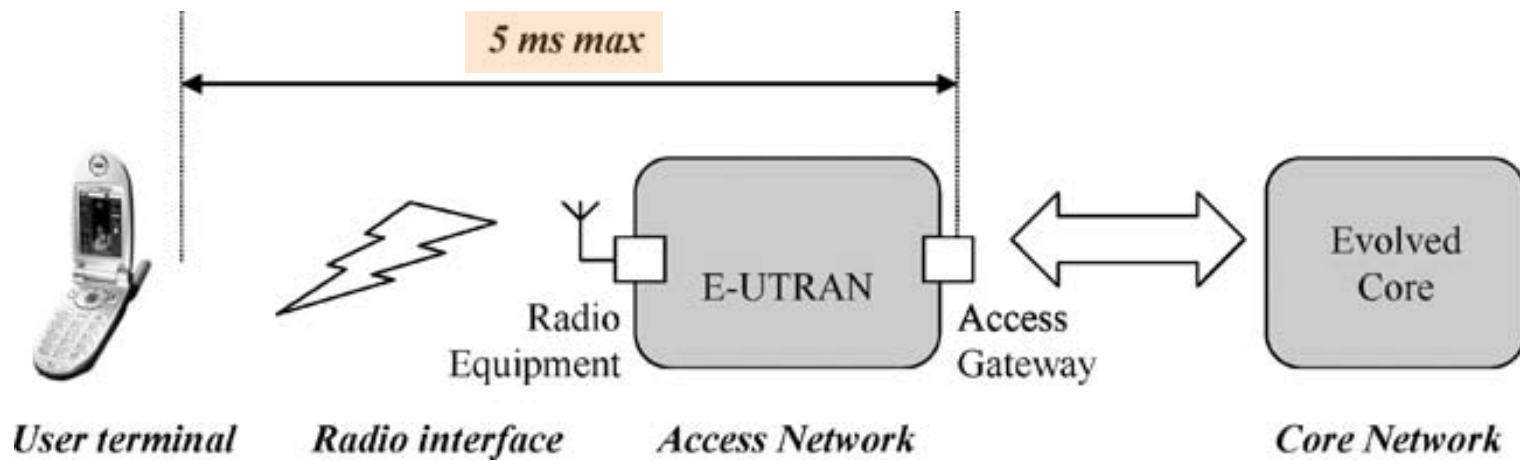
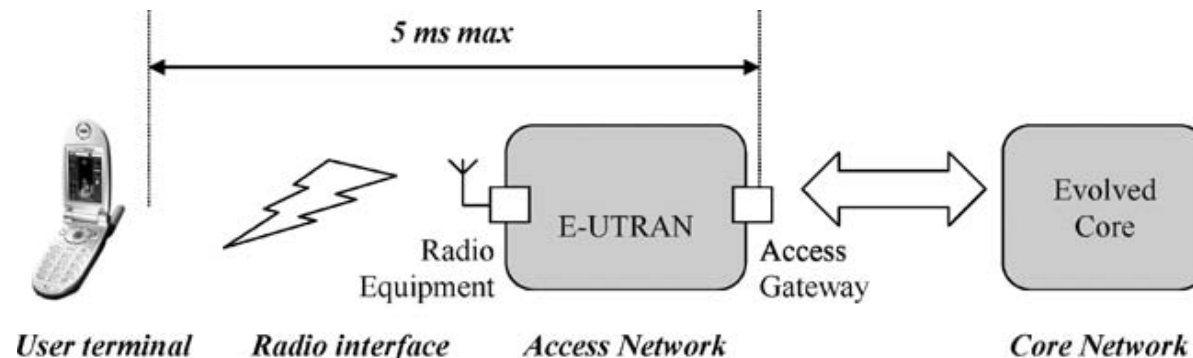


Figure 2.1 E-UTRAN latency requirements.

- E-UTRAN Access Network will be suitable for the most demanding existing and upcoming real-time services
- For information, and for an audio or video conversation, the maximum one-way transfer delay that human perception can tolerate is 400 ms
  - ✓ 150ms is the preferred value under normal operation, as a commonly agreed value and as reflected by IMT-2000 performance and Quality of Service requirements
  - ✓ Above 400 ms transfer delay, the quality of experience is generally considered as non-acceptable for a conversational service

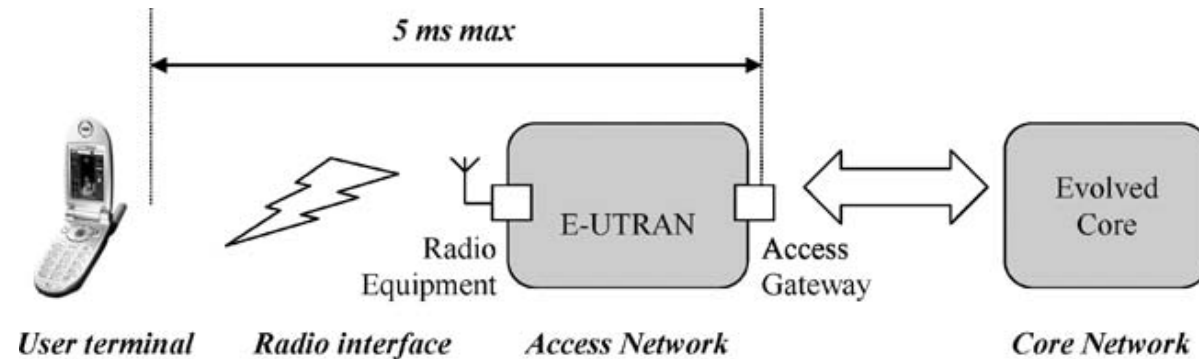
- ✓ 150 ms is an end-to-end value, including
  - ➔ Access Network
  - ➔ Data transmission within the Core Network
- ✓ The contribution of the evolved Access Network in terms of transfer delay is set to a very small value when compared with the overall time budget



# 1.3 Terminal State Transition

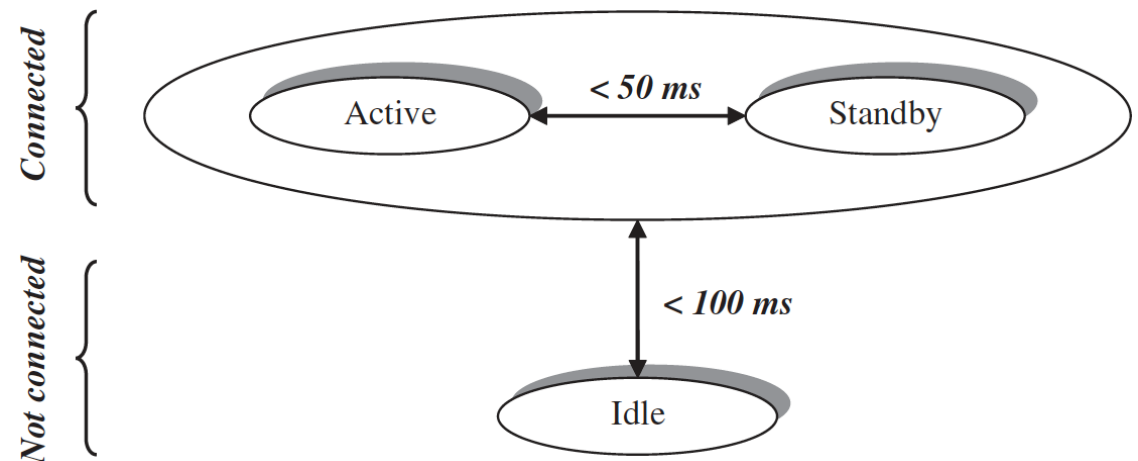
- This requirement is related to what is better known as efficient Always-On support
- Terminal states
  - ✓ **IDLE mode**
    - ➔ A state in which the mobile is reachable (e.g. user terminated call setup)
    - ➔ No communication sessions are active
  - ✓ **ACTIVE mode**
    - ➔ Corresponds to the active phase of a session
    - ➔ Data are actively transmitted to and from the user terminal
  - ✓ **STANDBY mode**
    - ➔ A state in which the user terminal is silent (very limited data exchange is allowed anyway) but always connected
    - ➔ It allows a very short period of time for transition to the ACTIVE mode in case end-user session activity is resumed

- The transition between the terminal states is under the Access Networks responsibility
  - ✓ This mechanism is closely related to radio activity and radio resource usage



- The support for efficient mechanisms to support always-connected terminals is a key requirement for services like
  - ✓ **Presence** (a group of people share each others availability information in real time)
  - ✓ **Instant Messaging** (people exchange a short set of information at any time)
  - ✓ **Push-To-Talk** (the voice version of Instant Messaging)

- Requirements on terminal state transition time
  - ✓ Transition from IDLE to ACTIVE state shall be less than 100 ms
    - ➔ This time does not include the time needed for paging procedures, in the case of mobile-terminated sessions
    - ➔ This corresponds only to the period of time needed for the network and the terminal to move from the IDLE state to an ACTIVE mode of operation in which a dedicated resource is allocated for the transmission of signaling or user information
  - ✓ Transition between ACTIVE and STANDBY states shall be less than 50 ms
    - ➔ Also excluding possible paging procedures, if needed



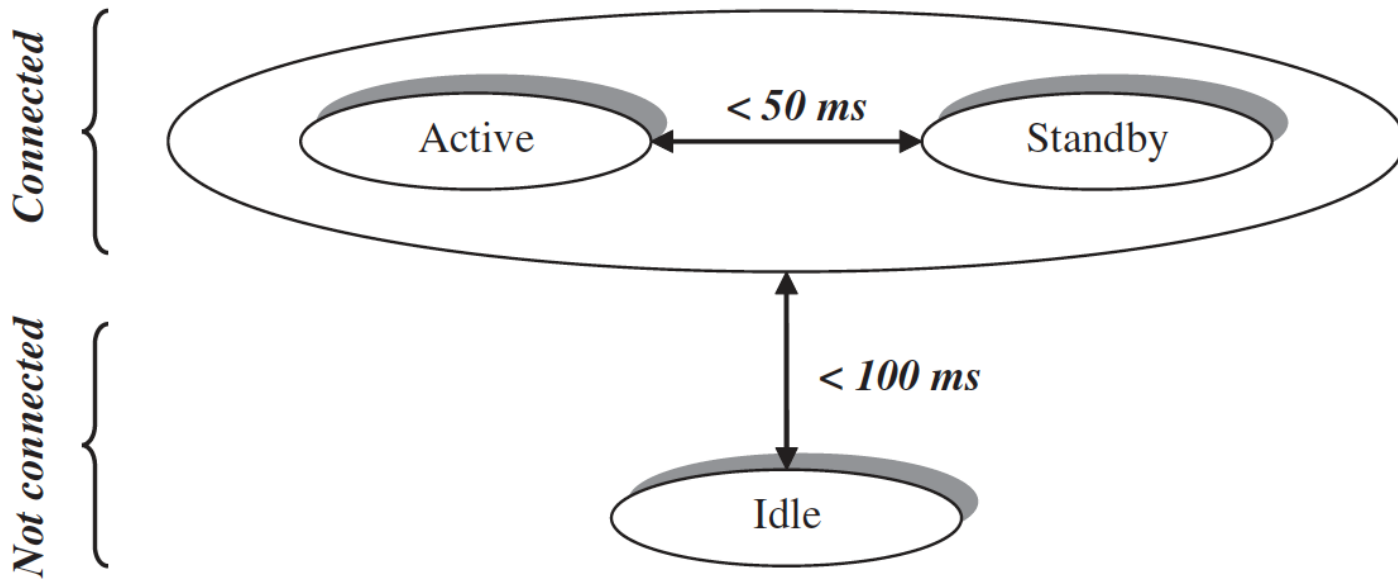


Figure 2.2 Terminal state transition requirements.

# 1.4 Mobility

- E-UTRAN requires that user connectivity across the cellular network shall be maintained at speeds from 120 to 350 km/h (or even up to 500 km/h, depending on the frequency band)

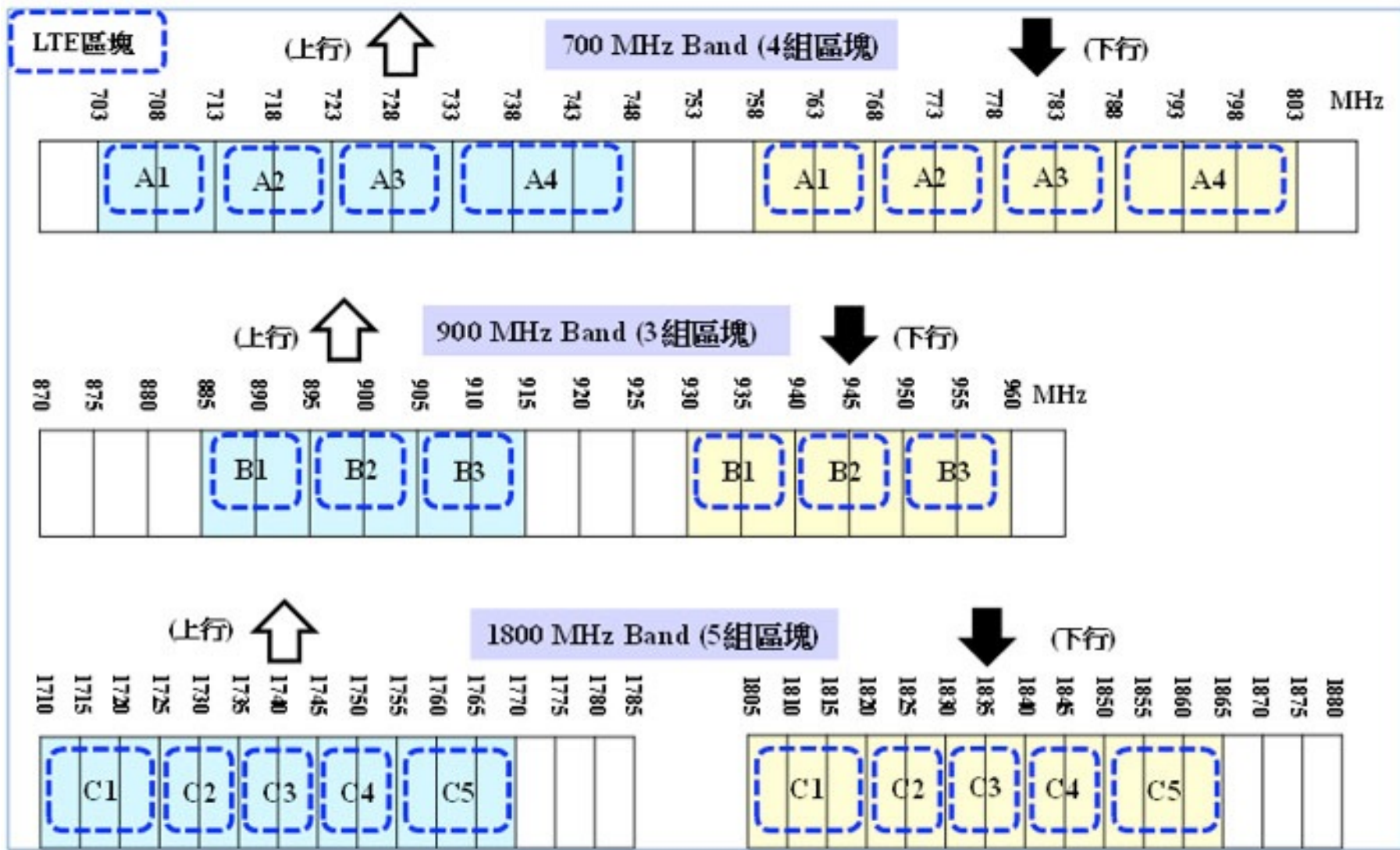
# 1.5 Spectrum Flexibility

- UMTS, the spectrum allocation possible schemes are very limited
  - ✓ FDD (Frequency Division Duplex) mode
    - ➔ Not less than **5MHz** of spectrum can be allocated to a given cell
    - ➔ This value is determined by the radio interface characteristic
      - CDMA direct spread system based on a chip rate of 3.84Mchips/s
  - ✓ TDD (Time Division Duplex) mode
    - ➔ TDD is also a CDMA direct spread system; however, two chip rates have been defined by the 3GPP
      - Low chip rate option (1.28 Mchips/s) corresponding to a channel occupation of **1.6MHz**
      - High chip rate option (3.84 Mchips/s) corresponding to a channel occupation of **5MHz**

- Evolved Access Network shall be able to operate in spectrum allocations of different sizes, including 1.25, 2.5, 5, 10, 15 and 20MHz, for both uplink and downlink
  - ✓ Allow flexible deployment and operation of spectrum accordingly to the expected traffic and service requirements
  - ✓ Evolved UMTS will be made easier in regions where large chunks of spectrum are scarce
  - ➔ Make the spectrum license price more affordable and allow Evolved UMTS deployment to operators not willing to pay a heavy price for spectrum that they don't plan to use

# 4G行動寬頻業務特許執照使用頻率 (釋照競價)(2013)

- 一、700 MHz 頻段：(4個區塊頻譜)
  - ✓ (一) A1：上行 703 ~ 713MHz；下行 758 ~ 768MHz (上下行各 10MHz)
  - ✓ (二) A2：上行 713 ~ 723MHz；下行 768 ~ 778MHz (上下行各 10MHz)
  - ✓ (三) A3：上行 723 ~ 733MHz；下行 778 ~ 788MHz (上下行各 10MHz)
  - ✓ (四) A4：上行 733 ~ 748MHz；下行 788 ~ 803MHz (上下行各 15MHz)
- 二、900MHz 頻段：(3個區塊頻譜)
  - ✓ (一) B1：上行 885 ~ 895MHz；下行 930 ~ 940MHz (上下行各 10MHz)
  - ✓ (二) B2：上行 895 ~ 905MHz；下行 940 ~ 950MHz (上下行各 10MHz)
  - ✓ (三) B3：上行 905 ~ 915MHz；下行 950 ~ 960MHz (上下行各 10MHz)
- 三、1800 MHz頻段：(5個區塊頻譜)
  - ✓ (一) C1：上行 1710 ~ 1725MHz；下行 1805 ~ 1820MHz (上下行各 15MHz)
  - ✓ (二) C2：上行 1725 ~ 1735MHz；下行 1820 ~ 1830MHz (上下行各 10MHz)
  - ✓ (三) C3：上行 1735 ~ 1745MHz；下行 1830 ~ 1840MHz (上下行各 10MHz)
  - ✓ (四) C4：上行 1745 ~ 1755MHz；下行 1840 ~ 1850MHz (上下行各 10MHz)
  - ✓ (五) C5：上行 1755 ~ 1770MHz；下行 1850 ~ 1865MHz (上下行各 15MHz)



# 3G vs. 4G 競標小檔案



3G

4G

5	<b>得標家數</b>	6
19天 180回合	<b>競標時間</b>	40天 393回合
336億元	<b>底標</b>	359億元
489億元	<b>總結標金</b>	1186.5億元
遠致電信(遠傳) 35MHz 101.69億元	<b>業者 得標金額</b>	中華電信 ..... 35MHz 390.75億元
聯邦電信(威寶) 25MHz 77億元		台灣大哥大 30MHz 290.1億元
台灣大哥大 35MHz 102.81億元		遠傳電信 30MHz 313.15億元
中華電信 35MHz 101.79億元		亞太電信 ..... 10MHz 64.15億元
亞太行動寬頻 40MHz 105.7億元		國碁電子 20MHz 91.8億元
		台灣之星移動 10MHz 36.55億元

# 1.6 Co-existence and Inter-Working with Existing UMTS

- From the beginning of UMTS standardization, inter-working between new and old technologies has always been a subject of concern
- Interruption time for handover between E-UTRAN and UTRAN/GERAN shall be
  - ✓ Less than *300 ms* for real-time services
  - ✓ Less than *500 ms* for non-real-time services

# 2. Evolved UMTS Concepts

- The move towards packet only architecture
- The evolution towards a fully shared radio interface
- The opening towards other access types

# 2.1 A Packet-Only Architecture

- **2.1.1 2G Initial Architecture**

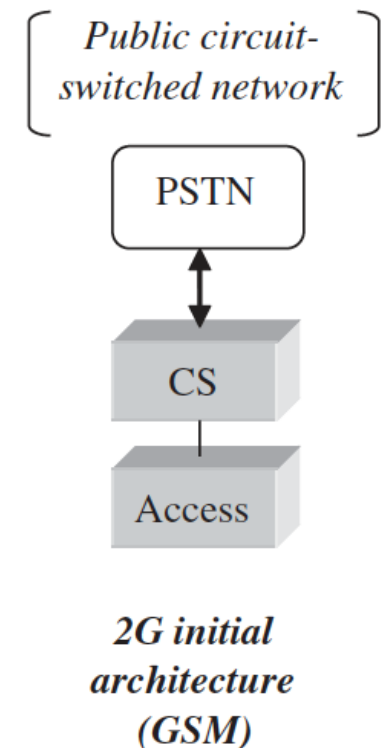
- ✓ 2G GSM cellular networks were initially designed for voice and circuit-switched services
- ✓ The architecture of such networks was comparatively simple and comprises two main parts

- ➔ **Access Network part**

- Includes radio interface as well as network nodes and interfaces supporting radio-related functions
- The radio interface was specifically designed and optimized for voice or low bit rate circuit data transmission

- ➔ **CS part** (Circuit-Switched core network domain)

- Providing circuit services support (includes call setup, authentication and billing)
- Inter-working with classical PSTN (Public Switched Telephone Network)



- **2.1.2 2G Packet Evolution**

- ✓ With the emergence of IP and Web services, 2G GSM networks eventually evolved to efficiently support packet data transmission

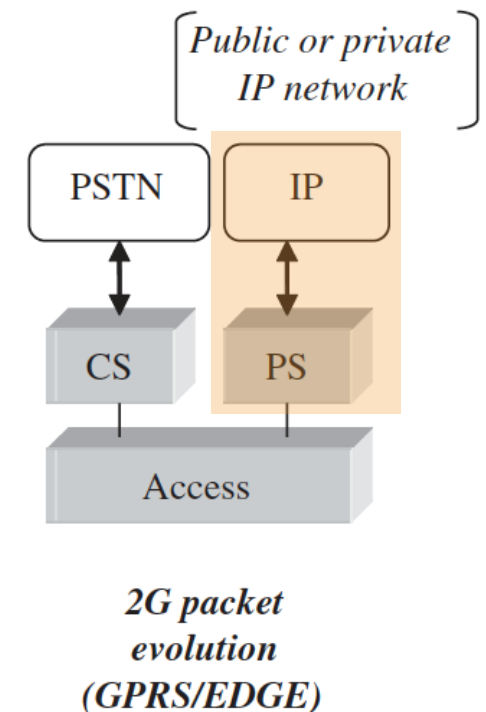
- ✓ **Access Network part**

- ➔ Partly redesigned to support packet transmission and shared resource allocation schemes – for GPRS and EDGE evolutions

- ✓ **New Core Network domain** (PS for Packet Switched) was added, in parallel to CS domain

- ➔ Support for packet transmission (including authentication and billing)

- ➔ Inter-working with public or private Internet (or IP) networks



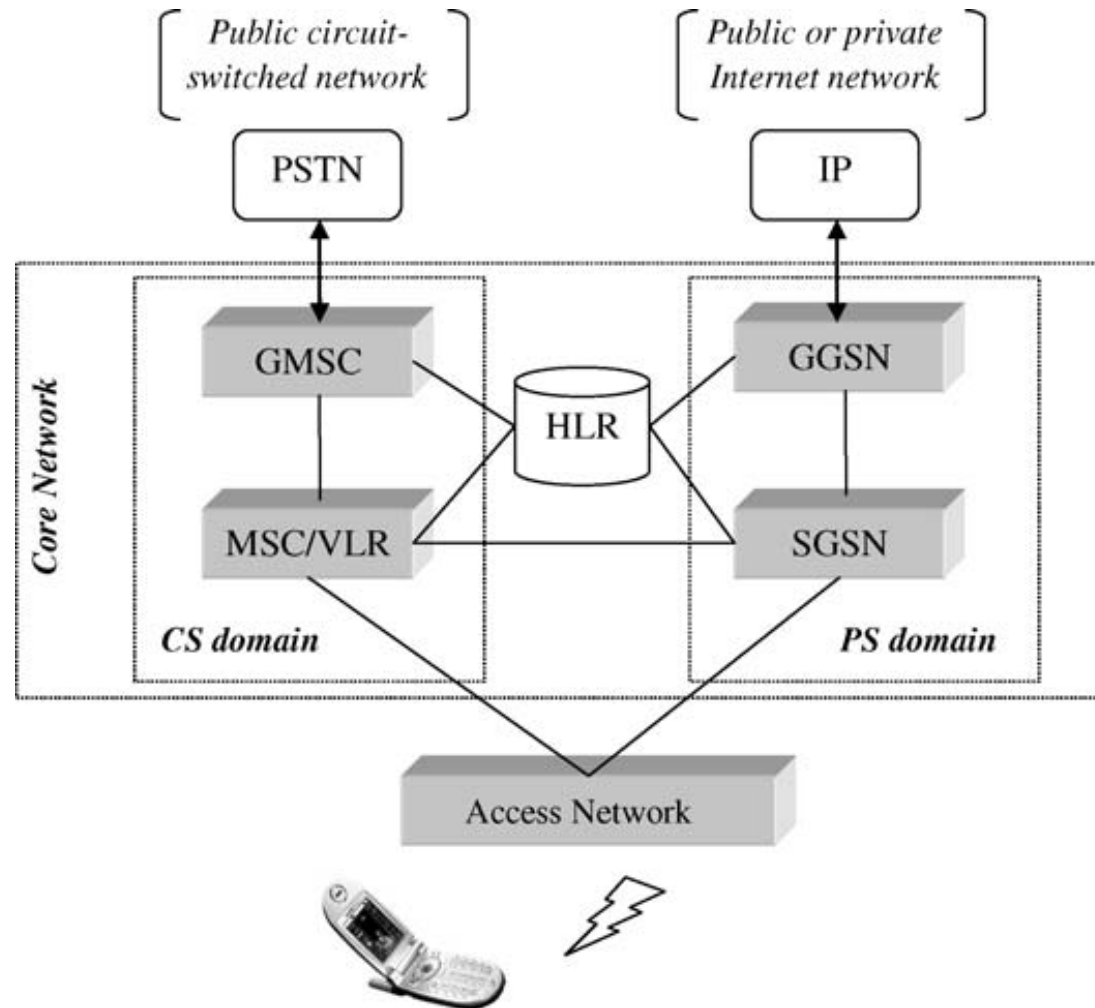


Figure 2.3 The 2G dual Core Network model.

## ✓ CS domain

### ➔ MSC/VLR (Mobile Switching Center / Visitor Location Register)

- Responsible for end-to-end call setup
- In charge of maintaining user location information (used to page a user terminal in order to establish user-terminated communication sessions)

### ➔ GMSC (Gateway MSC)

- A specific type of MSC, as being the gateway switch responsible for PSTN inter-working

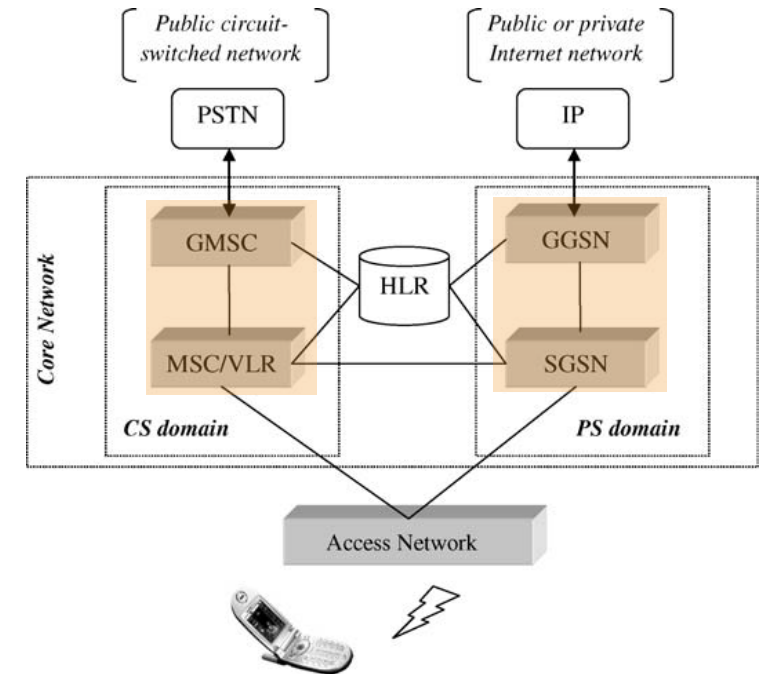
## ✓ PS domain

### ➔ SGSN (Serving GPRS Support Node)

- Basically plays the role of a MSC/VLR for the packet domain

### ➔ GGSN (Gateway GPRS Support Node)

- Equivalent to the GMSC for inter-working with external packet networks



✓ PS and CS domains may possibly be linked together in order to

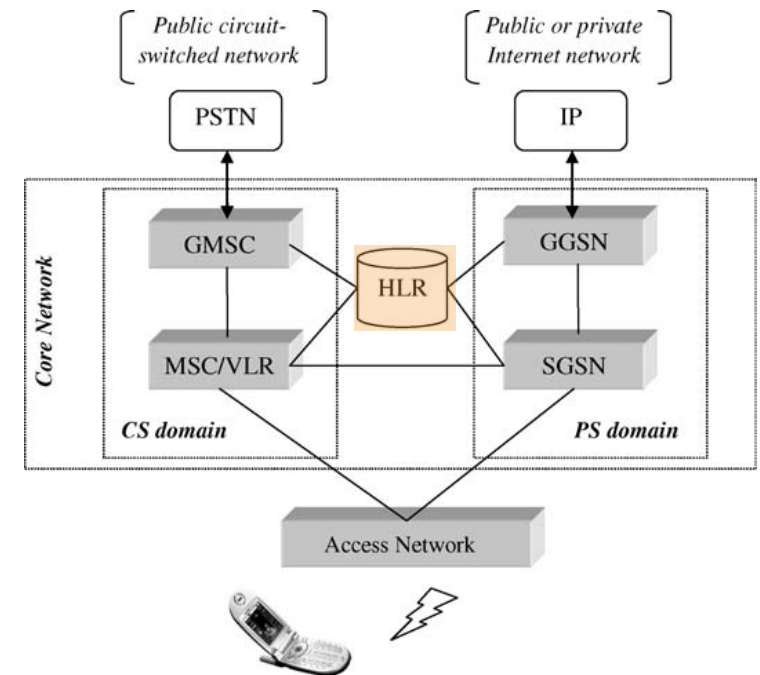
➔ Maintain consistent user location information between the two domains

➔ Reduce the amount of radio and network signaling

✓ HLR (Home Location Register), accessed by both CS and PS domains

➔ Contain all information related to user subscription

➔ The user terminal location needs to be known by both domains



- **2.1.3 3G IMS Evolution**

- Initial 3G UMTS network architecture includes both circuit and packet Core Networks

- A new domain was added on top of PS domain: the IMS (IP Multimedia Subsystem)

- ✓ Objective: allow the creation of standard and interoperable IP services (like Push-To-Talk, Presence or Instant Messaging) in a consistent way across 3GPP wireless networks

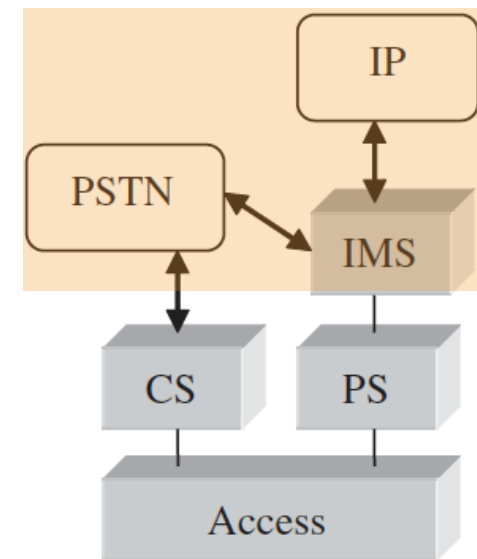
- ✓ The interoperability of IMS-based services

- ➔ Comes from the fact that IMS is based on flexible protocols like SIP (Session Initiation Protocol) developed by IETF (Internet Engineering Task Force)

- ✓ IMS standard

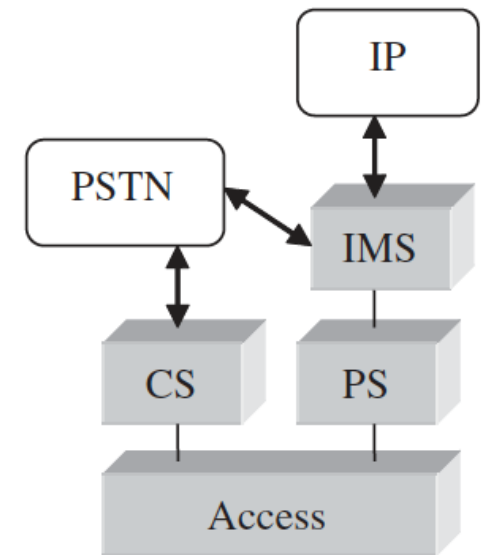
- ➔ Offers VoIP (Voice over IP) support

- ➔ Provides interworking with classical PSTN through signaling and media gateways



*3G IMS evolution*

- The CS domain was still part of the 3G Core Network architecture, along with the PS/IMS structure
  - ✓ Main reason: the need to support the still dominant
    - ➔ Circuit-switched voice services
    - ➔ H.324M-based video-telephony support



*3G IMS  
evolution*

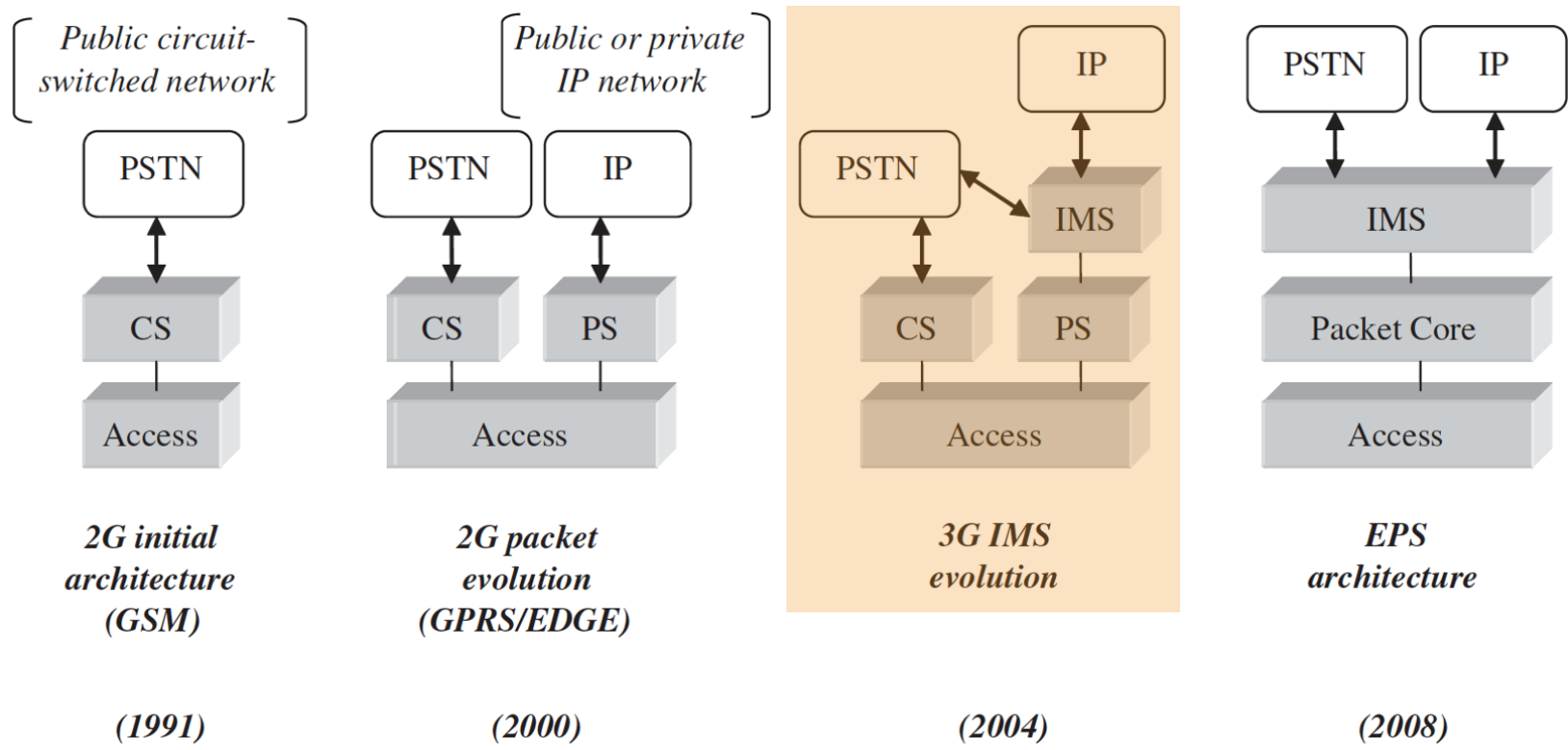


Figure 2.4 Evolution of network architecture (from circuit to packet).

- **2.1.4 EPS Architecture**

- Evolved UMTS networks have a clear objective to integrate all applications over a simplified and common architecture

- Main components of EPS architecture

- ✓ **Packet-optimized Access Network**

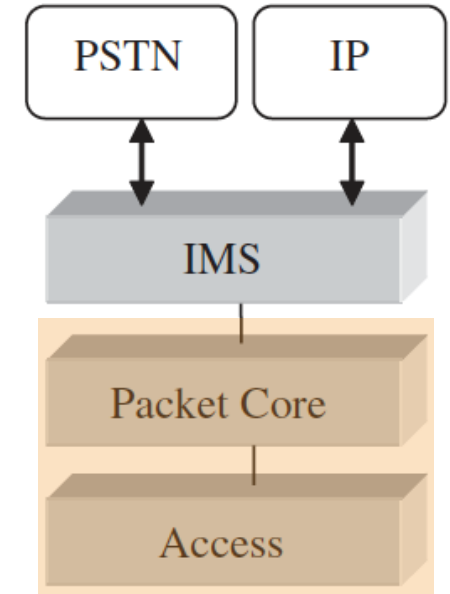
- ➔ Efficiently support IP-based non-real-time services as well as circuit-like services requiring constant delay and constant bit rate transmission

- ✓ **Simplified Core Network**

- ➔ Composed of only one packet domain, supporting all PS services (possibly IMS-based) and inter-working capabilities towards traditional PSTN

- ➔ The CS domain is no longer present, as all applications (including the most real-time constraining ones) are supported over PS domain

- Requires specific gateway nodes – part of the IMS architecture – so that IP traffic is converted to PSTN circuit-switched-based transport



*EPS  
architecture*

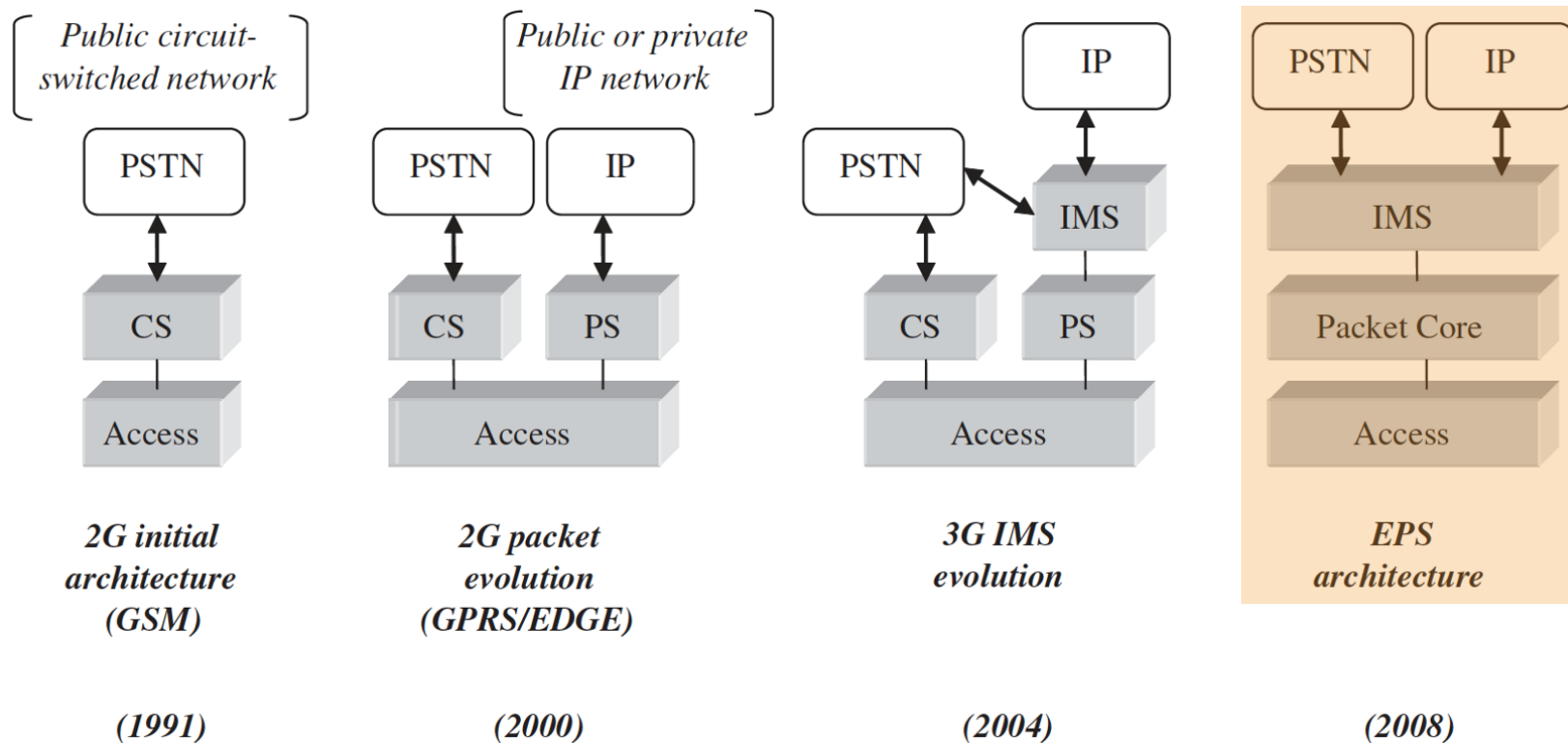
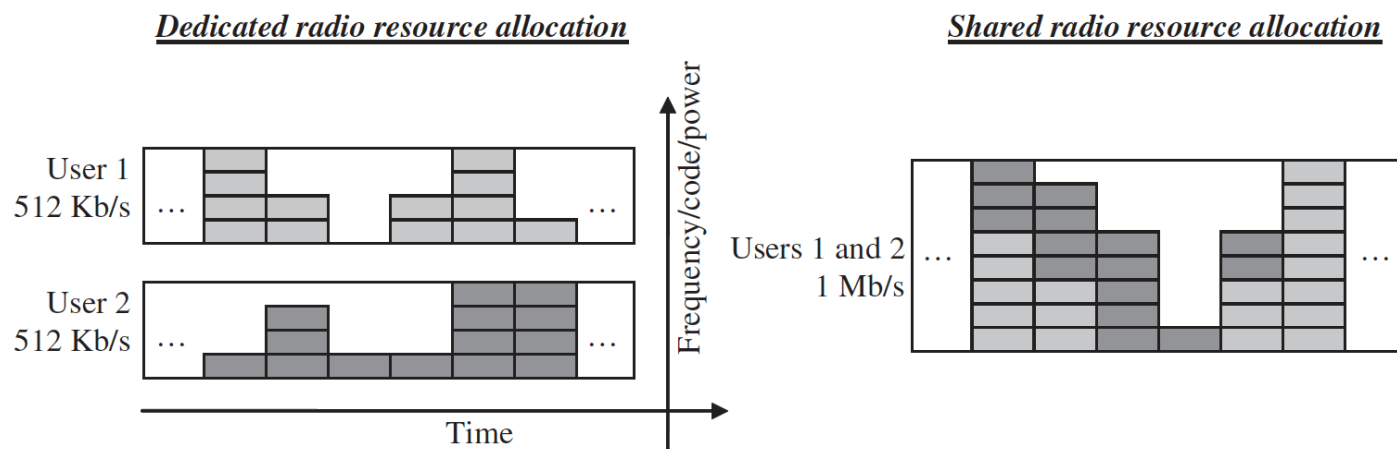


Figure 2.4 Evolution of network architecture (from circuit to packet).

# 2.2 A Shared Radio Interface

- As Core Network architecture is moving towards packet or all-IP architecture, it becomes critical that the Access Network provides efficient radio transmission schemes for packet data
  - ✓ When using dedicated resources, as in early UMTS implementations, it is required to allocate to each user a fixed amount of resource which may be used well under its capacity for certain periods of time
  - ✓ Evolved UTRAN relies on a fully shared radio resource allocation scheme, which allows maximizing resource usage by combining all radio bearers on a sort of shared high bit rate radio pipe



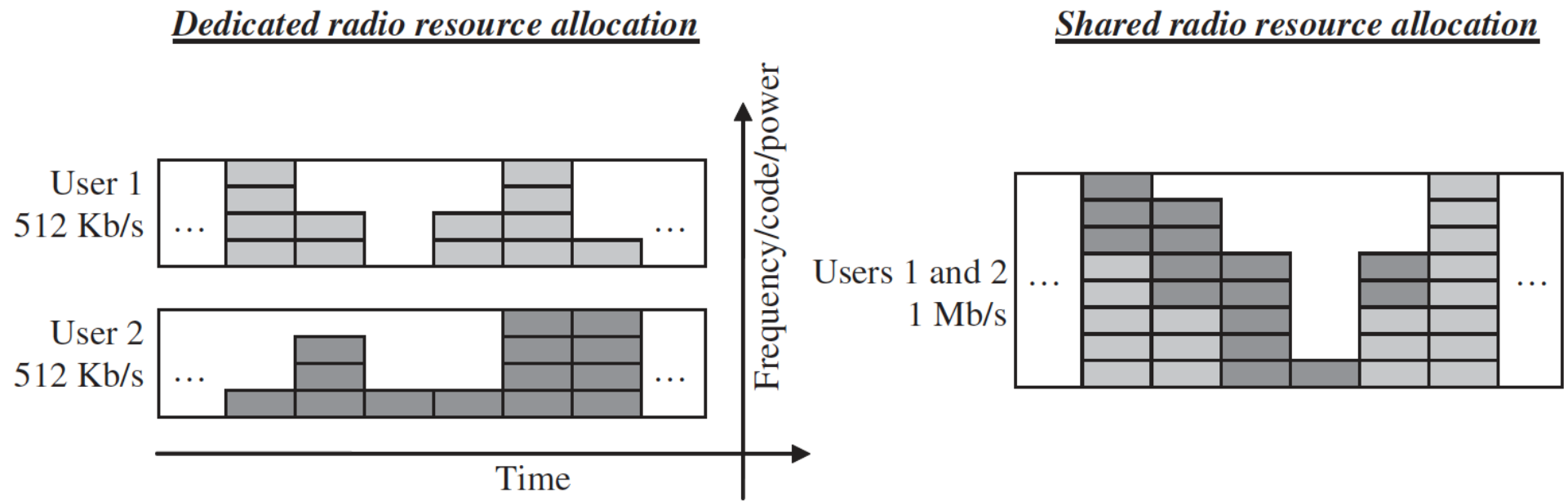


Figure 2.5 Dedicated versus shared resource allocation.

- All services are therefore supported over shared radio resource, including
  - ✓ Background or interactive services
    - ➔ like Web browsing
  - ✓ Real-time-constraining services
    - ➔ like voice or streaming applications
  - ✓ Requires a fine and specific radio resource management scheme to
    - ➔ Ensure all real-time services can be supported according to their requirements in terms of bit rate and transfer delay

QCI	Bearer Type	Application Example	Packet Delay	Packet Loss	Priority
1	GBR	Conversational VoIP	100ms	$10^{-2}$	2
2		Conversational Video (Live Streaming)	150ms	$10^{-3}$	4
3		Non-Conversational Video (Buffered Streaming)	300ms	$10^{-6}$	5
4		Real Time Gaming	50ms	$10^{-3}$	3
5	NON-GBR	IMS Signaling	100ms	$10^{-6}$	1
6		Voice, Video, Interactive Games	100ms	$10^{-3}$	7
7		Video (Buffered Streaming)	300ms	$10^{-6}$	6
8		TCP apps (web, email, ftp)			8
9		Platinum vs. gold user			9

Figure 2: LTE QoS-based Data Flow Specifications (QCI)

QCI	Bearer Type	Application Example	Packet Delay	Packet Loss	Priority
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8		TCP apps (web, email, ftp)			8
9		Platinum vs. gold user			9

*Figure 2: LTE QoS-based Data Flow Specifications (QCI)*

## 2.3 Other Access Technologies

- From early 2000, lots of high-speed and high-performance radio interfaces have been developed for the use of WLAN or Wireless local networking
  - ✓ Wifi family
    - ➔ IEEE 802.11b, 802.11g as well 802.11n multiple antenna evolution
  - ✓ IEEE 802.16 WiMAX
- Those technologies can provide data rates which are actually quite close to what UTRAN and E-UTRAN propose
  - ✓ Evolved UMTS follows that path in providing support to seamless mobility between heterogeneous access networks

---

Radio technology	Peak bit rate over the air
802.11b	11 Mb/s
802.11g	54 Mb/s
802.11n	200 Mb/s
802.16	70 Mb/s

---

Table 2.1 IEEE radio access technologies.

- 802.11ac 在單一空間流(spatial streams)中使用不同頻寬 bandwidth與不同調變 modulation 之理論傳輸速率 Mbps

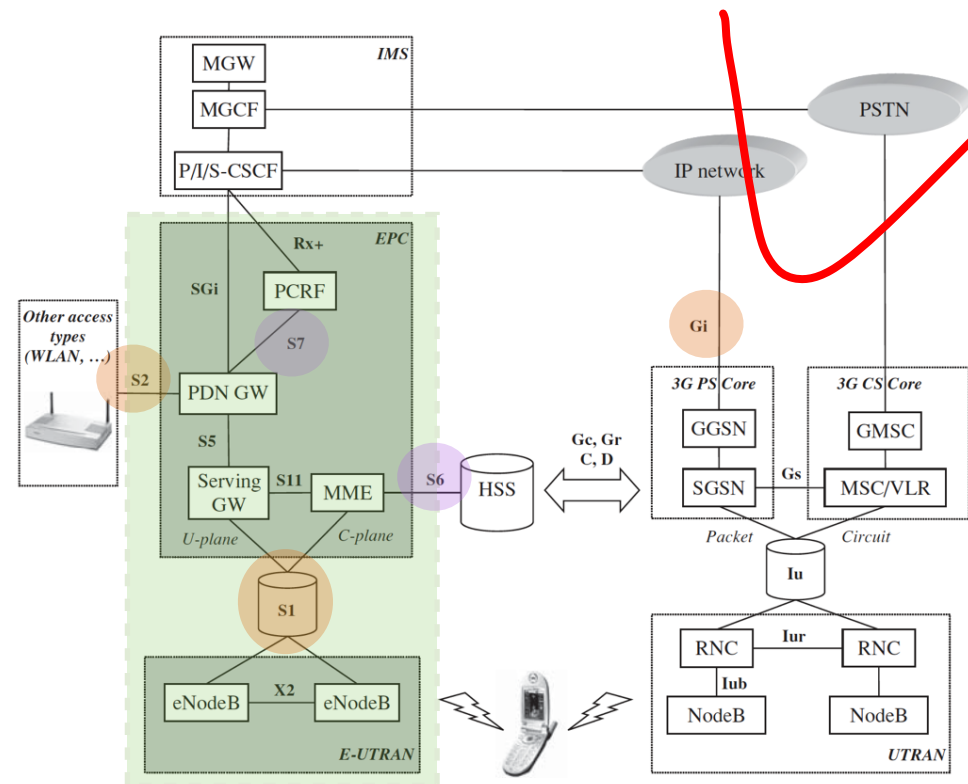
Modulation	Coding rate	20 MHz channels		40 MHz channels		80 MHz channels		160 MHz channels	
		800 ns GI	400 ns GI	800 ns GI	400 ns GI	800 ns GI	400 ns GI	800 ns GI	400 ns GI
BPSK	1/2	6.5	7.2	13.5	15	29.3	32.5	58.5	65
QPSK	1/2	13	14.4	27	30	58.5	65	117	130
QPSK	3/4	19.5	21.7	40.5	45	87.8	97.5	175.5	195
16-QAM	1/2	26	28.9	54	60	117	130	234	260
16-QAM	3/4	39	43.3	81	90	175.5	195	351	390
64-QAM	2/3	52	57.8	108	120	234	260	468	520
64-QAM	3/4	58.5	65	121.5	135	263.3	292.5	526.5	585
64-QAM	5/6	65	72.2	135	150	292.5	325	585	650
256-QAM	3/4	78	86.7	162	180	351	390	702	780
256-QAM	5/6	N/A	N/A	180	200	390	433.3	780	866.7

GI: Guard Interval (timing between wireless frames)

- 若802.11ac 使用最高 **160 MHz bandwidth**，與最佳之調變 **256-QAM**，在**8**個空間流(spatial streams)之情況下，最高可達 **6.93 Gbps (=8 x 866.7 Mbps)**之理論傳輸速率

# 3. Overall Evolved UMTS Architecture

- The figure describes the overall network architecture
  - ✓ Evolved Packet Core (EPC)
  - ✓ Access Network (E-UTRAN)
  - ✓ Other blocks
- For simplification, the picture only shows the signaling interfaces
  - ✓ Support both user data and signaling
    - ➔ S1, S2 or 3G PS Gi interfaces
  - ✓ Only support signaling
    - ➔ S6 and S7 interfaces



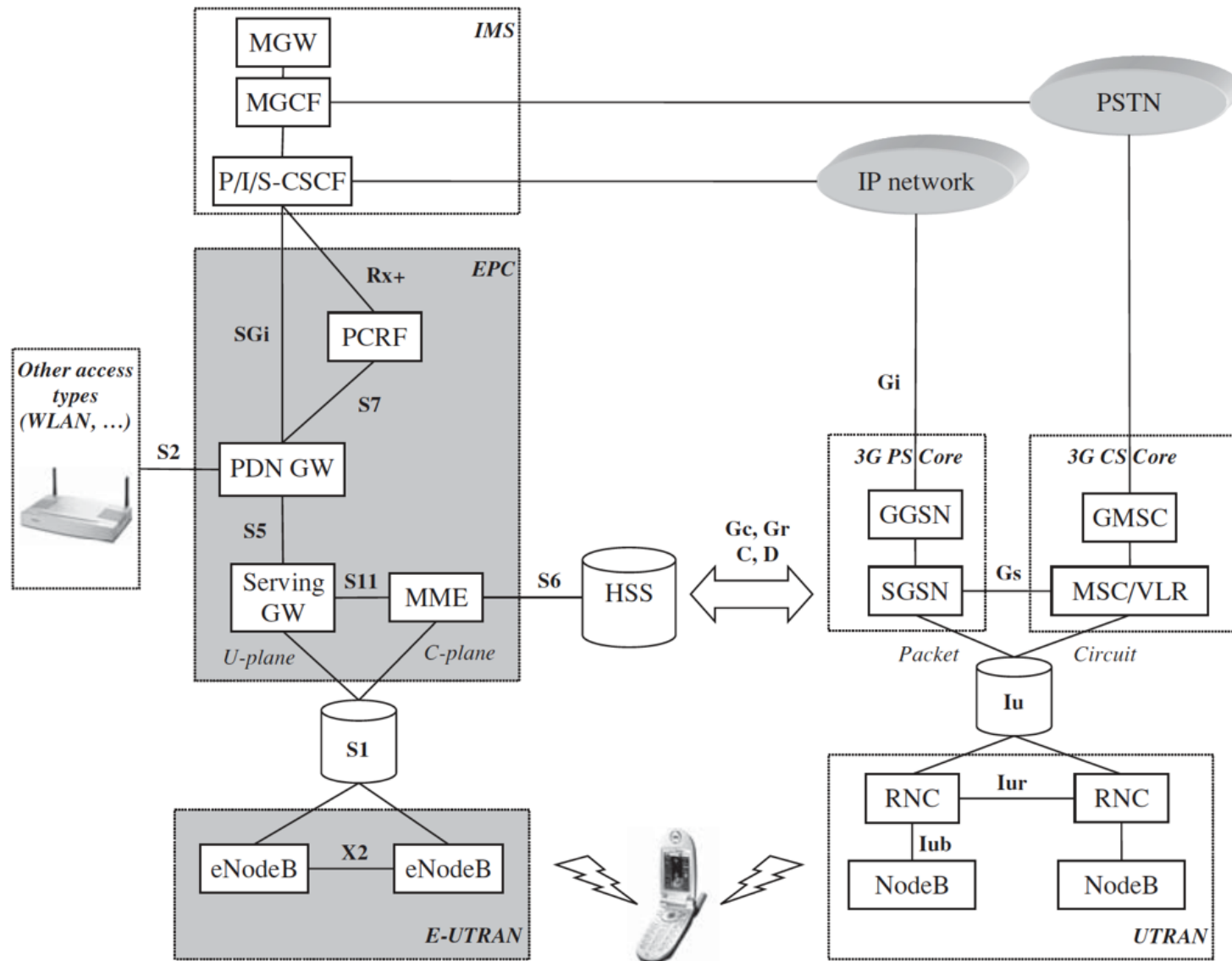
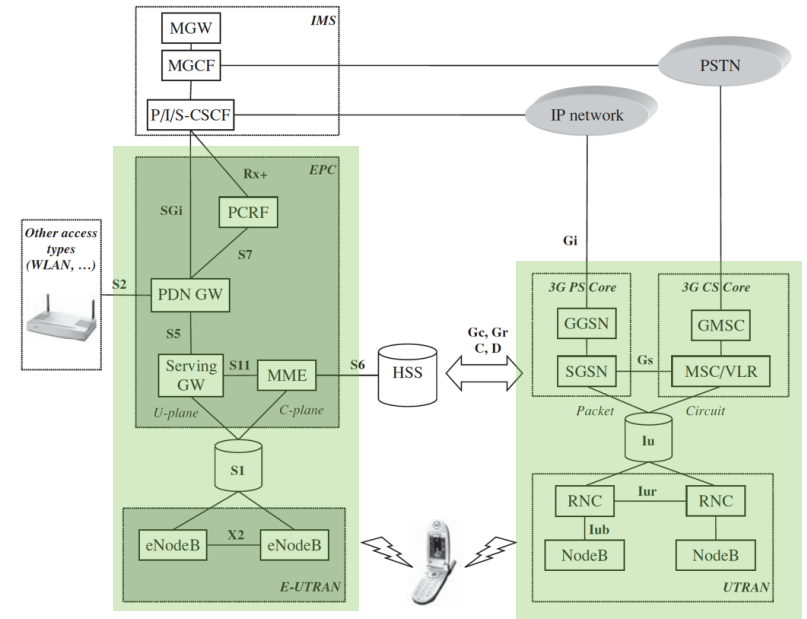
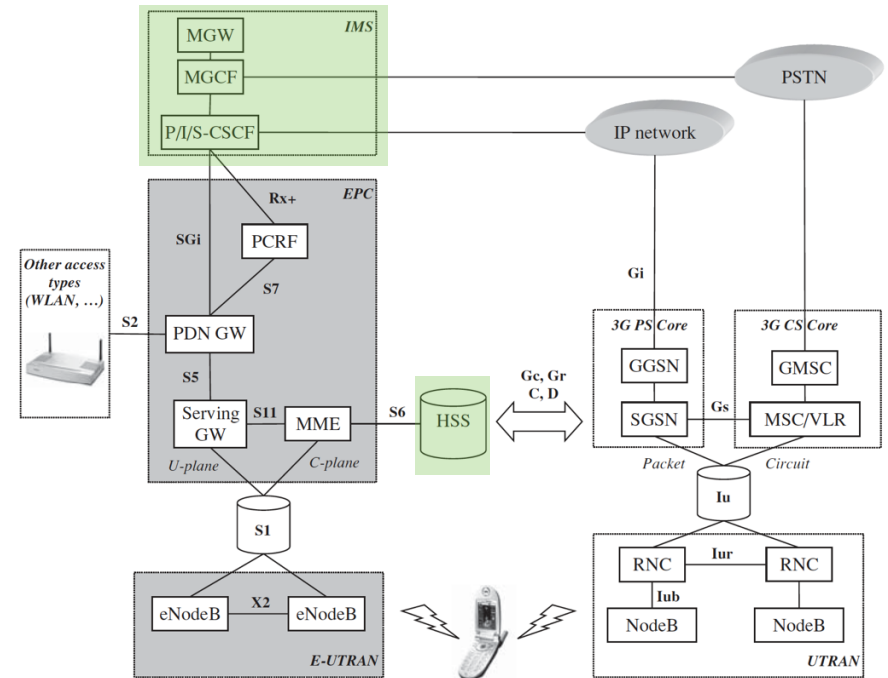


Figure 2.6 The overall EPS architecture.

- The new blocks specific to Evolved UMTS evolution
  - ✓ Known as Evolved Packet System (EPS)
    - ➔ EPS = Evolved Packet Core (EPC) + Evolved UTRAN (E-UTRAN)
- Other blocks from the classical UMTS architecture
  - ✓ UTRAN (UMTS Access Network)
  - ✓ PS Core Network connected to the public (or any private) IP Network
  - ✓ CS Core Networks connected to the Telephone Network

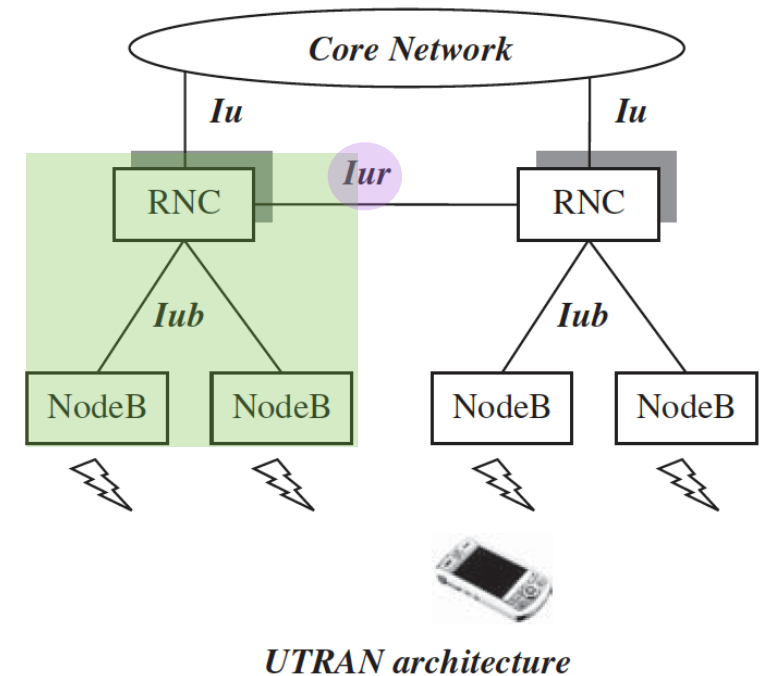


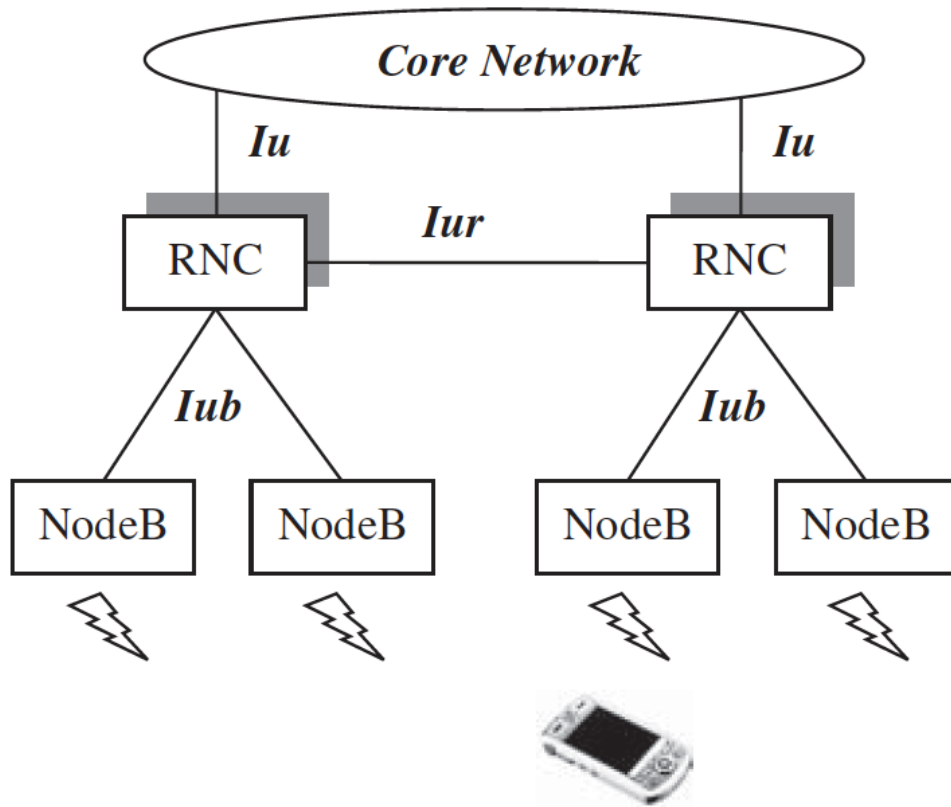
- IMS (IP Multimedia Subsystem)
  - ✓ Located on top of the Packet Core blocks
  - ✓ Provide access to
    - ➔ Public or private IP networks
    - ➔ Public telephone network via Media Gateway (MGW) network entities
- HSS (Home Subscriber Server)
  - ✓ Manages user subscription information is shown as a central node
  - ✓ Provides services to all Core Network blocks of 3G and evolved 3G architecture



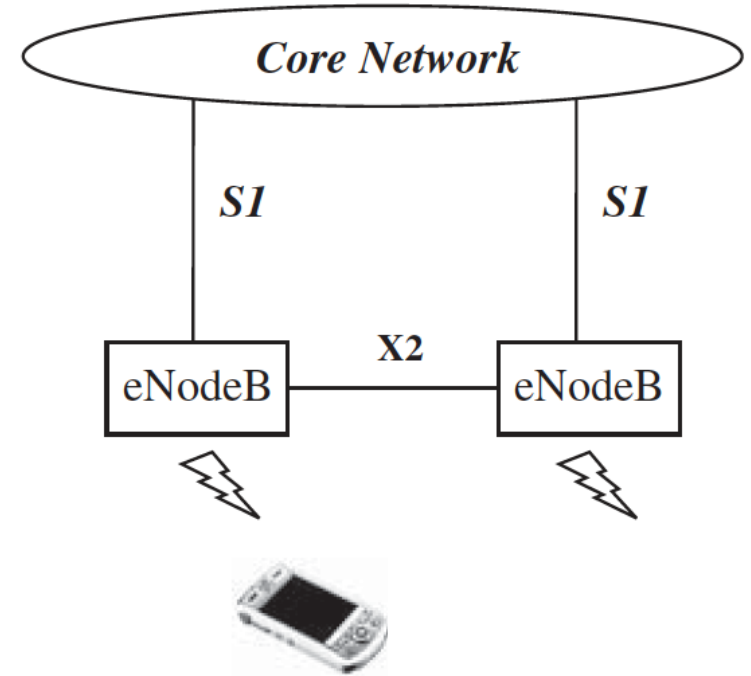
# 3.1 E-UTRAN: The Evolved Access Network

- UTRAN network is composed of
  - ✓ Radio equipment (NodeB)
    - ➔ In charge of transmission and reception over the radio interface
  - ✓ RNC (Radio Network Controller)
    - ➔ In charge of NodeB configuration and radio resource allocation
    - ➔ A single controller (RNC) may possibly control a large number – the typical number in commercial networks is about several hundreds – of radio Base Stations (NodeB) over the Iub interface
    - ➔ An inter-RNC Iur interface
      - Allow UTRAN call anchoring at the RNC level and macro-diversity between different NodeB controlled by different RNCs





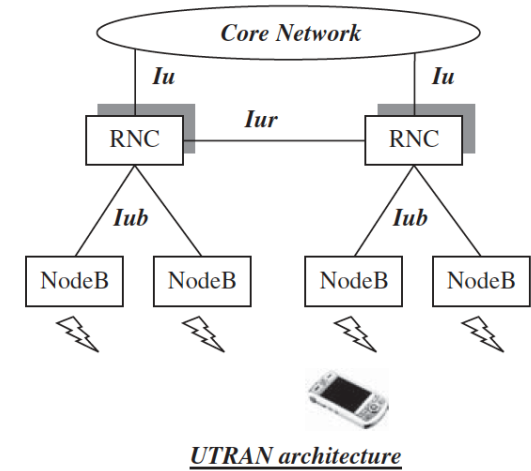
UTRAN architecture



E-UTRAN architecture

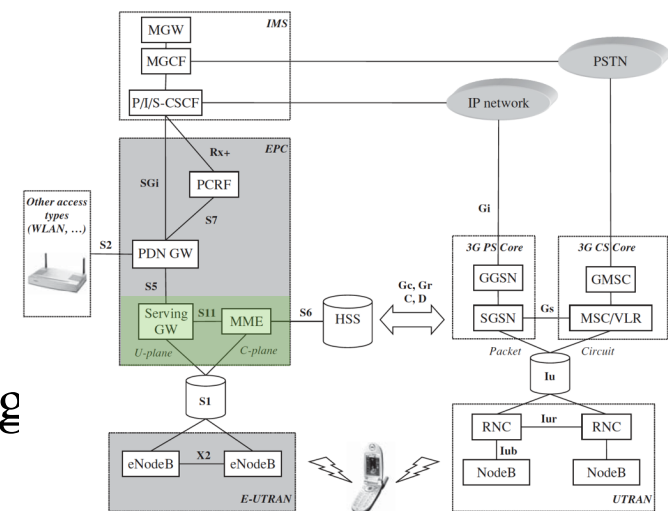
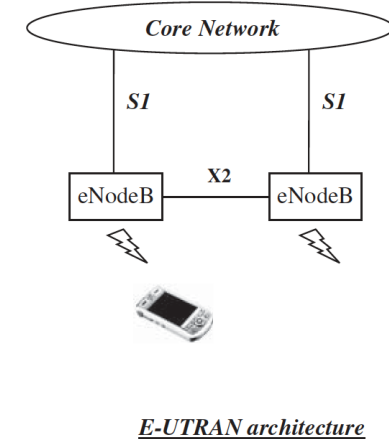
Figure 2.7 UTRAN and Evolved UTRAN architectures.

- The initial UTRAN architecture resulted in
  - ✓ A simplified NodeB implementation
  - ✓ A relatively complex, sensitive, high capacity and feature-rich RNC design
    - ➔ Support resource and traffic management features as well as a significant part of the radio protocols



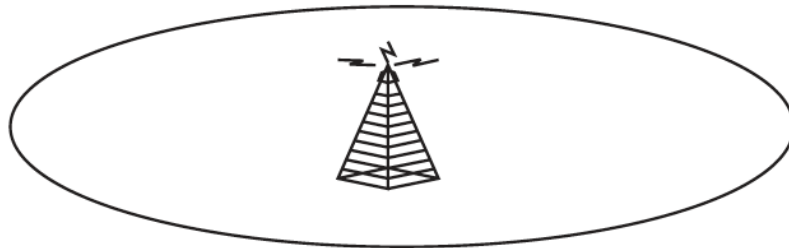
- E-UTRAN OFDM-based structure

- ✓ Only composed of one network element: eNodeB (evolved NodeB)
- ✓ RNC has disappeared from E-UTRAN
- ✓ eNodeB is directly connected to the Core Network using the S1 interface
- ✓ The features supported by RNC have been distributed between eNodeB or Core Network MME (Mobility Management Entity) or Serving Gateway entities

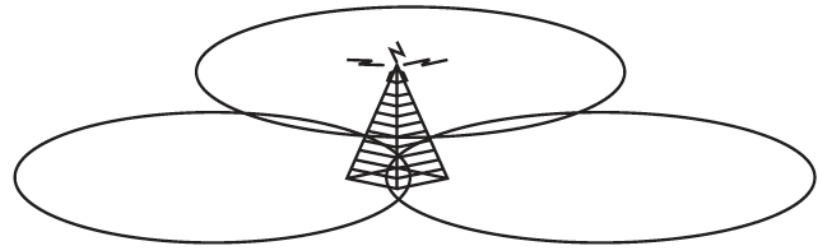


✓ eNodeB

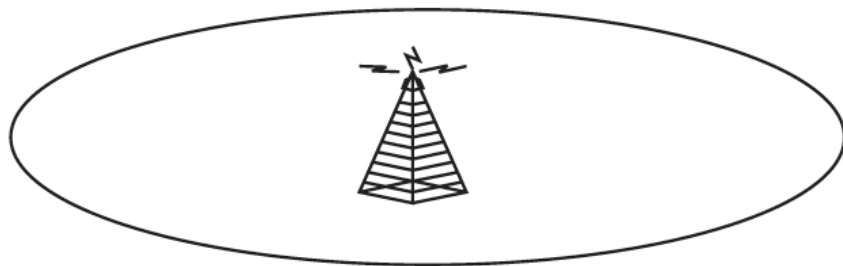
- ➔ Responsible for radio transmission and reception in one or more cells to the terminals
- ➔ eNodeB can be implemented either as
  - Single-cell equipment providing coverage and services in one cell only, or
  - Multi-cell node, each cell covering a given geographical sector



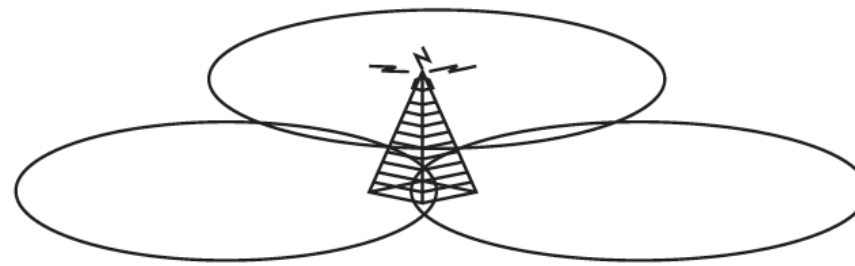
*The omnidirectional model*



*The sectorized (multi-cell) model*



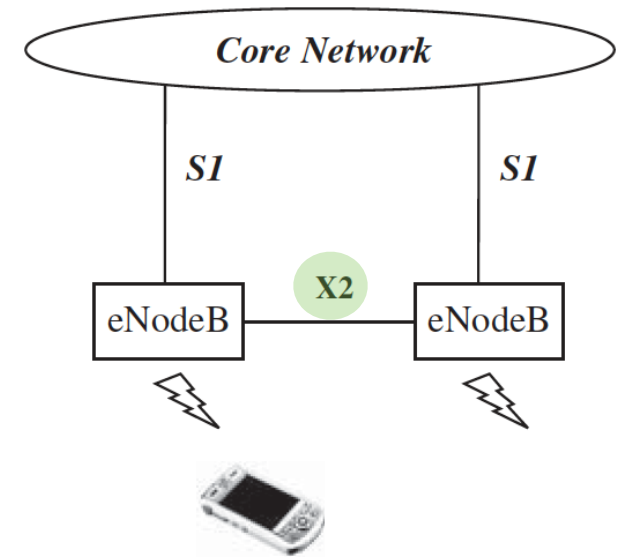
*The omnidirectional model*



*The sectorized (multi-cell) model*

Figure 2.8 Possible eNodeB models.

- Interface X2
  - ✓ Between eNodeB, working in a meshed way (all NodeBs may possibly be linked together)
  - ✓ Main purpose: minimize packet loss due to user mobility
    - ➔ As the terminal moves across the access network, unsent or unacknowledged packets stored in the old eNodeB queues can be forwarded or tunneled to the new eNodeB thanks to the X2 interface



E-UTRAN architecture

- From a high-level perspective, the new E-UTRAN architecture is actually moving towards WLAN network structures and Wifi or WiMAX Base Stations functional definition

- ✓ eNodeB – as WLAN access points – support all Layer 1 and Layer 2 features associated to E-UTRAN OFDM physical interface, and they are directly connected to network routers

- ✓ No more intermediate controlling node (like 2G/BSC or 3G/RNC)

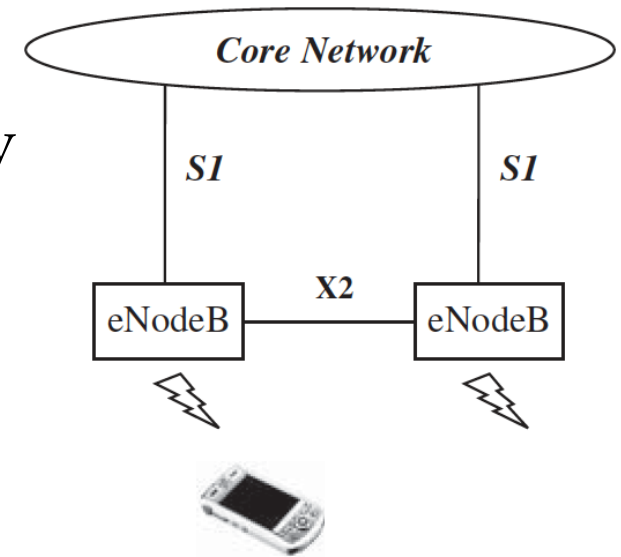
- ✓ Advantages

- ➔ Simpler network architecture

- Fewer nodes of different types, which means simplified network operation

- ➔ Better performance over the radio interface

- e.g. less data-transmission delay



E-UTRAN architecture

- From a functional perspective, eNodeB supports a set of legacy features, all related to physical layer procedures for transmission and reception over the radio interface

### ✓ Modulation and de-modulation

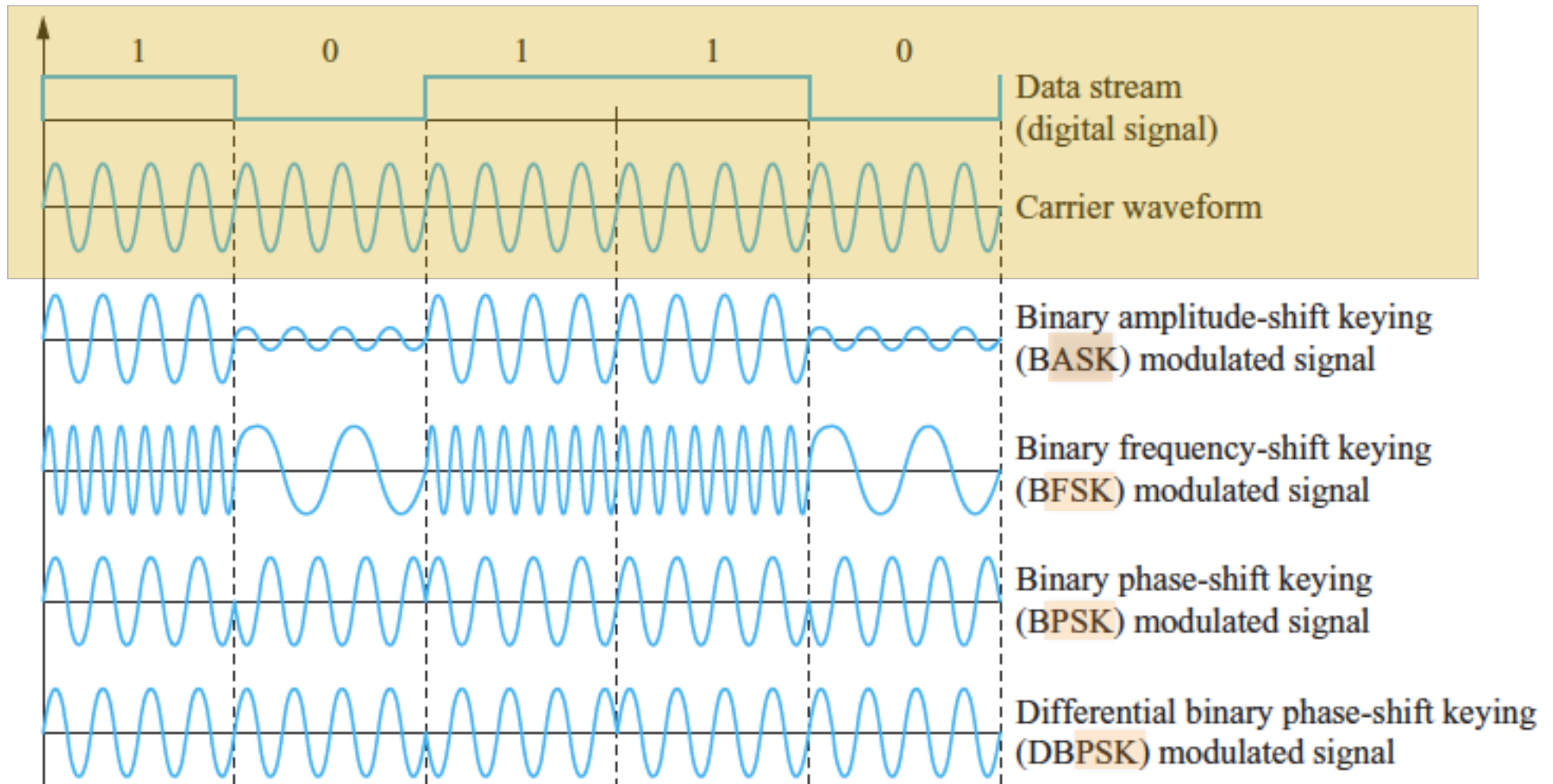
- ➔ In electronics and telecommunications, modulation is the process of varying one or more properties (frequency, amplitude, phase) of a periodic waveform, called the carrier signal, with a modulating signal which typically contains information to be transmitted

➔ Fundamental digital modulation methods

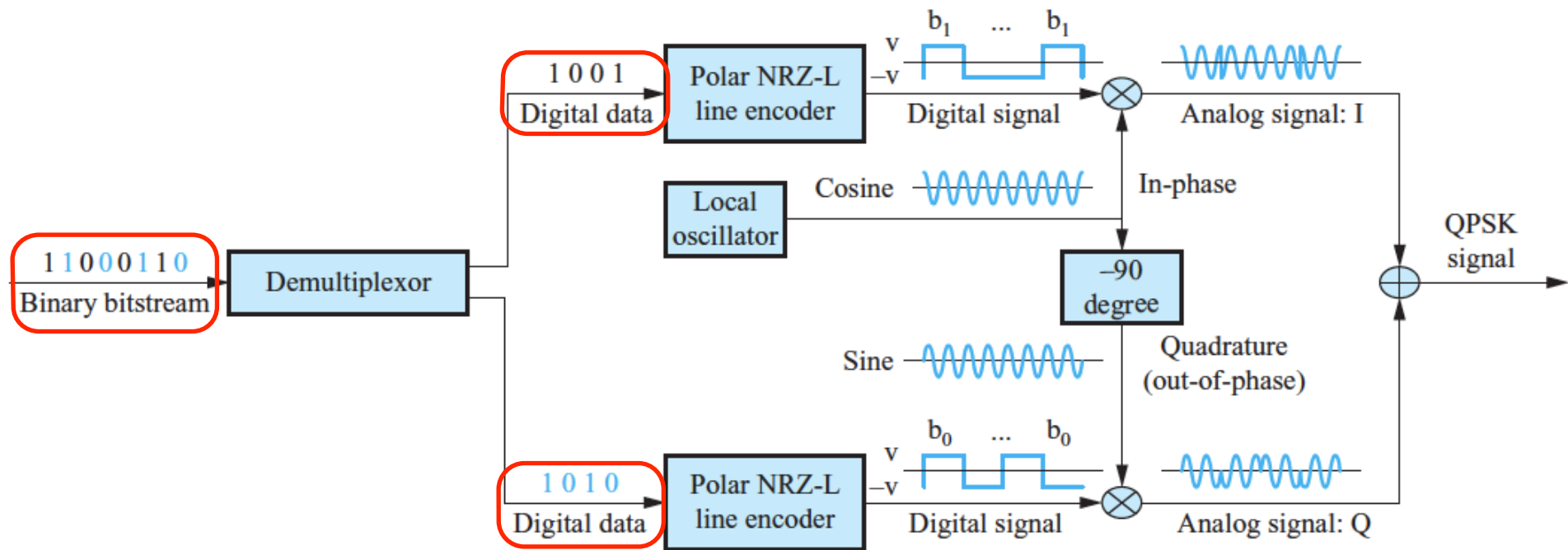
- PSK (Phase-Shift Keying): a finite number of phases are used
- FSK (Frequency-Shift Keying): a finite number of frequencies are used
- ASK (Amplitude-Shift Keying): a finite number of amplitudes are used
- QAM (Quadrature Amplitude Modulation): a finite number of at least two phases and at least two amplitudes are used

Modulation	Coding rate	20 MHz channels		40 MHz channels		80 MHz channels		160 MHz channels	
		800 ns GI	400 ns GI	800 ns GI	400 ns GI	800 ns GI	400 ns GI	800 ns GI	400 ns GI
BPSK	1/2	6.5	7.2	13.5	15	29.3	32.5	58.5	65
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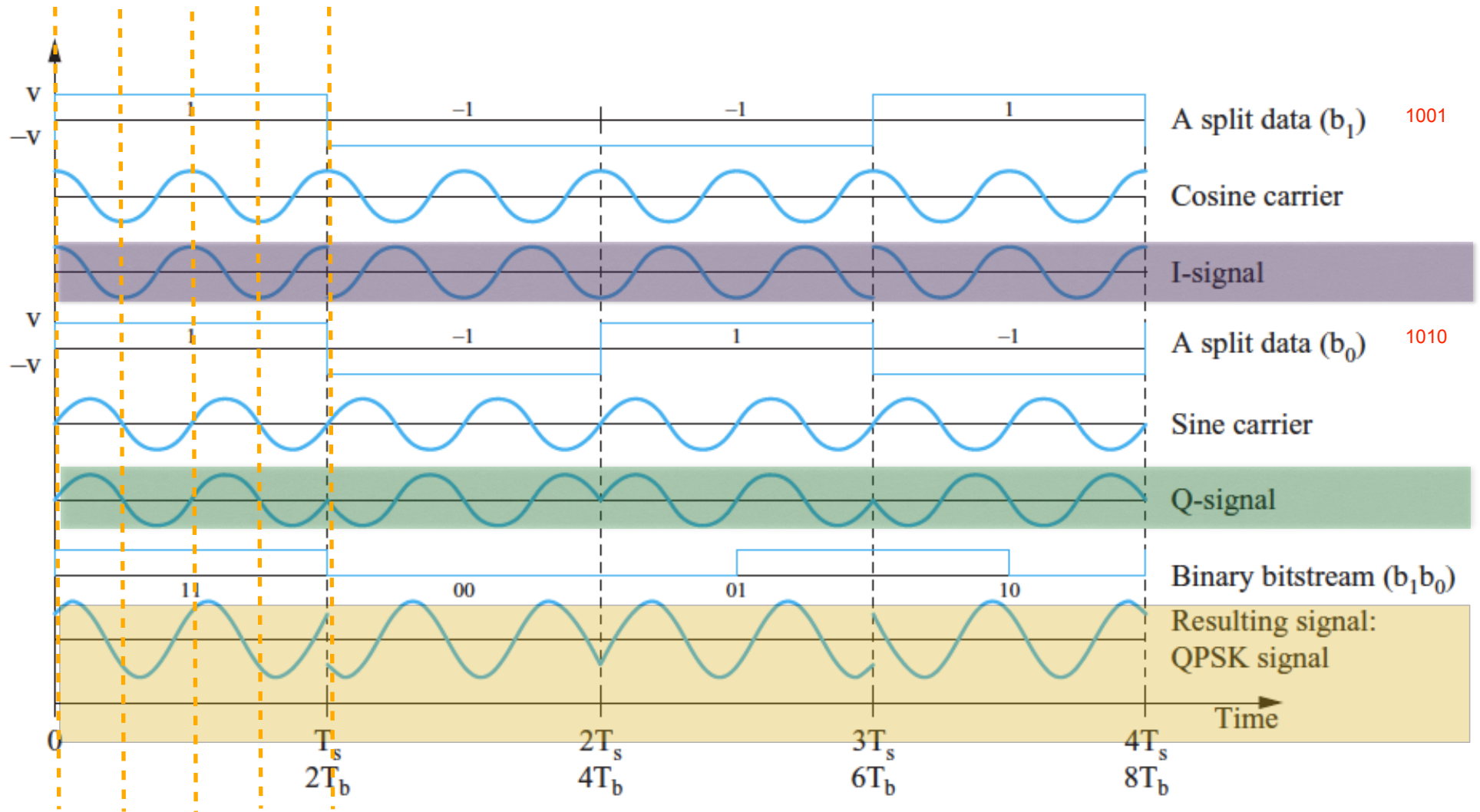
# Note: ASK, FSK, PSK, and DPSK Modulations



# Note: QPSK Modulation



**FIGURE 2.23** A simplified implementation of QPSK.



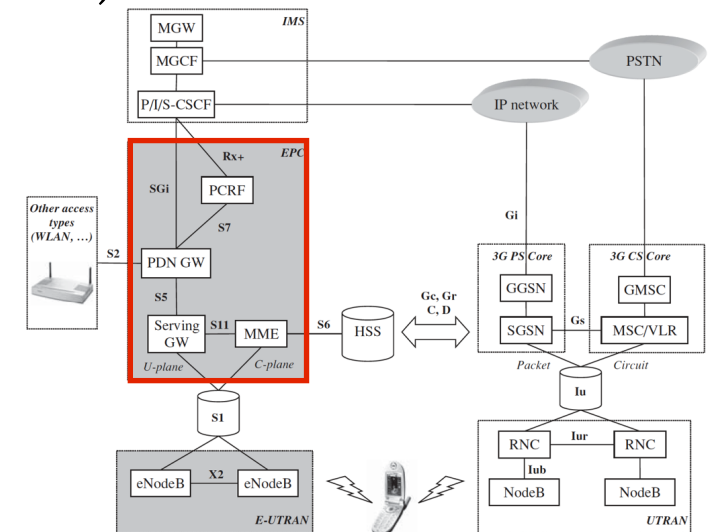
## ✓ Channel coding and de-coding

- ➔ Channel coding is referred to the processes done in both transmitter and receiver of a digital communications system
- ➔ Require allocating extra bits, also known as parity bits, and consuming extra bandwidth
- ➔ Using this amount of communications resources results in more reliable connection between transmitter and its receiver
- ➔ Two policies to deal with channel coding
  - Forward Error Correction (FEC)
    - ▶ FEC tries to discover the errors and correct them if it can
  - Automatic Repeat-reQuest (ARQ)
    - ▶ Discovers the error and sends a resend request to the transmitter
  - FEC-based methods are more complex in comparison with ARQ ones

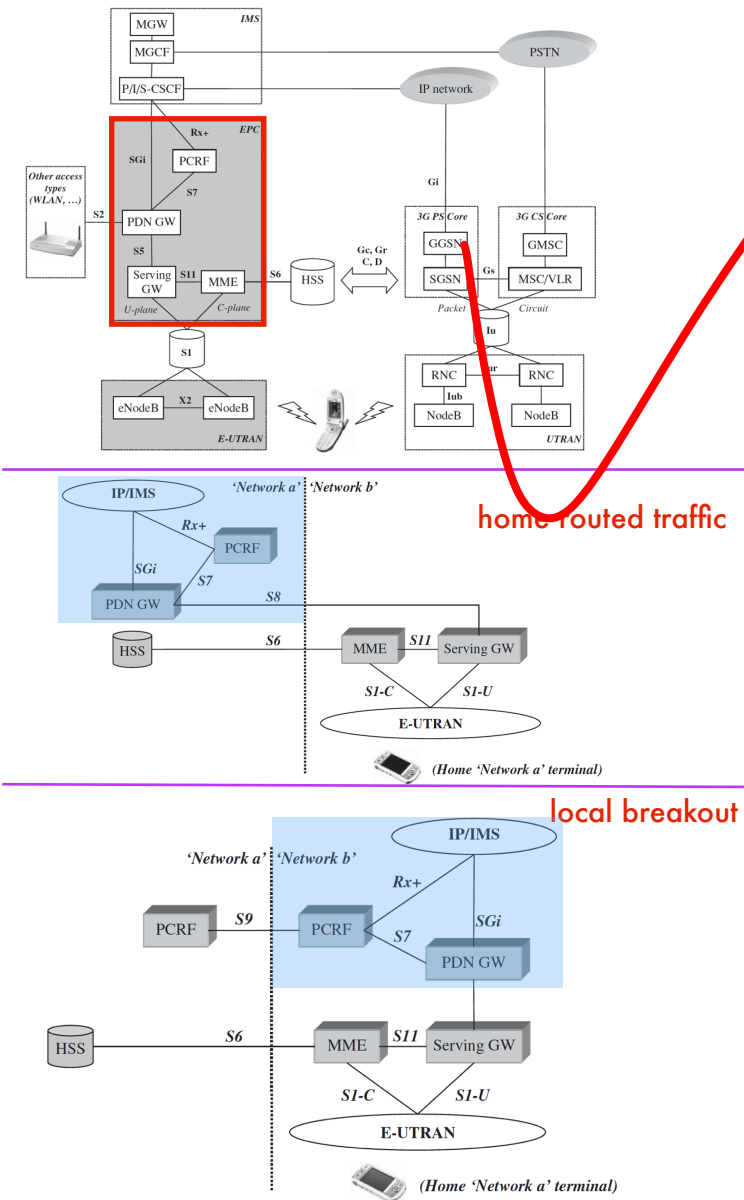
- eNodeB includes additional features
  - ✓ Radio resource control
    - ➔ Relates to the allocation, modification and release of resources for the transmission over the radio interface between user terminal and eNodeB
  - ✓ Radio mobility management
    - ➔ Refers to a measurement processing and handover decision
  - ✓ Radio interface full Layer 2 protocol
    - ➔ In the OSI Data Link way, the layer 2 purpose is to ensure transfer of data between network entities
    - ➔ This implies detection and possibly correction of errors that may occur in the physical layer

# 3.2 EPC: The Evolved Packet Core Network

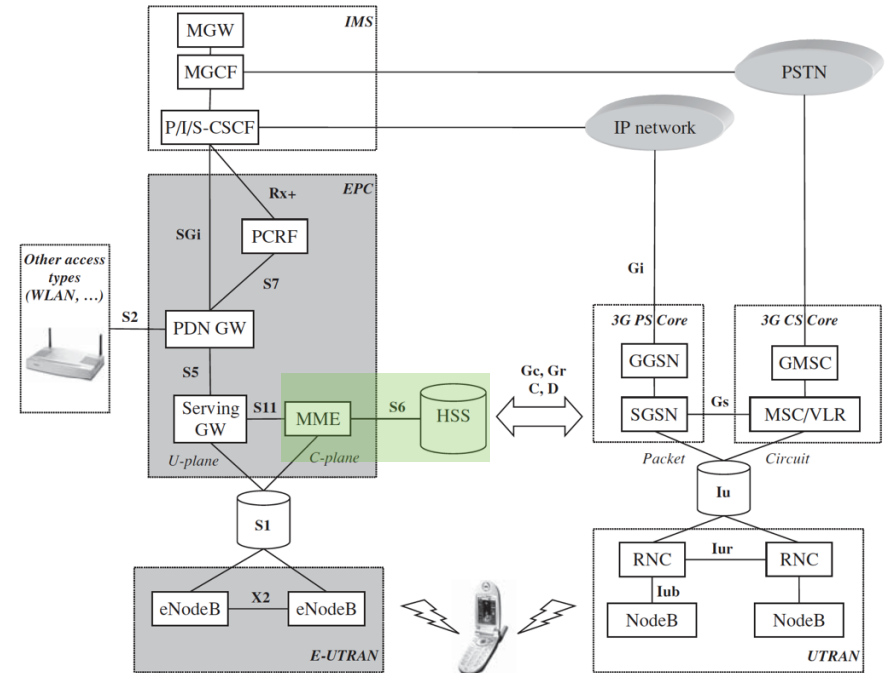
- EPC (Evolved Packet Core) is composed of several functional entities
  - ✓ MME (Mobility Management Entity)
  - ✓ Serving Gateway
  - ✓ PDN (Packet Data Network) Gateway
  - ✓ PCRF (Policy and Charging Rules Function)



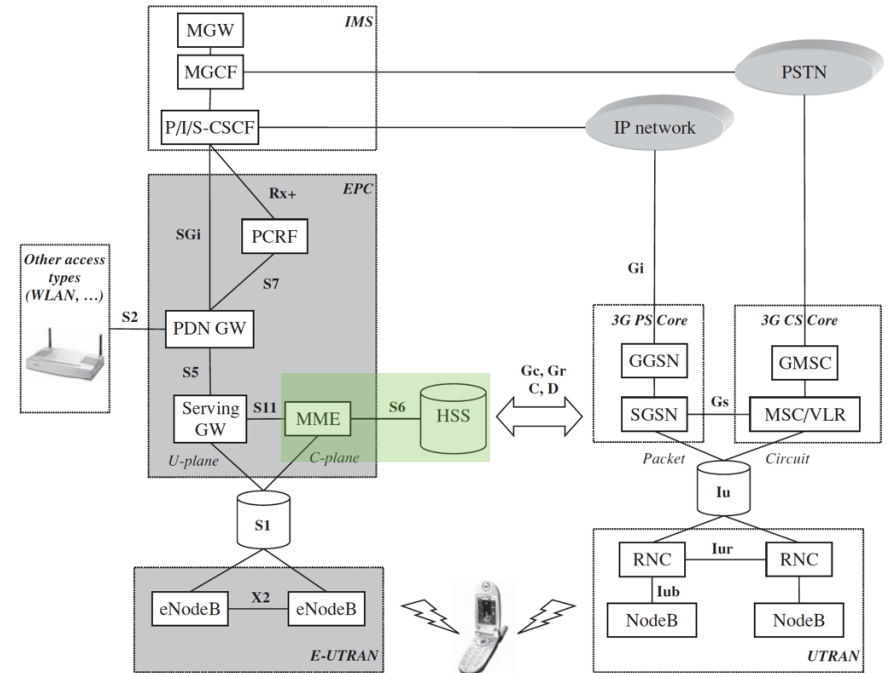
- EPC architecture interaction in the following cases
  - ✓ Non-roaming architecture – the simplest EPC architecture case
  - ✓ Roaming architecture – how the EPC works in a roaming situation in the home routed traffic and local breakout cases
  - ✓ Non-3GPP access case – how the EPC interacts with non-3GPP access technologies like WLAN, in trusted and non-trusted modes
  - ✓ 2G/3G mobility architecture – how the EPC interacts with 2G/3G PS Core nodes in cases of user mobility



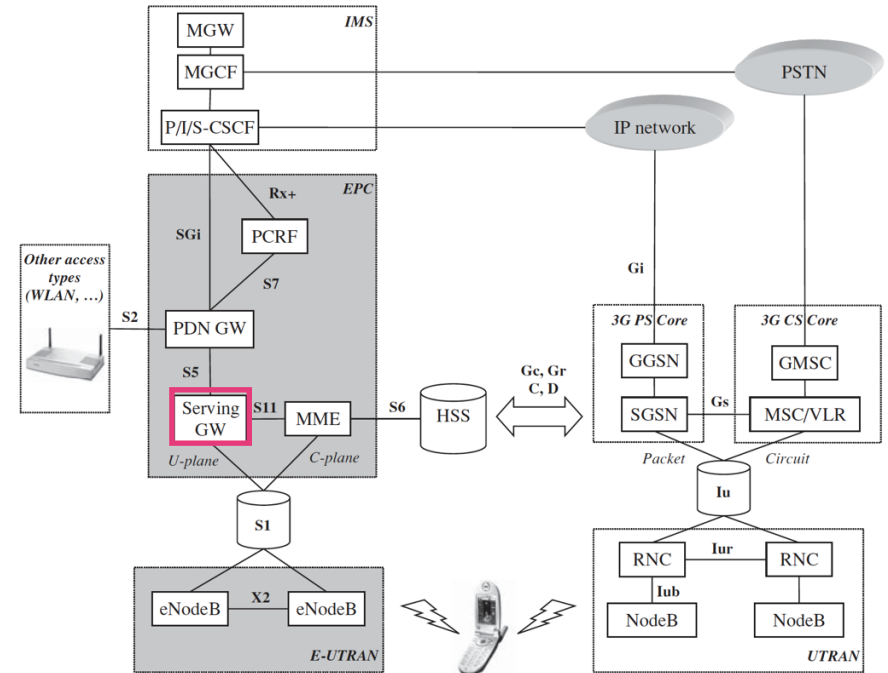
- 3.2.1 MME (Mobility Management Entity)
- MME
  - ✓ In charge of all the Control plane functions related to subscriber and session management
  - ✓ Linked through S6 interface to HSS
  - ✓ HSS supports the database containing all the user subscription information



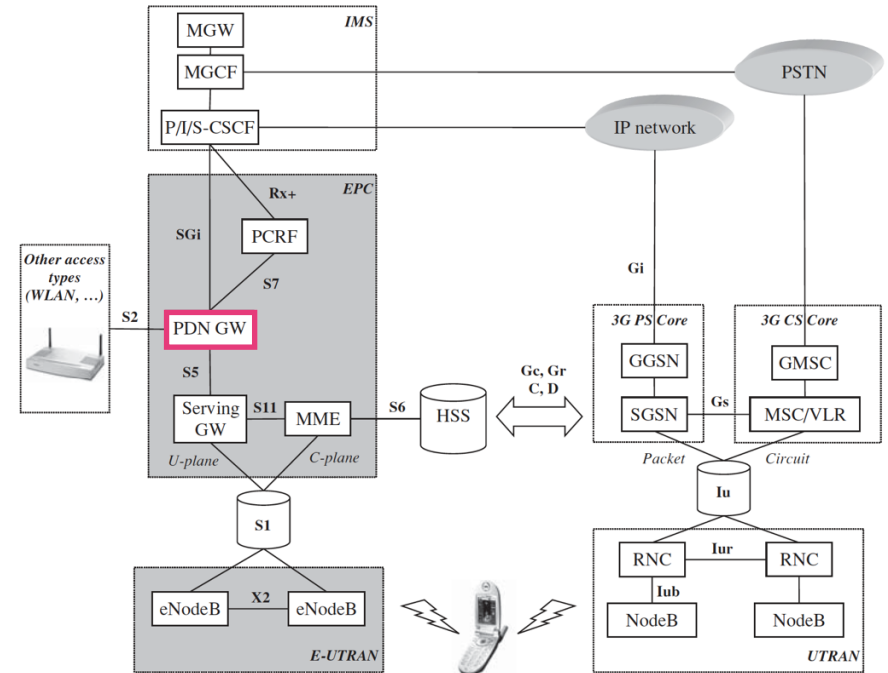
- MME supports the following
  - ✓ Security procedures
    - ➔ End-user authentication as well as initiation and negotiation of ciphering and integrity protection algorithms
  - ✓ Terminal-to-network session handling
    - ➔ All the signaling procedures used to set up Packet Data context and negotiate associated parameters like Quality of Service
  - ✓ Idle terminal location management
    - ➔ The tracking area update process used for the network to be able to join terminals in case of incoming sessions



- 3.2.2 Serving GW (Serving Gateway)
- Serving GW
  - ✓ The termination point of the packet data interface towards E-UTRAN
- When terminals move across eNodeB in E-UTRAN, the Serving GW serves as a local mobility anchor
  - ✓ Packets are routed through this point for intra E-UTRAN mobility, and
  - ✓ Mobility with other 3GPP technologies, such as 2G/GSM and 3G/UMTS



- 3.2.3 PDN GW (Packet Data Network Gateway)
- PDN gateway
  - ✓ The termination point of the packet data interface towards Packet Data Network
- As an anchor point for sessions towards external Packet Data Networks
- PDN GW also supports
  - ✓ Policy enforcement features
    - ➔ Apply operator-defined rules for resource allocation and usage
  - ✓ Packet filtering
    - ➔ e.g. deep packet inspection for virus signature detection
  - ✓ Charging support
    - ➔ e.g. per URL charging



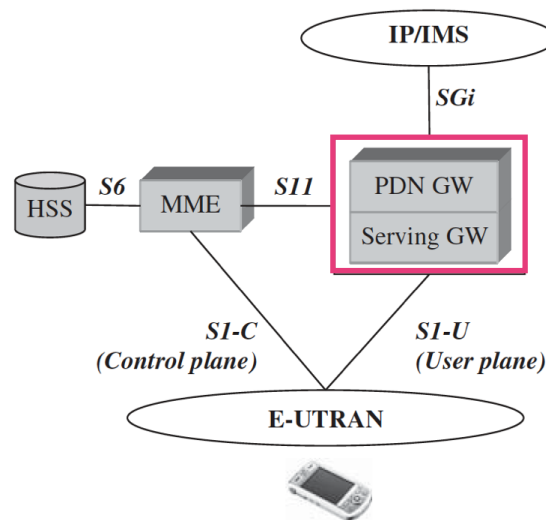
- **3.2.4 Non-Roaming Architecture**

- The standard does not require any physical architecture for EPC node implementation

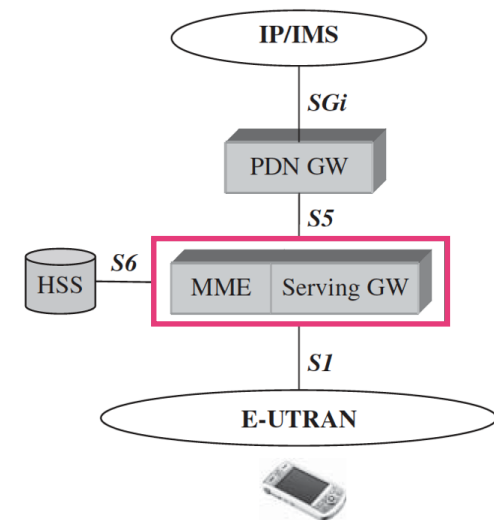
- For example, it may be possible that

- ✓ Serving and PDN Gateways are supported by a single node, or

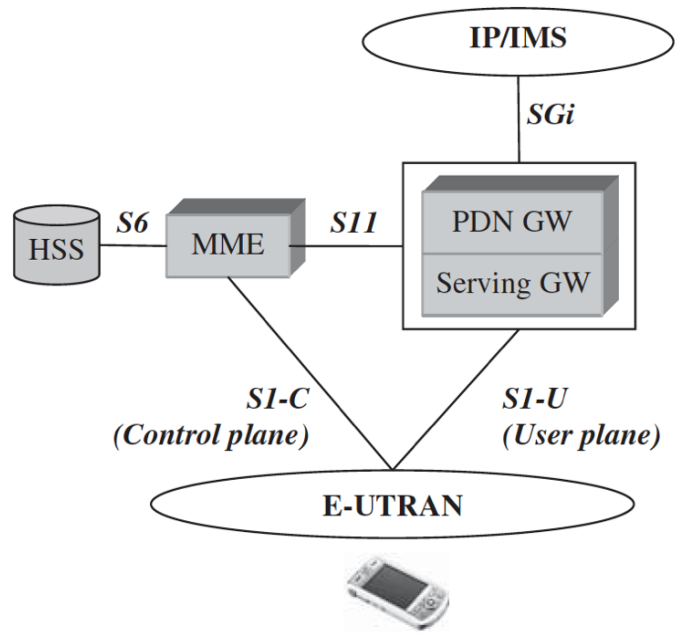
- ✓ MME and Serving Gateway are implemented in one physical node



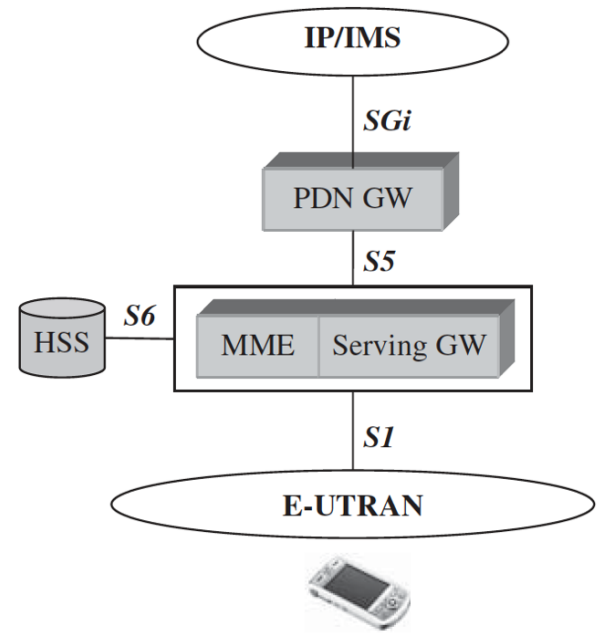
Merging the two gateways



Merging SI Control and User planes



Merging the two gateways

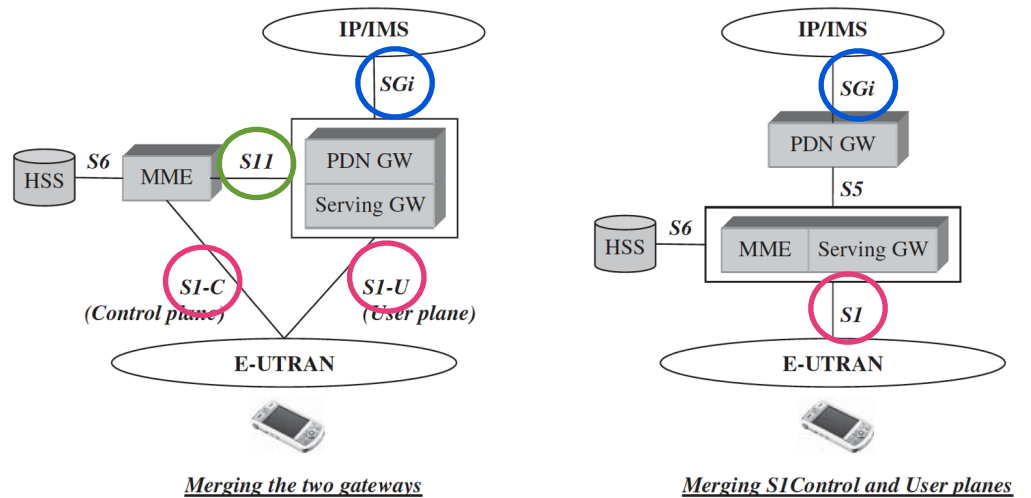


Merging S1Control and User planes

Figure 2.9 Different options for merged EPC physical node implementation.

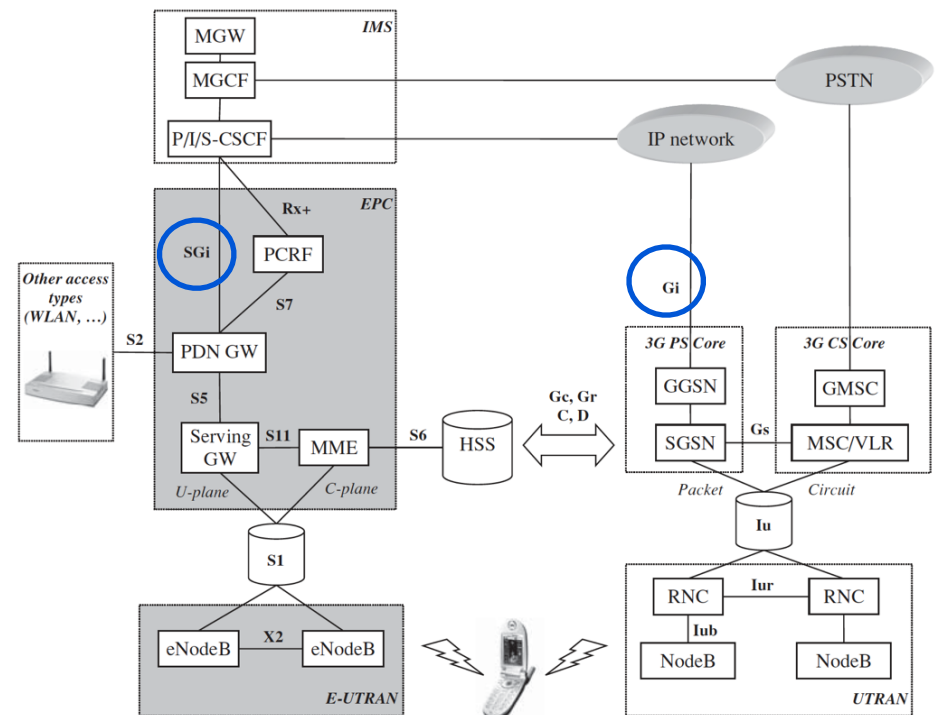
- S1 interface

- ✓ Transports both signaling (S1-C part) and User plane data (S1-U part) between E-UTRAN and EPC



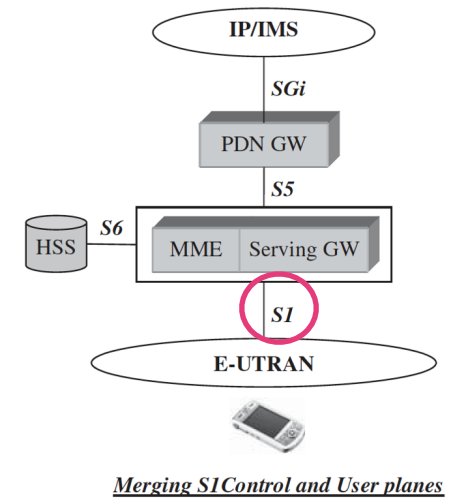
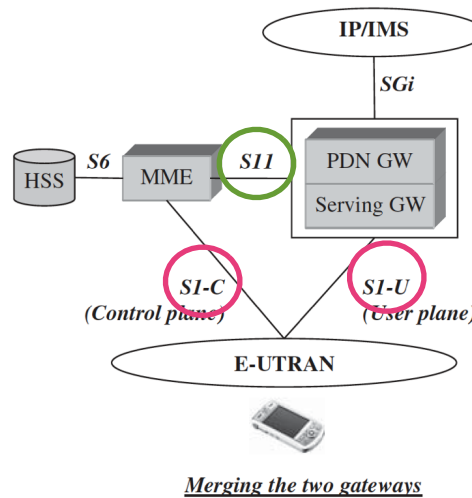
- SGi interface

- ✓ The equivalent of the 2G and 3G Packet Core *Gi*
- ➔ Towards public or private external IP networks, or IMS domain



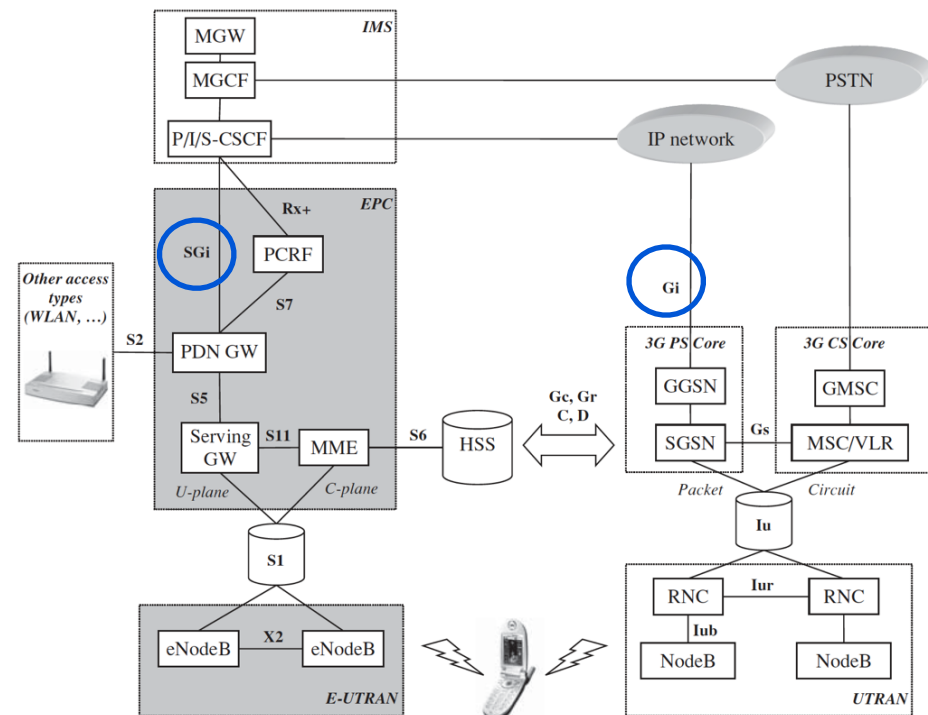
- Merging *S1* Control and User planes

- ✓ A simpler solution to operate a Packet Core network since it does not require implementing and operating *S11* signaling interface between MME and Serving GW



- Merging PDN GW & Serving GW

- ✓ Implements separated MME and User plane functions allows further flexibility in terms of deployment
- ✓ Allows independent scalability between the signaling load on Control plane and traffic handling on User plane



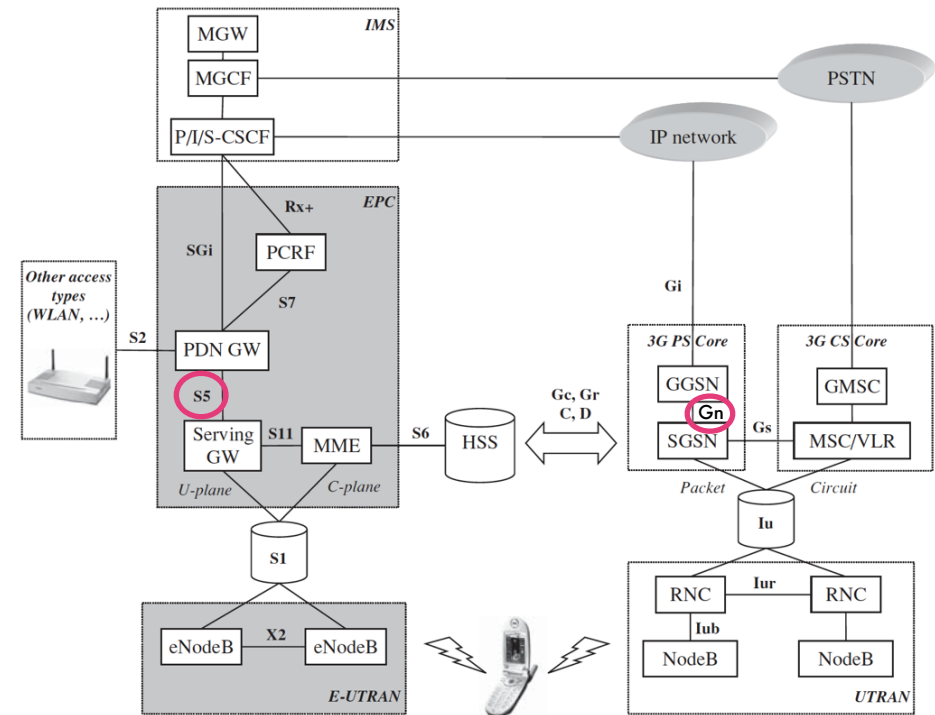
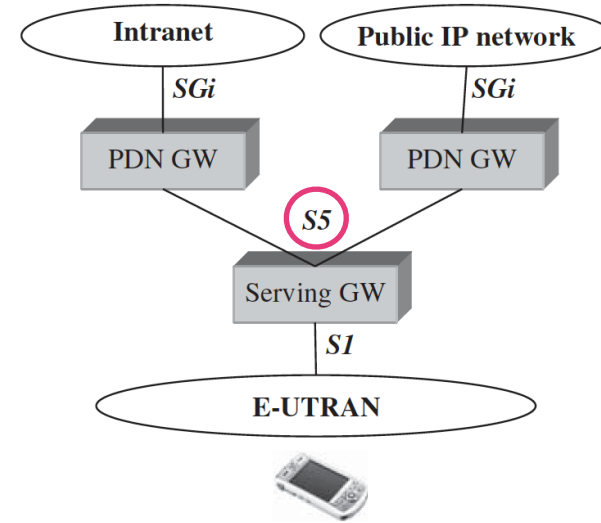
- S5 interface

- ✓ Allow connectivity to multiple Packet Data Networks, providing the same flexibility as the Gn interface defined between SGSN and GGSN 2G/3G nodes

- ➔ S5 interface is actually an evolved version of the Gn interface based on GTP (GPRS Tunneling Protocol)

- ✓ The typical use case of such a configuration would be, for example, to separate the access to an Intranet from the public IP network access

- ➔ In this case, access to each of the networks is done through a specific PDN GW, which allows implementing specific policy enforcement rules, or packet-filtering algorithms, depending on the type of packet network being addressed



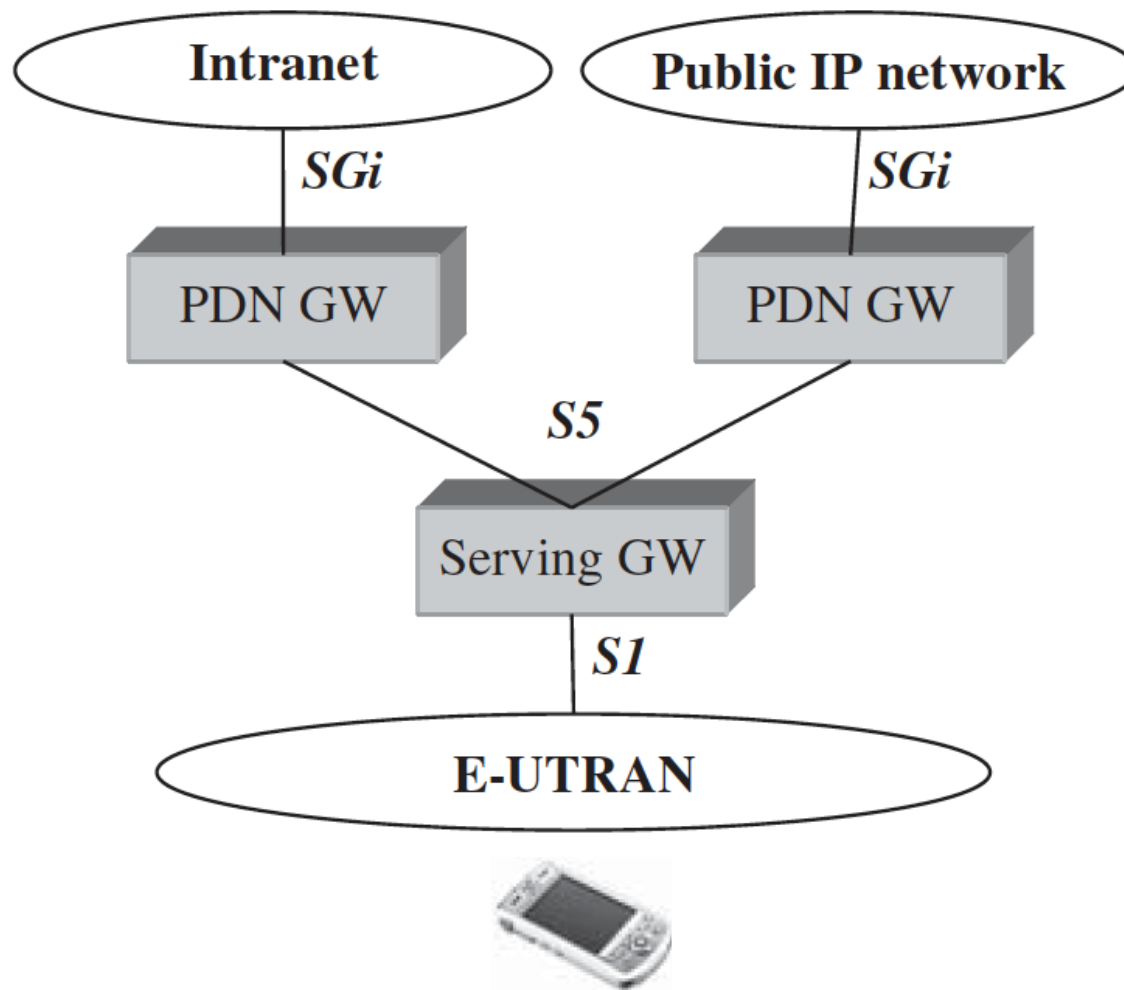
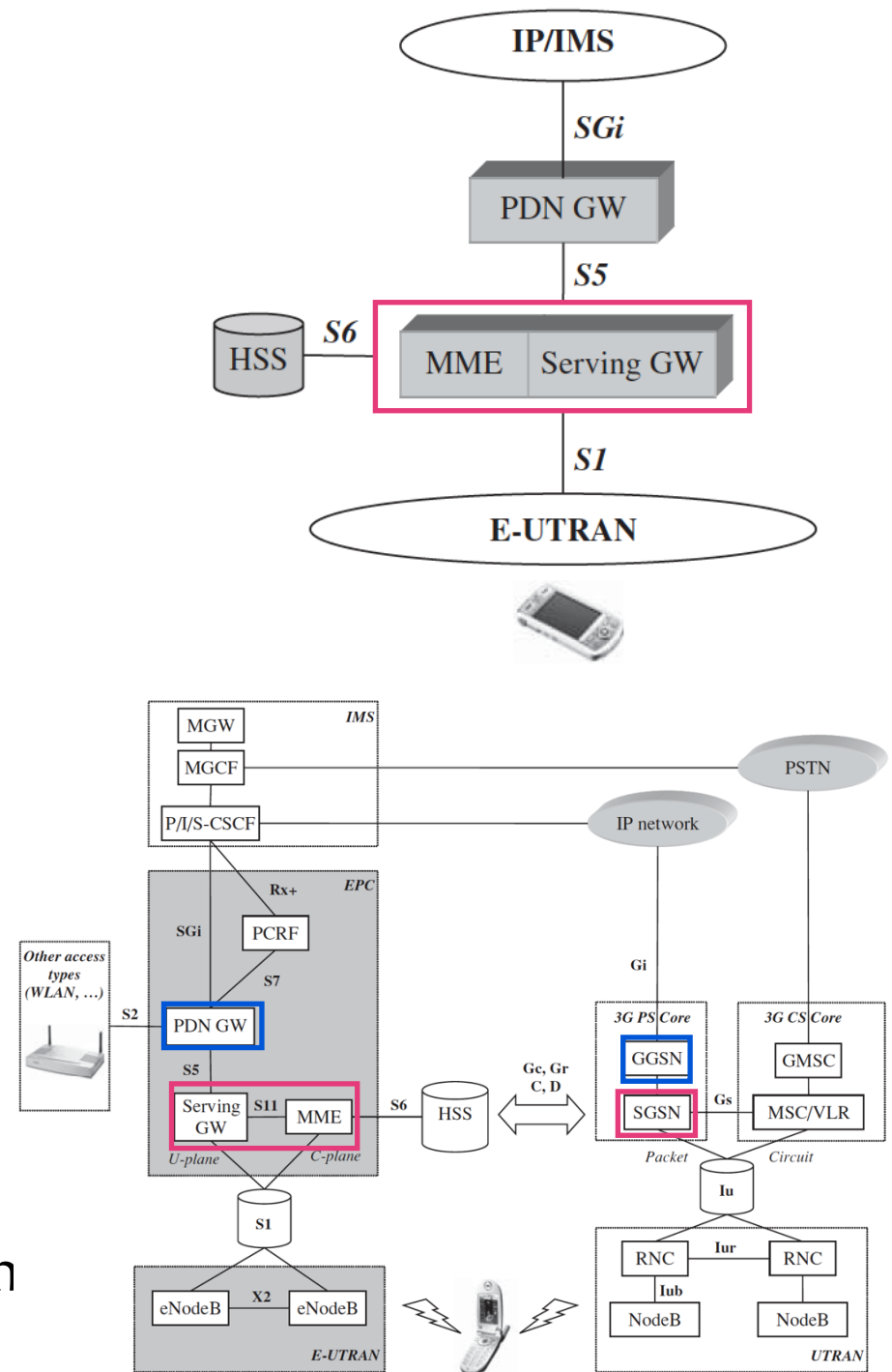


Figure 2.10 An example of S5 connectivity to multiple packet networks.

- From a functional perspective
  - ✓ The association of MME and Serving GW features is actually very close to a combination of 2G/3G SGSN
  - ✓ The PDN GW logical node can be considered as a kind of 2G/3G GGSN, supports

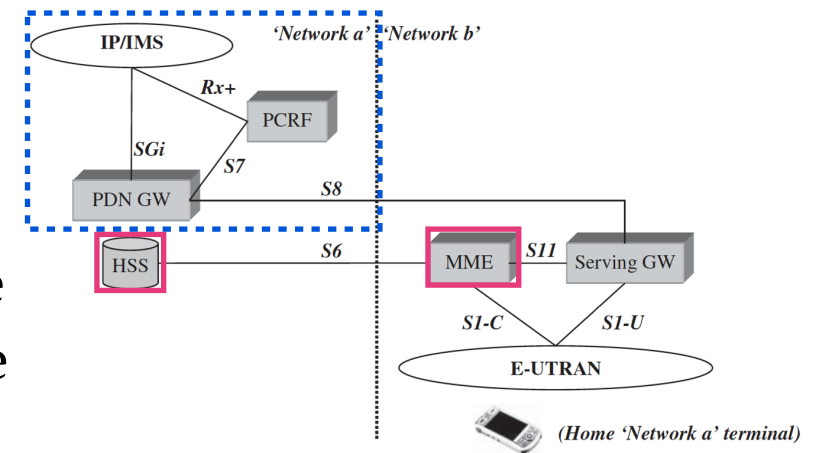
- ➔ Policy-enforcement and charging rules
- ➔ Inter-working with external packet networks
- ➔ Terminal IP address allocation



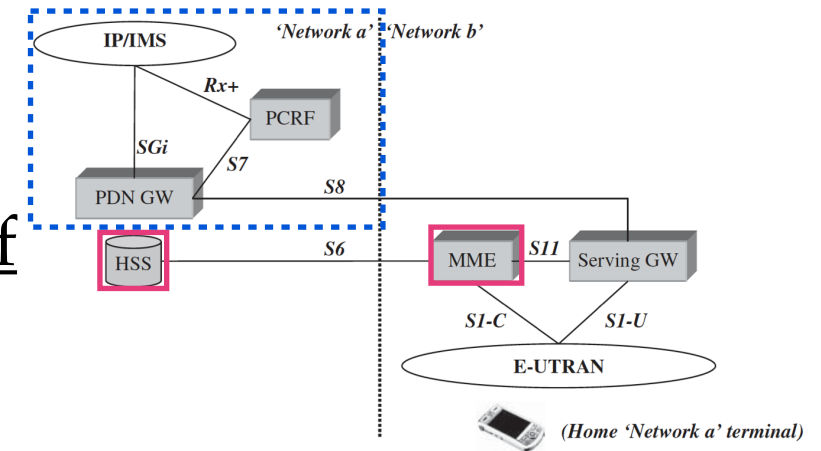
- 3.2.5 The Roaming Architecture

- Home routed traffic

- In this example, a user has subscribed to Network a but is currently under the coverage of the visited Network b
- This kind of situation may happen while the user is traveling to another country, or in the case in which a national roaming agreement has been set up between operators
- In such a roaming situation, part of the session is handled by the visited network, includes
  - ✓ E-UTRAN access network support
  - ✓ Session signaling handling by MME
  - ✓ User plane routing through the local Serving GW nodes



- The visited network is then able to build and send charging tickets to the subscriber home operator
- ✓ Corresponding to the amount of data transferred and the Quality of Service allocated
- However, since the terminal user has no subscription with the visited network
- ✓ The MME needs to be linked to the HSS of the user home network, at least to retrieve the user-specific security credential needed for authentication and ciphering



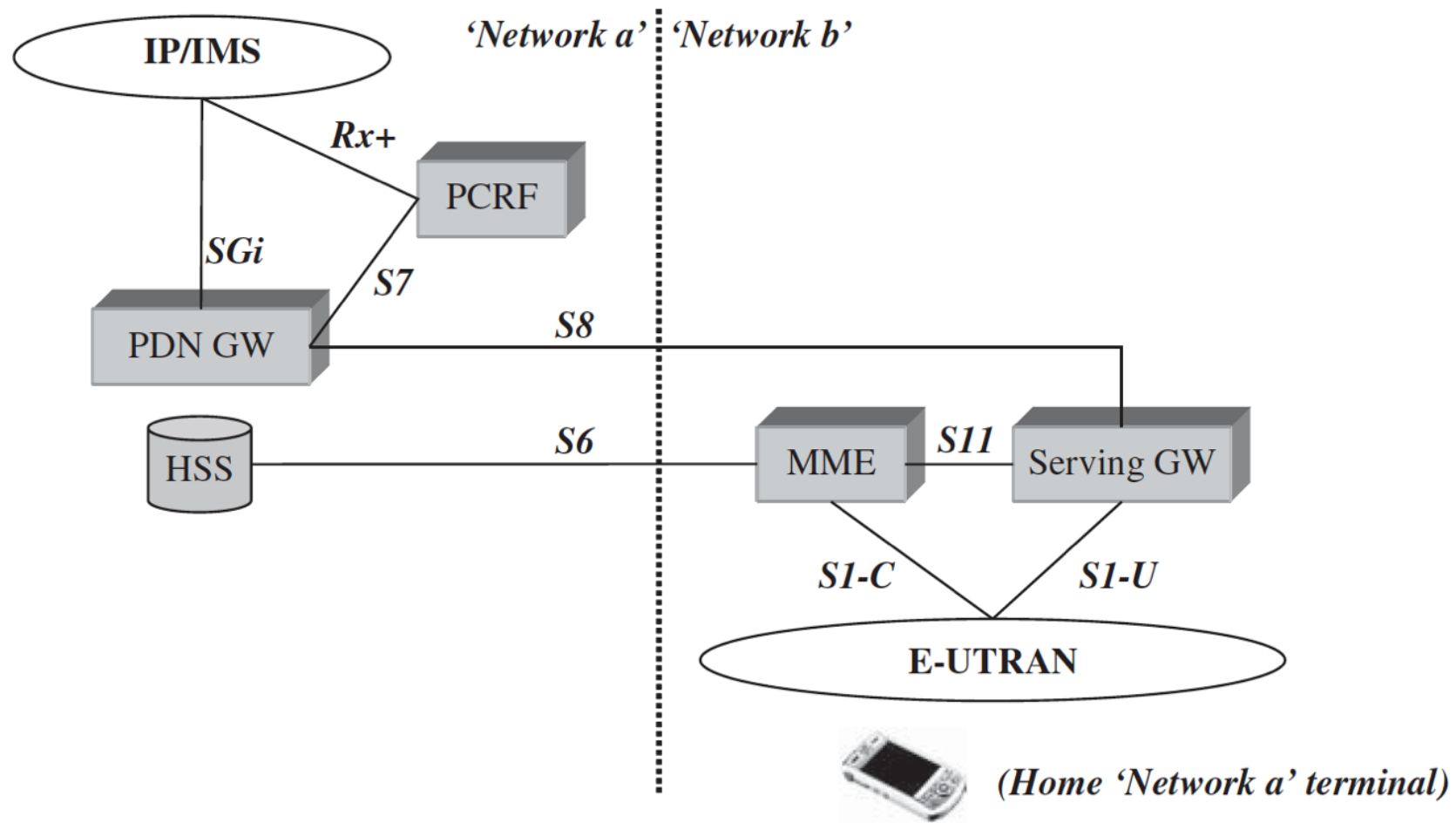
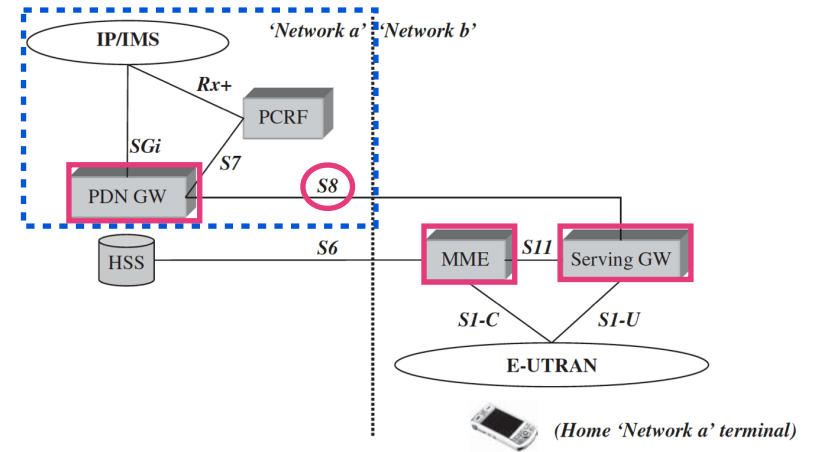
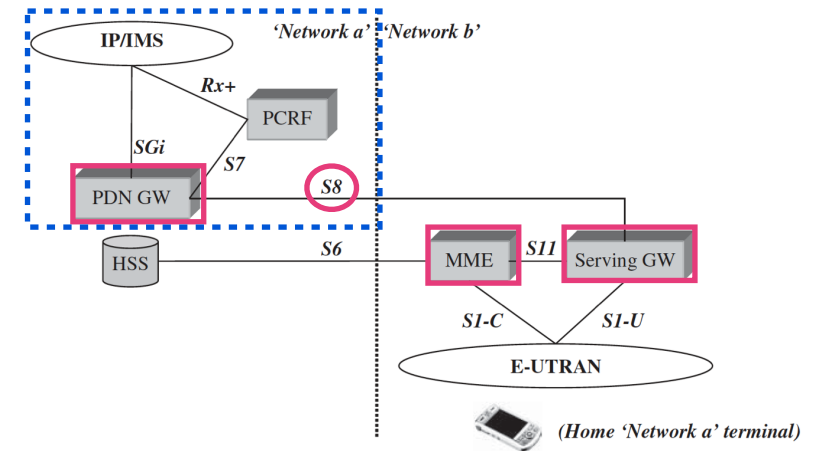


Figure 2.12 The EPC roaming architecture  
 – **home**-routed traffic.

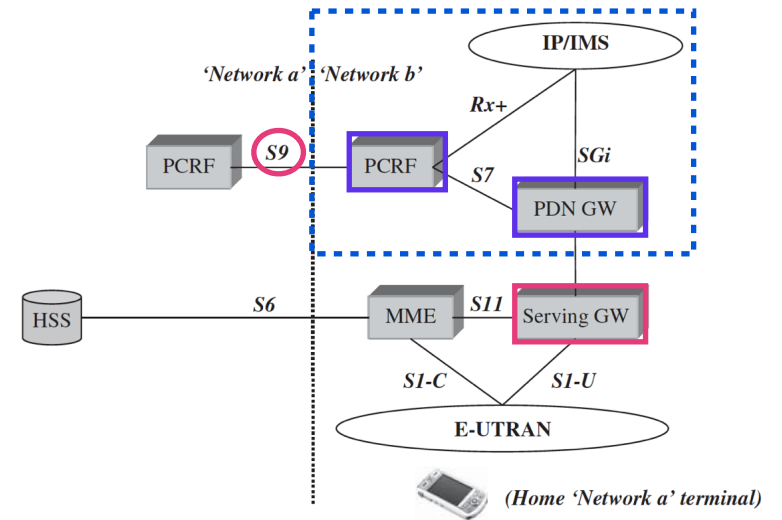
- In the roaming architecture, the session path goes through home PDN GW over the S8 interface, so as to
  - ✓ Apply policy and charging rules in the home network corresponding to the user-subscription parameters
- The S8 interface in this model
  - ✓ Supports both signaling and data transfer between the visited Serving GW and the home PDN GW



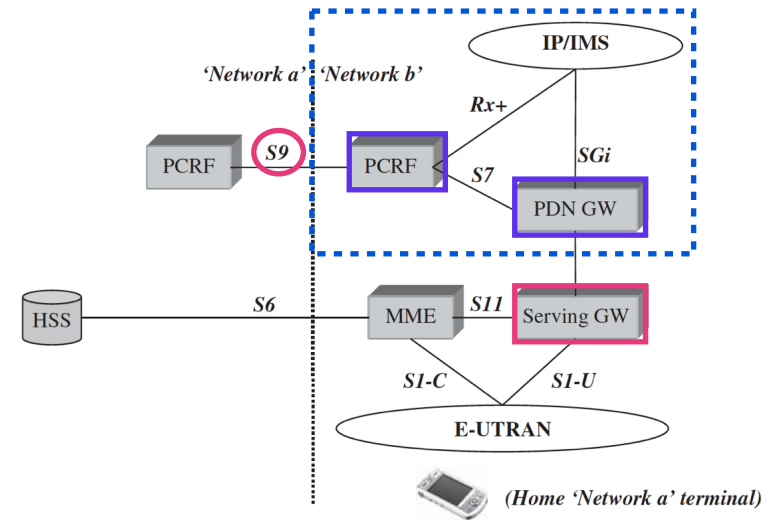
- The visited network
  - ✓ Provides the access connectivity (involves the basic session signaling procedures supported by the visited MME, with the support of home HSS)
- The home network
  - ✓ Provides the access to external networks, possibly including IMS-based services
- In this model, the call is still anchored to the home PDN GW
  - ✓ The user packet routing in such a scheme may be quite inefficient in terms of cost and network resources, as the home PDN GW and visited Serving GW may be very far from each other



- Local breakout (local traffic routing)
- 3GPP standard allows the possibility of the user traffic to be routed via a visited PDN GW, as an optimization
- ✓ Very beneficial in the example of
  - ➔ Public Internet access – as routing the traffic to the home network does not add any value to the end-user
  - ➔ IMS session established between a roaming user and a subscriber of the visited network



- Local traffic routing avoids a complete round trip of user data through the home network packet gateways
- The figure shows the traffic is routed locally, both Gateways are part of the visited network
- ✓ The visited PCRF (Policy and Charging Rules Function) retrieves Quality of Service policy and charging control information from the Home PCRF via the new S9 interface



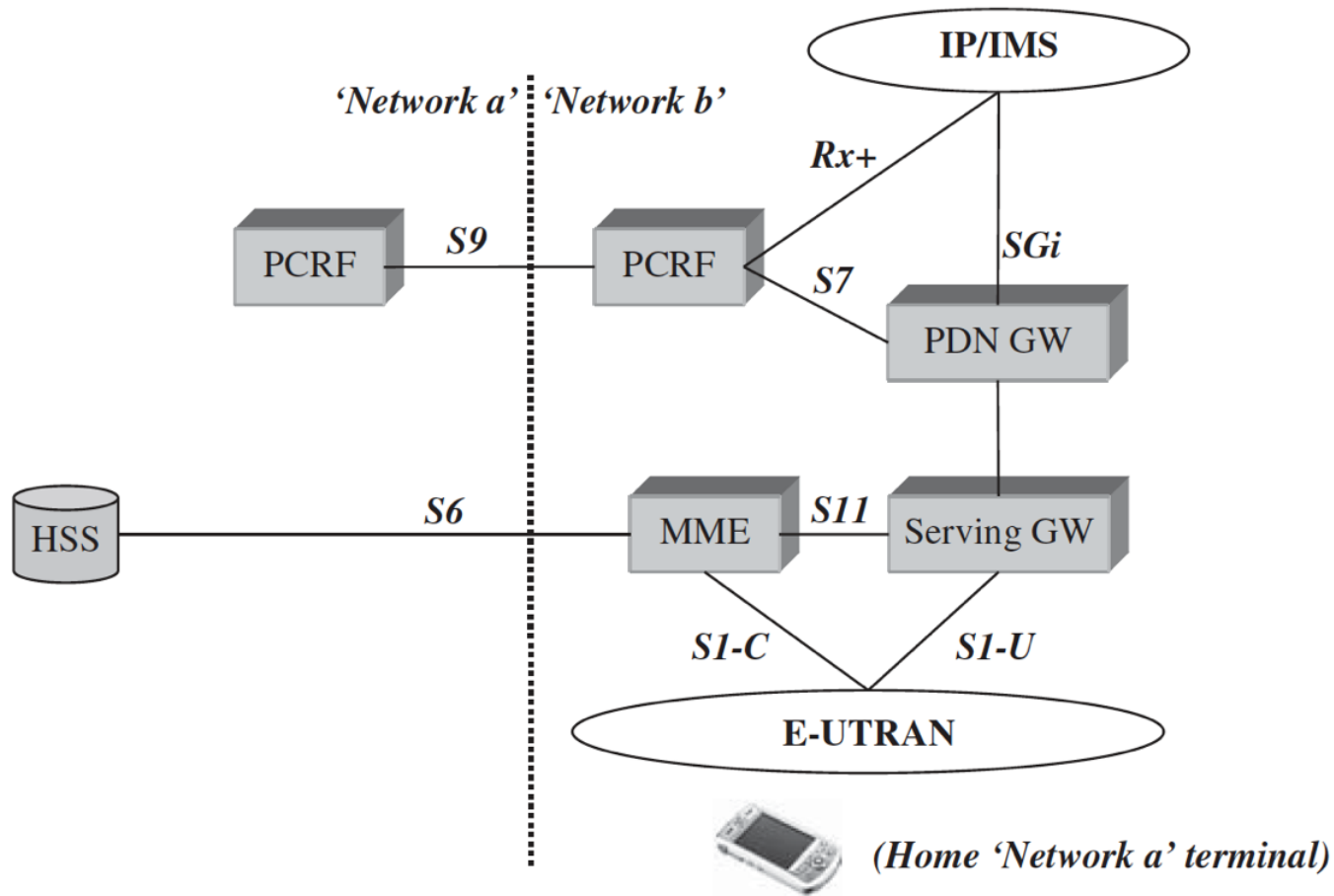
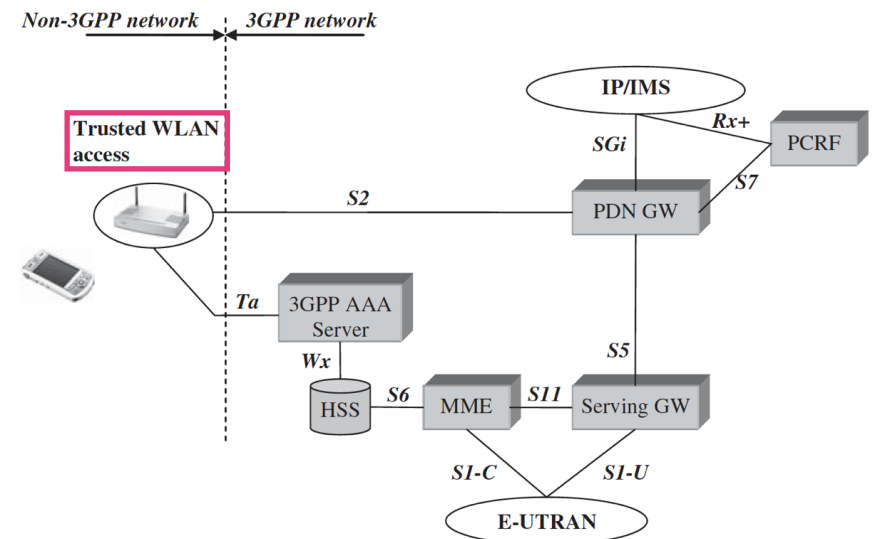


Figure 2.13 The EPC roaming architecture  
 – local breakout.

- **3.2.6 The Non-3GPP Access Architecture**
- The network architecture providing IP connectivity to the EPC using non-3GPP type of access
- This architecture is independent from the access technology, which could be WiFi, WiMAX or any other kind of access types
- Trusted WLAN access
- This figure applies to the trusted WLAN access
  - ✓ Corresponds to the situations where the WLAN network is controlled by the operator itself or by another entity (local operator or service provider) which can be trusted due to the existence of mutual agreements



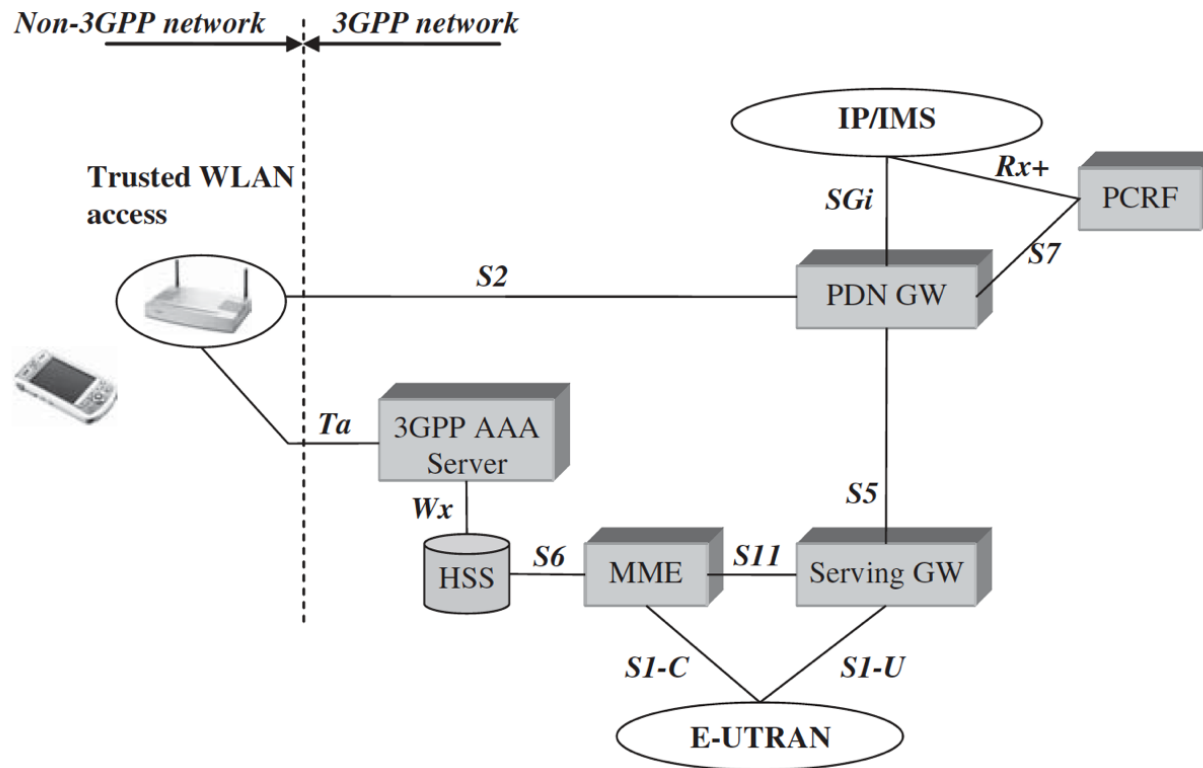
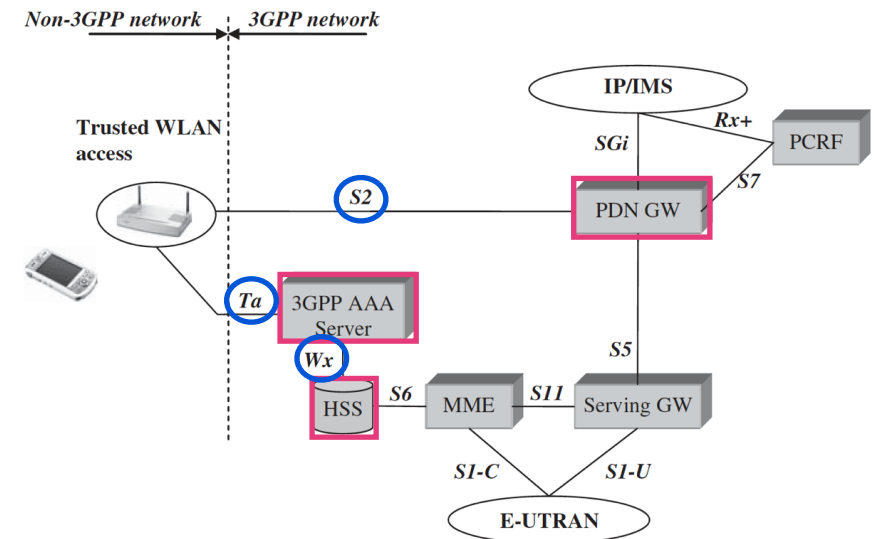


Figure 2.14 The EPC architecture for **trusted** WLAN access.

- On the terminal side
  - ✓ No changes are required except some slight software adaptations
  - ✓ This comes from the fact that AAA (Authentication, Authorization and Accounting) mechanisms for mutual authentication and access control are based on known IETF protocols but make use of 3GPP UICC stored credentials



**UICC** (Universal Integrated Circuit Card)

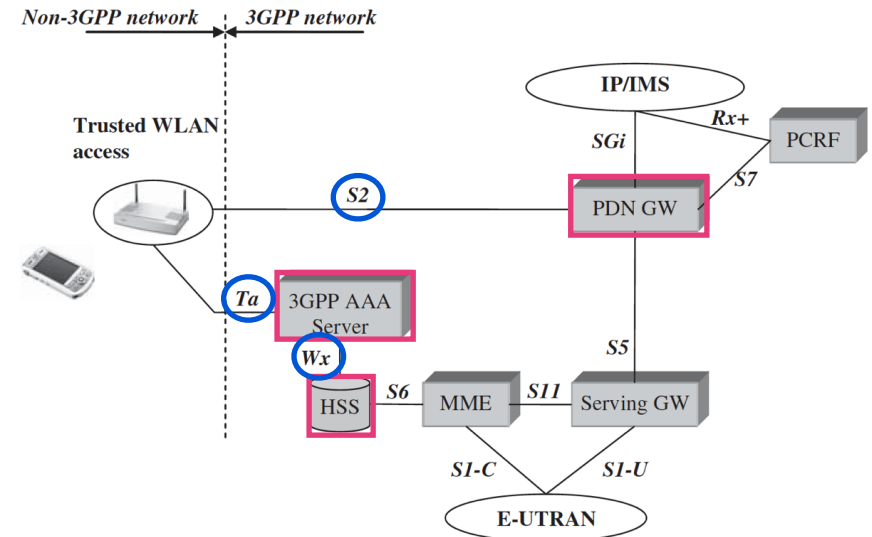
- The smart card used in mobile terminals in GSM and UMTS networks
- It ensures the integrity and security of all kinds of personal data

- 3GPP AAA Server

- ✓ Act as an inter-working unit between 3GPP world and IETF standard-driven WLAN networks from security perspective

- ✓ Allow end-to-end authentication with WLAN terminals using 3GPP credentials

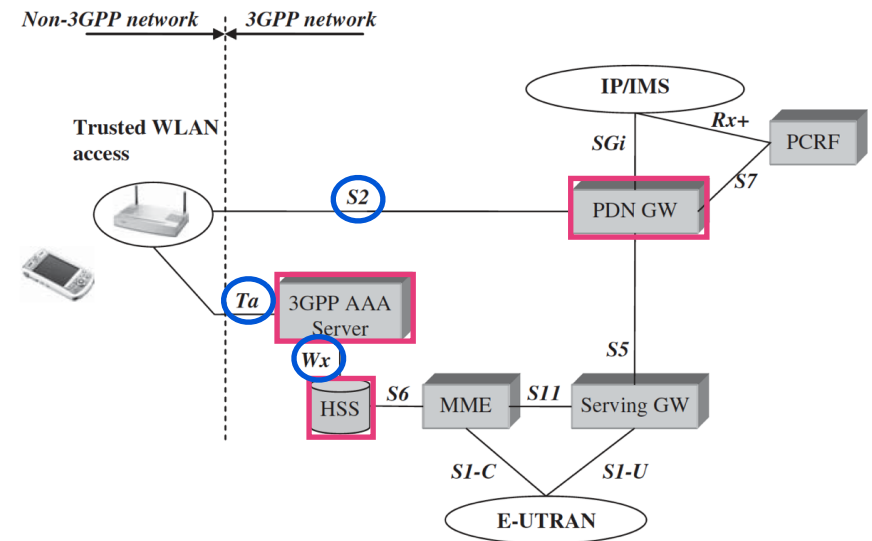
- ✓ 3GPP AAA Server has an access to HSS through Wx interface, so as to retrieve user related subscription information and 3GPP authentication vectors



UICC (Universal Integrated Circuit Card)

- The smart card used in mobile terminals in GSM and UMTS networks
- It ensures the integrity and security of all kinds of personal data

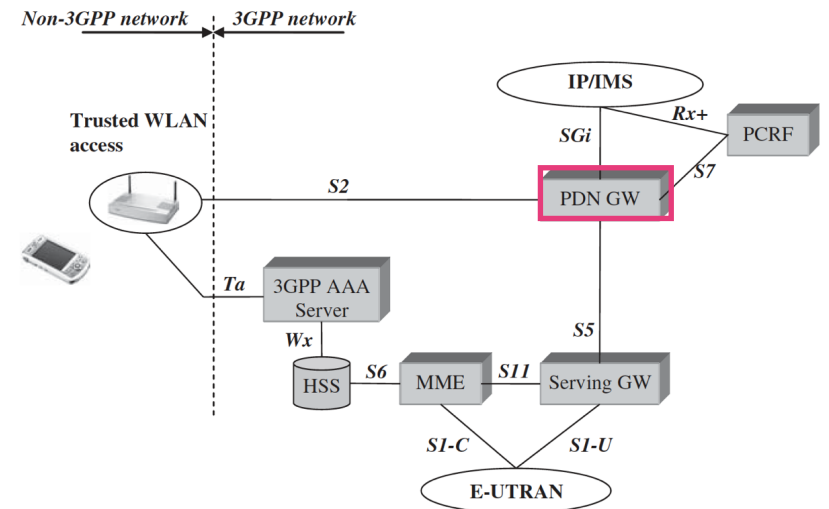
- From 3GPP AAA Server
  - ✓ Ta interface has been defined with the trusted access network, aiming at transporting authentication, authorization and charging-related information in a secure manner
- From User plane perspective
  - ✓ User data are transmitted from WLAN network to PDN GW through S2 interface



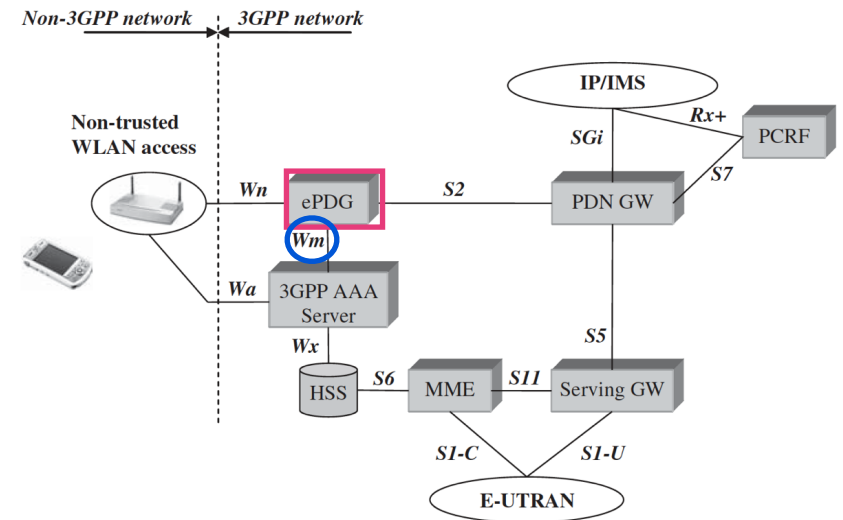
UICC (Universal Integrated Circuit Card)

- The smart card used in mobile terminals in GSM and UMTS networks
- It ensures the integrity and security of all kinds of personal data

- PDN GW
  - ✓ Serves as an anchor point for user traffic
- Terminal location management
  - ✓ Under the responsibility of WLAN Access as well as packet session signaling
  - ✓ Does not need any support from 3GPP EPC nodes
- In the example of a 802.11 WiFi access point, the following operations are handled by the access point itself
  - ✓ User association (a WiFi terminal connects to an access point)
  - ✓ Security features
  - ✓ Radio protocols



- Non-trusted WLAN access
- This may corresponds to a business entity deploying a WLAN for its internal use and willing to offer 3GPP connectivity to some of its customers
- ePDG node (evolved Packet Data Gateway)
  - ✓ Concentrates all the traffic issued or directed to WLAN network
  - ✓ Main role
    - ➔ Establish a secure tunnel for user data transmission with the terminal using IPSec
    - ➔ Filter unauthorized traffic
- *Wm* interface
  - ✓ Exchange user related information from 3GPP AAA Server to ePDG
  - ✓ Allow ePDG to enable proper user data tunneling and encryption to the terminal



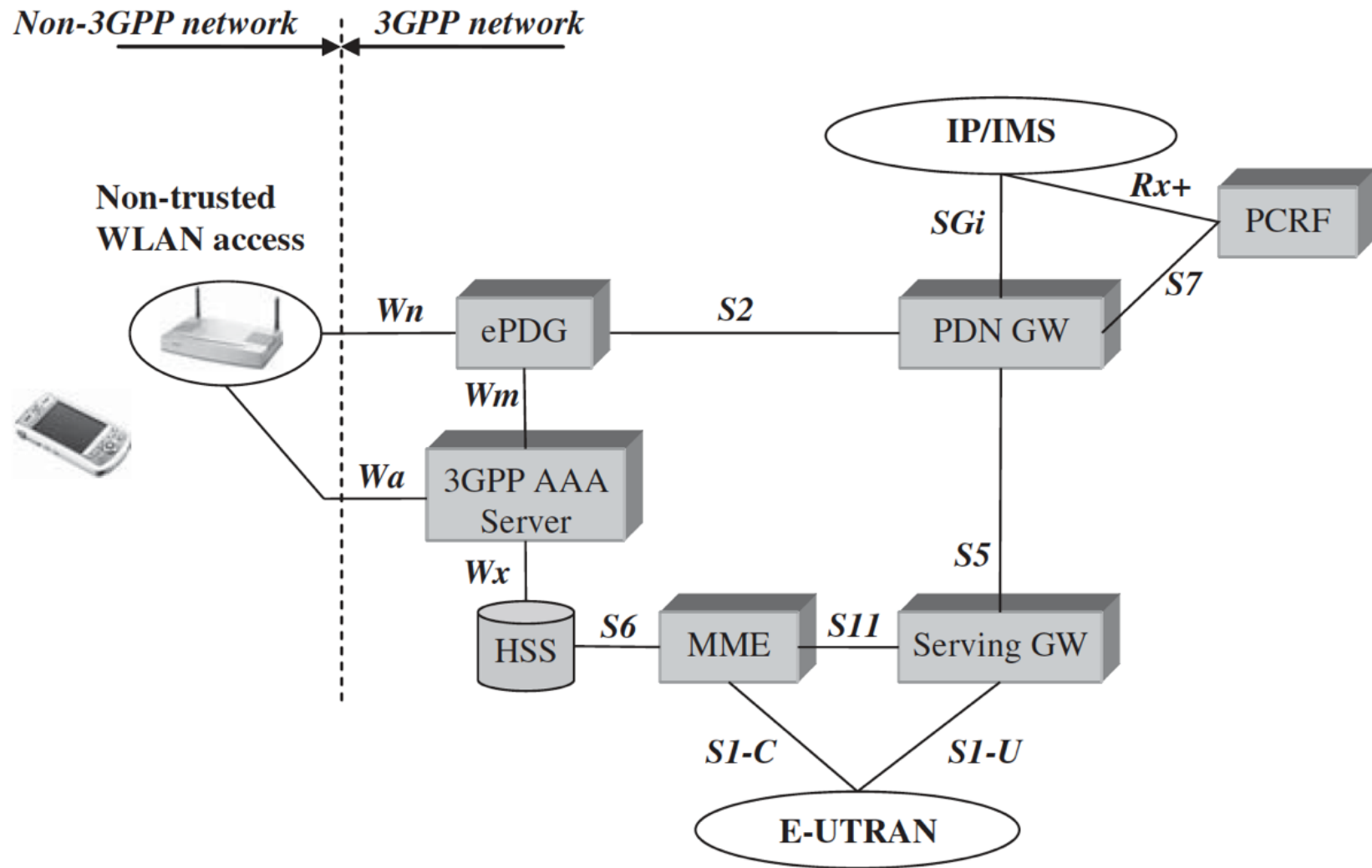


Figure 2.15 The EPC architecture for non-trusted WLAN access.

# Note: Internet Protocol Security (IPsec)

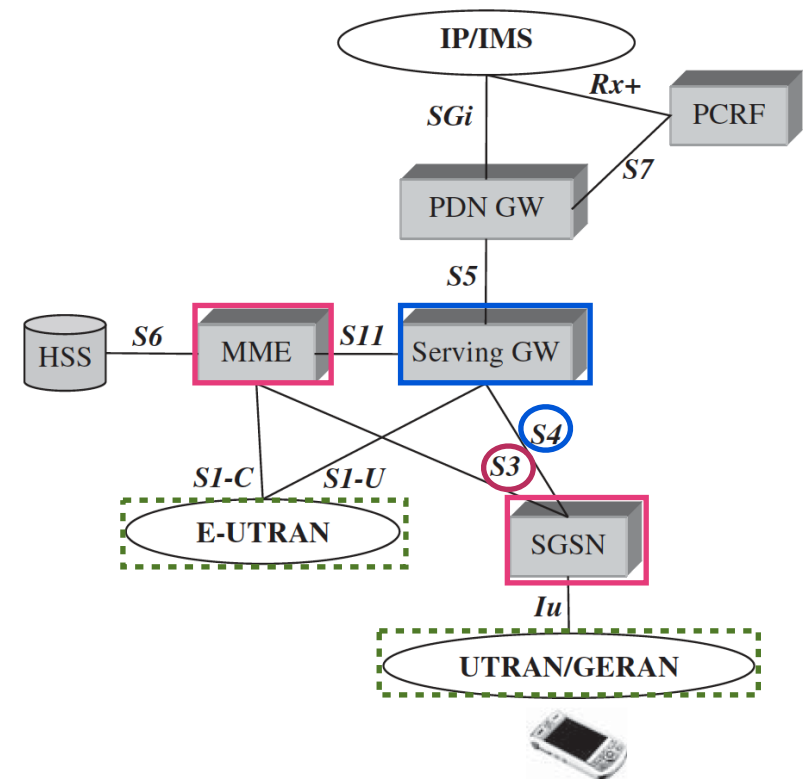
- A protocol suite for securing Internet Protocol (IP) communications by authenticating and encrypting each IP packet of a communication session
- Includes protocols for establishing mutual authentication between agents at the beginning of the session and negotiation of cryptographic keys to be used during the session
- Can be used in protecting data flows between a pair of hosts (host-to-host), between a pair of security gateways (network-to-network), or between a security gateway and a host (network-to-host)

- Uses cryptographic security services to protect communications over Internet Protocol (IP) networks
- Supports network-level peer authentication, data origin authentication, data integrity, data confidentiality (encryption), and replay protection
- An end-to-end security scheme operating in the Internet Layer of the Internet Protocol Suite, while some other Internet security systems in widespread use, such as Transport Layer Security (TLS) and Secure Shell (SSH), operate in the upper layers at Application layer
- Only IPsec protects any application traffic over an IP network at the IP layer

- IPsec suite security architecture
  - Authentication Headers (AH)
    - Provide connectionless integrity and data origin authentication for IP datagrams and provides protection against replay attacks
  - Encapsulating Security Payloads (ESP)
    - Provide confidentiality, data-origin authentication, connectionless integrity, an anti-replay service (a form of partial sequence integrity), and limited traffic-flow confidentiality

- Security Associations (SA)
  - Provide the bundle of algorithms and data that provide the parameters necessary to AH and / or ESP operations
  - The Internet Security Association and Key Management Protocol (ISAKMP) provides a framework for authentication and key exchange

- **3.2.7 The 2G/3G Mobility Architecture**
- EPC interactions with 2G/3G Packet Core nodes
- This model is applicable to terminal mobility cases between E-UTRAN cells on one side and 3G/UTRAN or 2G/GERAN on the other side while a packet data context or a packet session is active
- ✓ GERAN (GPRS EDGE RAN) refers to the 2G/GSM access network



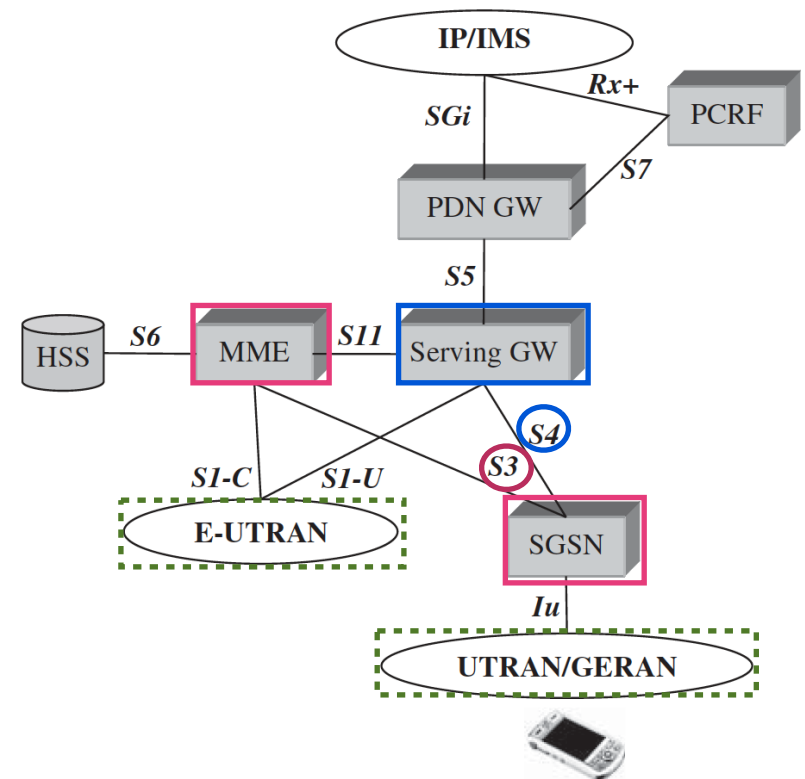
- The 2G/3G mobility architecture model introduces two interfaces

- ✓ S3 interface

- ➔ Support user and bearer information exchange between SGSN and MME, as the terminal is moving from one access type to the other

- ✓ S4 interface

- ➔ Associated with the session User plane
- ➔ Supports packet data transfer between SGSN and Serving GW which plays the role of a mobility anchor point within the EPC architecture



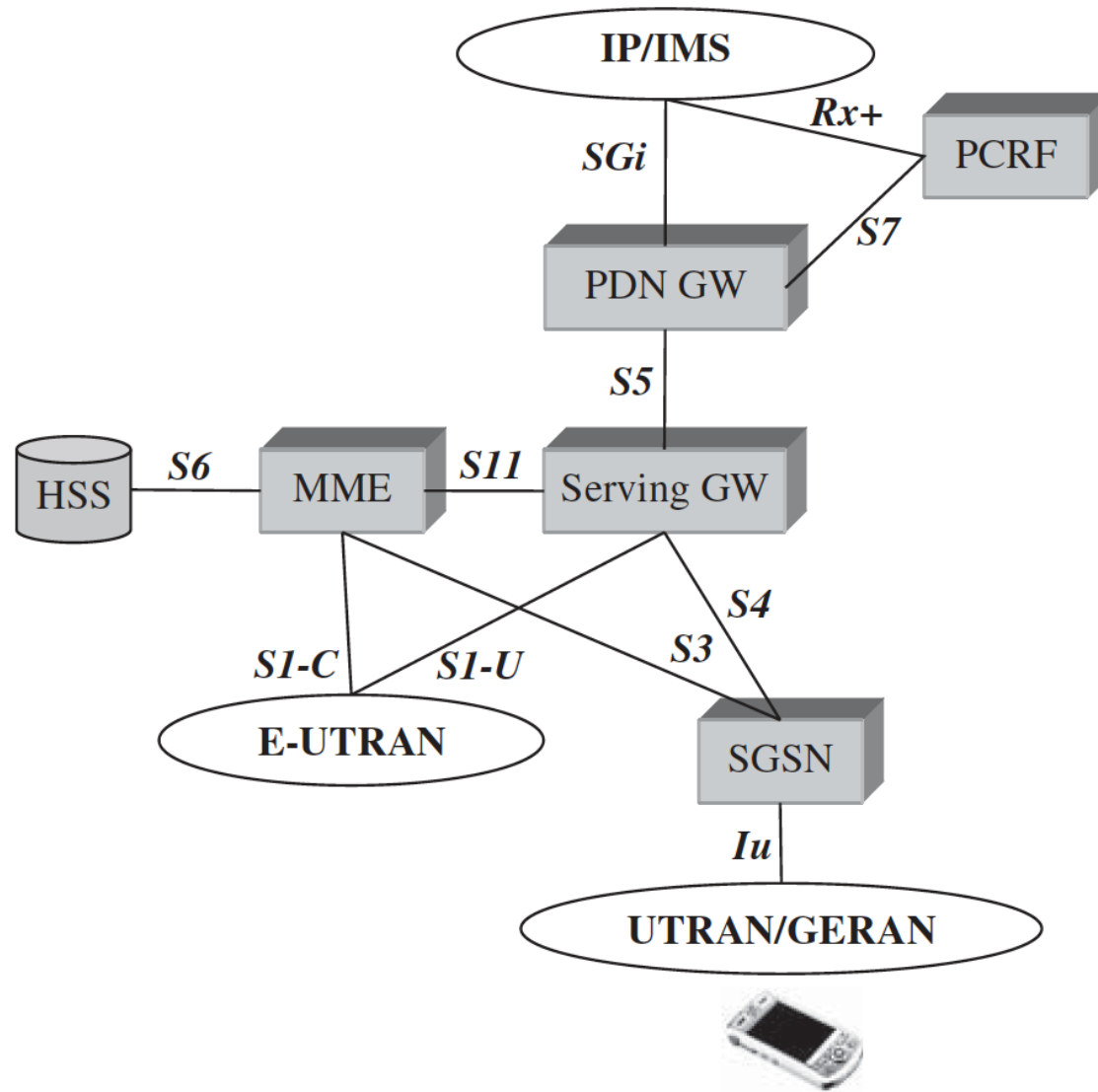
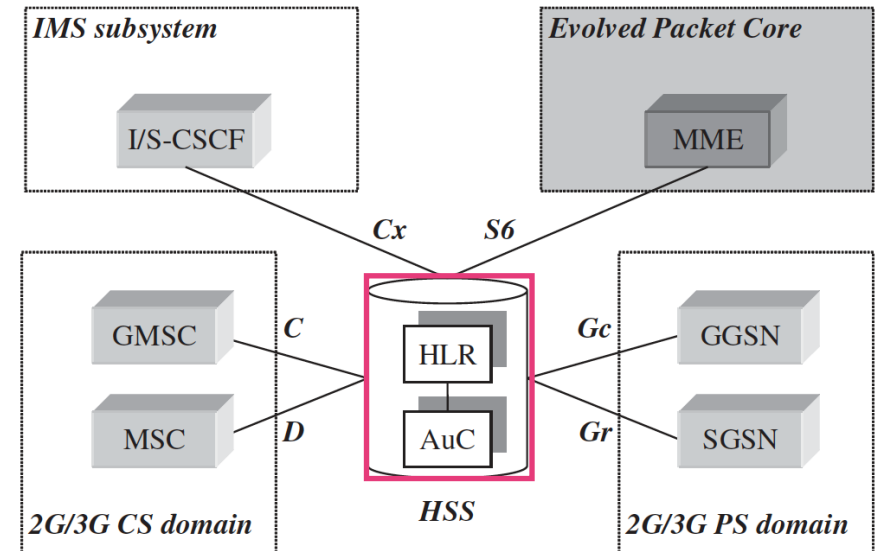


Figure 2.16 The EPC architecture for inter-working with 2G/3G access.

# 3.3 The HSS

- HSS (Home Subscriber Server)
  - ✓ The concatenation of HLR (Home Location Register) and AuC (Authentication Center)
  - ✓ These two functions being already present in pre-IMS 2G / GSM and 3G / UMTS networks



- HLR

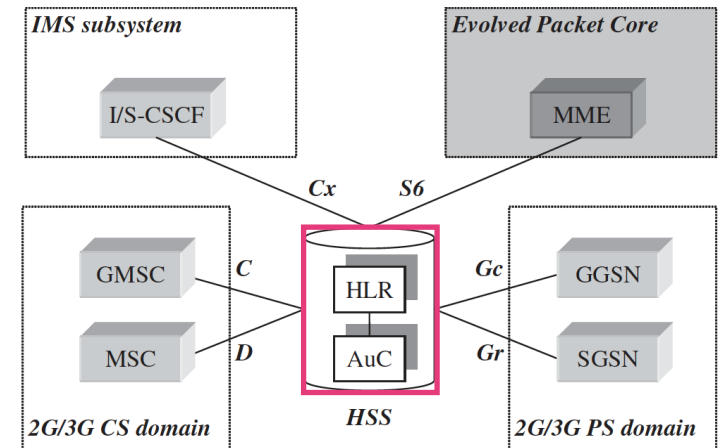
- ✓ In charge of storing and updating when necessary the database containing all the user subscription information, including (non-exhaustive)

- ➔ User identification and addressing

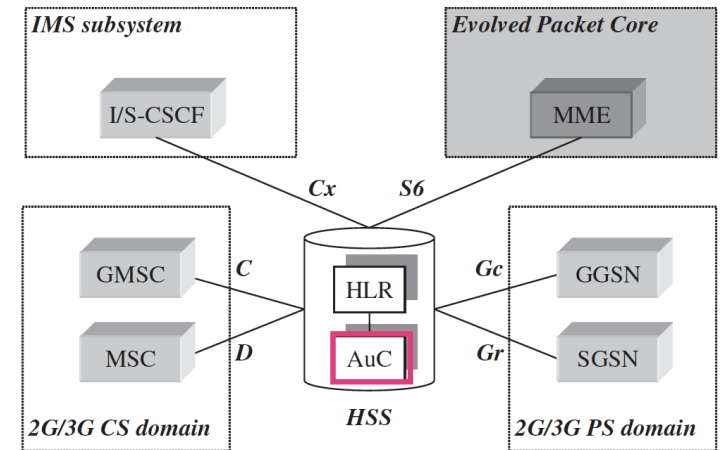
- Corresponds to IMSI (International Mobile Subscriber Identity) and MSISDN (Mobile Subscriber ISDN Number) or mobile telephone number

- ➔ User profile information

- Includes service subscription states and user-subscribed Quality of Service information (such as max allowed bit rate or allowed traffic class)



- AuC
  - ✓ In charge of generating security information from user identity keys
  - ✓ This security information is provided to HLR and further communicated to other entities in the network
  - ✓ Security information is mainly used for
    - ➔ Mutual network-terminal authentication
    - ➔ Radio path ciphering and integrity protection, to ensure data and signaling transmitted between network and terminal is neither eavesdropped nor altered

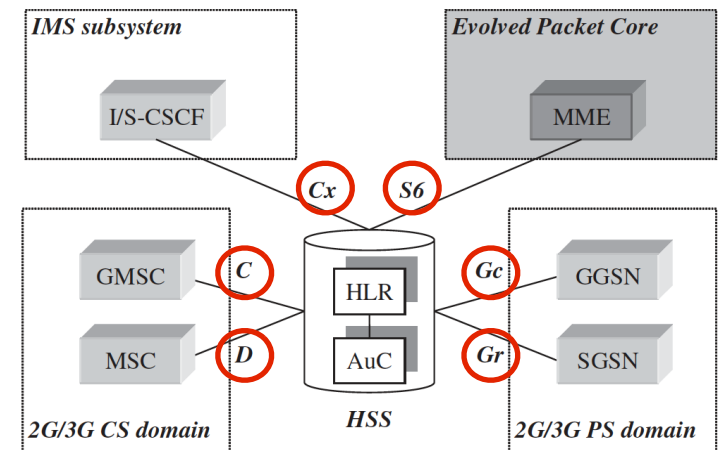


- The HSS of Evolved UMTS networks integrates both HLR and AuC features, including

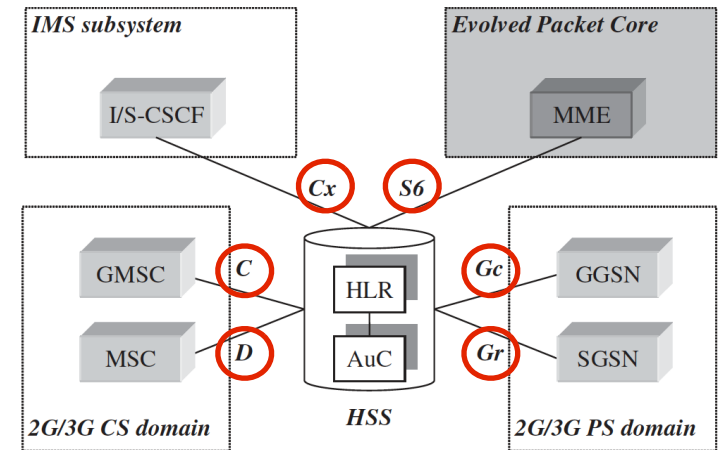
- ✓ Classical MAP (Mobile Application Part) features (support circuit and packet-based sessions) [*C*, *D*, *Gc*, *Gr*]

- ✓ IMS-related functions [*Cx*]

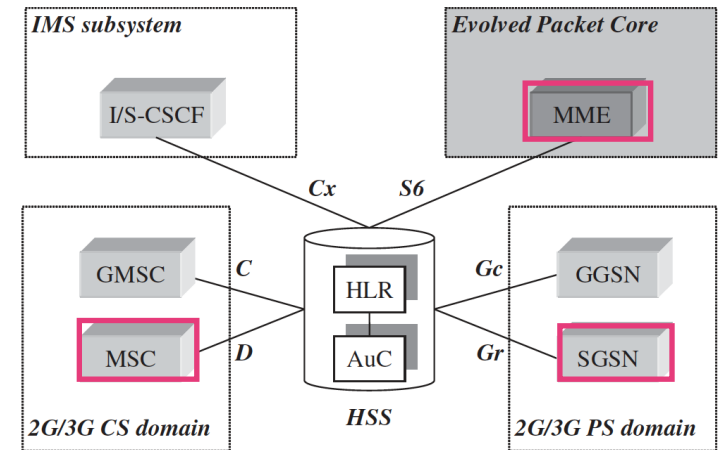
- ✓ All necessary functions related to the new Evolved Packet Core [*S6*]



- HSS interfaces
  - ✓ S6: to evolved Packet Core
  - ✓ Cx: to IMS CSCF nodes
  - ✓ C: to GMSC  
(3G non-IMS Core Network - CS domain)
  - ✓ D: to MSC  
(3G non-IMS Core Network - CS domain)
  - ✓ Gr: to SGSN  
(3G non-IMS Core Network - PS domain)
  - ✓ Gc: to GGSN  
(3G non-IMS Core Network - PS domain)



- Three main cases in which the HSS is actively involved
  - ✓ User registration
    - ➔ HSS is interrogated by the corresponding Core Network node as the user attempts to register to the network in order to check the user subscription rights
    - ➔ This can be done by either MSC, SGSN or MME, depending on the type of network and registration being requested
  - ✓ Terminal location update
    - ➔ As the terminal changes location areas, HSS is kept updated and maintains a reference of the last known area
  - ✓ User-terminated session request
    - ➔ HSS is interrogated and provides a reference of the Core Network node corresponding to the current user location



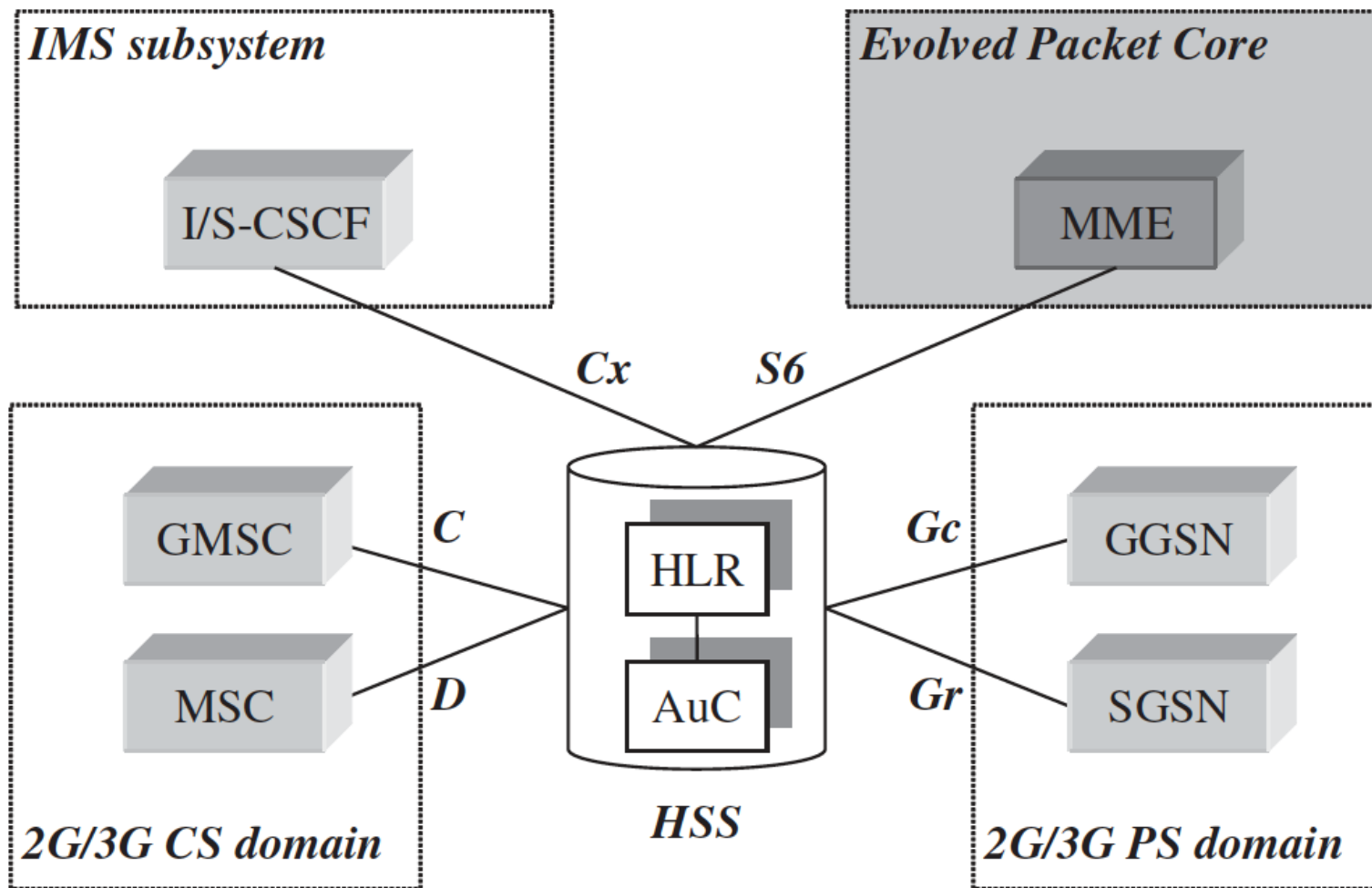


Figure 2.17 HSS structure and external interfaces.

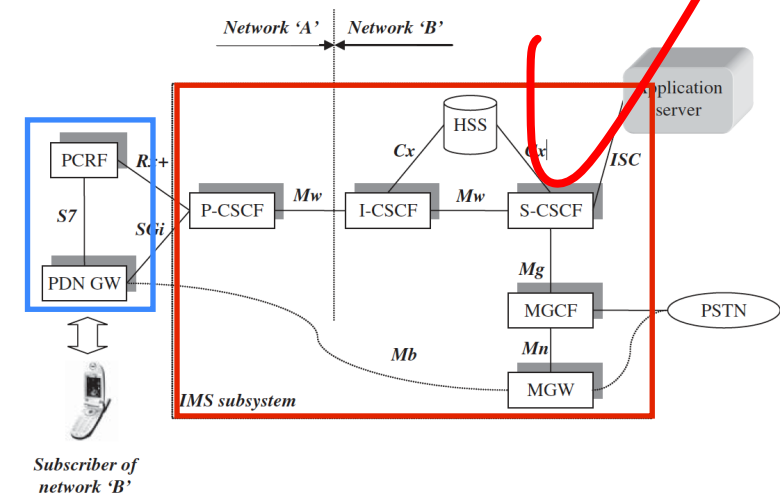
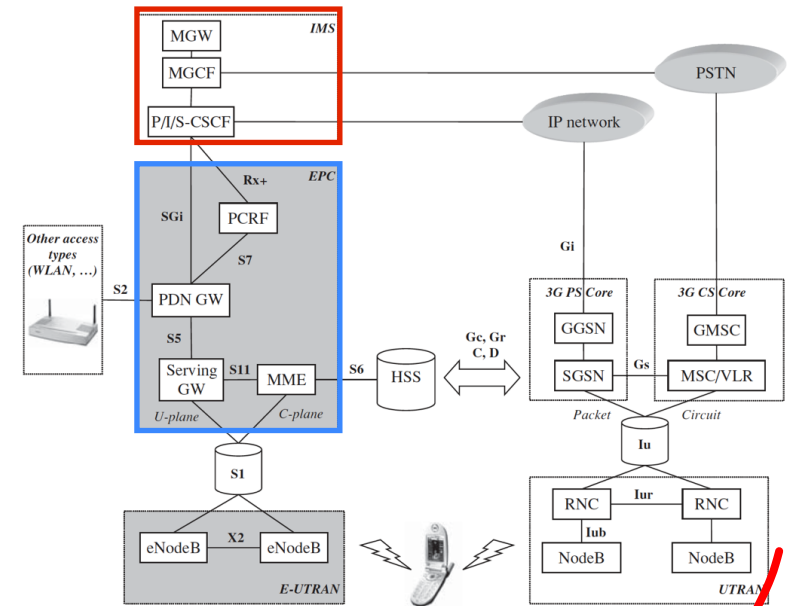
- Table 2.2 describes part of the user subscription information handled by HSS
  - ✓ The HSS information can be split into different categories
    - ➔ General information (mainly containing identifiers or security parameters)
    - ➔ GPRS-related information
    - ➔ IMS-related parameters
    - ➔ Other categories not listed in this table
      - e.g. data related to supplementary service or location services
  - ✓ For each of the information pieces, the standard specifies whether it is
    - ➔ Permanent data
      - Can only be changed by administration means, or
    - ➔ Temporary data
      - The data may possibly change resulting from normal system operation

<i>General data</i>		
IMSI	International Mobile Subscriber Identity	Permanent
MSISDN	Mobile Subscriber ISDN Number	Permanent
Authentication vector	Security information for user authentication, data confidentiality and data integrity	Temporary
...	...	...
<i>GPRS-related data</i>		
SGSN Address	Address of the SGSN the user is currently registered to	Temporary
Subscribed QoS	Specifies the Quality of Service attributes the user has subscribed to	Permanent
...	...	...
<i>IMS-related data</i>		
Authorized networks	List of visited network identifiers the user is allowed for roaming	Permanent
Private user identity	In the form of 'user@realm'	Permanent
Public user identities	List of user identities in the form of 'sip:user@domain'	Permanent
Registration status	State of registration of a user IMS identity	Temporary
S-CSCF name	Identifies the S-CSCF the subscriber is registered to	Temporary
...	...	...

Table 2.2 Subset of user information data stored in the HSS.

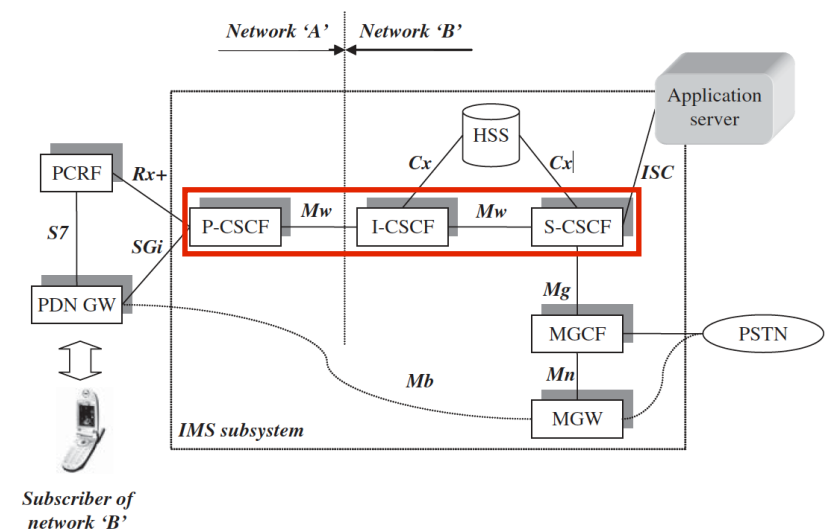
# 4. The IMS Subsystem

- IMS (IP Multimedia Subsystem)
  - ✓ A generic platform offering IP-based multimedia services
  - ✓ Provides functions and common procedures for
    - ➔ Session control
    - ➔ Bearer control
    - ➔ Policy
    - ➔ Charging
- IMS can be deployed on top of
  - ✓ UTRAN access
  - ✓ 2G GPRS / EDGE network
- Evolved UTRAN will add a lot of value to IMS and allow more quality-demanding services to be supported in a more efficient way



# 4.1 The Session Control Function

- CSCF (Call Session Control Function)
  - ✓ Plays a key role in IMS architecture, for establishing, terminating or modifying IMS sessions
  - ✓ A specific type of SIP (Session Initiation Protocol) server
    - ➔ SIP is the base protocol developed by IETF for management of IP-based multimedia sessions and services
- CSCF can play three different roles in IMS network
  - ✓ Proxy (P-CSCF)
  - ✓ Interrogating (I-CSCF)
  - ✓ Serving (S-CSCF)



- P-CSCF

- ✓ The first contact point reached by user terminal SIP messaging within IMS subsystem

- ✓ In the case of roaming, P-CSCF

- ➔ Belongs to visited network

- ➔ Forwards user-originated SIP requests towards the relevant I-CSCF or S-CSCF

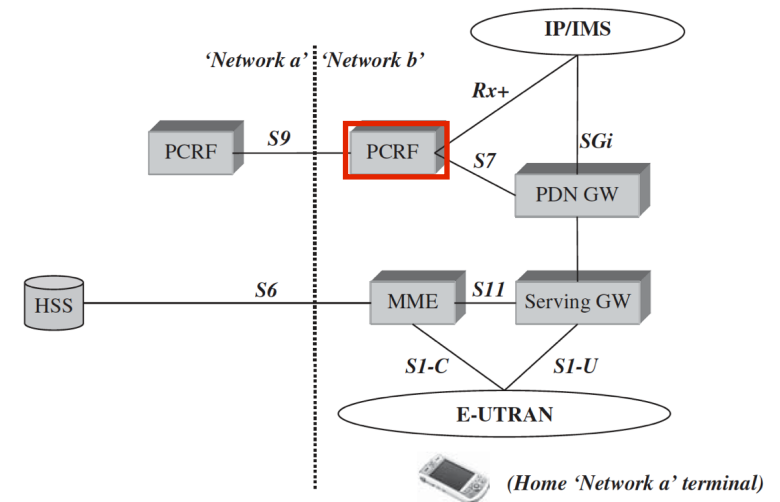
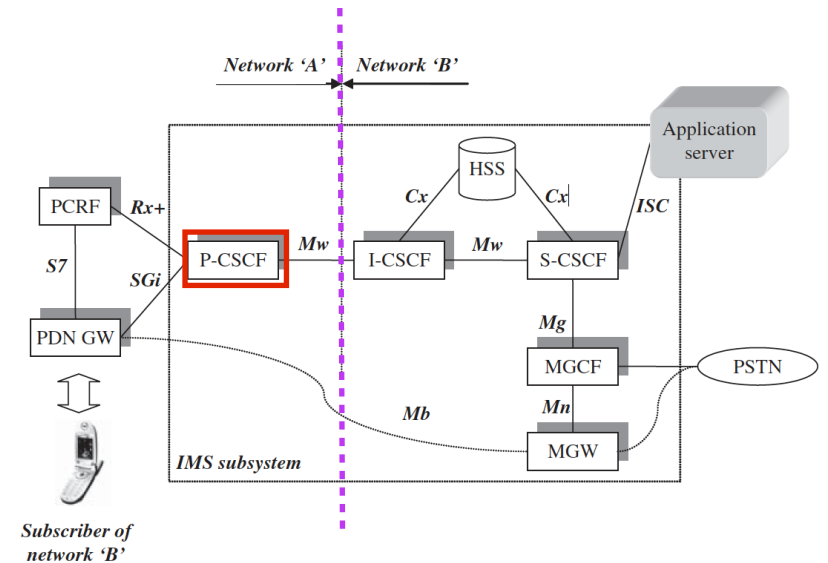
- ✓ P-CSCF supports two main functions

- ➔ Control of allocated bearers within the visited network

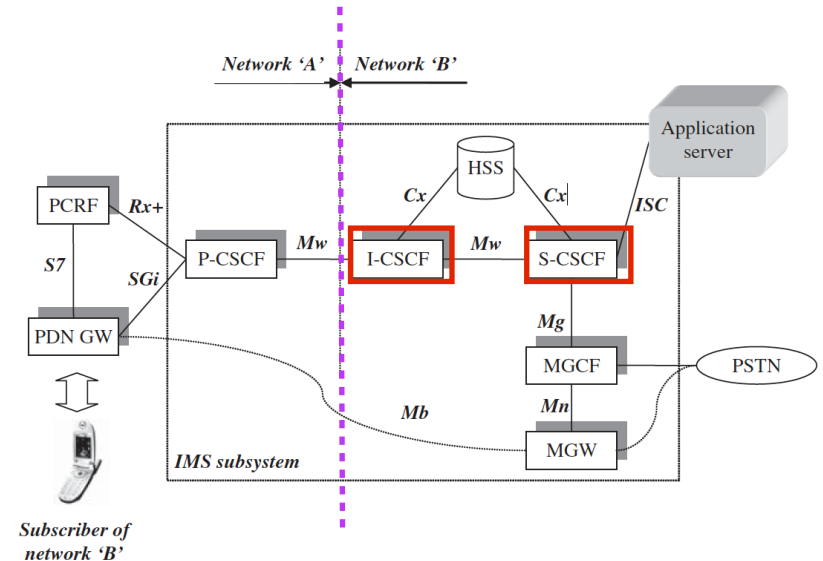
- ➔ Generation of charging records, so that the visited network can charge the user home network according to the allocation and usage of resources for this part of the session path

- ✓ P-CSCF is responsible for SIP header compression

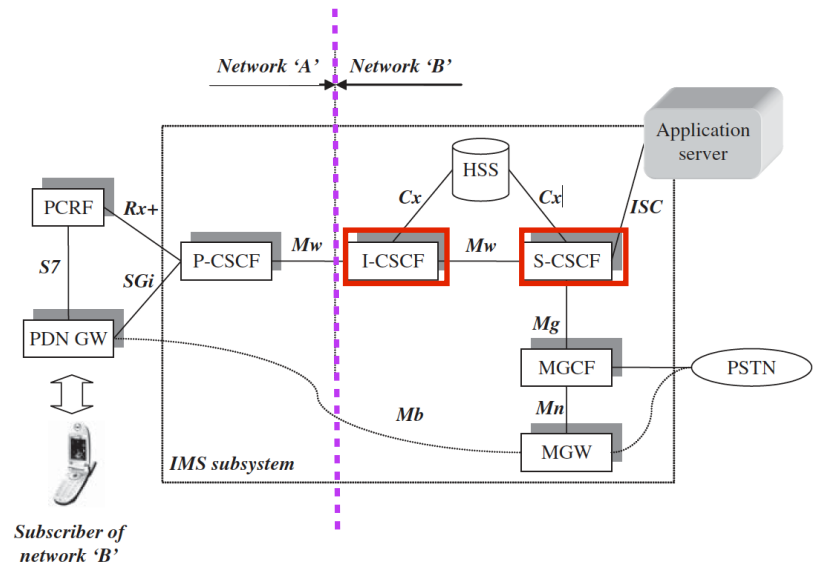
- ➔ To minimize the bandwidth requirement for the transmission of SIP signaling over the visited access network



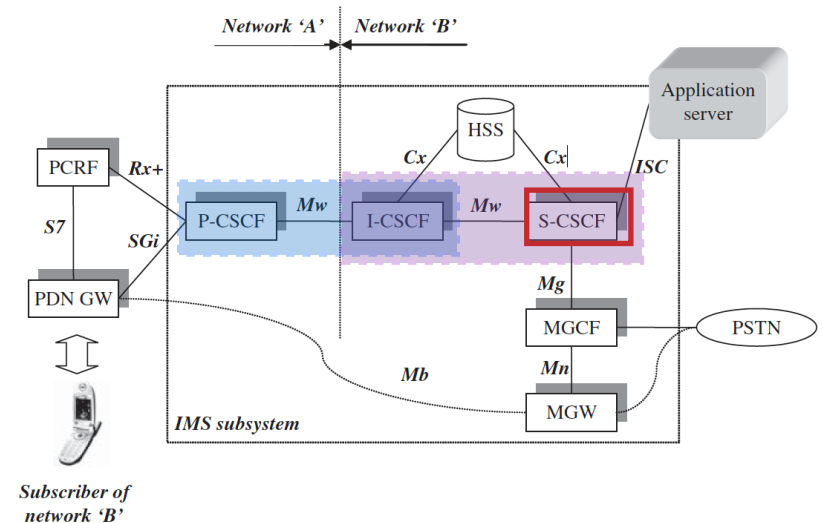
- I-CSCF
  - ✓ An entry point for all connections related to a user belonging to its network
  - ✓ Main task
    - ➔ Identify the relevant S-CSCF (based on HSS interrogation) for a user performing SIP registration
    - ➔ Forward the registration request accordingly
  - ✓ I-CSCF may serve as a THIG (Topology Hiding Inter-network Gateway)
    - ➔ In case an operator has some specific security requirements and
    - ➔ Would like to hide the configuration and topology of its network from the outside



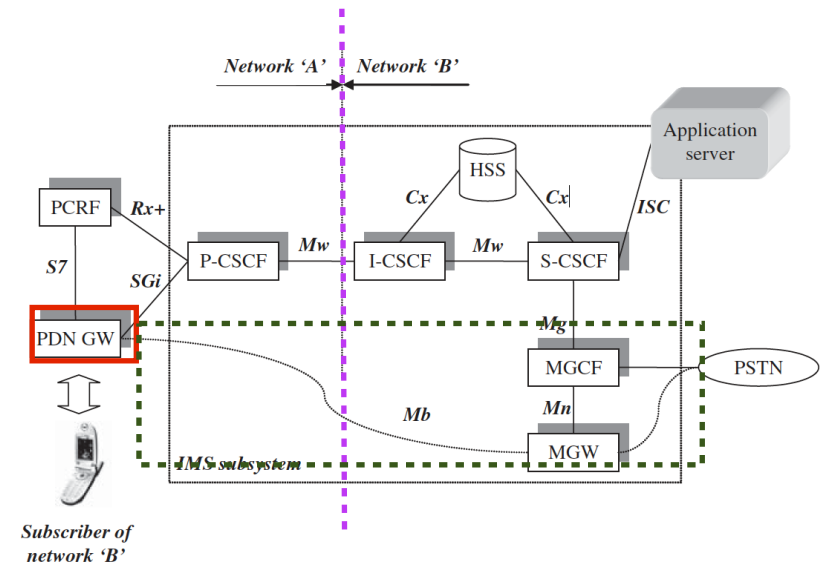
- S-CSCF
  - ✓ The SIP server to which the user will be registered
  - ✓ Provides access to Application Servers to the end-user
- S-CSCF plays three types of roles
  - ✓ Registrar
    - ➔ The entity to which the SIP user is registered
  - ✓ Proxy server
    - ➔ When SIP service requests are forwarded to another SIP server
  - ✓ User agent
    - ➔ When SIP request terminates at the P-CSCF



- S-CSCF
  - ✓ Performs session control services for UE
    - ➔ Maintains a session state by the network operator for support of the services
  - ✓ In charge of CDR generation (Charging Data Record)
    - ➔ The end-user can be charged according to
      - Requested service
      - Quality of Service
      - Amount of resource being allocated to the session
- It is possible that some network implementers
  - ✓ Aggregate P-CSCF and I-CSCF logical nodes into one physical network entity, or
  - ✓ I-CSCF and S-CSCF may also be integrated into one single physical box



- In IMS architecture, in the case of a roaming subscriber accessing a home server from a visited network
  - ✓ The P-CSCF belongs to the visited network A, whereas the I-CSCF and S-CSCF to which the user will register belong to the home network 'B'
  - ✓ This case corresponds to the local breakout where traffic is routed through the local PDN GW
  - ✓ The figure only describes the signaling path between network entities
  - ✓ The data bearer follows a different path and is not processed by CSCF nodes
  - ✓ A SIP server (like the CSCF nodes) only cares about session signaling



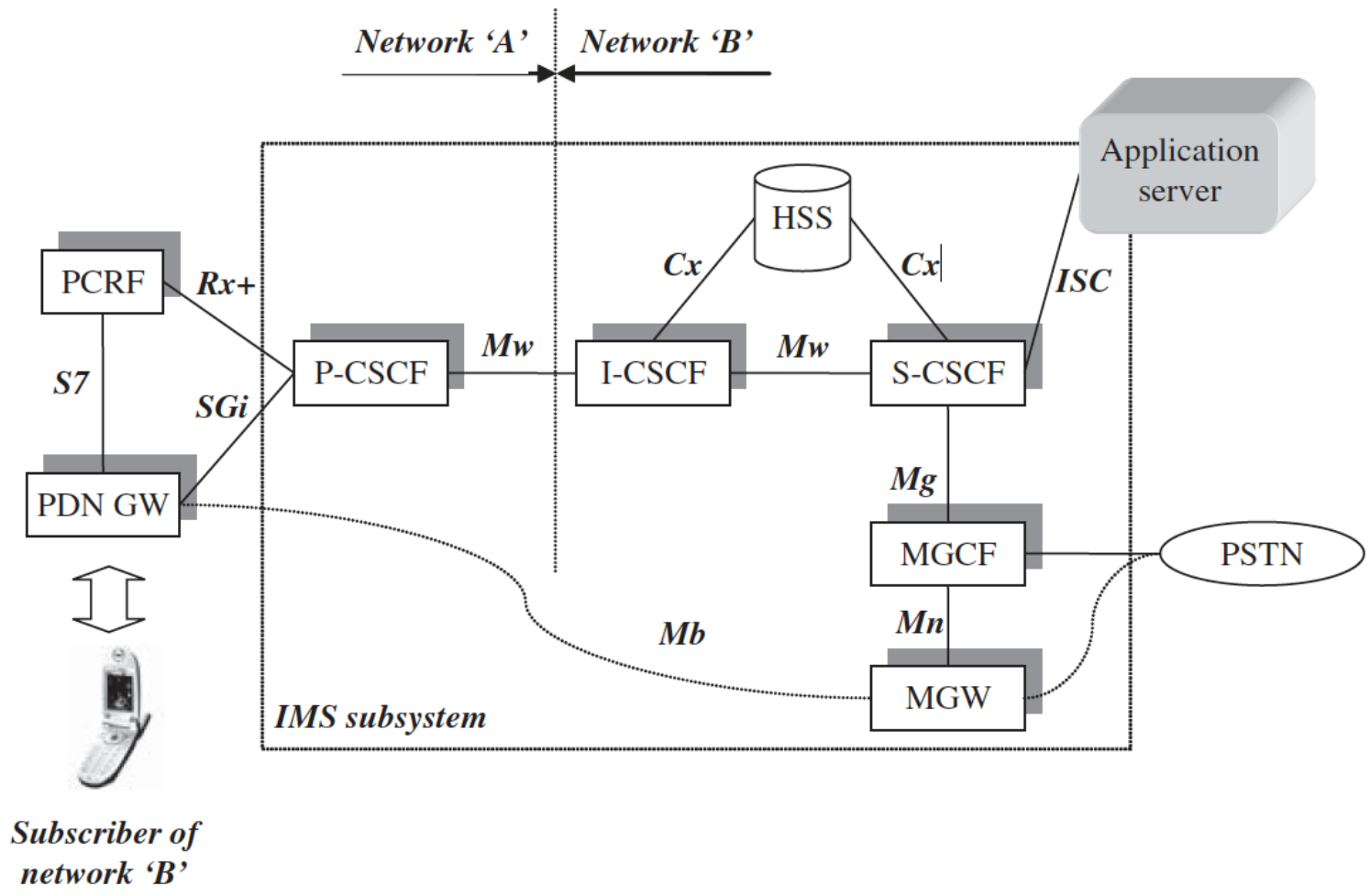


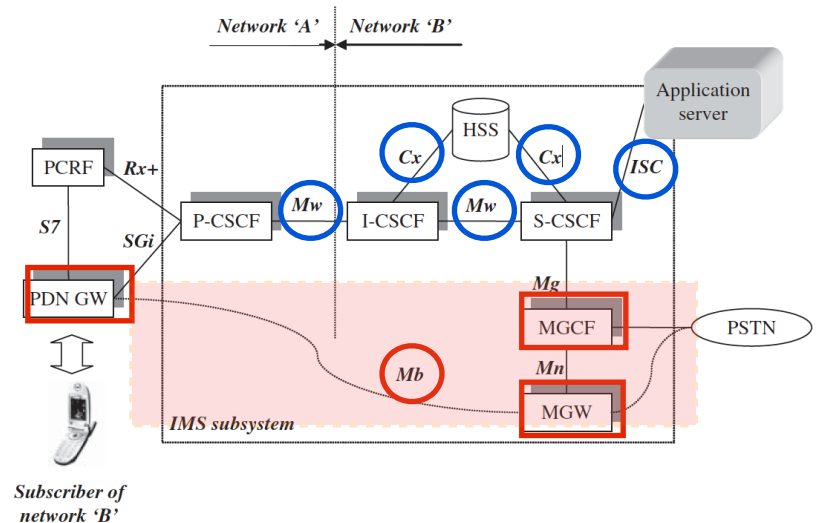
Figure 2.18 The IMS subsystem architecture.

- The figure shows one example of a data bearer path, using dotted lines over the Mb interface, in the case of a mobile terminal to fixed-line terminal voice call (PSTN)

✓ Mb interface: represents the User plane of the Gi interface coming from PDN GW node

✓ Part of the bearer path, up to MGW (Media Gateway), is carried over IP

✓ The call setup signaling procedures are SIP-based, up to MGCF (Media Gateway Control Function) which is in charge of signaling translation



- Main interfaces

- ✓ *Mw* & *ISC* (IMS Service Control) interfaces

- ➔ Carry SIP signaling exchanged

- ➔ *Mw*: between CSCF session control servers or

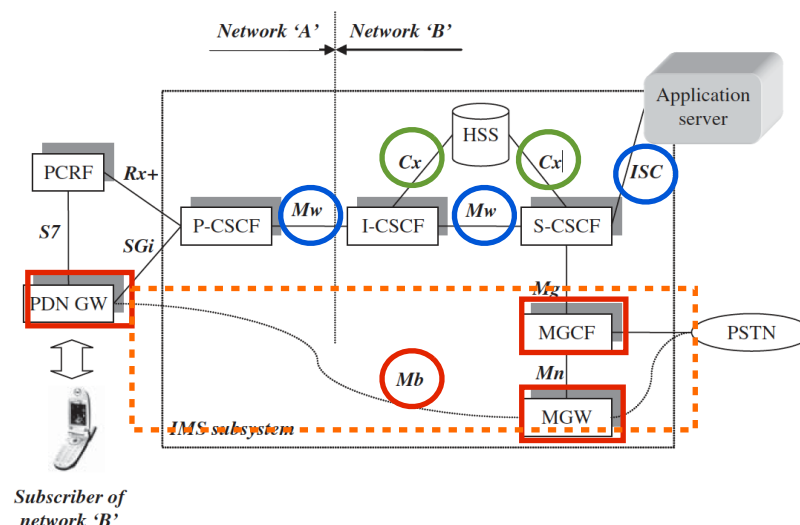
- ➔ *ISC*: between S-CSCF and Application Servers

- ✓ *Cx* interface

- ➔ CSCF nodes are connected to HSS via *Cx* interface

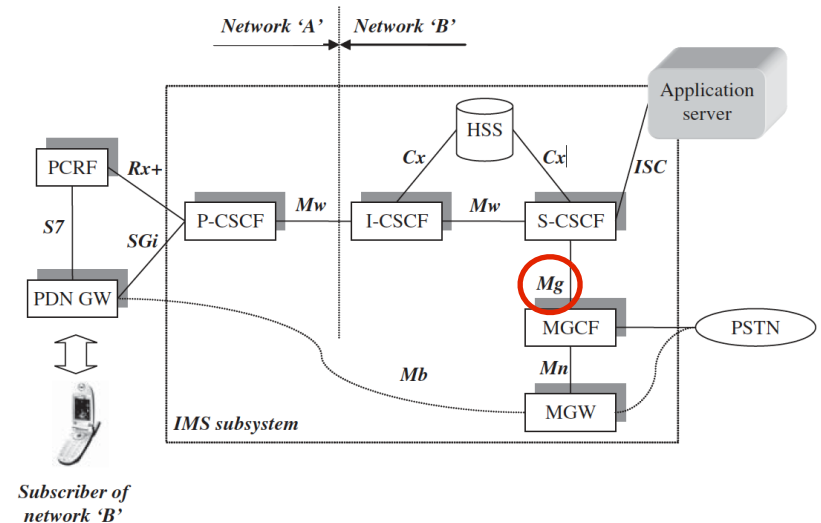
- ➔ Provides services for user data handling and user authentication

- ➔ *Cx* interface uses Diameter, an IETF-originated protocol, for network access and IP mobility AAA (Authentication, Authorization and Accounting)



# 4.2 The Media Gateway Nodes

- One of the IMS objectives: interact with legacy PSTN (Public Switched Telephone Network) for voice services
- IMS handles voice as IP traffic
  - ✓ Requires some adaptations for signaling and voice traffic, performed by MGCF and MGW nodes
- MGCF (Media Gateway Control Function) supports three main functions
  - ✓ Call control protocol conversion
  - ✓ MGW (Media Gateway) control
  - ✓ I-CSCF identification
    - ➔ Select the relevant I-CSCF when a mobile-terminated call request is arriving from PSTN
    - ➔ Performed on the basis of the analysis of the called party routing number provided by PSTN
- SIP signaling is used to set up session
  - ✓ Forwarded by S-CSCF to MGCF over Mg interface
  - ✓ This SIP signaling is then translated into ISUP (ISDN User Part) signaling by MGCF before transmission to PSTN network, and vice versa



- MGW (Media Gateway) is responsible for the following processes under the control of MGCF

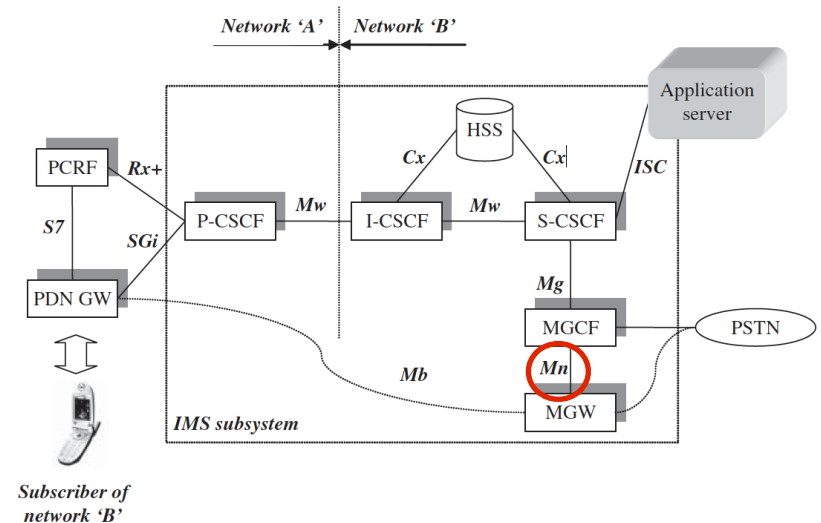
- ✓ Media conversion
- ✓ Bearer control
- ✓ Payload processing (e.g. codec, echo canceller, conference bridge)

- *Mn* interface

- ✓ Between MGW and MGCF using H.248 protocol

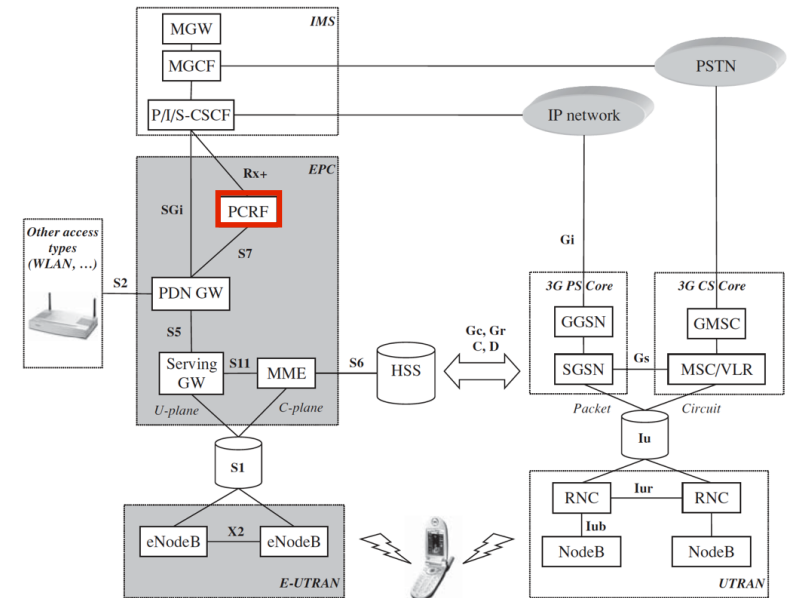
➔ It is a sort of toolbox which contains all the necessary and generic features to describe, create, modify and delete media streams within a Media Gateway

➔ H.248 standard, published by ITU, is the international standard for media gateway control



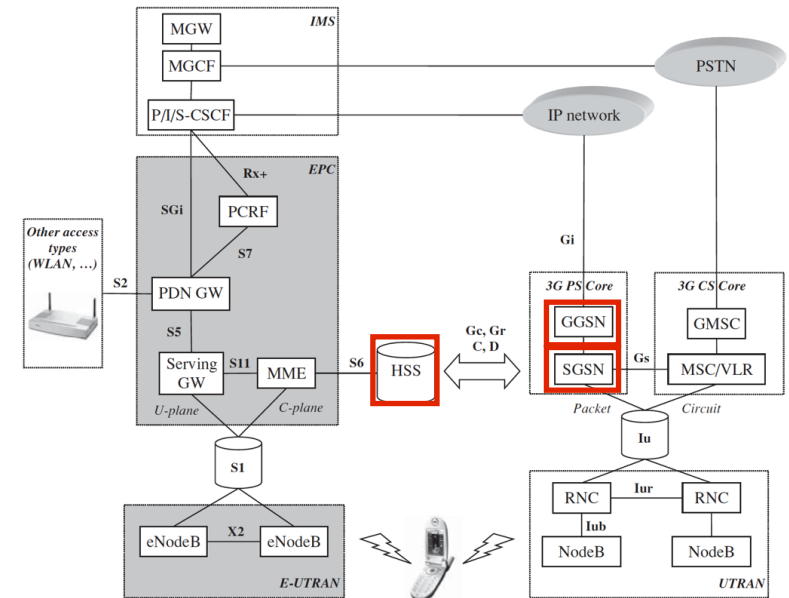
# 5. Policy Control and Charging

- Policy control
  - ✓ The application of rules to determine resource access and usage
- Policy control interacts with
  - ✓ Packet Core nodes, and
  - ✓ The SIP servers belonging to IMS subsystem, such as P-CSCF



# 5.1 Policy Control in UMTS

- In early UMTS implementation (including UMTS 3GPP Release 5 specifications), Policy Control was user-terminal driven
  - ✓ Depending on the requested service (Web browsing, streaming, Push-To-Talk)
    - ➔ The user terminal was requesting a PDP context (Packet Data Protocol context) with Quality of Service attributes being set accordingly to the type of the service (real-time vs. non real-time service, maximum and mean bit rate, delay requirements, etc.)
  - ✓ The requested QoS parameters were eventually checked by SGSN based on user subscription limitation stored in HSS



- Using a set of CDR (Charging Data Record) generated by network elements such as SGSN and GGSN

✓ The operator had the possibility of charging the end customer on

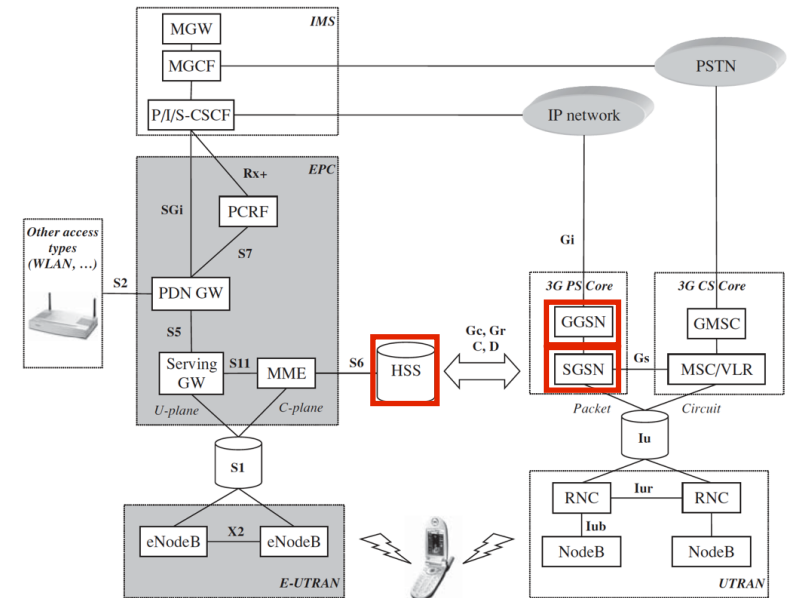
➔ time

➔ volume

➔ allocated Quality of Service

- As IMS really began to emerge from the standard, and considering the future of IP-based applications (including VoIP transition)

✓ The 3GPP community decided to define a new architecture for more flexible policy control and charging mechanisms



- **5.1.1 The Flow Based Control Enhancement**

- Pre-Release 6 UMTS standard

- ✓ One PDP context corresponds to one set of negotiated Quality of Service attributes

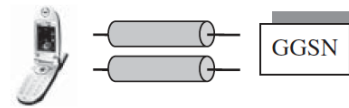
- ✓ Charging is applied to each PDP context

- Release 6 evolution

- ✓ The network has the possibility to identify the different SDF (Service Data Flows) being aggregated within a single PDP context

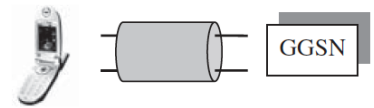
- ✓ This gives the possibility to the network of controlling (meaning allowing or blocking) each of the flows and charging the end-user having a much better accuracy

*1 PDP bearers = 1 QoS flow  
→ PDP-based charging*



Up to UMTS R5

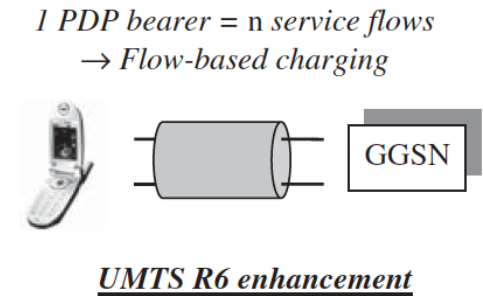
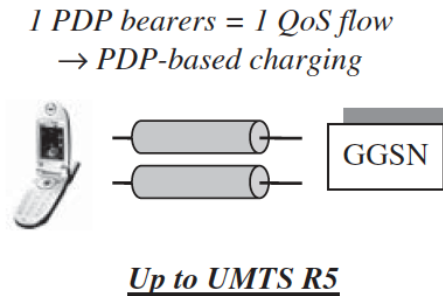
*1 PDP bearer = n service flows  
→ Flow-based charging*



UMTS R6 enhancement

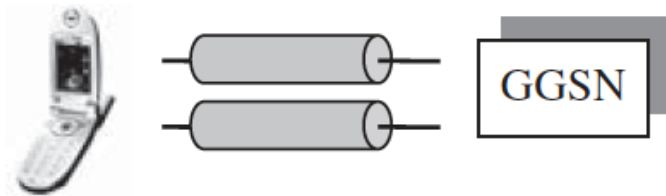
- Each of those elementary flows, known as SDF (Service Data Flow), is defined as a 5-tuple

- ✓ Source IP address
- ✓ Destination IP address
- ✓ Source port
- ✓ Destination port
- ✓ Protocol used above IP



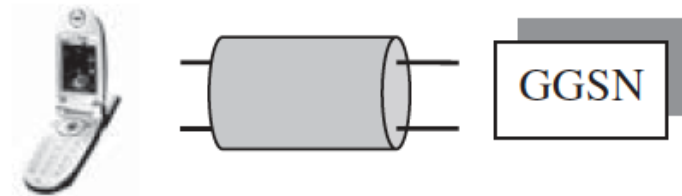
- This definition allows identifying each of the information flows from the mass of IP packets sent and received by the terminal, for example
  - ✓ A Web-browsing session towards server A
  - ✓ Another Web-browsing session towards server B
  - ✓ A streaming session from server Y
  - ✓ A SIP-signaling flow associated to an IMS service
  - ✓ . . . .

*1 PDP bearers = 1 QoS flow*  
→ PDP-based charging



*Up to UMTS R5*

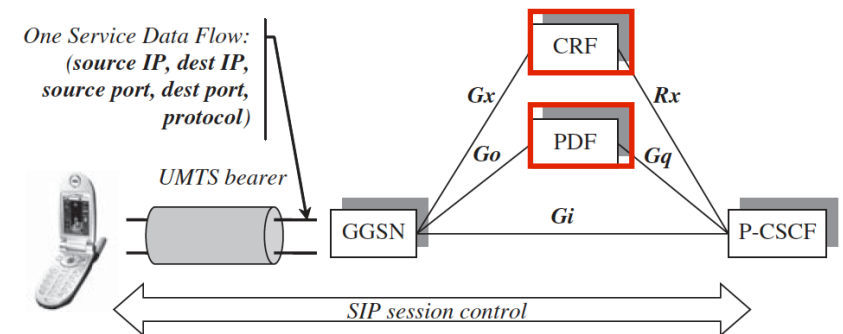
*1 PDP bearer = n service flows*  
→ Flow-based charging



*UMTS R6 enhancement*

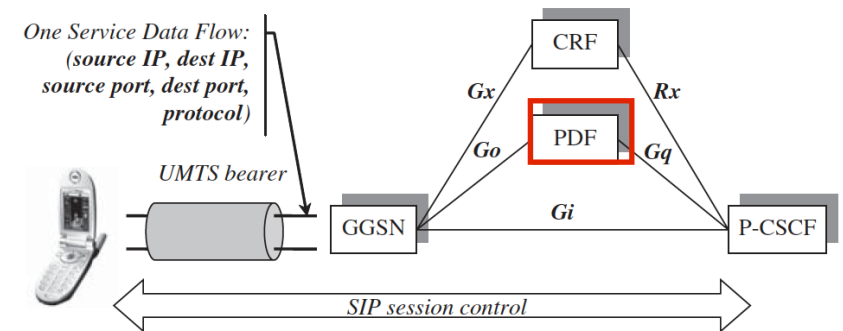
Figure 2.19 The evolution of Policy Control and Charging.

- Figure 2.20 illustrates the two new network elements introduced in R6 standard to allow flow-based policy control and charging
  - ✓ Policy Decision Function (PDF)
  - ✓ Charging Rules Function (CRF)

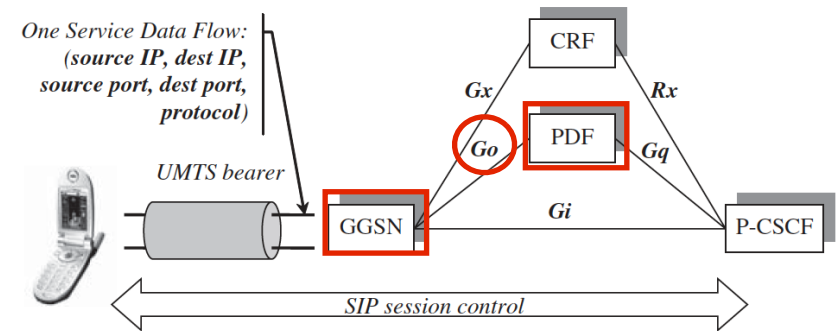


- **PDF (Policy Decision Function)**

- ✓ The network entity where the policy decisions are made
- ✓ As the IMS session is being set up
  - ➔ SIP signaling containing media requirements are exchanged between terminal and P-CSCF
- ✓ At some time in the session establishment process, the PDF receives those requirements from P-CSCF and makes decisions based on network operator rules, such as
  - ➔ Allowing or rejecting the media request
  - ➔ Using new or existing PDP context for an incoming media request
  - ➔ Checking the allocation of new resources against the maximum authorized



- GGSN
  - ✓ In charge of enforcing policy decisions received from PDF over G<sub>o</sub> interface
- Policy rules
  - ✓ Either pushed by PDF, e.g. as new media are added to an existing session, or
  - ✓ Requested by GGSN itself, when the establishment of a new PDP context is requested by terminal
- Policy-enforcement process performed by GGSN
  - ✓ Each packet received by GGSN in the upstream or downstream direction is
    - ➔ Classified (meaning associated with one of the existing Service Data Flow) and
    - ➔ Checked against filters being defined by PDF for the corresponding Service Data Flow (SDF)



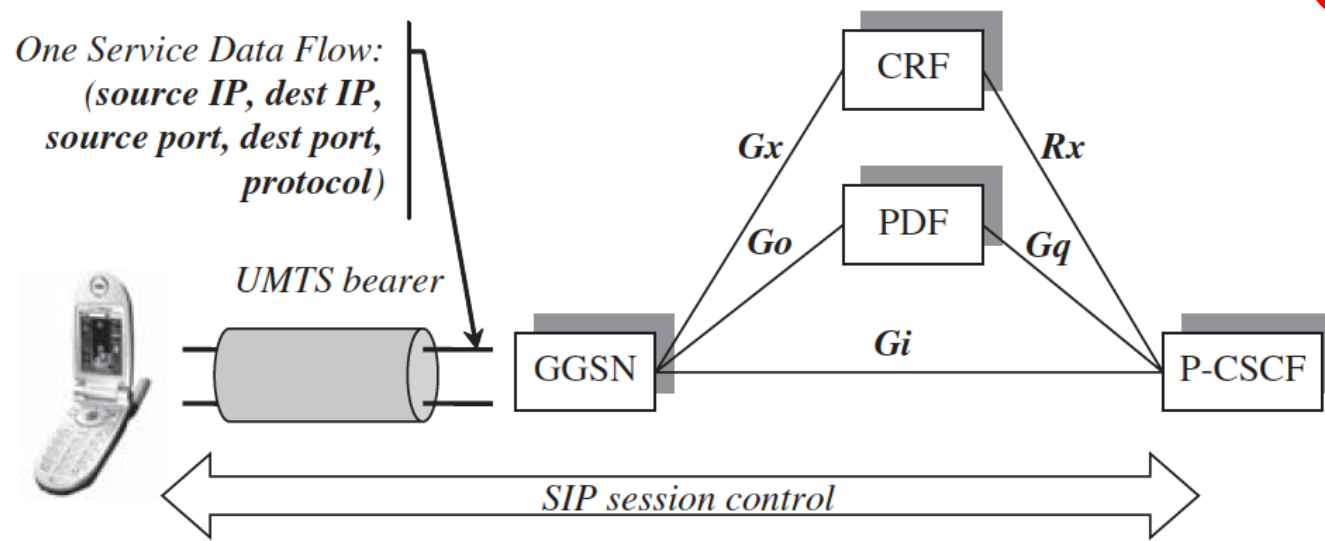


Figure 2.20 UMTS R6 Policy Control architecture.

- **CRF (Charging Rules Function)**

- ✓ Provide operator-defined charging rules applicable to each service data flow

- ✓ CRF selects the relevant charging rules based on information provided by P-CSCF, such as

- ➔ Application identifier

- ➔ Type of stream (audio, video, etc.)

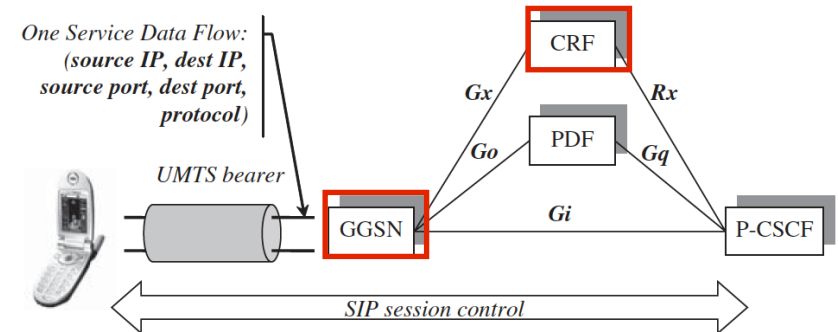
- ➔ Application data rate, etc.

- ✓ Charging rules are then provided by CRF to GGSN in the form of a packet filter similar to the 5-tuple gate definition (*source IP, dest IP, source port, dest port, protocol*)

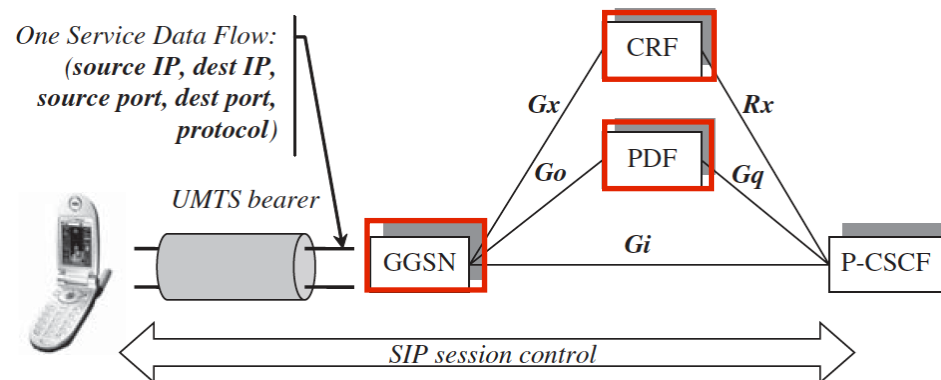
- ✓ Using the charging rules, GGSN is able to

- ➔ Count packets for each of the service data flows

- ➔ Generate corresponding charging records

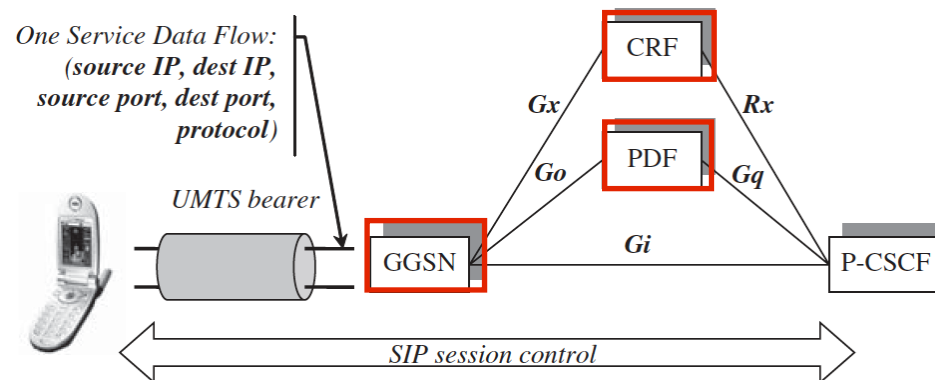


- CRF and PDF network nodes interact with GGSN and P-CSCF using specific interfaces
  - ✓  $Gx$ ,  $Go$ ,  $Gq$  and  $Rx$  interfaces make use of already existing IETF protocols
  - ✓  $Go$ : based on COPS (Common Open Policy Service)

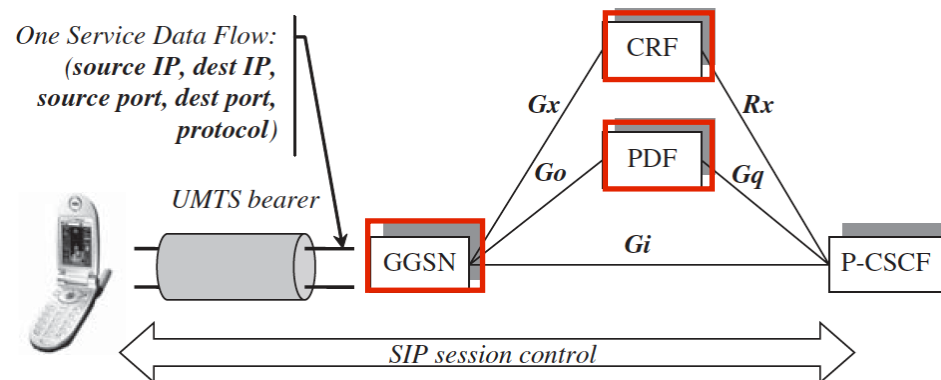


## ✓ COPS (Go interface)

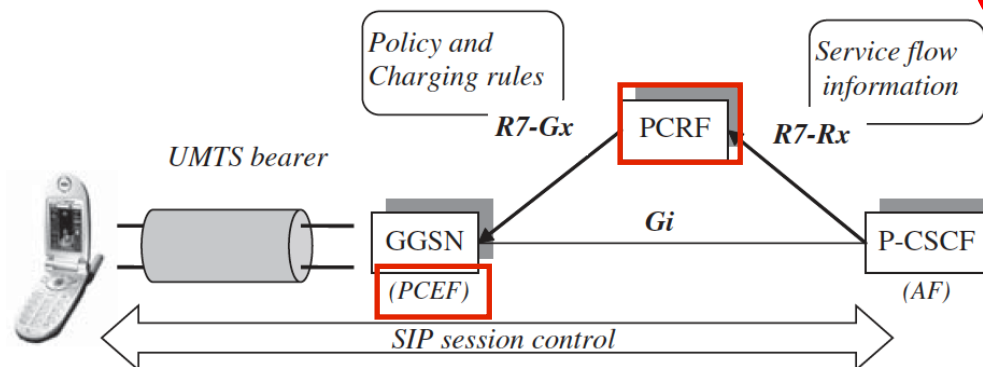
- ➔ Proposes generic policy control for packet networks and is based on a simple client/server model
- ➔ Two entities are defined
  - PDP (Policy Decision Point)
    - ▶ The policy server making the decision – in the UMTS case, this role is supported by PDF
  - PEP (Policy Enforcement Point)
    - ▶ The policy client, responsible for enforcing the policy decisions – in the UMTS case, this role is supported by GGSN



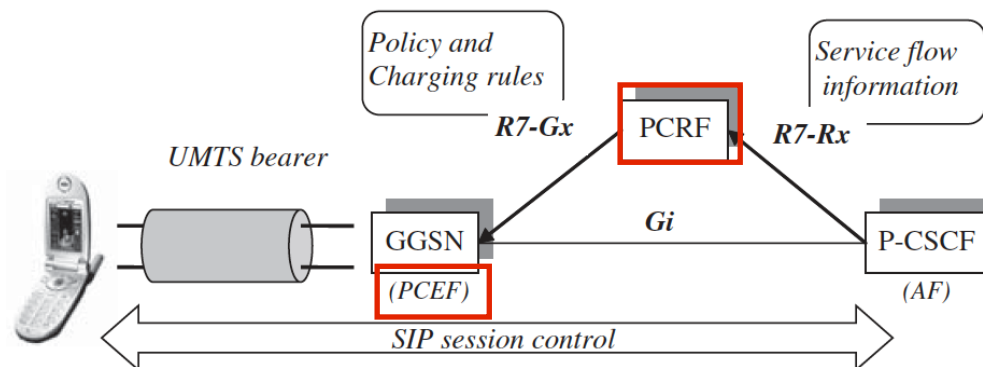
- ✓ Other policy control and charging interfaces:  $Gq$ ,  $Gx$  and  $Rx$
- ➔ Based on an extended version of IETF Diameter protocol, similarly to the  $Cx$  interface mentioned in the HSS section above



- **5.1.2 The 3GPP R7 UMTS Enhancement**
- 3GPP Release 7 defines a new converged architecture to optimize the interactions between policy and charging functions
  - ✓ PCRF (Policy and Charging Rules Function)
    - ➔ A concatenation of PDF and CRF
  - ✓ This model is actually not specific to UMTS or UTRAN access networks, as it was defined for all types of IP access, including
    - ➔ 3GPP access
    - ➔ WLAN access
    - ➔ Fixed IP broadband access



- In the generic policy and charging control 3GPP model
  - ✓ PCEF (Policy and Charging Enforcement Function) supports
    - ➔ Service data flow detection
    - ➔ Policy enforcement
    - ➔ Flow-based charging
- In the case of WLAN non-3GPP access
  - ✓ The PCEF is implemented by PDG (Packet Data Gateway)



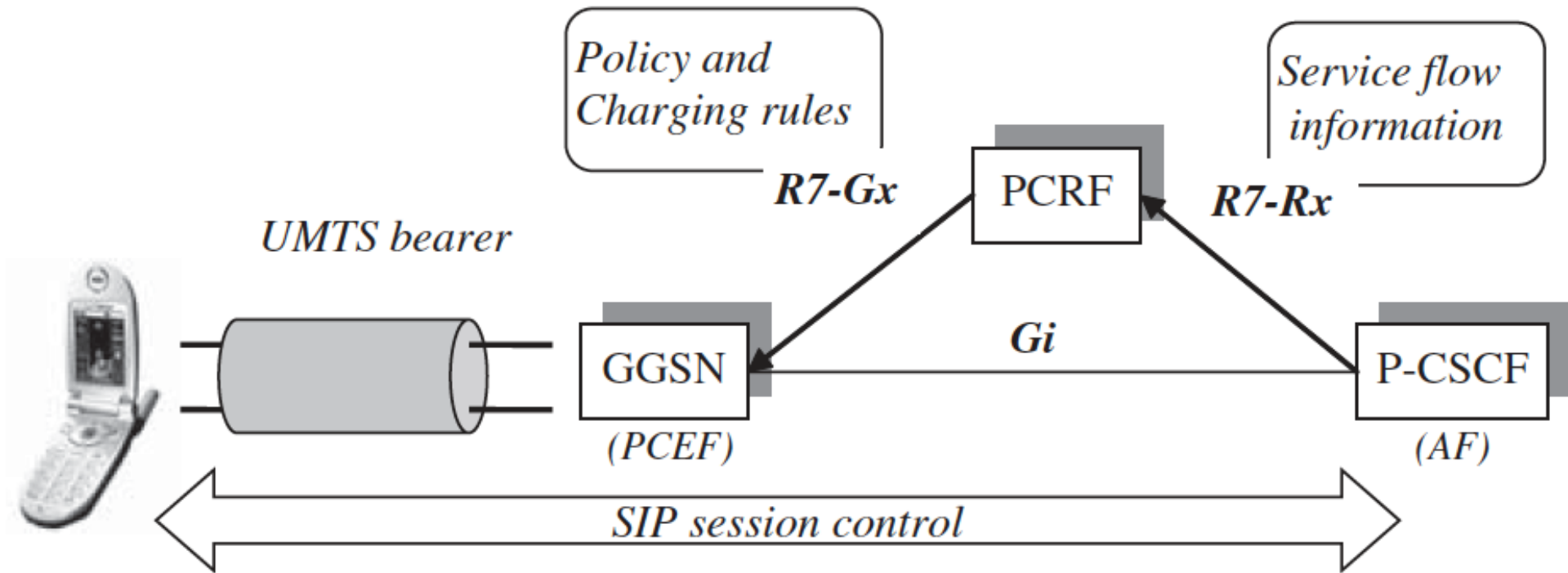
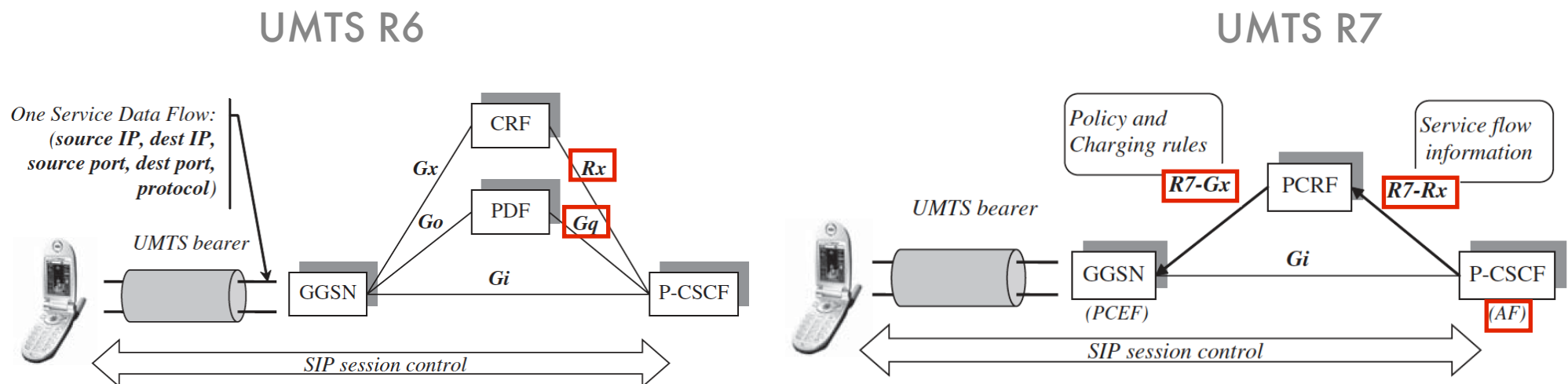


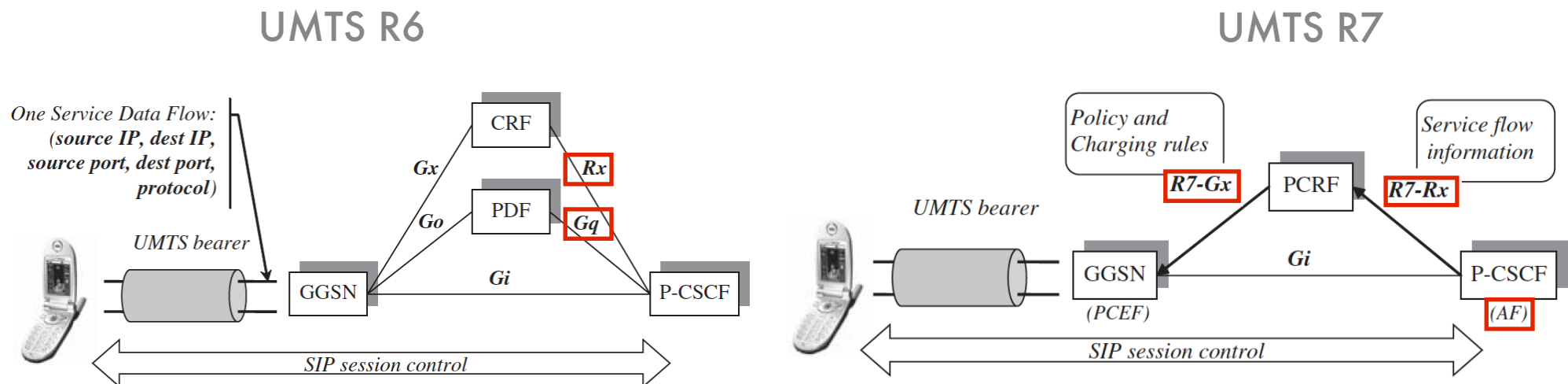
Figure 2.21 The UMTS R7 evolution.

- AF (Application Function)
  - ✓ The network element which supports applications that require dynamic policy and / or charging control
    - ➔ In the IMS model, AF is implemented by P-CSCF
- R7-Rx interface
  - ✓ Combines both the former Rx and Gq with message definition – both based on the Diameter IETF protocol
  - ✓ P-CSCF can therefore provide service-dynamic information to PCRF



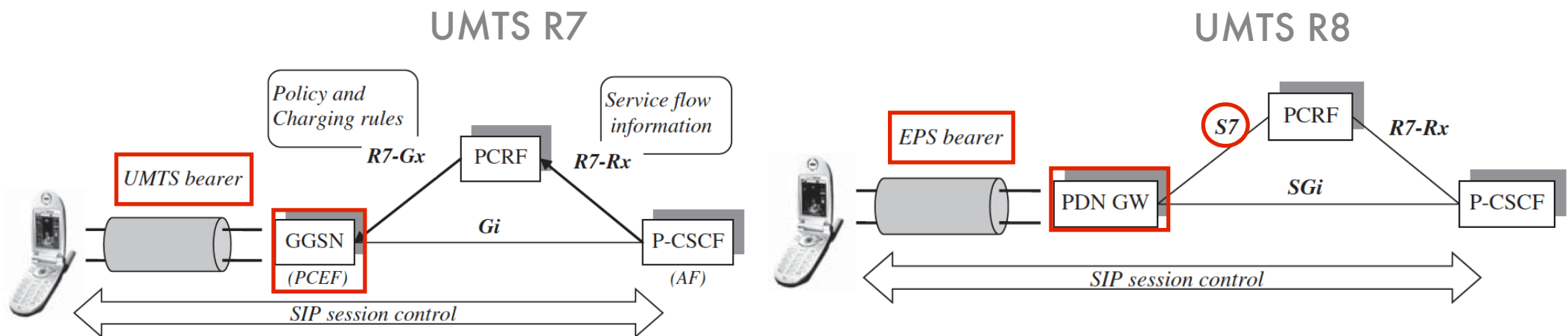
- *R7-Rx* interface

- ✓ Defined in a backward-compatible way, in order to ease introduction in already deployed networks
- ✓ This means that a R7 PCRF can interact with R6 P-CSCF using former *Rx* and *Gq* interfaces
- ✓ Similarly, a R7 P-CSCF can also interact with R6 PDF and CRF nodes



# 5.2 Evolved UMTS Policy Control

- The model for policy and charging architecture in EPS networks is aligned with the latest 3GPP UMTS Release 7 evolution
  - ✓ The new S7 interface introduced in EPC is based on its *R7-Gx*
  - ✓ The PDN gateway plays the role of PCEF, as an equivalent of the GGSN for the policy and charging control functions



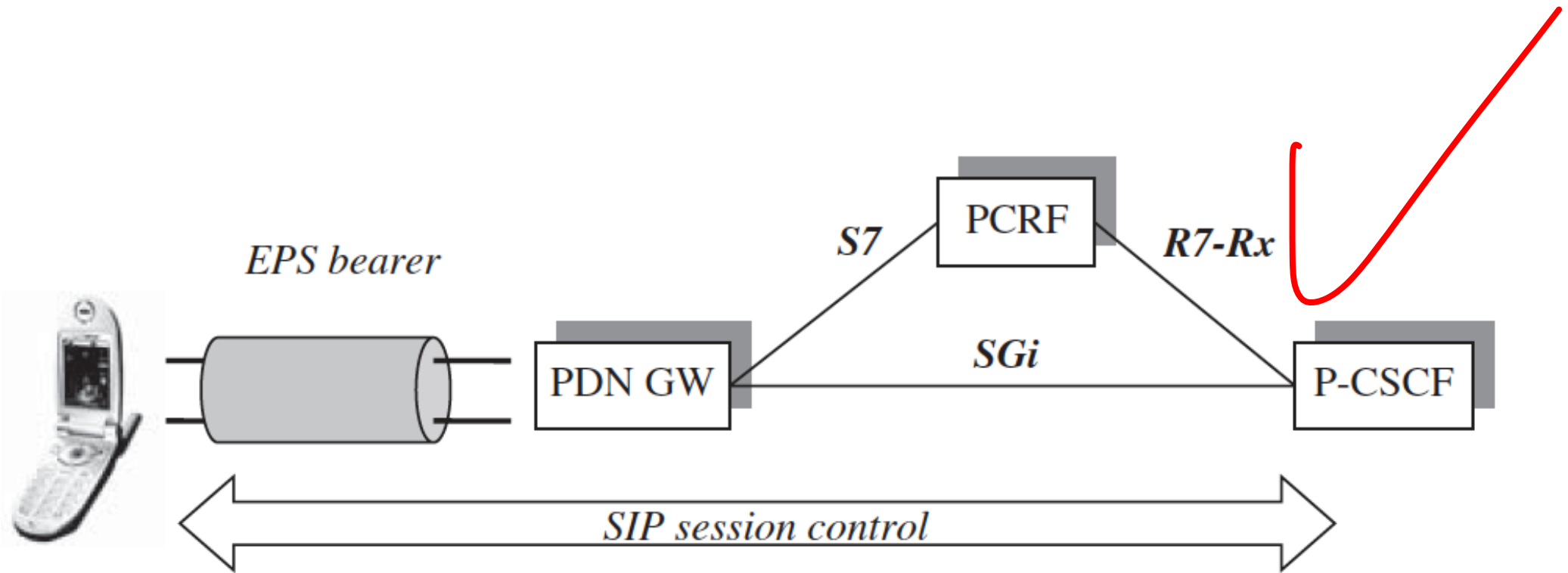


Figure 2.22 The EPS policy and charging architecture.

# 5.3 The Charging Architecture

- In legacy 2G or 3G circuit-switched based networks, charging was quite an easy task
  - ✓ Any granted user service request involved the allocation of a fixed amount of resource for a given time
  - ✓ Because circuit switched technology means guaranteed bandwidth and delay
    - ➔ The charging rules are generally simply based on the allocated resource size and use time
  - ✓ When using packet applications and packet transmission
    - ➔ The end-user may be inactive for long periods of time, e.g.
      - During the silent phase of a PoC (Push-to-talk over Cellular) session or
      - During the time needed to read a Web page freshly downloaded
    - ➔ During those inactivity phases, the resources may be used for another purpose
  - ✓ Therefore, it may be seen as quite unfair to only charge the end-user for connection time or service-use duration

- The standard does not specify the charging schemes, leaving to the operator the choice to charge the end-user based on any of the following (non exhaustive list)

- ✓ Data volume

- ✓ Session or connection time

- ✓ Service type (Web, email, MMS, etc.)

- ✓ Allocated Quality of Service

- ✓ Type of technology being used (2G, 3G, evolved 3G, WLAN, etc.)

- 3GPP standard proposes all the necessary features to allow a flexible charging scheme to be implemented by operators
- The charging process is based on
  - ✓ The collection of various events and information which are stored in a formatted record called CDR (Charging Data Record)
- The format of the CDR is specified by 3GPP standard and depends on each type of service
  - ✓ PS domain access (as in 2G and 3G networks)
  - ✓ IMS service
  - ✓ Any type of service hosted by an AS (Application Server) under the control of the operator
    - ➔ Multimedia Messaging Service (MMS)
    - ➔ Push-to-talk over Cellular (PoC)
    - ➔ Multimedia Broadcast and Multicast Service (MBMS)

---

**PS domain CDR**

---

IMSI	International Mobile Subscriber Identity
IMEI	The IMEI (International Mobile station Equipment Identifier) of the user terminal
Charging ID	An identifier of the PDP context being used
Record opening time	Time stamp when PDP context is activated
Duration	Duration of this record
Traffic data volumes	The amount of data per Quality of Service type
RAT type	Type of Radio Access Technology being used by the terminal
...	...

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**IMS CDR**

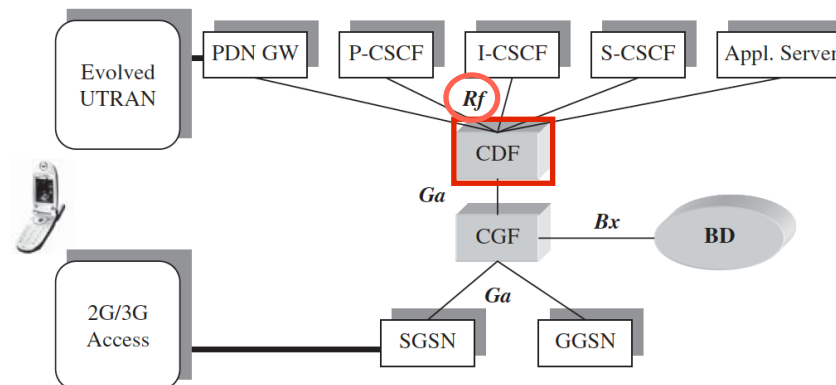
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Session ID	The SIP session ID, as defined in the SIP specification
Role of node	Indicates if the CDR is issued by a P, I or S-CSCF
Service starting time	The SIP session starting time
Service ending time	The SIP session closing time
SDP description	Description of the session, the list of media components being used
...	...

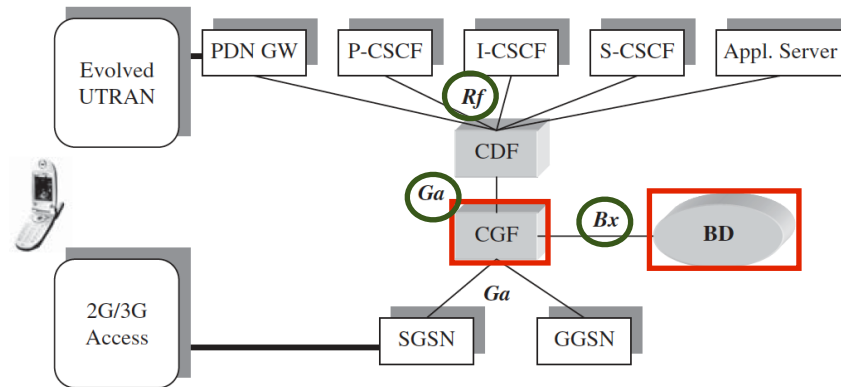
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Table 2.3 Examples of CDR  
(for PS domain and IMS session).

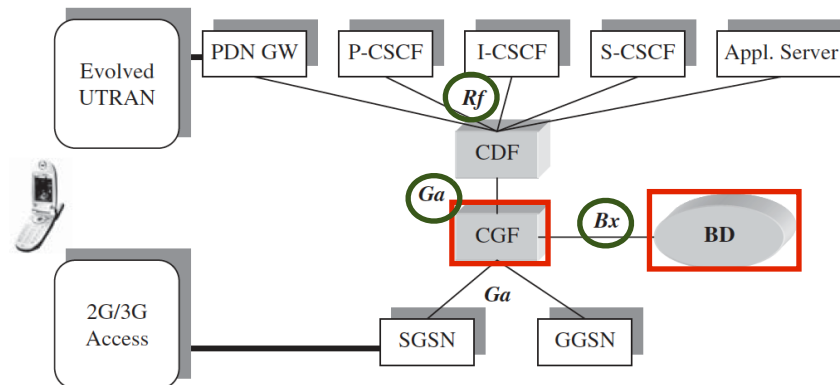
- Figure 2.23 presents the network elements involved in the charging process and their interaction with 2G, 3G and IMS network nodes
  - ✓ CDF (Charging Data Function)
    - ➔ Collect charging information from different nodes through Rf interface and build the corresponding CDR
  - ✓ The type of nodes being linked to CDF is not limited, it includes
    - ➔ PDN Gateway from EPC architecture
    - ➔ IMS nodes (e.g. CSCF servers)
    - ➔ All kinds of Application Servers like
      - BM-SC (Broadcast Multicast Service Centre)
      - PoC server (Push-to-talk over Cellular)



- *Rf* interface
  - ✓ Based on Diameter IETF protocol
  - ✓ Also used in many IMS interfaces
  - ✓ The *Rf* inclination of Diameter makes use of extensions specific to the charging process



- CGF (Charging Gateway Function)
  - ✓ A gateway between Core Network nodes and BD (Billing Domain)
  - ✓ Main task
    - ➔ CDR collection through Ga interface
      - Ga interface is based on a simple UDP/IP tunneling protocol whose only purpose is to transfer the CDR
    - ➔ CDR storage
    - ➔ CDR management (like CDR opening, closing, deleting)
    - ➔ Secure transfer to BD
      - The default CDR transfer method over Bx interface proposed by 3GPP standard is FTP (File Transfer Protocol)



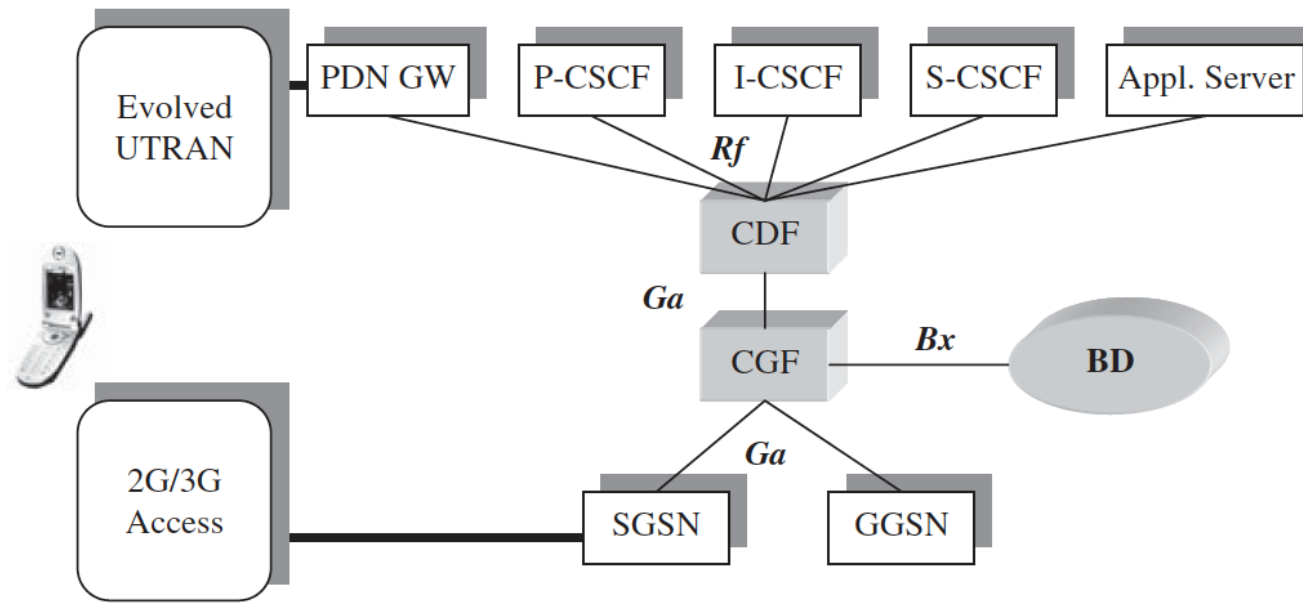
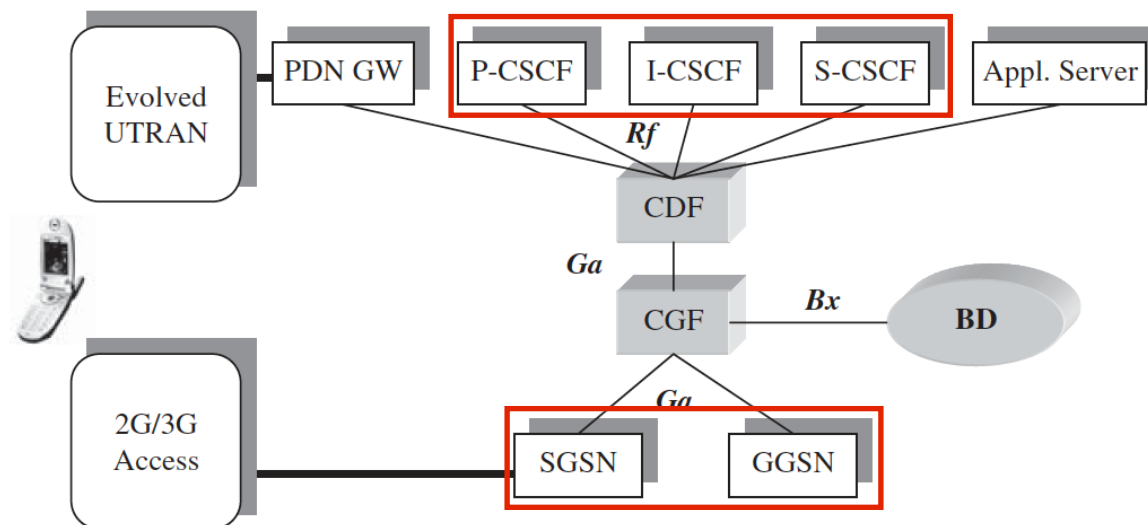


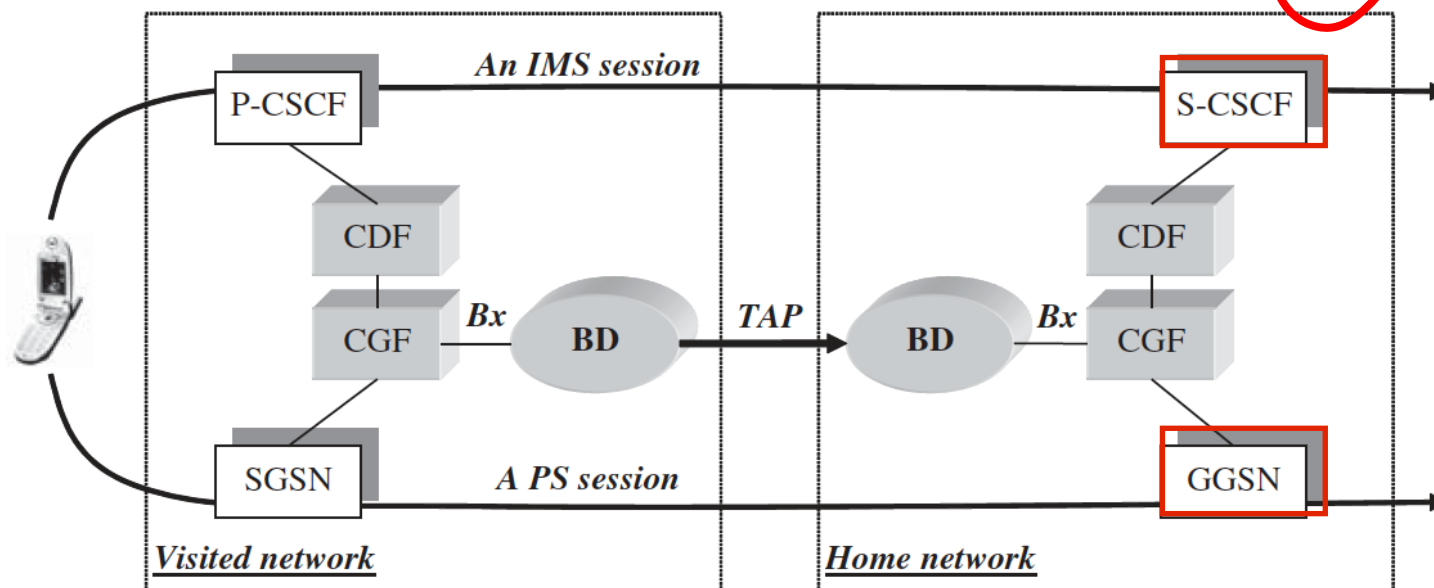
Figure 2.23 The architecture for Charging.

- For a given session, charging information is issued by different network nodes
  - ✓ SGSN and GGSN for a PS session
  - ✓ P, I or S-CSCF for an IMS session
- The charging information
  - ✓ Used by CDF or CGF to build complete CDR
- The redundant information (such as data traffic volumes or session start and stop Timestamp)
  - ✓ Used to check the consistency between the views reported by network elements

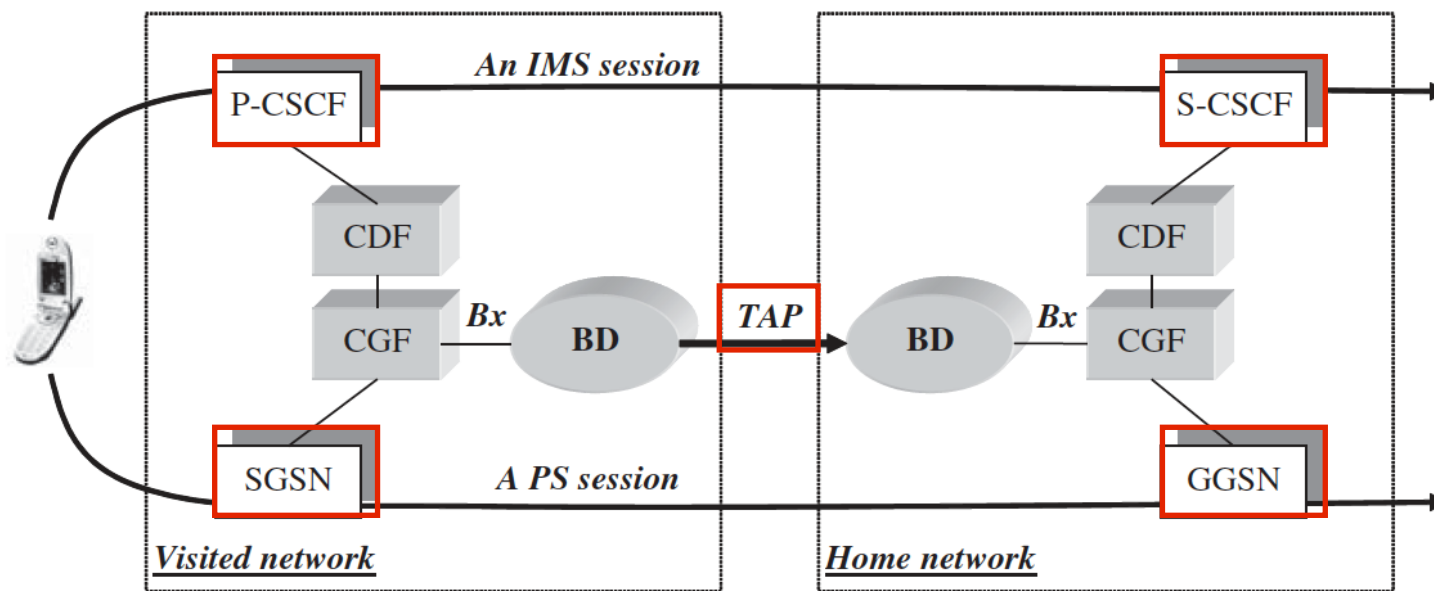


- **The Roaming Case**

- ✓ Revenues generated from active subscribers in visited networks represent a significant part of operators revenues
- ✓ The roaming case requires specific mechanisms to be implemented between networks to ensure that a network operator gets the revenues corresponding to the resources being used in its network by other networks subscribers



- Figure 2.24 presents the different network elements and interfaces involved in a roaming situation
  - ✓ Charging information needs to be collected by both visited and home networks
  - ✓ In the case of IMS session
    - ➔ The visited network P-CSCF collects local information about the SIP session
    - ➔ The visited SGSN gathers information related to the PDP context being allocated (including allocated Quality of Service and data volumes)
    - ➔ So does the home network through S-CSCF and GGSN
    - ➔ When the session is over, the visited network will send the bill to the subscriber home network using TAP (Transferred Account Procedure)



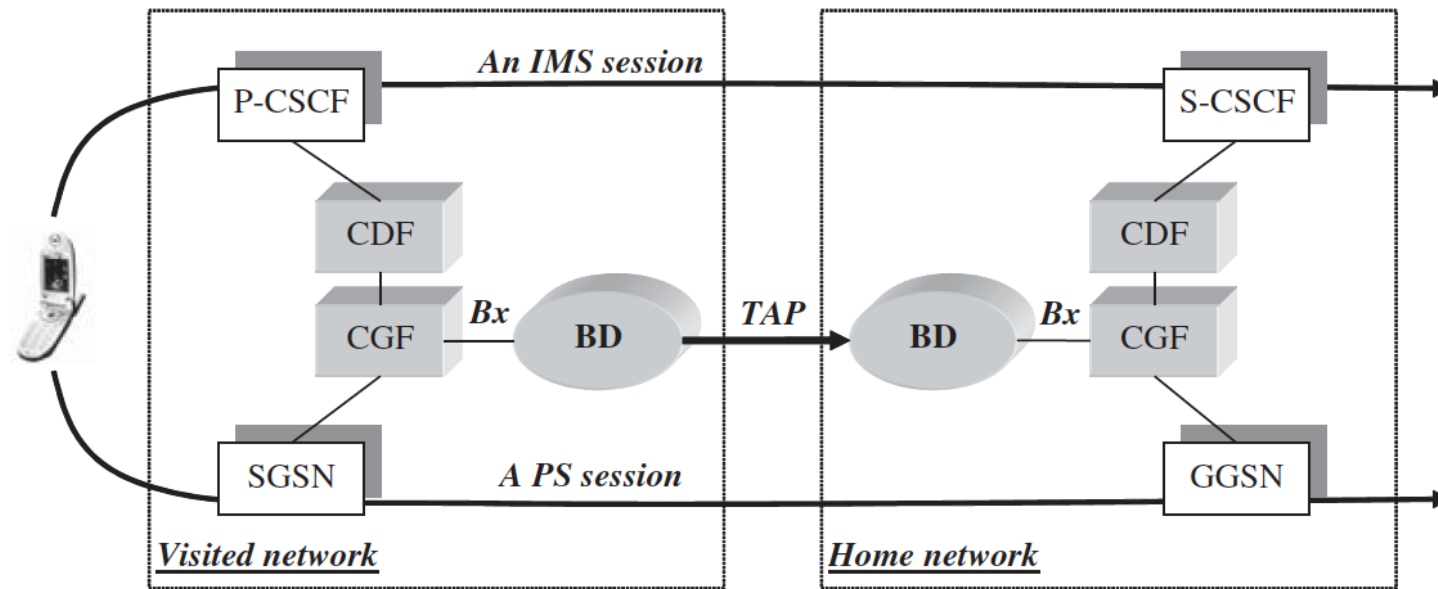
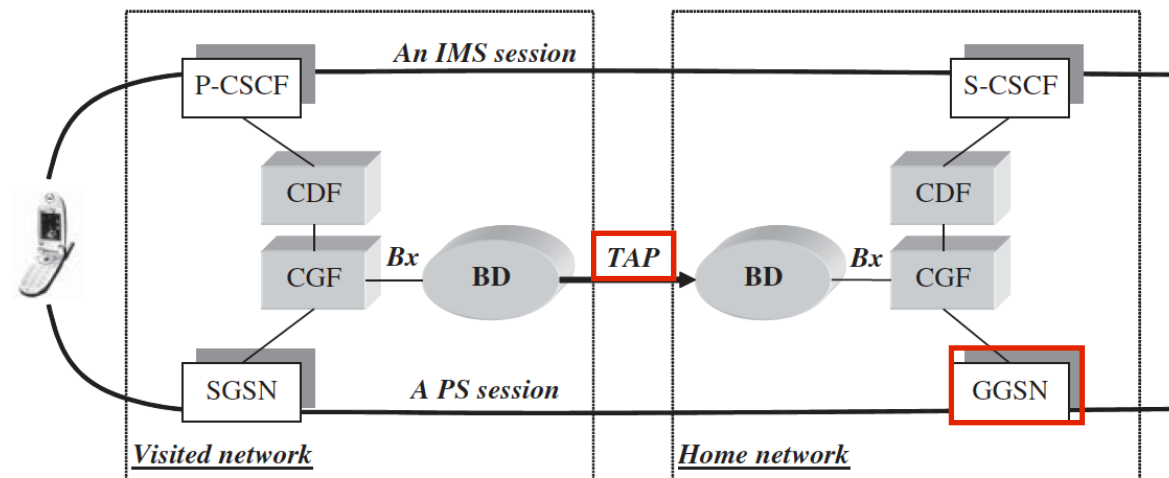


Figure 2.24 Charging in a roaming case.

- TAP
  - ✓ A protocol defined by the GSM Association for interchange of billing data between different network operators, allowing them to bill each other for the use of networks and services through a standard process
- TAP format
  - ✓ Originally defined for GSM circuit-switched services, has been enhanced to also cover packet-switched and IMS sessions
  - ✓ This includes specification of new TAP record attributes such as
    - ➔ Data volume counts
    - ➔ Timestamps
    - ➔ IP address
    - ➔ Access Point Number (APN – representing the GGSN the user has accessed to)
    - ➔ Requested and negotiated Quality of Service



- Information contained in TAP record
  - ✓ TAP record creation date and time
  - ✓ Charged units
  - ✓ Charge rate
  - ✓ Taxation information (including tax rate and type)
  - ✓ Discount rate (when applicable)
  - ✓ Local currency and exchange rates
  - ✓ Details about allocated PDP context
  - ✓ User data volumes
  - ✓ User connection time
  - ✓ ...

# 6. The Evolved UMTS Interfaces

- The interfaces defined in the scope of EPS networks
  - ✓ Some of them are brand new ones
  - ✓ Some others rely on existing 3G/UMTS ones – sometimes with different names
- Table 2.6 shows all the EPS interfaces named in this chapter and in the rest of the book

# Table 2.6 Summary of Evolved UMTS Interfaces

Name	Comments
S1	Between MME/Serving GW and eNodeB. Supports the user and control plane traffic between the E-UTRAN and EPC.
S2	Between PDN GW and non-3GPP access. Supports control and mobility procedures for non-3GPP access technologies.
S3	Between MME and 2G/3G SGSN. Supports user and bearer information exchange for inter-system mobility in idle or active state. Based on the 2G/3G Gn interface (GTP protocol).
S4	Between Serving GW and 2G/3G SGSN. Supports user plane data transfer for inter-system mobility. Based on the 2G/3G Gn interface (GTP protocol).
S5	Between Serving GW and PDN GW. Supports bearer management and user plane data tunnelling between the two gateways. Based on GTP.
S6	Between the Evolved Packet Core nodes and the HSS. Supports the procedures for user subscription data retrieval and location update. Based on Diameter.
S7	Between the PDN GW and the PCRF. Supports the procedures for Policy and Charging rule transfer from the PCRF to the EPC. This interface is based on the 3GPP R7 Gx definition.
S8	Between the visited Serving GW and home PDN GW. It supports packet and user plane transfer between the two gateways for the roaming cases. This interface is a variant of S5, based on 2G/3G Gp interface (GTP protocol).
S9	Between the visited PCRF and the home PCRF. This interface is a variant of S7 for the roaming cases.

S10	Between the MME nodes. This interface is used in case of inter-MME mobility (or relocation) to exchange session and user contexts between nodes. Based on the Control part of GTP protocol (GTP-C).
S11	Between the MME and Serving GW. Supports bearer management e.g. at user attachment or service request. Based on the Control part of GTP protocol (GTP-C).
X2	Between eNodeBs. Supports mobility and user plane tunnelling features. Based on the same user plane protocol as S1.
Rx	Between PCRF and P-CSCF. Used to provide service dynamic information to the PCRF. Based on an evolution of the IETF Diameter protocol.
SGi	Between the PDN Gateway and the packet data network. Based on the 2G/3G Gi interface.
Ga	Between CDF and CGF. Supports the transfer of CDR (Charging Data Record) from the CDF to the CGF. Based on UDP/IP tunnelling.
Bx	Between the CGF and the BD. Supports secured transfer of the CDR to the BD. Based on the FTP protocol.
Rf	Between an IMS network entity or an Application Server and the CDF. Supports charging information transfer to the CDF. Based on an evolution of the IETF Diameter protocol.

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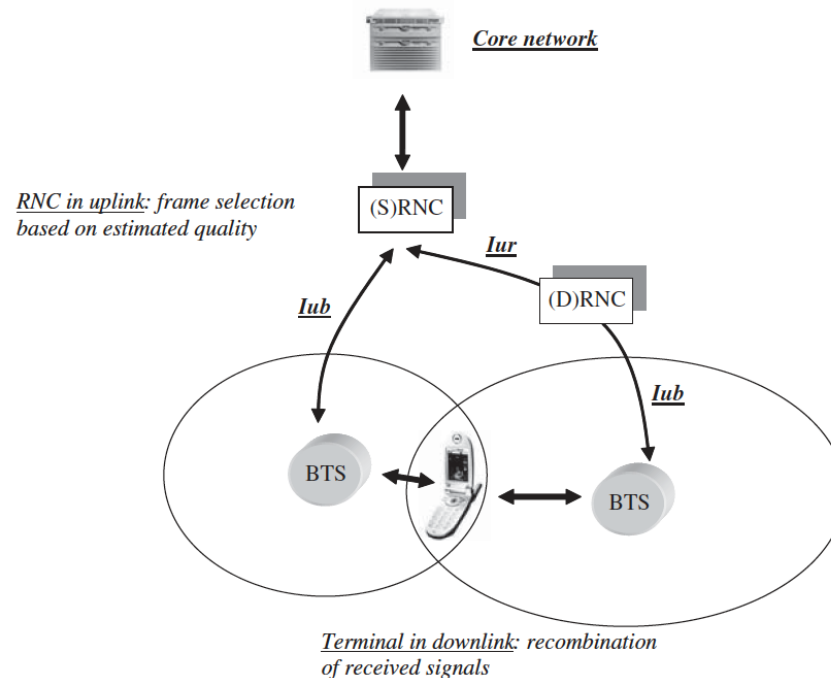
# 7. Major Disruptions with 3G UTRAN-FDD Networks

- The choice of OFDM technology on the radio interface and the various options chosen for E-UTRAN radio interface have some significant and disruptive impacts on the way the overall network behaves
- This section aims at describing the main impacts of some E-UTRAN technical choices made in the standard definition on network architectures and supported features, as regards to 3G/UTRAN FDD networks

# 7.1 About Soft Handover

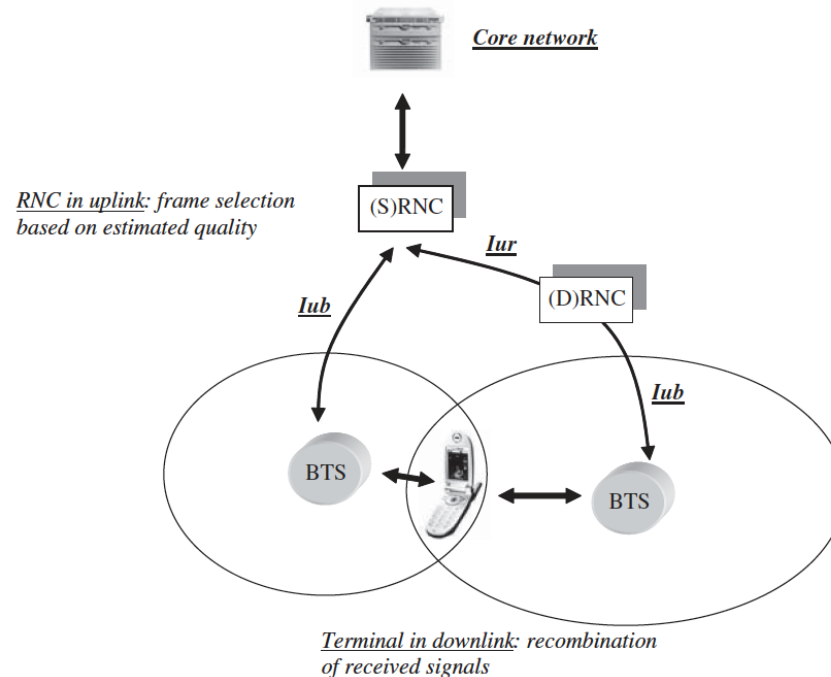
- One of the main consequences of using a CDMA-based radio interface is about the need for soft handover, known as macro-diversity
  - ✓ In CDMA, each transmission channel behaves as an interferer for the other channels
  - ✓ The consequence is that transmission power tuning is a key point to preserve CDMA system capacity
  - ✓ This becomes critical at cell edge or in poor coverage areas
    - ➔ Where maintaining the radio link transmission quality is often a synonym to increased transmission power
  - ✓ This is where soft handover helps
    - ➔ Allowing the information to be transmitted on different links – called the active set – and adding transmission diversity gain

- Figure 2.29 illustrates
  - ✓ Soft handover is a mechanism by which a terminal maintains simultaneously several radio links in different cells for one single session or data flow
  - ✓ Information is then recombined from the received radio links, either on the network or on the terminal side



- In 3G/UTRAN

- ✓ Soft handover is applied to all dedicated channel transmission, including HSUPA (the high-speed transmission technique for the uplink) also based on dedicated channels
- ✓ However, soft handover does not apply to HSDPA data transmission, which makes use of a physical shared channel



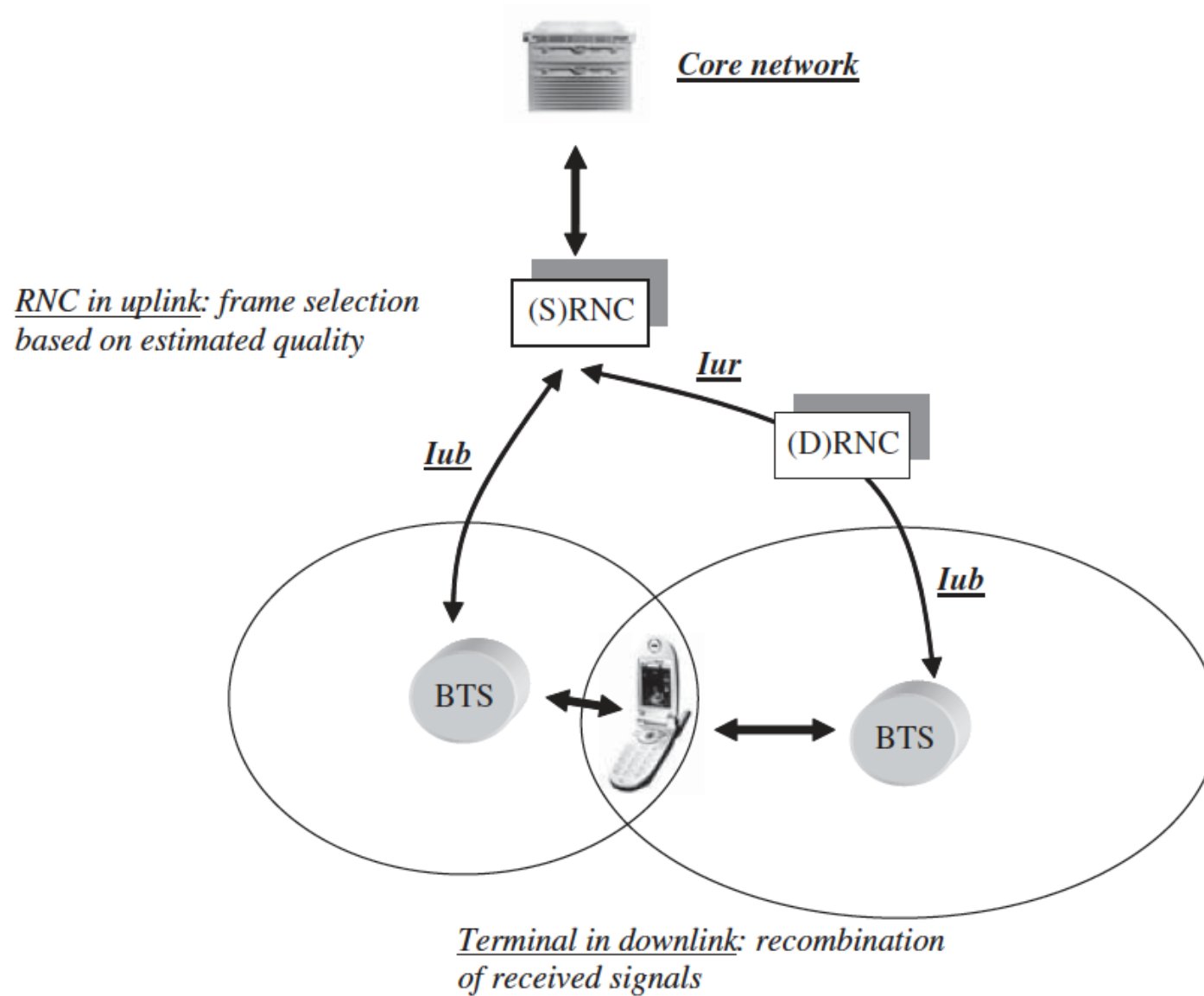
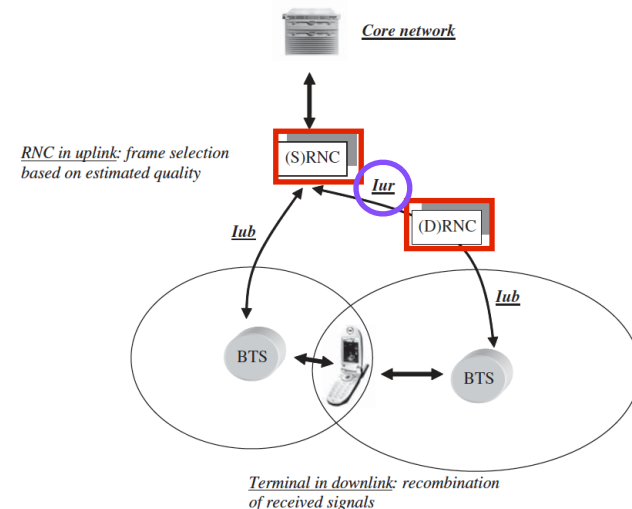
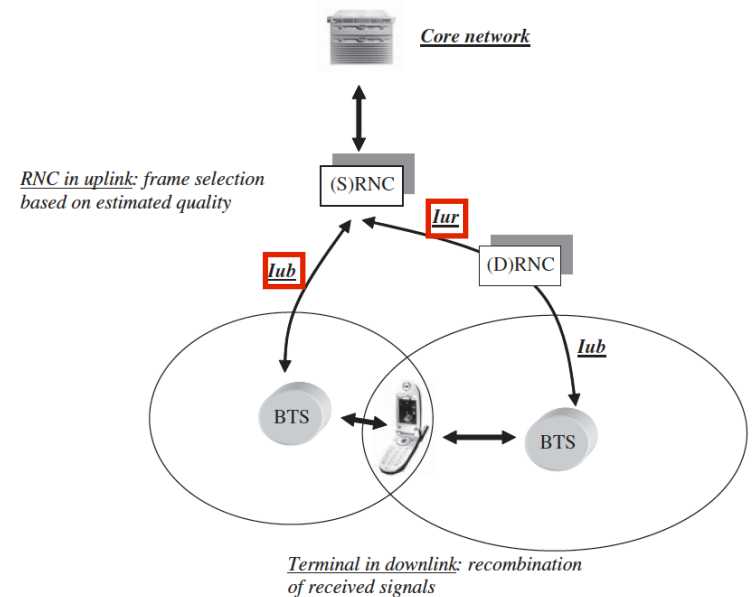


Figure 2.29 An example of UTRAN soft handover.

- The consequence of soft handover on 3G/UTRAN architecture is that the Iur interface between RNC is mandatory in case the different BTS involved by the soft handover are not controlled by the same RNC
- 3G/UTRAN standards distinguishes the SRNC from the DRNC
  - ✓ SRNC (Serving RNC)
    - ➔ The RNC which controls the communication with the terminal
  - ✓ DRNC (Drift RNC)
    - ➔ The RNC which only controls the BTS involved in a soft handover



- The cost for having an Iur interface is not negligible from an operational perspective
  - ✓ When an operator mixes equipments from different manufacturers in the access network, or decides to upgrade parts of it, lots of care has to be taken on interoperability between the RNC nodes being connected through Iur
  - ✓ In addition, the Iur requires the operator to pay for supporting the inter-RNC connectivity and the traffic sent over the Iur
- There is still the cost of multiple Iub link transmission to be supported between the SRNC and all the BTS
- It is usually admitted that a RNC can control several hundreds of cells



- **In E-UTRAN**

- ✓ Soft handover is no longer needed or required, which is a significant change in terms of overall access network definition and operation

- ✓ E-UTRAN architecture introduces an X2 interface between eNodeBs

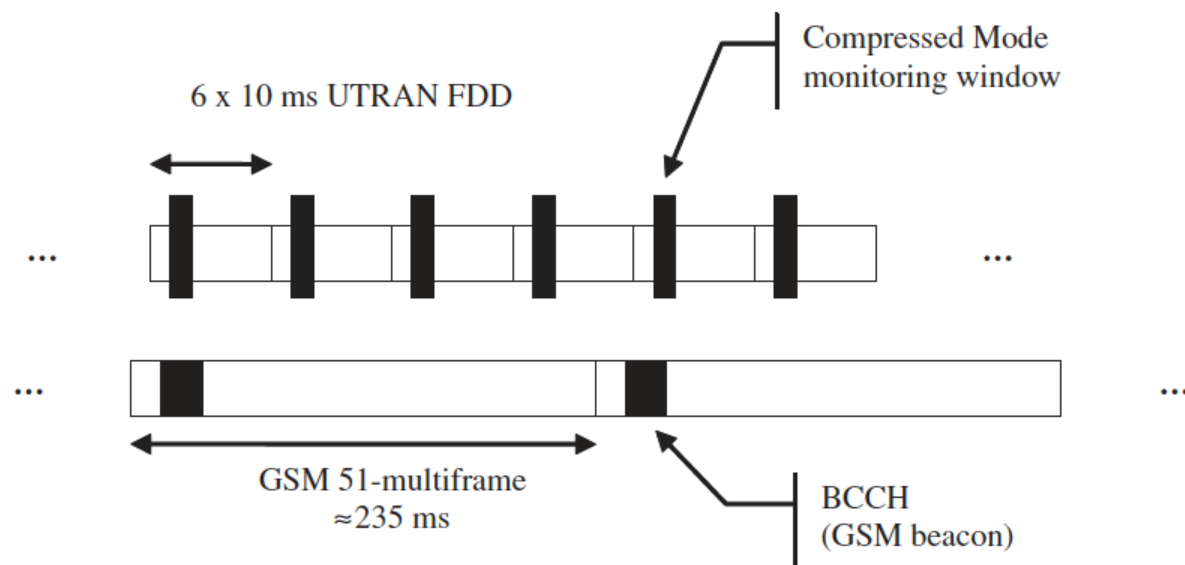
- ➔ This new interface is not an *Iur* equivalent, as there is no soft handover support in E-UTRAN

- ➔ X2 is actually an optional interface, which provides a data-forwarding service in case of inter-eNodeB mobility, for the sake of lossless mobility

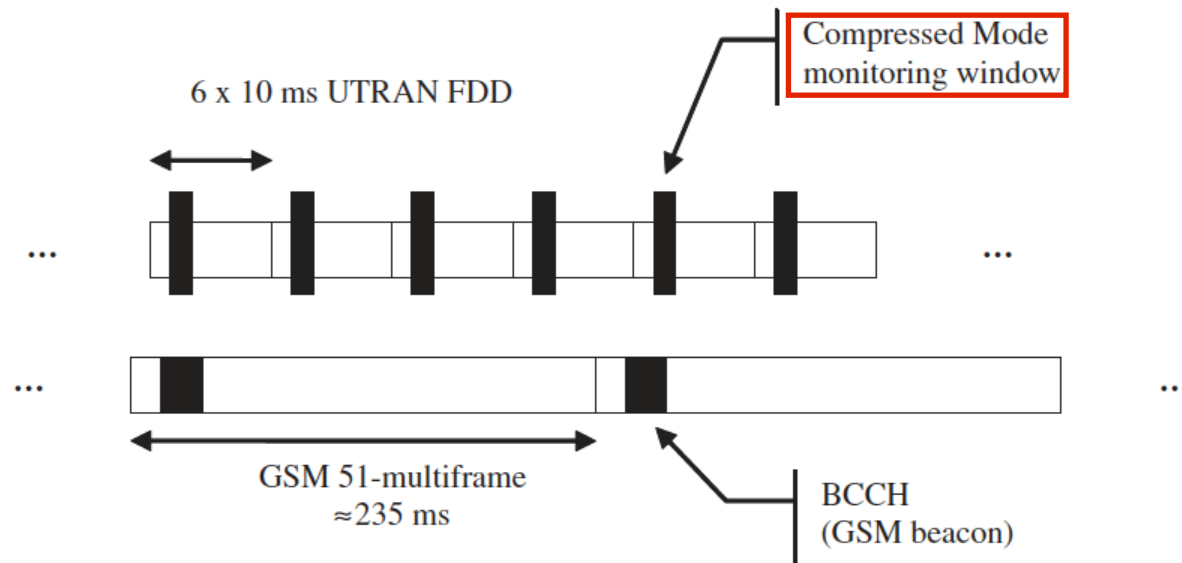
# 7.2 About Compressed Mode

- One fundamental point of CDMA radio interface is that radio transmission is continuous, and simultaneous for both uplink and downlink transmission
- When moving around cells of the same frequency
  - ✓ The terminal CDMA receiver can quite easily monitor them – build its own list of best cell, so that the active set is managed at best, thanks to the soft handover mechanism
- However, problems arise in the case of multi-frequency or multi-access technology deployment, as is more and more the case in countries where cellular communications have reached maturity
  - ✓ When continuously receiving radio frames, the CDMA terminal has no time to switch its receiver to another frequency, and monitor neighboring cells, e.g. in 2G/GSM, of using another UMTS/FDD frequency band

- ✓ There may be multiple solutions to this issue
  - ➔ Build multiple receiver terminals, which is a very costly and power-consuming option
  - ➔ Another solution brought by the 3GPP standard was to change the CDMA radio frame structure in order to artificially create some holes so that the terminal has time to perform other frequency of radio-system monitoring
    - This mechanism, widely deployed in UMTS networks, is known as Compressed Mode



- Figure 2.30 shows an example of Compressed Mode operation
  - ✓ Periodic monitoring windows are created in uplink and/or downlink radio frames using Compressed Mode, so that the terminal can decode beacon information of a neighboring GSM cell



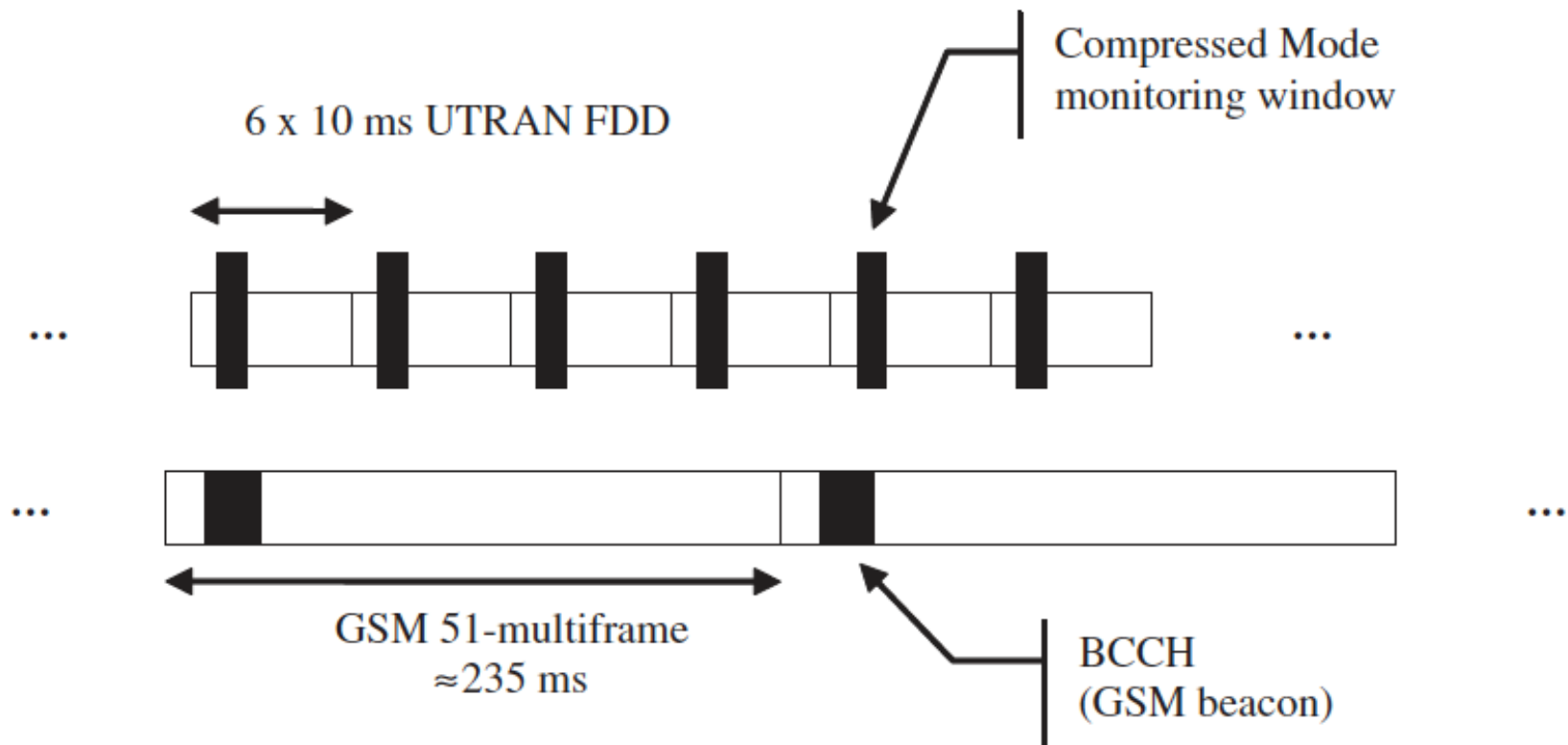


Figure 2.30 An example of UTRAN Compressed Mode operation.

- 3GPP UTRAN standards define different methods for **creating** these transmission gaps
  - ✓ Spreading Factor (SF) reduction
    - ➔ The same amount of data is sent in half the time thanks to the use of a reduced SF code
    - ➔ The decrease in spreading gain is then compensated by increased power during the time the code is used
    - ➔ Drawback
      - Requires more transmission power and creates more interference when the compressed mode is active, which has some impact on network capacity
  - ✓ Higher layer scheduling
    - ➔ Only suitable for non-real time communications, as it relies on the MAC data scheduler to limit data transmission at some specific time
    - ➔ Drawback
      - Though only results in a slight increase in radio transmission latency, but it is not applicable to circuit services like voice

- E-UTRAN OFDM-based radio interface
  - ✓ Relies on frequency and time slot allocation and does not mandate continuous transmission and reception
  - ✓ This leaves the possibility for an E-UTRAN terminal to monitor neighboring beacons, frequencies and systems when it is not required to receive or transmit data on the radio interface
  - ✓ For that reason, Compressed Mode is no longer needed in E-UTRAN