



4G Mobile Networks Long Term Evolution (LTE)

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Mobile Data Today

- The revolution is here (smartphones / tablets / netbooks)
- Broadband, anytime, anywhere
- Flat-rate data ?
- Data growth exponential; revenue growth linear.
- Scaling the network for data



Agenda



Evolution of Mobile Networks

LTE Architecture Overview

EPC Mobility

Services in LTE

Evolution of Mobile Networks

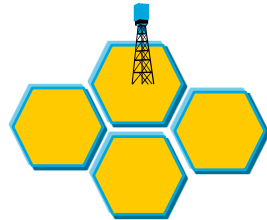


In the beginning ...

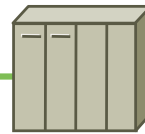
- There was wireless ISDN (aka GSM)



Mobile Station

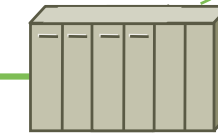


Base Transceiver System (BTS)



Base Station Controller (BSC)

Home Location Register (HLR) Service Control Point (SCP)



Mobile Switching Center + Visitor Location Register (MSC/VLR)

Connection Mgmt
Mobility Mgmt
Radio Resource Mgmt
LAP-Dm
GSM Radio

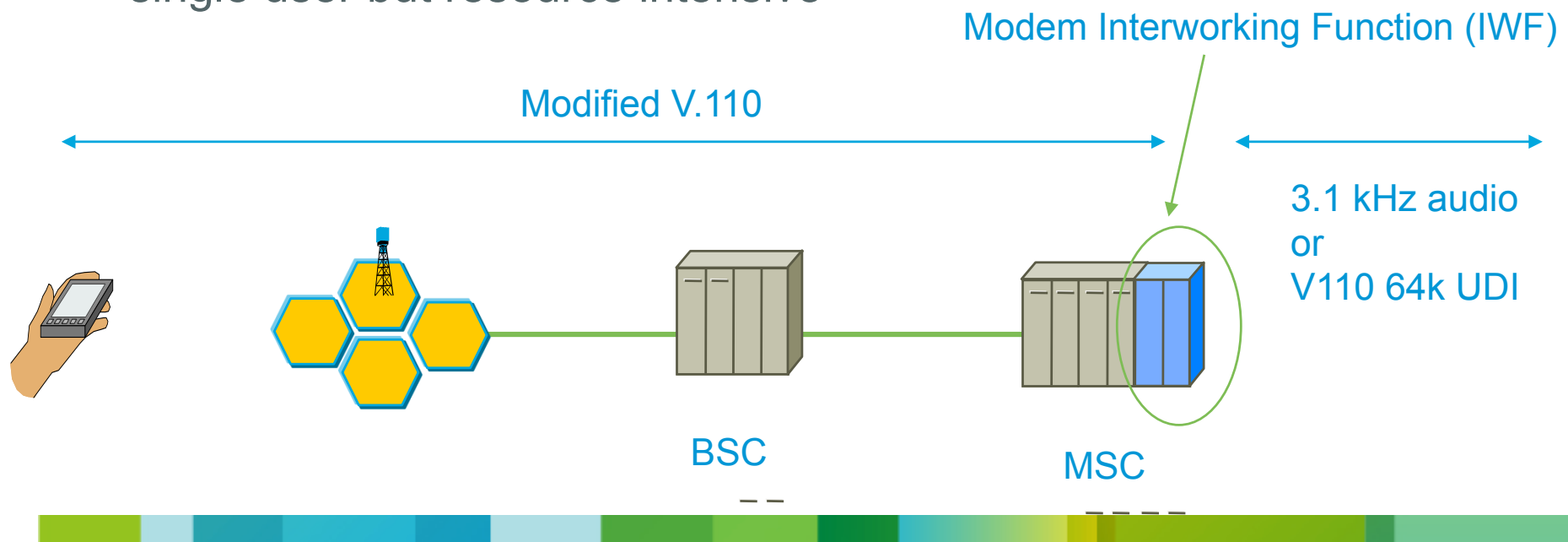
RR'	BTSM
LAP-Dm	LAP-D
GSM Radio	16/64 kbps

RR'	BSSAP
BTSM	SCCP
LAP-D	MTP/b
16/64 kbps	64/2048 kbps

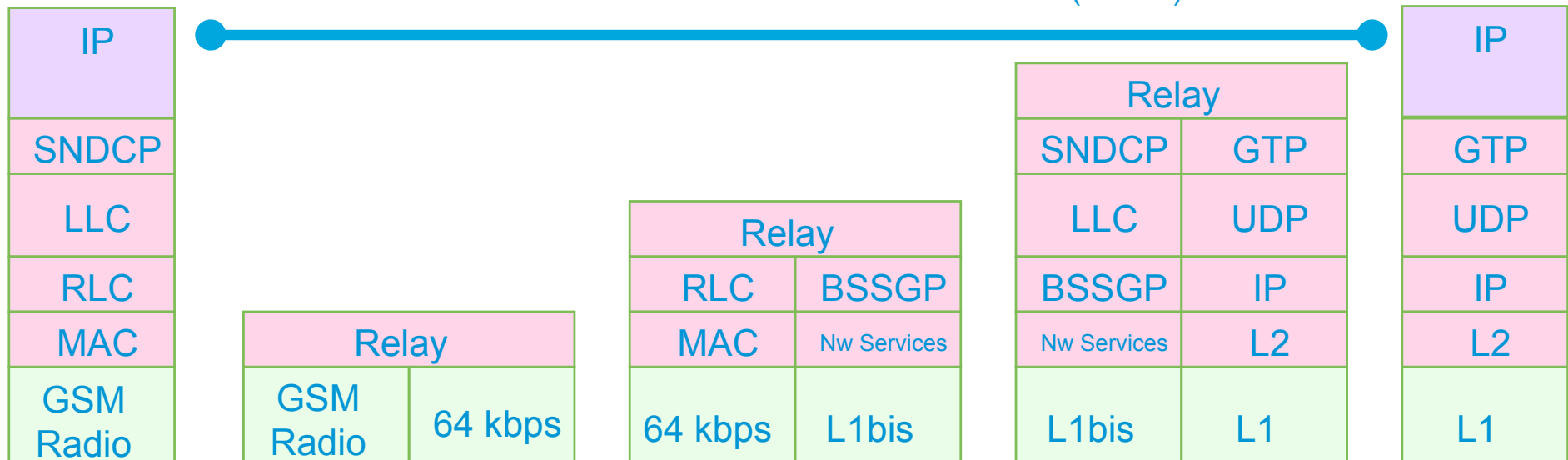
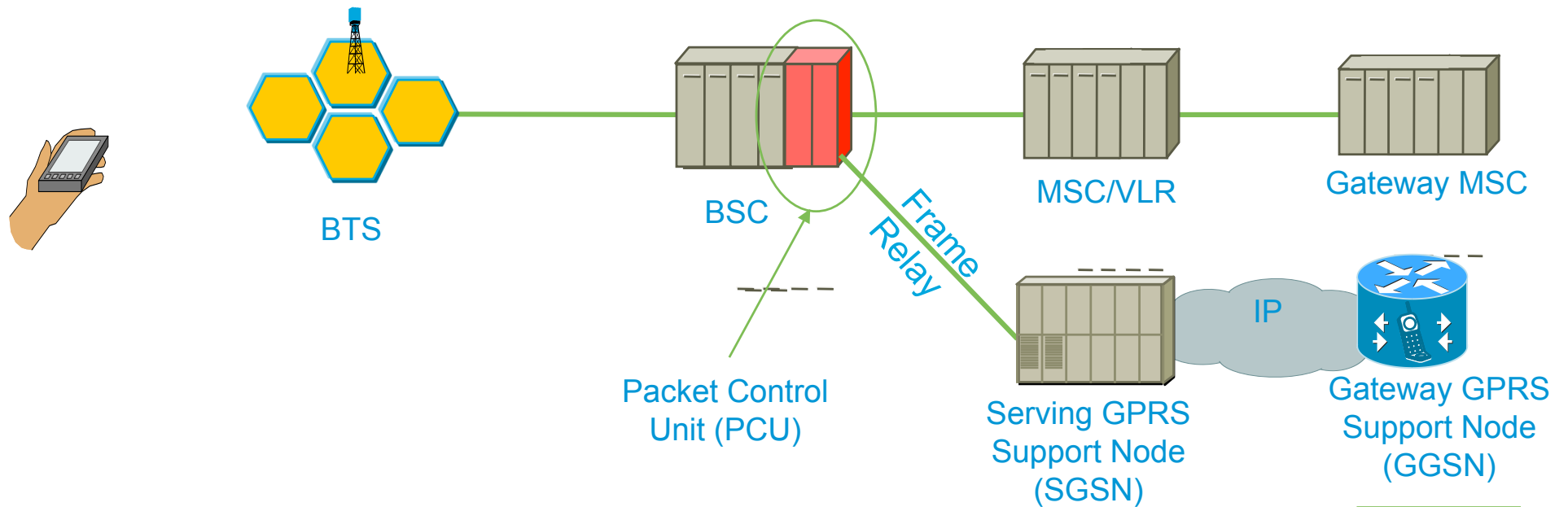
Connection Mgmt	BSSMAP	TUP	ISUP	INAP	MAP
Mobility Mgt					
DTAP					
BSSAP	TCAP				
SCCP				SCCP	
MTP/MTPb					
64/2048 kbps	MTP				
		64 kbps			

... data was circuit switched

- One burst every TDMA frame was sufficient to transport a speech frame with source rate of 13 kbit/s
- GSM Phase 2 (circa 1996) added Circuit Switched Data support offering 9.6 kbit/s service
- High Speed CSD consisted in aggregating multiple timeslot for a single user but resource intensive

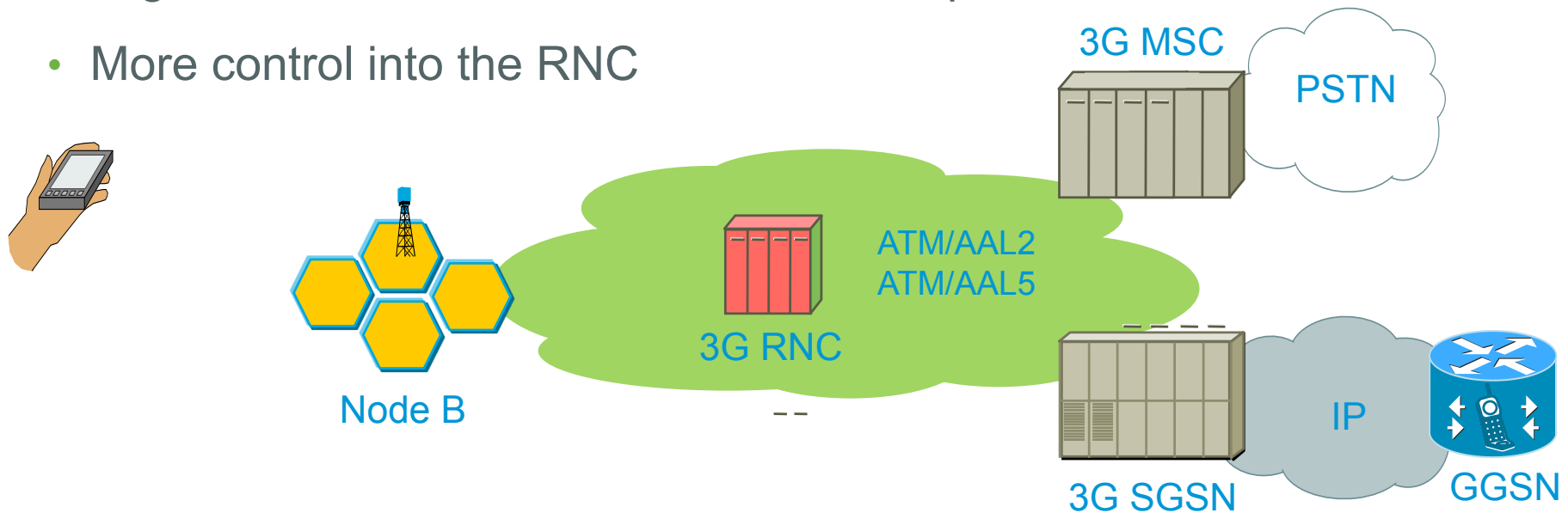


GPRS was added



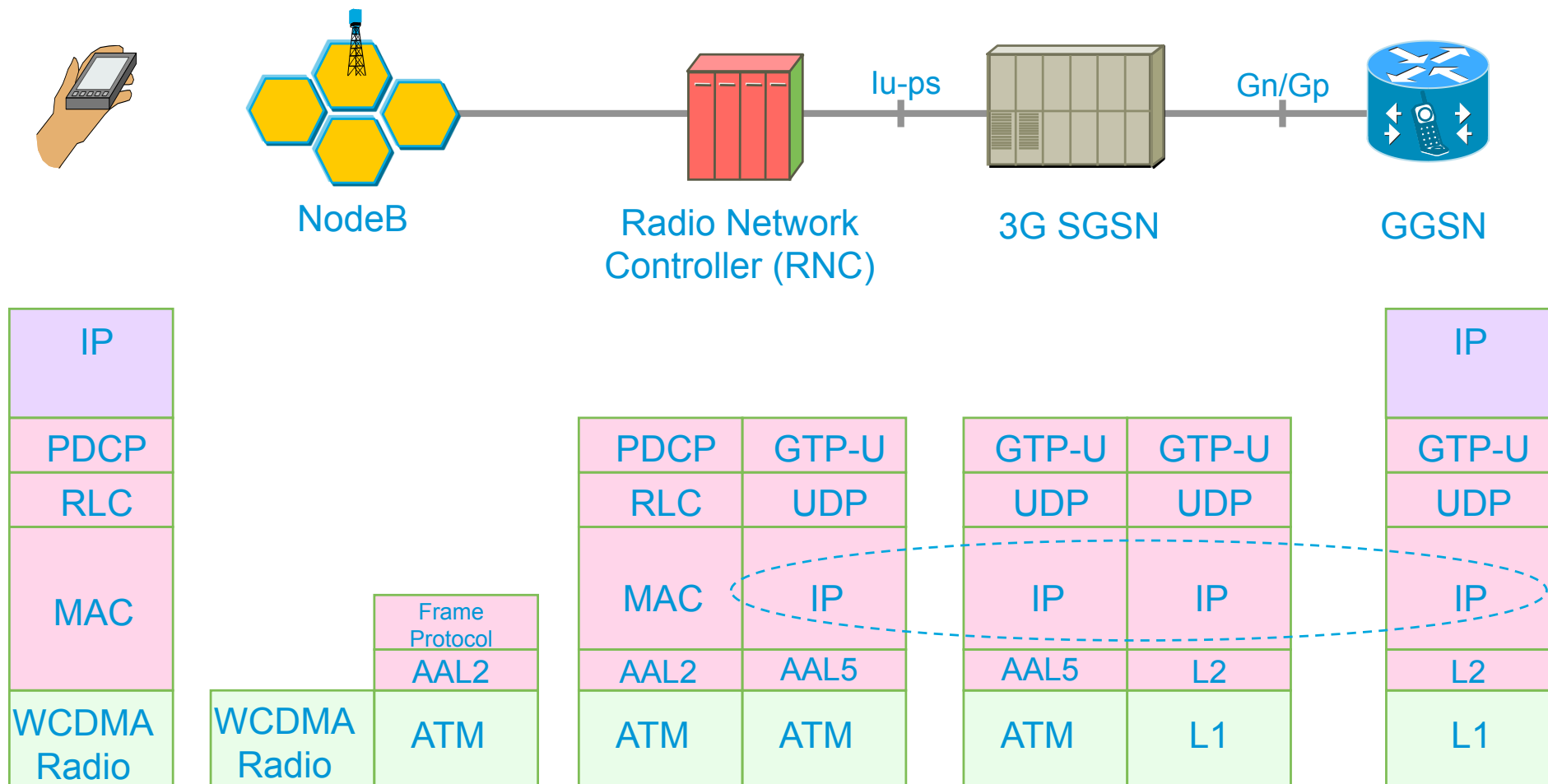
3GPP UMTS System

- First step towards an all IP network
- Designed to accommodate greater packet throughput (up to 2Mbits/s announced... In reality, can support up to 384 kbit/s)
- Core network remains largely unchanged from 2.5G
- Migration to ATM for Radio Access Transport
- More control into the RNC

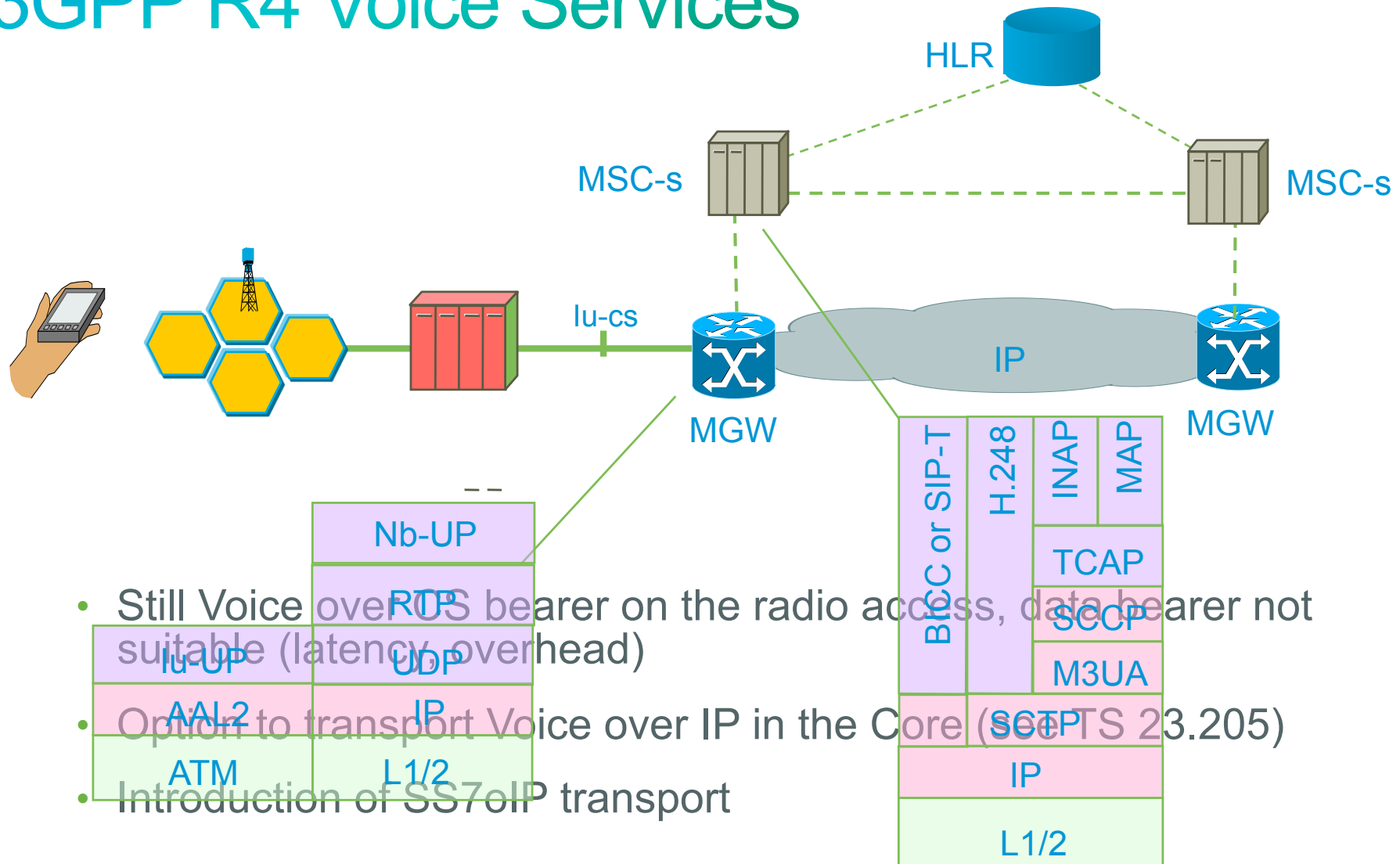


3G Packet Services

- So hopefully WCDMA got it right on packet services...



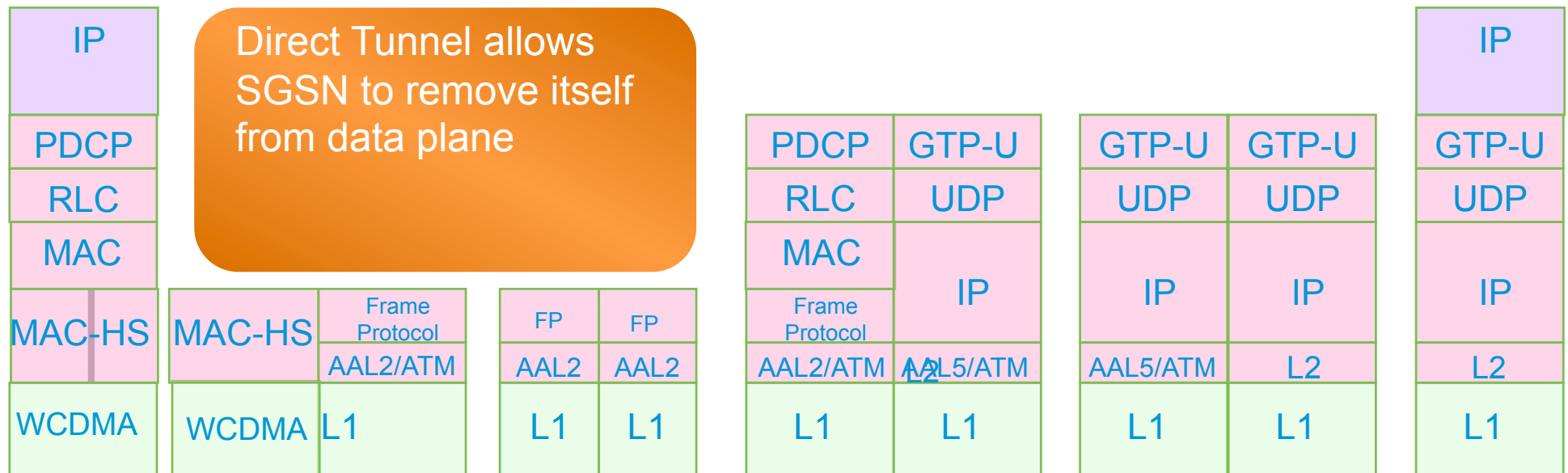
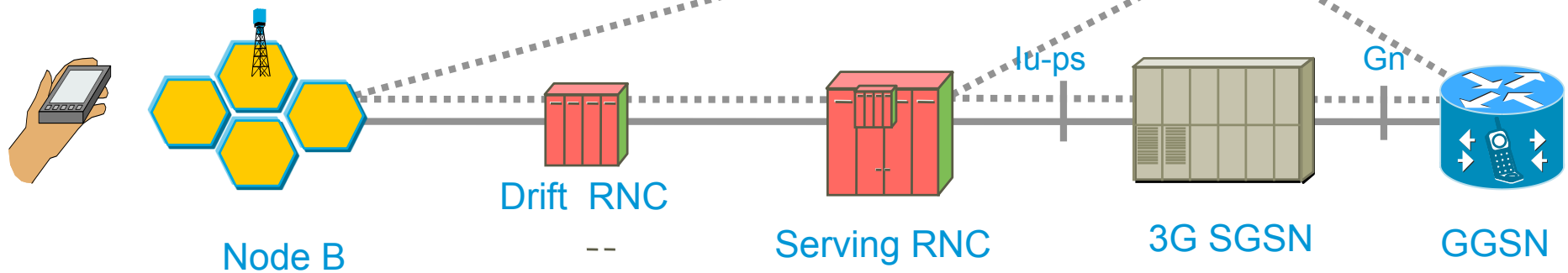
3GPP R4 Voice Services



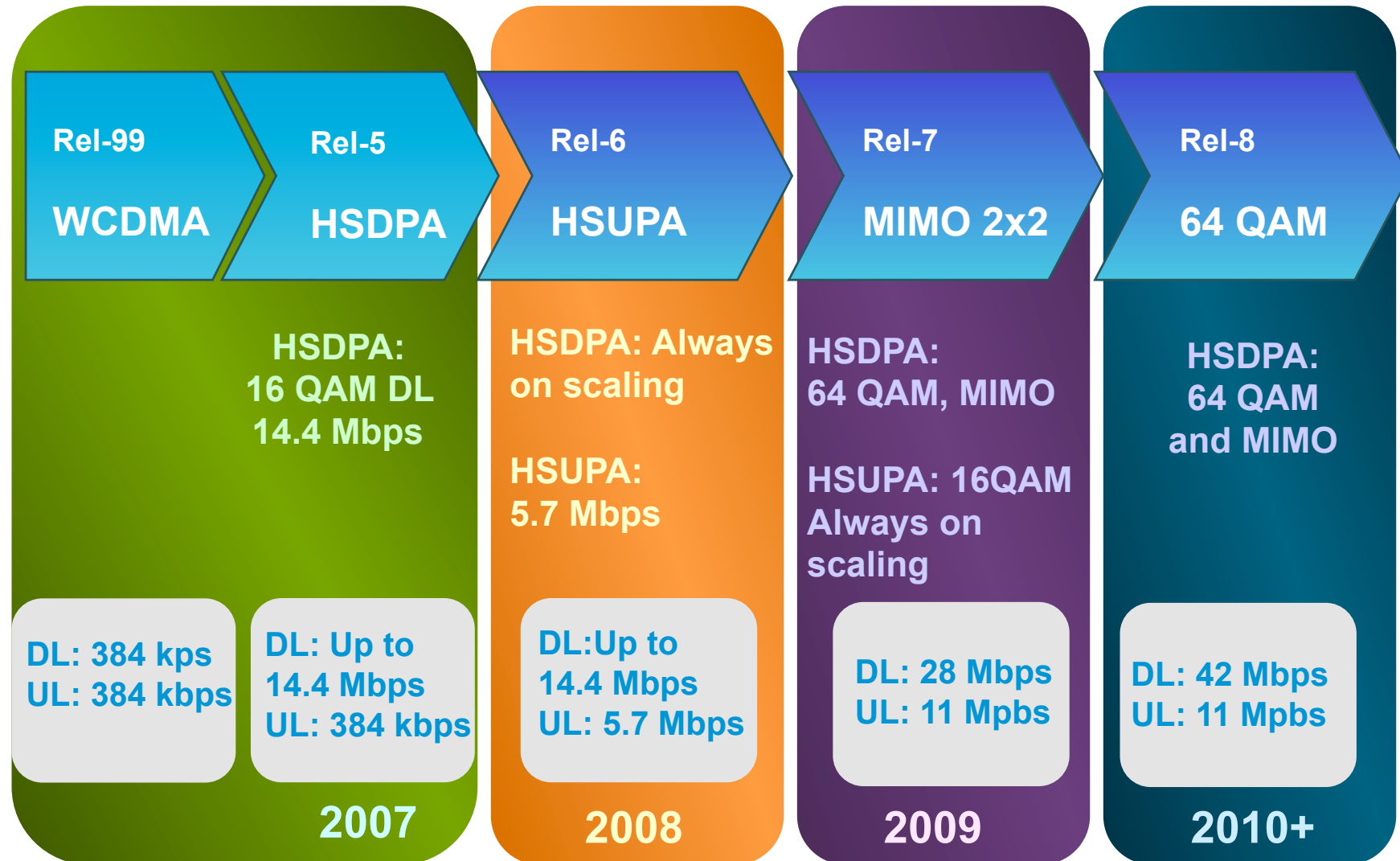
3GPP R5-R7 Addressing the Bottleneck

HSPA+: Distribute RNC
Data plane to Node B

Removes Drift RNC and
Intelligence to the Node B

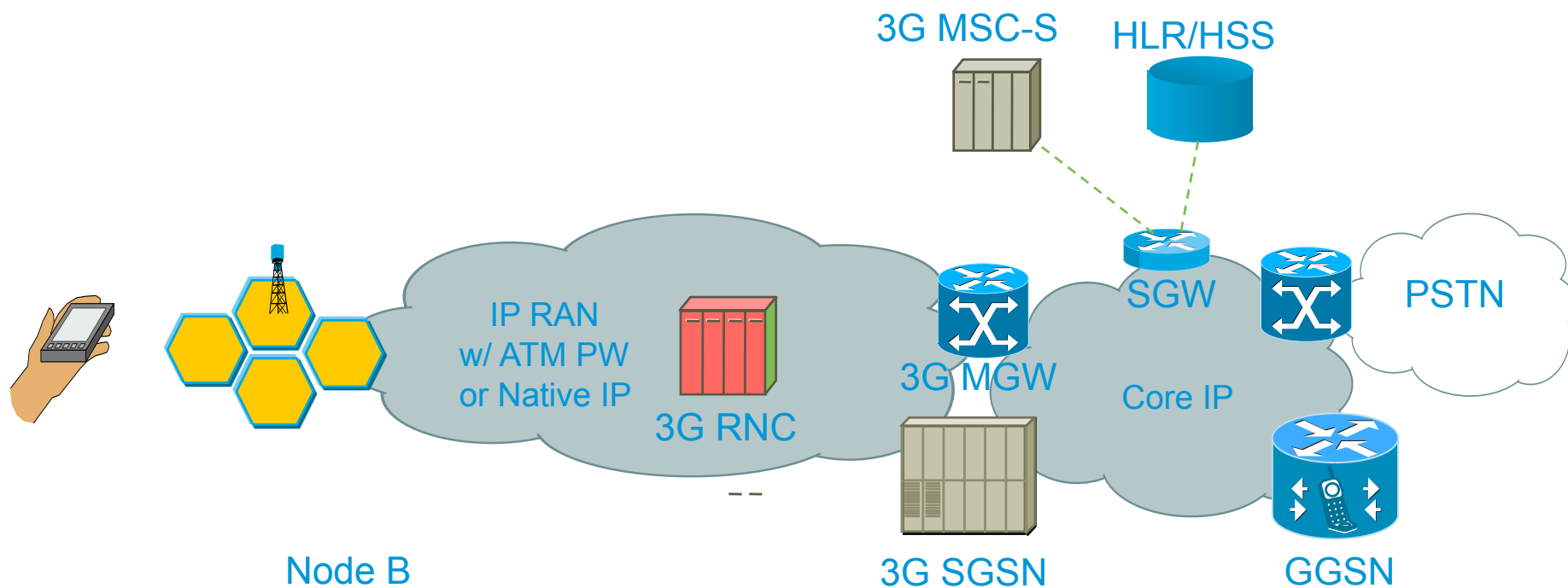


Mobile Data Peak Rate Evolution



3GPP Architecture Summary

- Highlighting the growing importance of IP transport



What is LTE/SAE ?

- Evolved Packet System (EPS) is the technology direction for 3GPP based networks
- Long Term Evolution (LTE) is the next generation 3GPP radio access network
Evolved UMTS Terrestrial Radio Access Network (E-UTRAN)
- System Architecture Evolution (SAE) is the 3GPP next generation standard for mobile networks providing:
 - Increased Bandwidth
 - End-to-End IP
 - Simplified Architecture
 - Support for multiple radio access technologies
- Evolved Packet Core (EPC) is the next generation 3GPP packet core
Consists of (3) main components (MME, SGW, and PGW)

The LTE Revolution

- Radio Side (Evolved UTRAN - EUTRAN)
 - Improvements in spectral efficiency, user throughput, latency
 - Simplification of the radio network
 - Efficient support of packet based services: Multicast, VoIP, etc.
- Network Side (Evolved Packet Core - EPC)
 - Improvement in latency, capacity, throughput, idle to active transitions
 - Simplification of the core network
 - Optimization for IP traffic and services
 - Simplified support and handover to non-3GPP access technologies

LTE/EPC Key Attributes

- Higher Bandwidth (>100 kbps per user on average) and improved latency
 - Transmission and transition delays <10 & 100ms resp. in unloaded conditions
- Service independent and data-only architecture
 - Strict data QoS mechanism with no voice dedicated bearer identification
- Always-on model
 - All registered users have a default bearer established used for signalling
- IP addressing
 - IPv6 by default with dual stack sessions (IPv4v6)
- Support of alternative access technologies
 - 3GPP and non-3GPP architecture, including possible wireline access
- Local breakout
 - Part of the traffic may be routed directly in the visited network

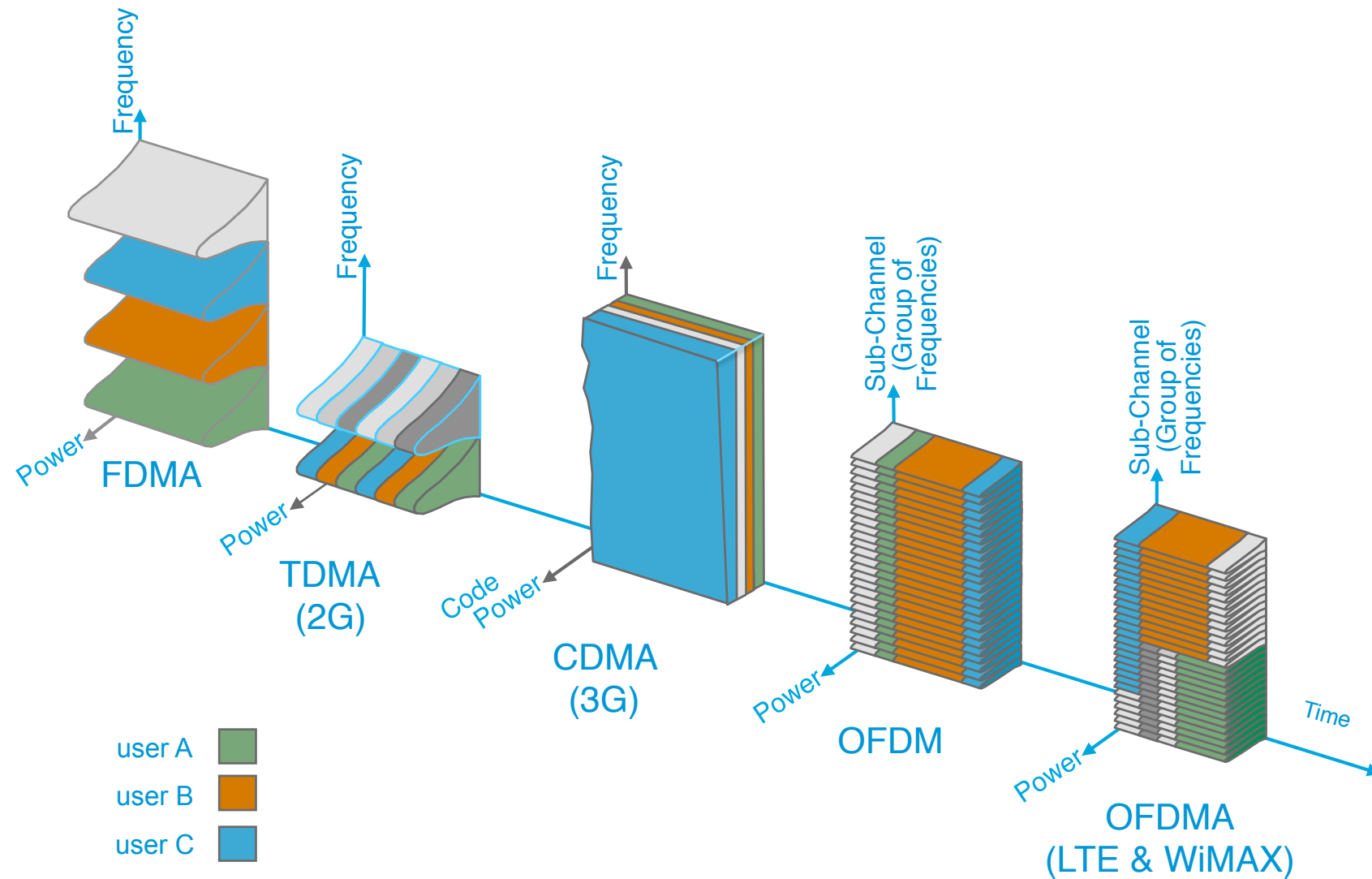
LTE Air Interface



LTE Physical Layer

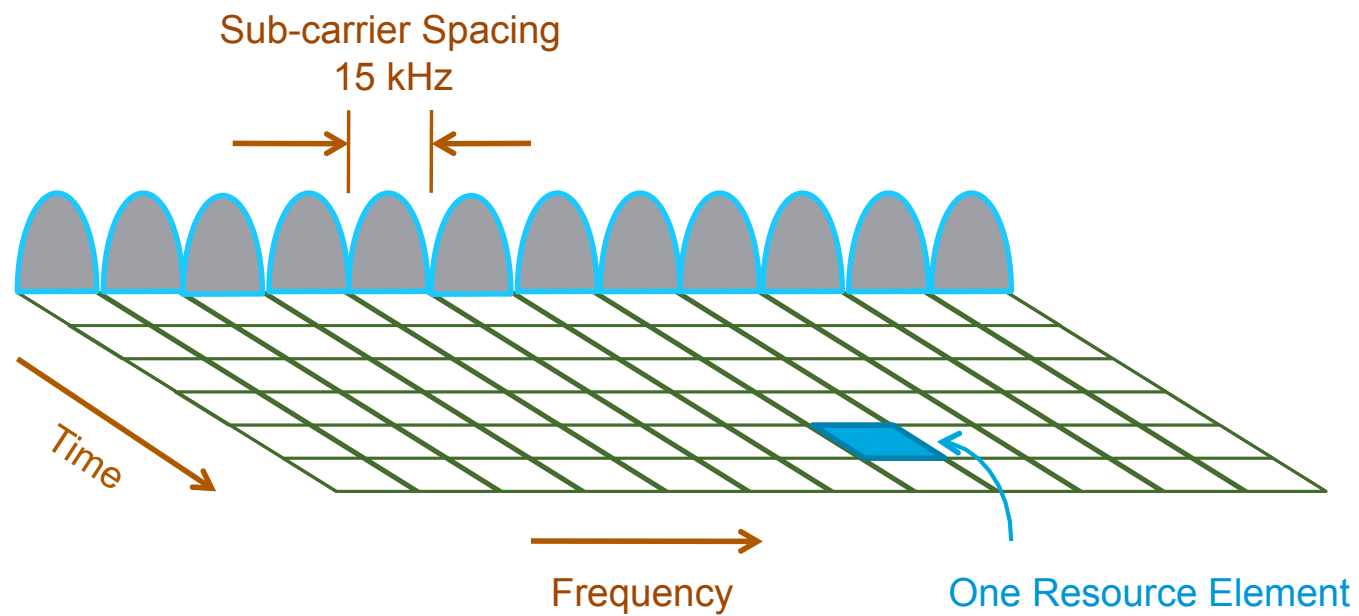
Duplex	FDD and TDD
Channel Bandwidth	1.25 – 20 MHz
Modulation Type	QPSK, 16-QAM, 64-QAM
Multiple Access Technique	DL: OFDMA, UL: SCFDMA
TDMA Frame Duration	10ms with 1ms subframe
Number of symbols per frame	140
Sub-carrier Spacing	15 kHz
Symbol Duration	66.7 us
Cyclic Prefix	4.69 us, 16.67 us
Multipath Mitigation	OFDM / Cyclic Prefix
eNB Synchronization	Frequency (FDD, TDD) Time (TDD, MBSFN)
Forward Error Correction	1/3 Convolutional and Turbo
Advanced Antenna Techniques	MIMO 2x2, 4x4

Radio Access Technology Evolution



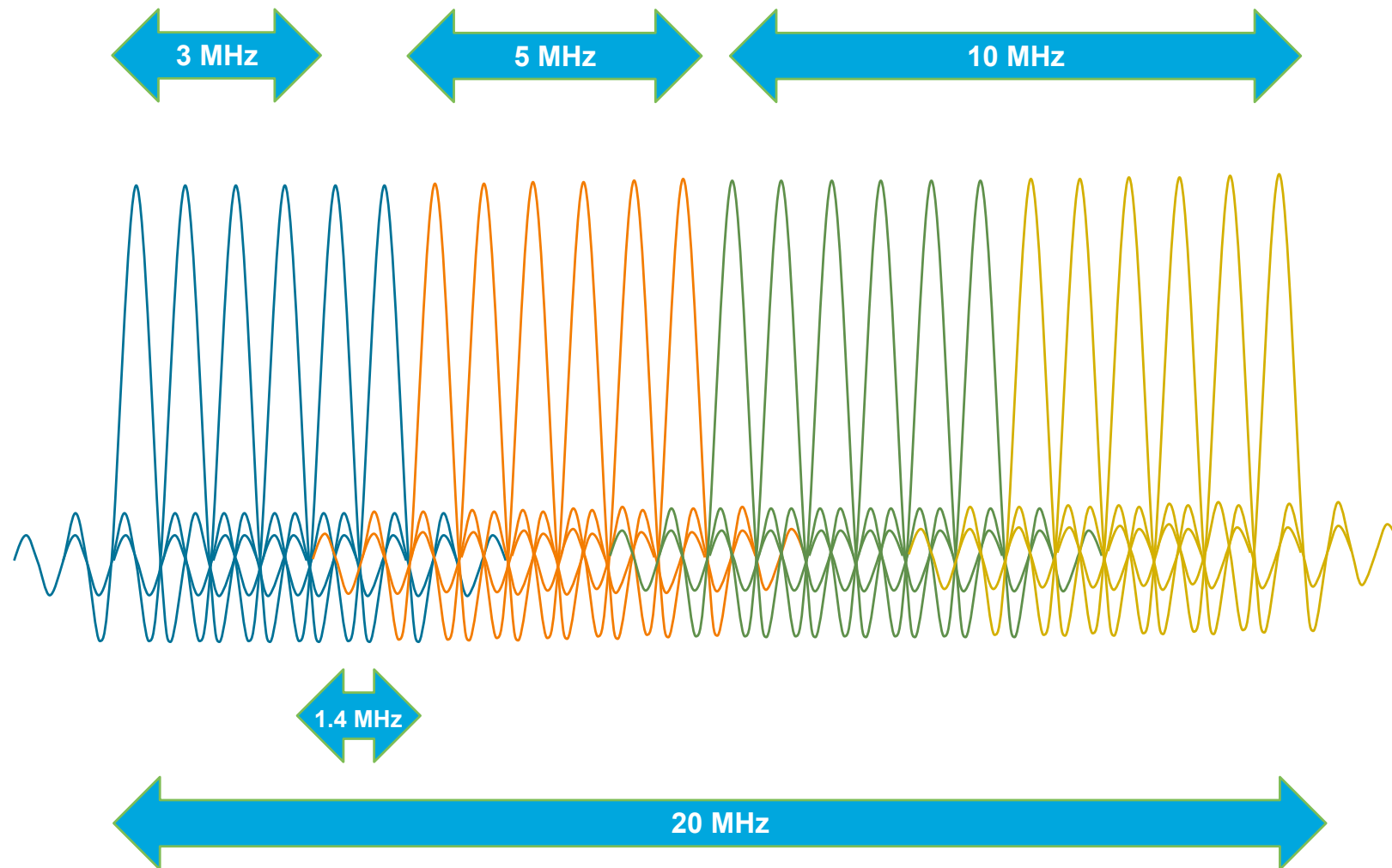
OFDMA

Resources Allocation in Time and Frequency

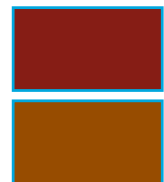
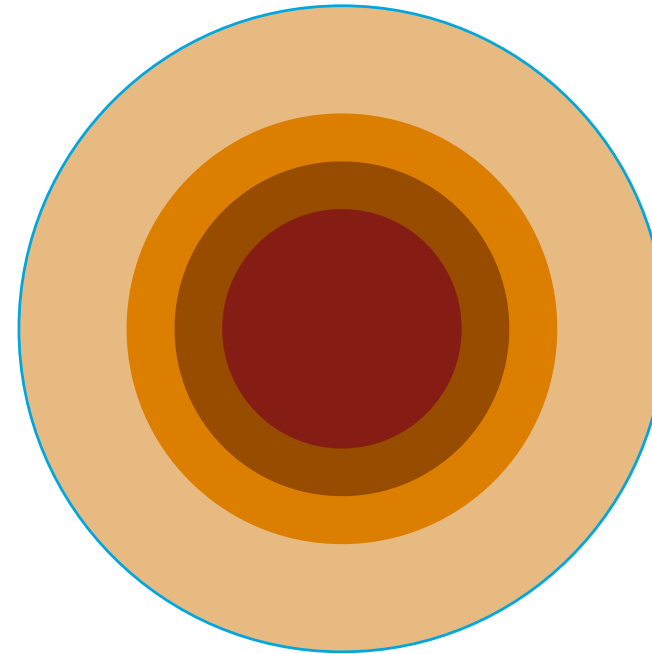
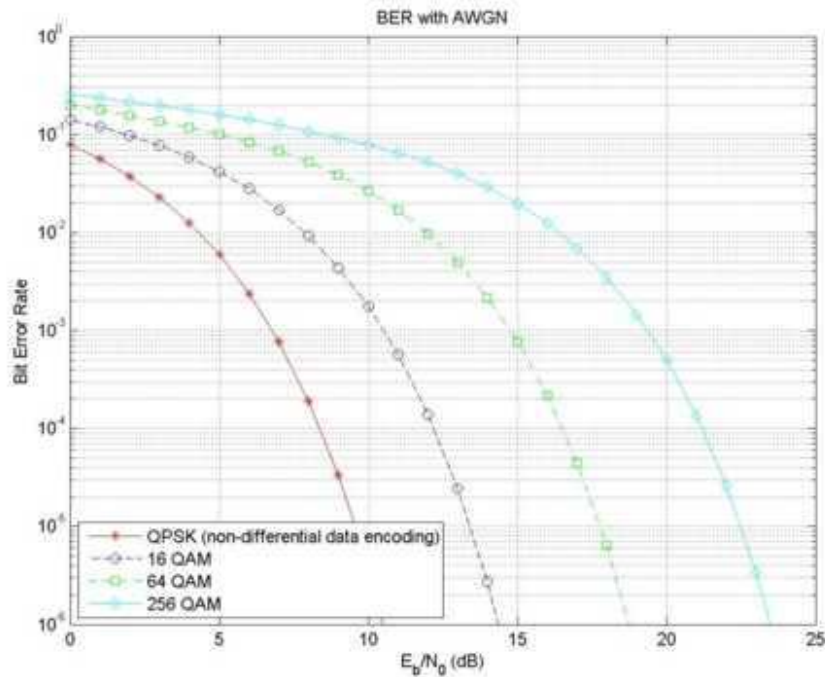


OFDMA

Flexible Channels Allocation



Changing Performance Across the Cell



256QAM (14% of cell area)

64QAM (13% of cell area)

16QAM (18% of cell area)

QPSK (55% of cell area)

- Maximising the bandwidth made available to the users by selecting the optimum modulation scheme (QPSK, 16QAM, 64QAM, etc.)

LTE Physical Channels

- Downlink

Physical Broadcast Channel (PBCH)

Physical Downlink Shared Channel (PDSCH)

Physical Downlink Control Channel (PDCCH)

Physical Control Format Indicator Channel (PCFICH)

Physical Hybrid ARQ Indicator Channel (PHICH)

- Uplink

Physical Random Access Channel (PRACH)

Physical Uplink Shared Channel (PUSCH)

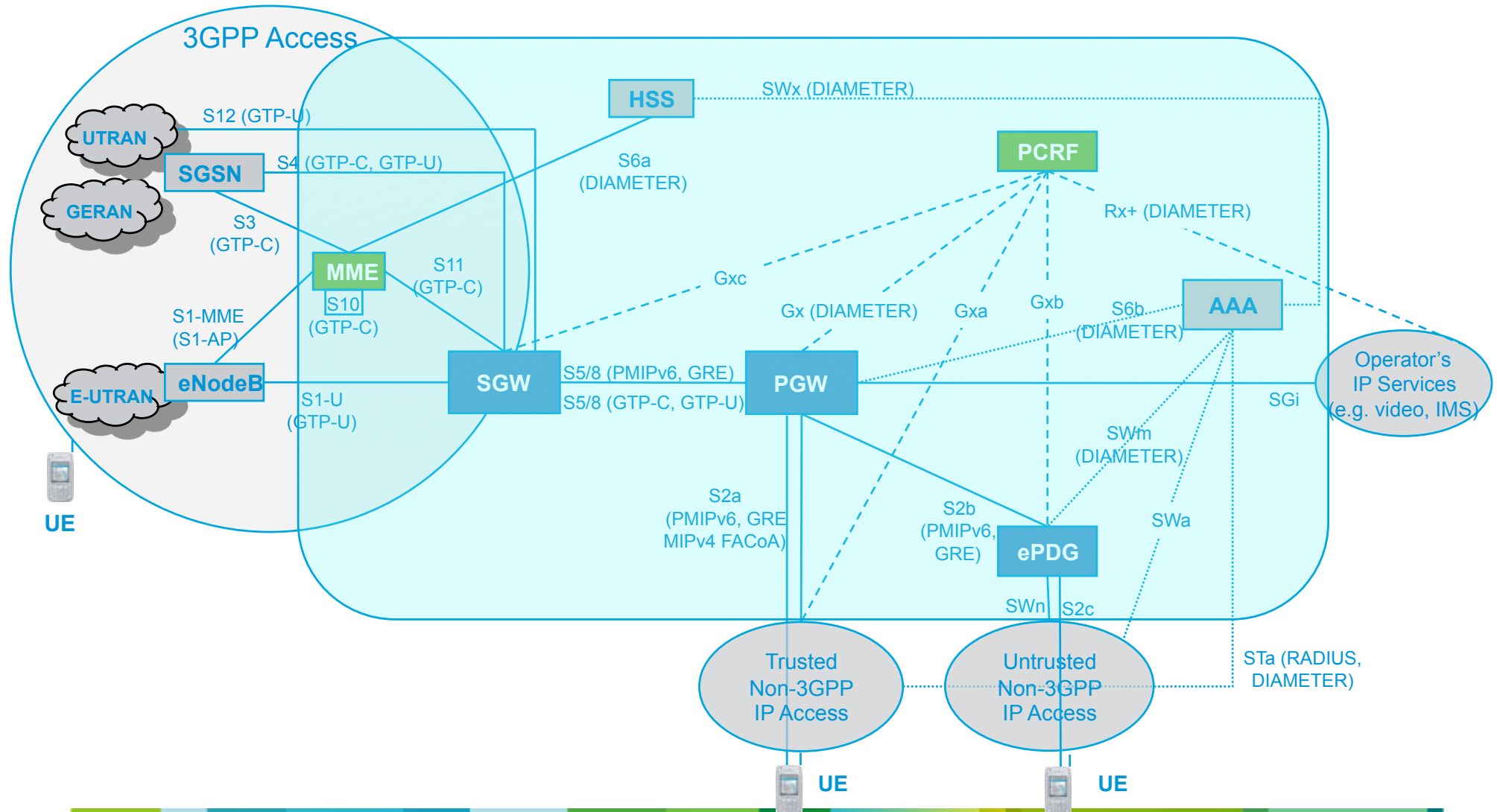
Physical Uplink Control Channel (PUCCH)



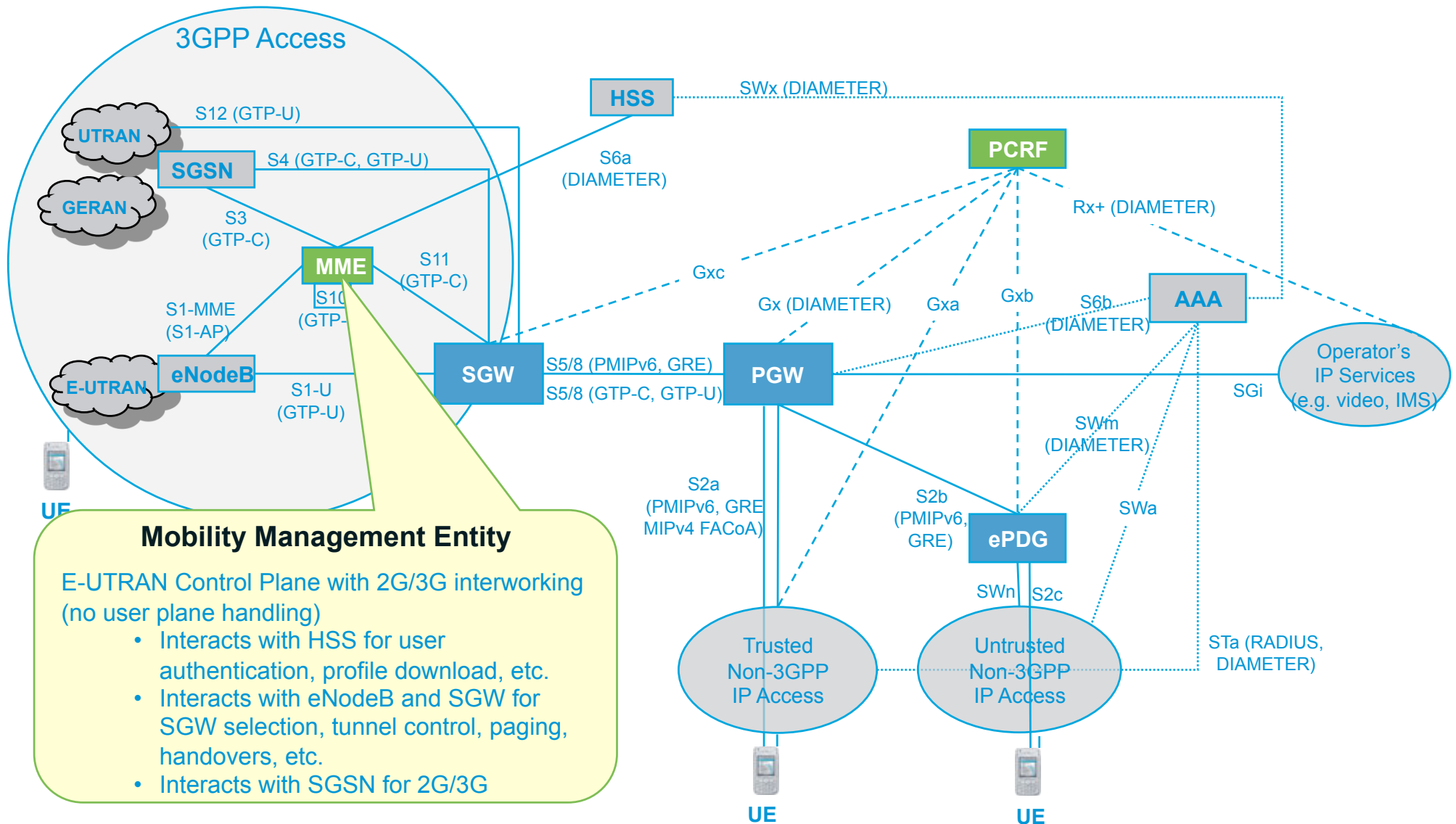
LTE Architecture



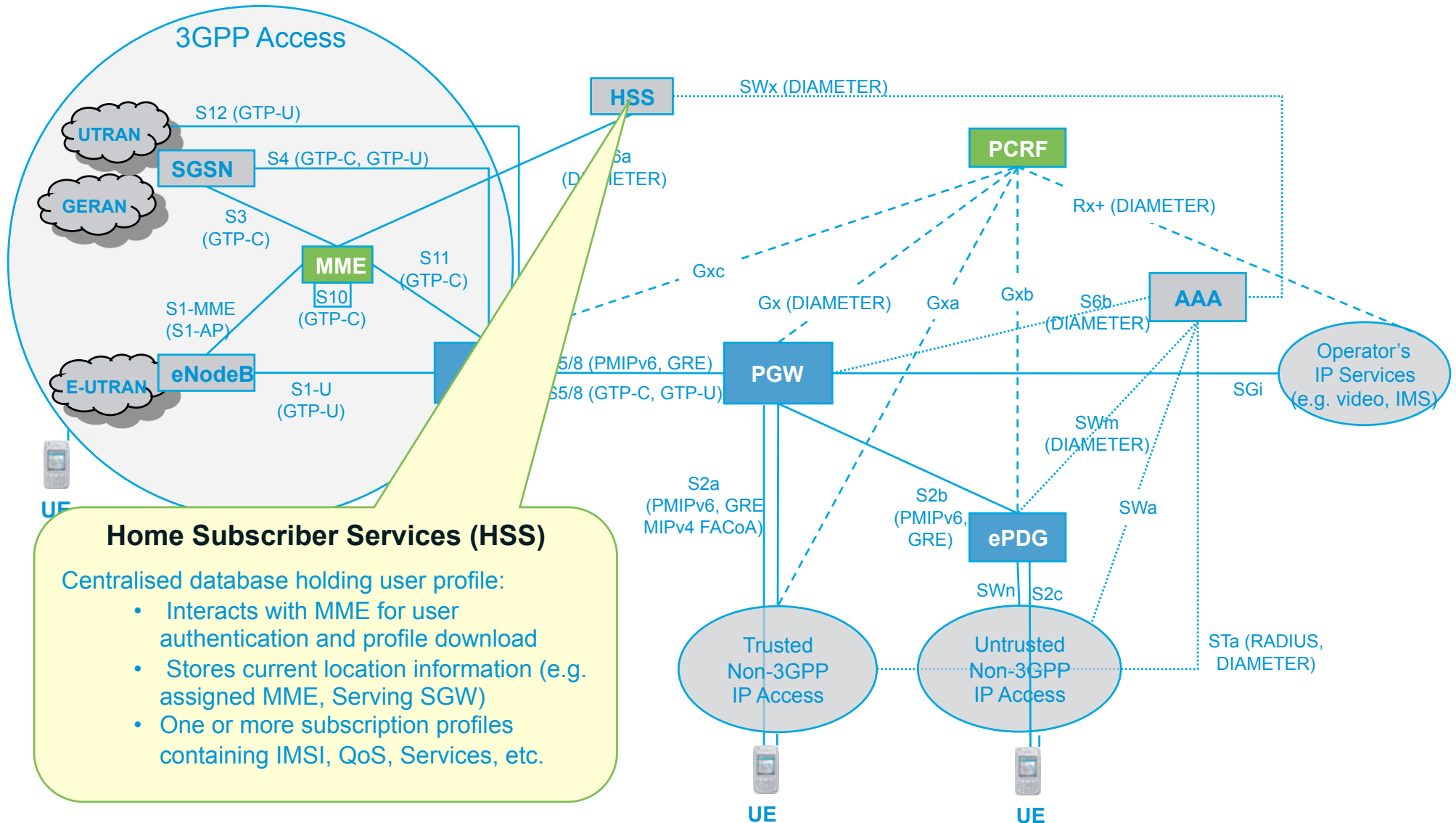
EPS Reference Architecture



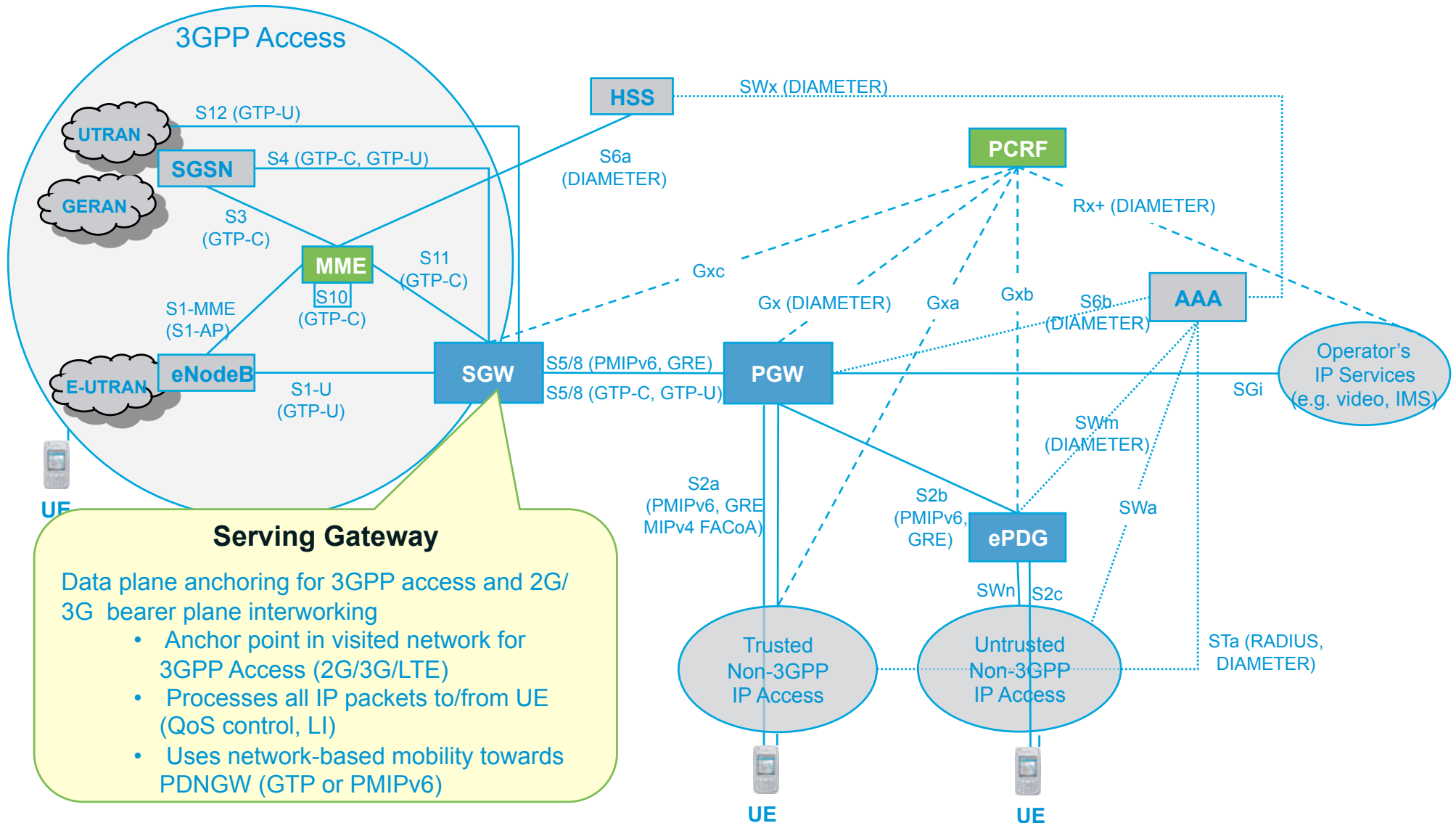
EPC – Mobility Management Entity (MME)



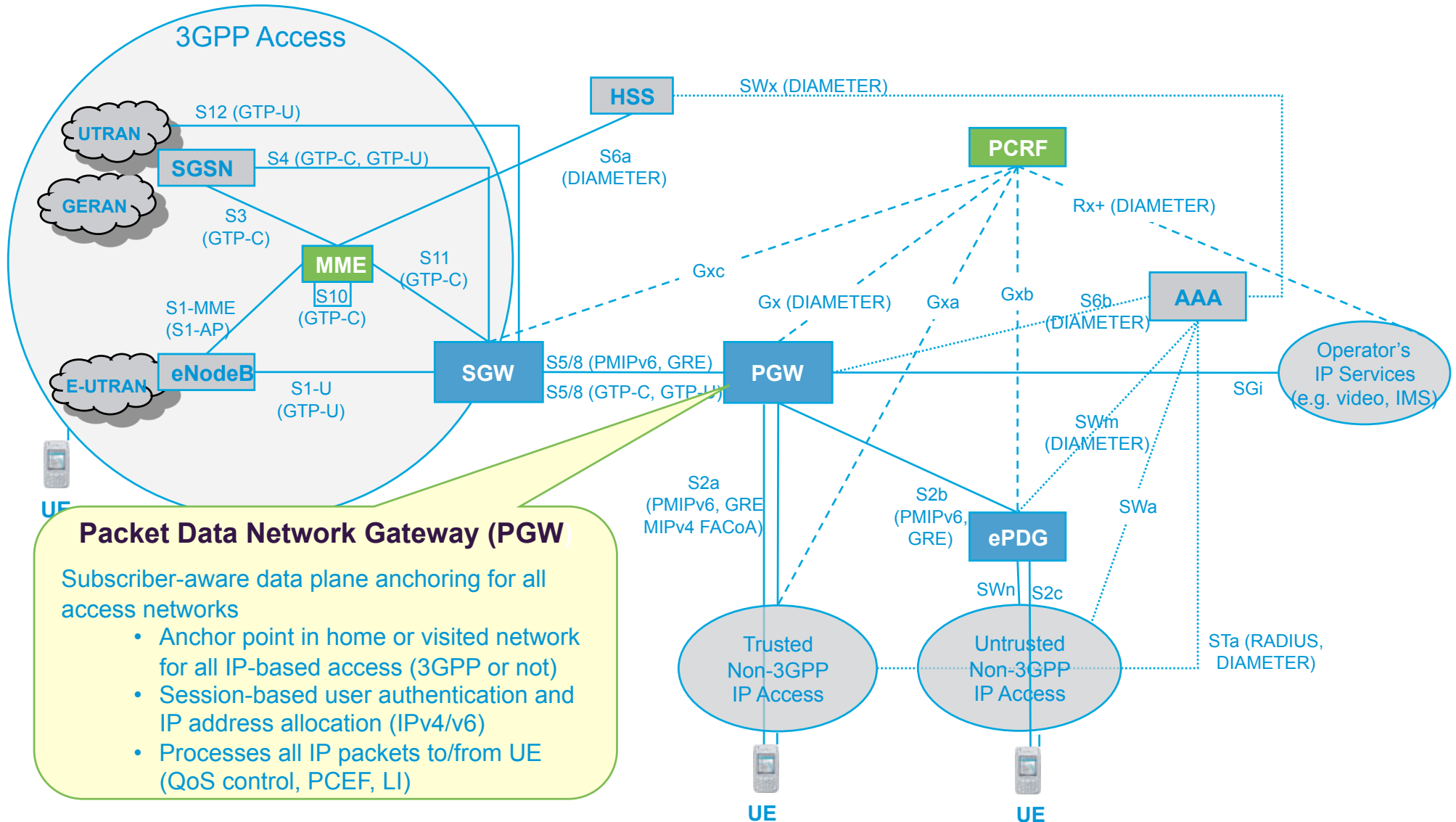
EPC – Home Subscriber System (HSS)



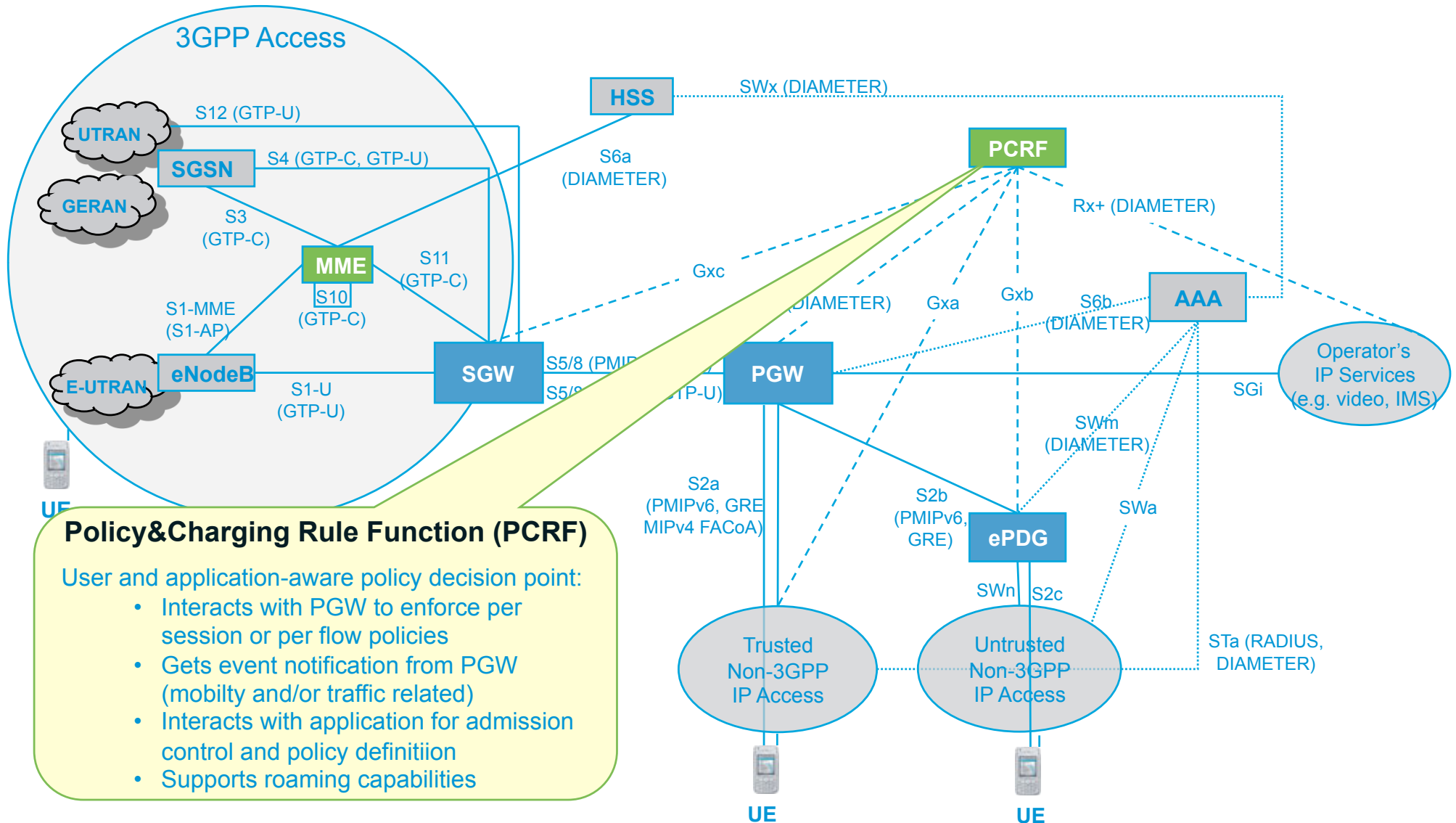
EPC – Serving Gateway (S-GW)



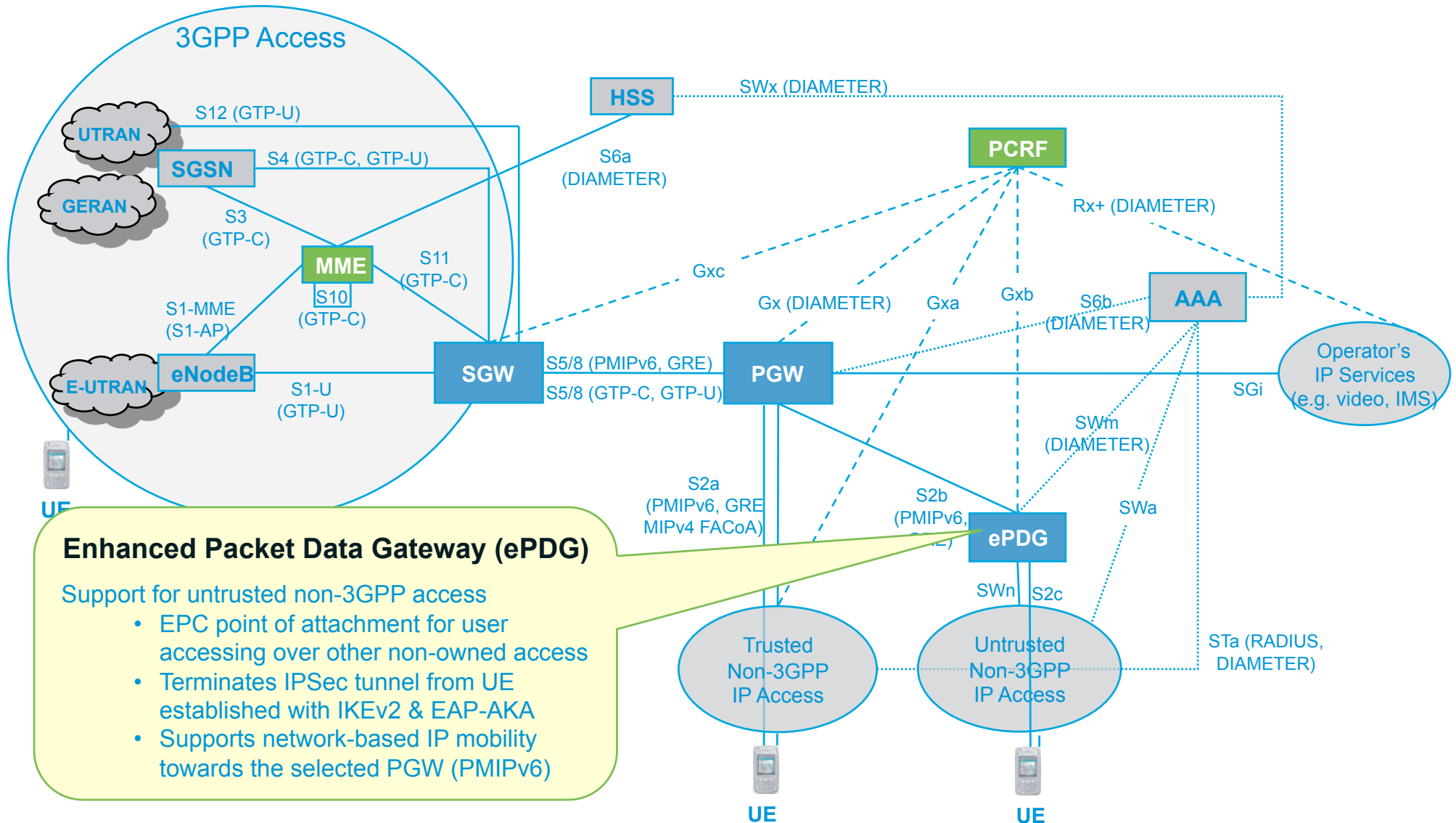
EPG – Packet Data Network Gateway (P-GW)



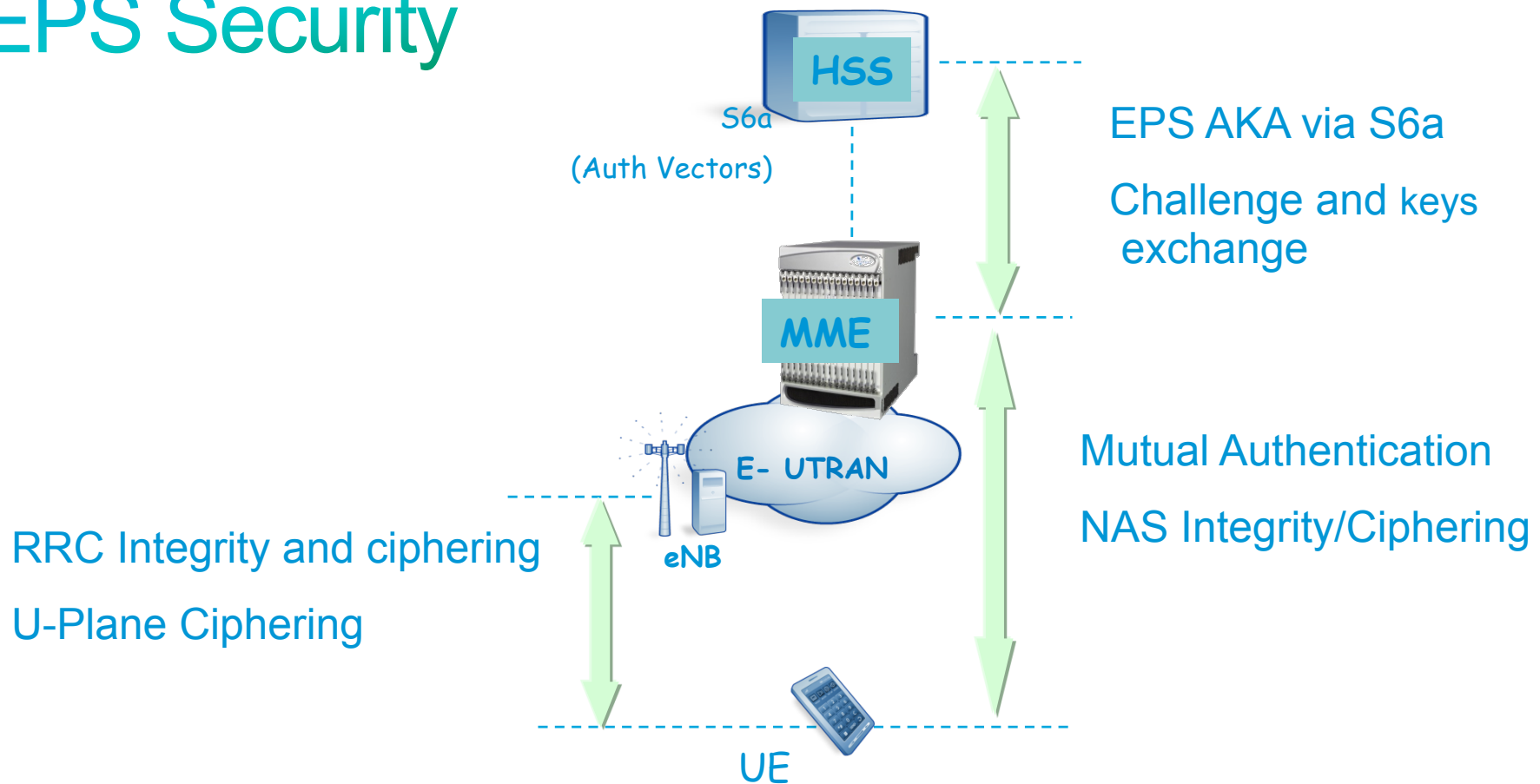
Policy and Charging Rule Function (PCRF)



Enhanced Packet Data Gateway (ePDG)

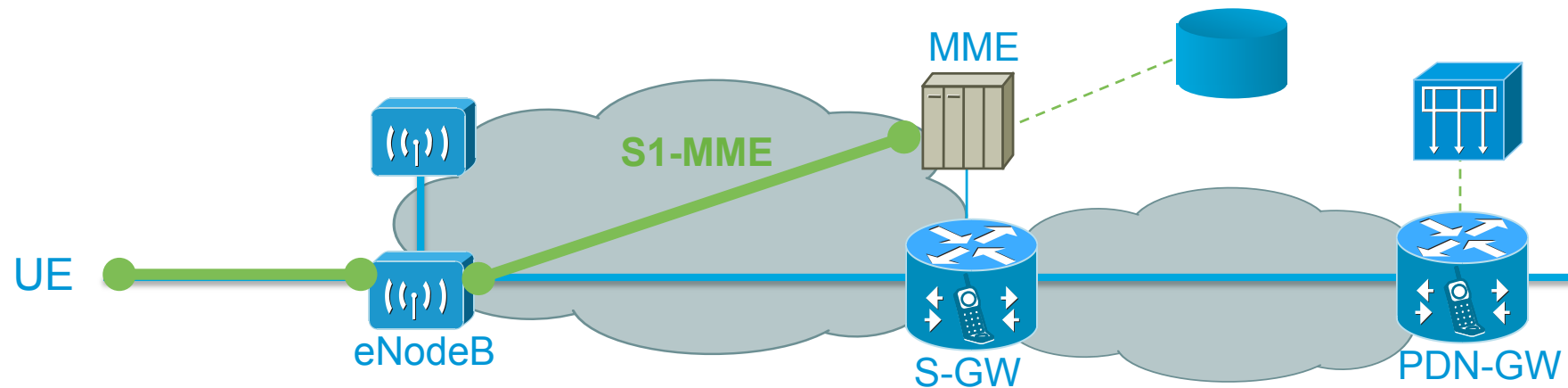


EPS Security



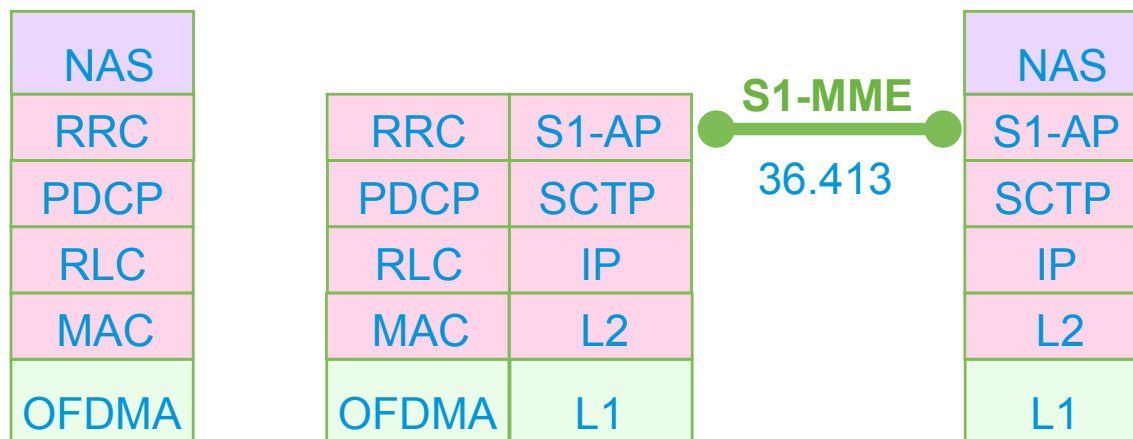
- USIM required for LTE
- Different set of keys used for ciphering, derived from the same original K stored in the USIM/HSS

EPC Protocol Stacks - Signalling

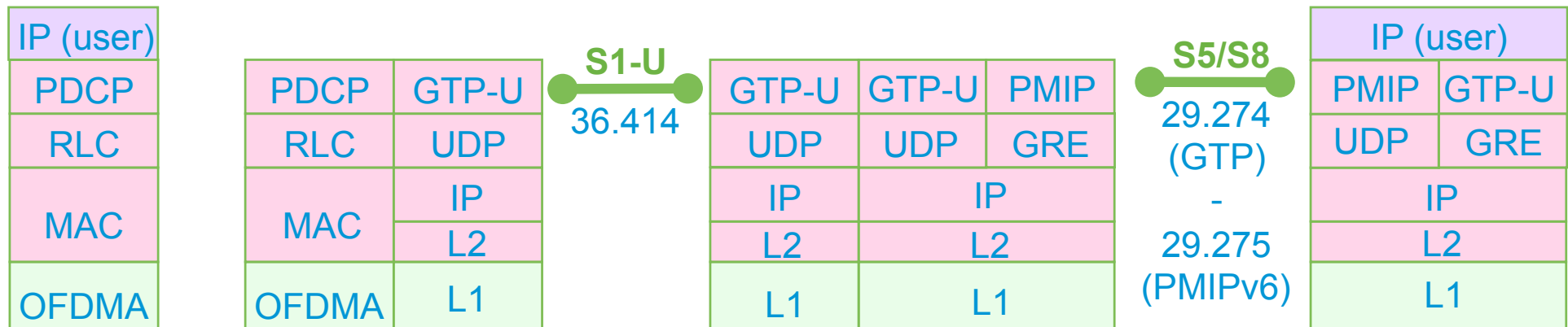
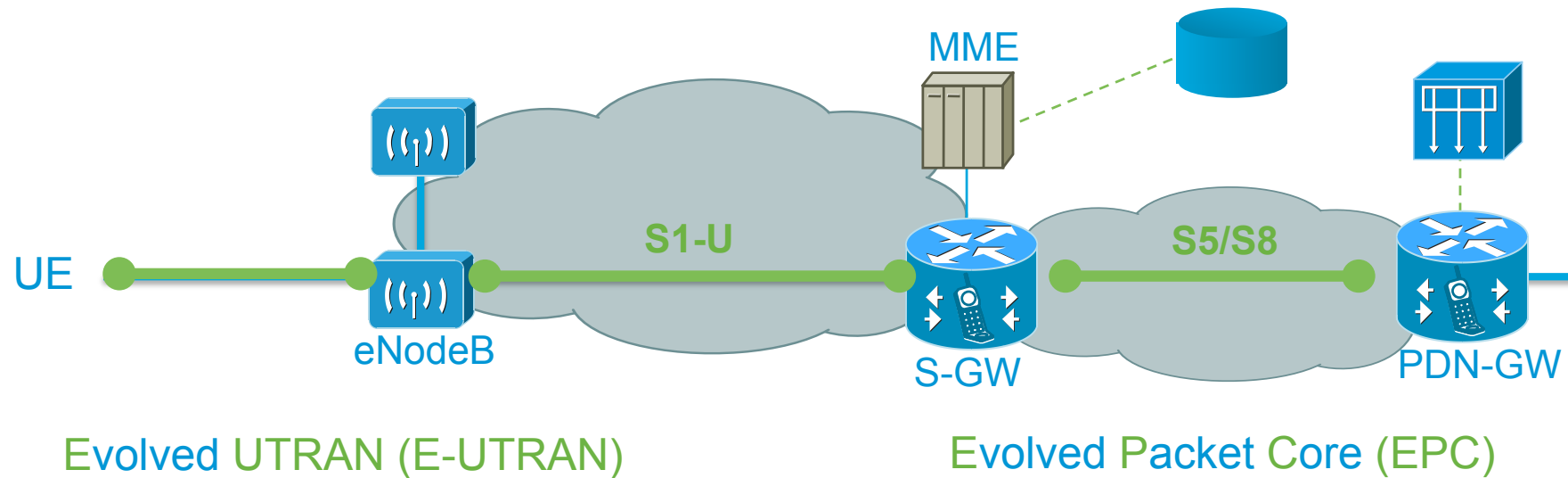


Evolved UTRAN (E-UTRAN)

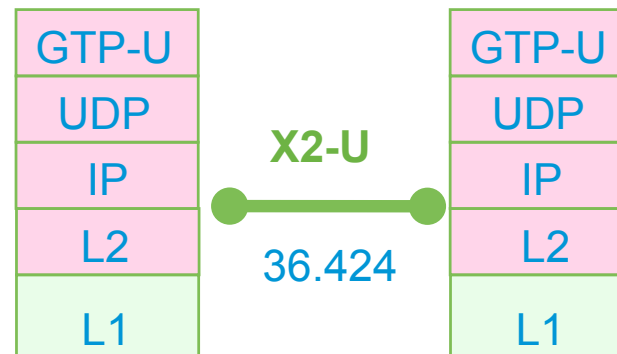
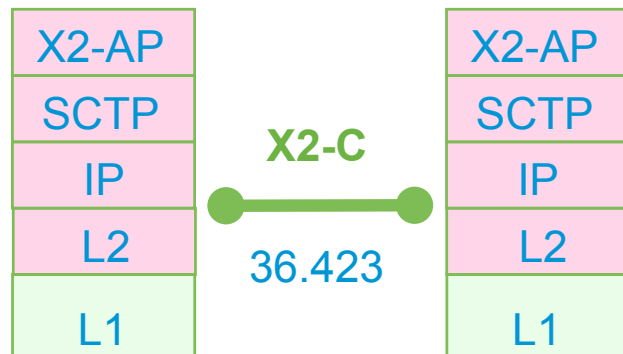
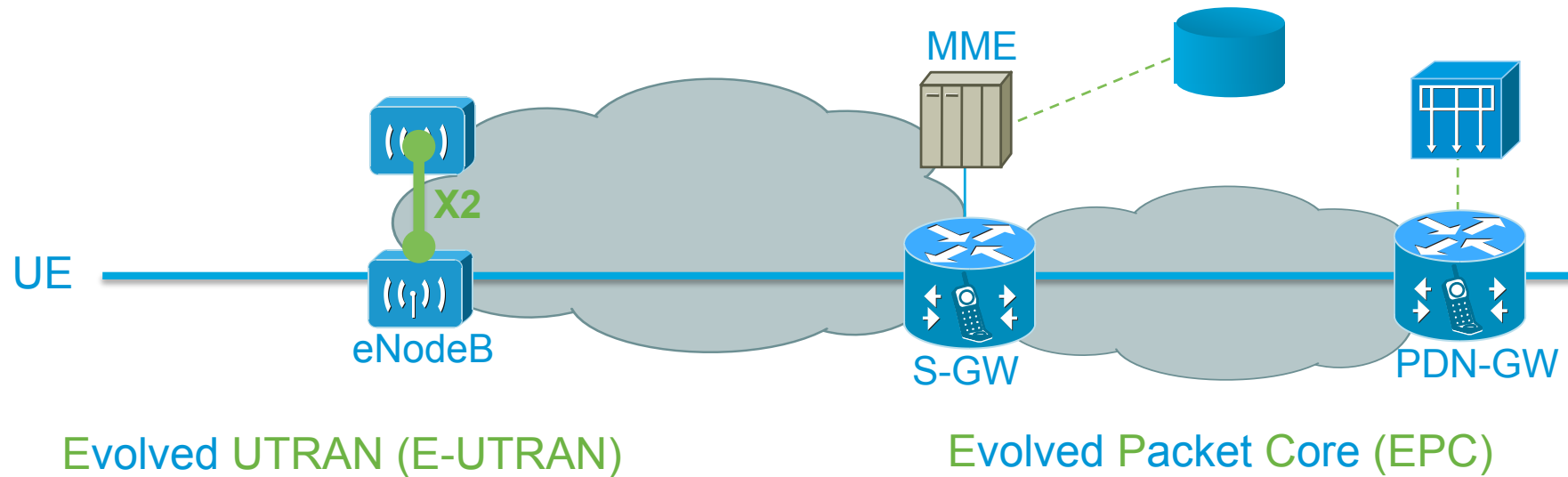
Evolved Packet Core (EPC)



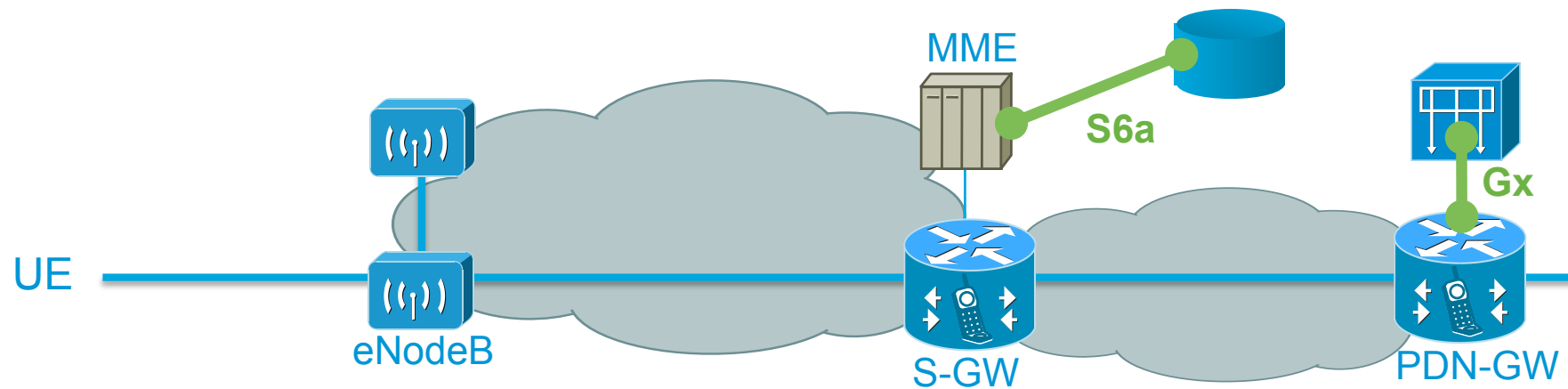
EPC Protocol Stacks – Data Plane



EPC Protocol Stack – X2 Interface

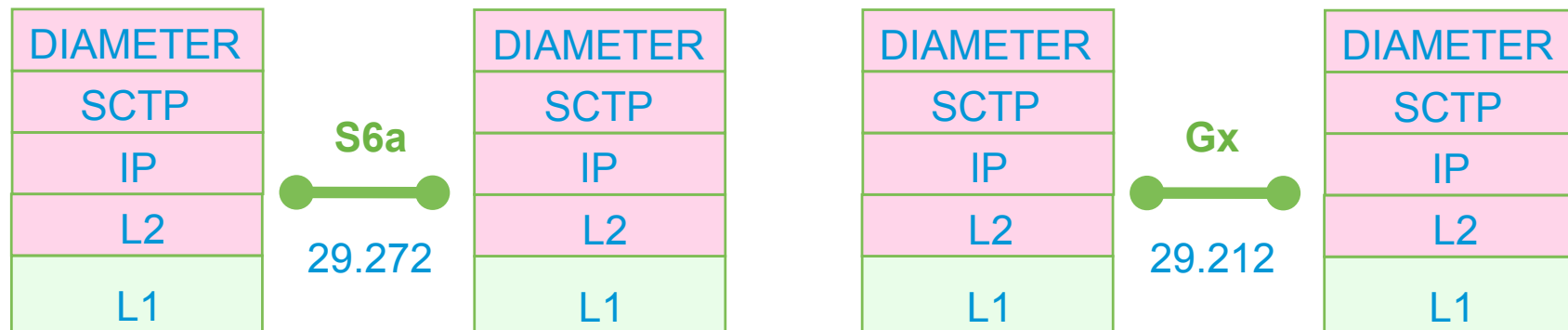


EPC Protocol Stacks – HSS and Policy



Evolved UTRAN (E-UTRAN)

Evolved Packet Core (EPC)



IPv6 in LTE/EPC

Extract from 3GPP TS 23.401 V8.3.0 (2008-09)

- A UE shall perform the address allocation procedures for at least one IP address (either IPv4 or IPv6)
- PDN types IPv4, IPv6 and IPv4v6 are supported
- /64 IPv6 prefix allocation via IPv6 Stateless Address autoconfiguration according to RFC 4862, if IPv6 is supported (Mandatory)
- IPv6 parameter configuration via Stateless DHCPv6 according to RFC 3736 (Optional)

“During default bearer establishment, the PDN GW sends the IPv6 prefix and Interface Identifier to the SGW, and then the S-GW forwards the IPv6 prefix and Interface Identifier to the MME or to the SGSN. The MME or the SGSN forwards the IPv6 Interface Identifier to the UE.”



LTE/EPC Mobility Procedures

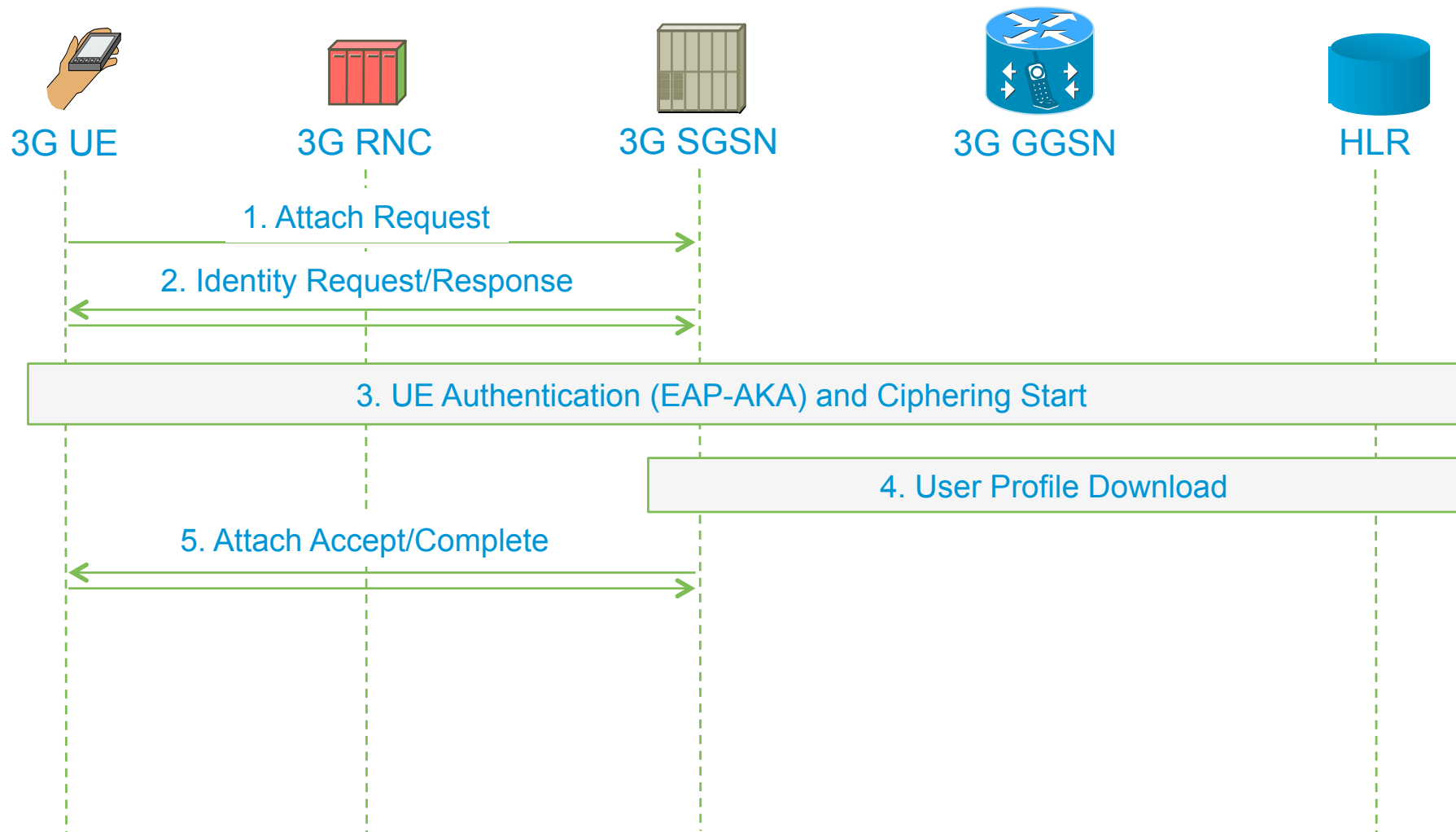


Essential Mobility Procedures

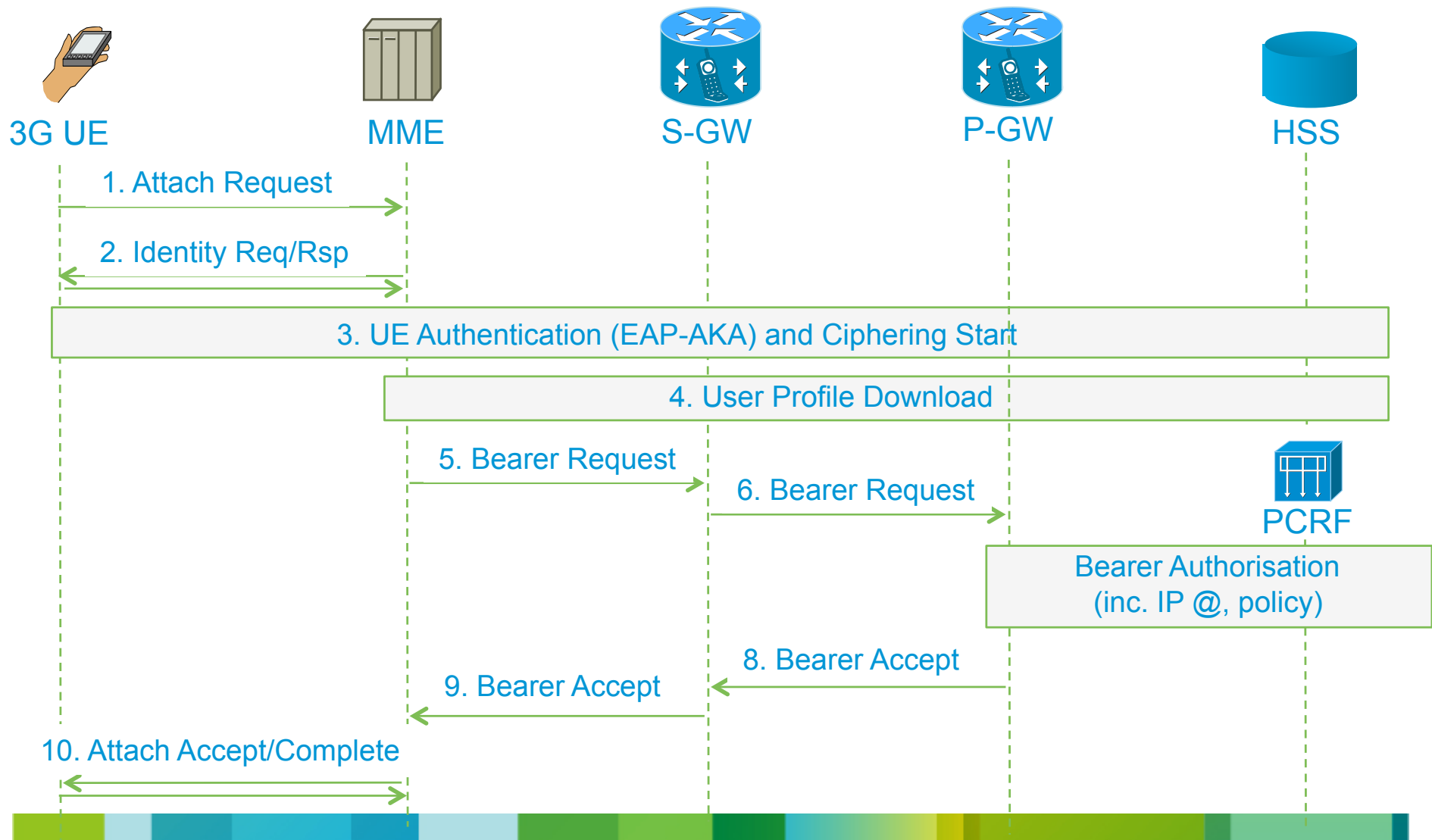
- Idle Mode Mobility procedures
 - UE Initial Attach
 - Periodic Location Update / Inter- and intra-RAT reselection
 - UE Detach
- Active Mode Mobility
 - Intra-RAT Intra- and inter-area handover
 - Inter-RAT handover
- RRC States
 - RRC-IDLE
 - RRC-CONNECTED



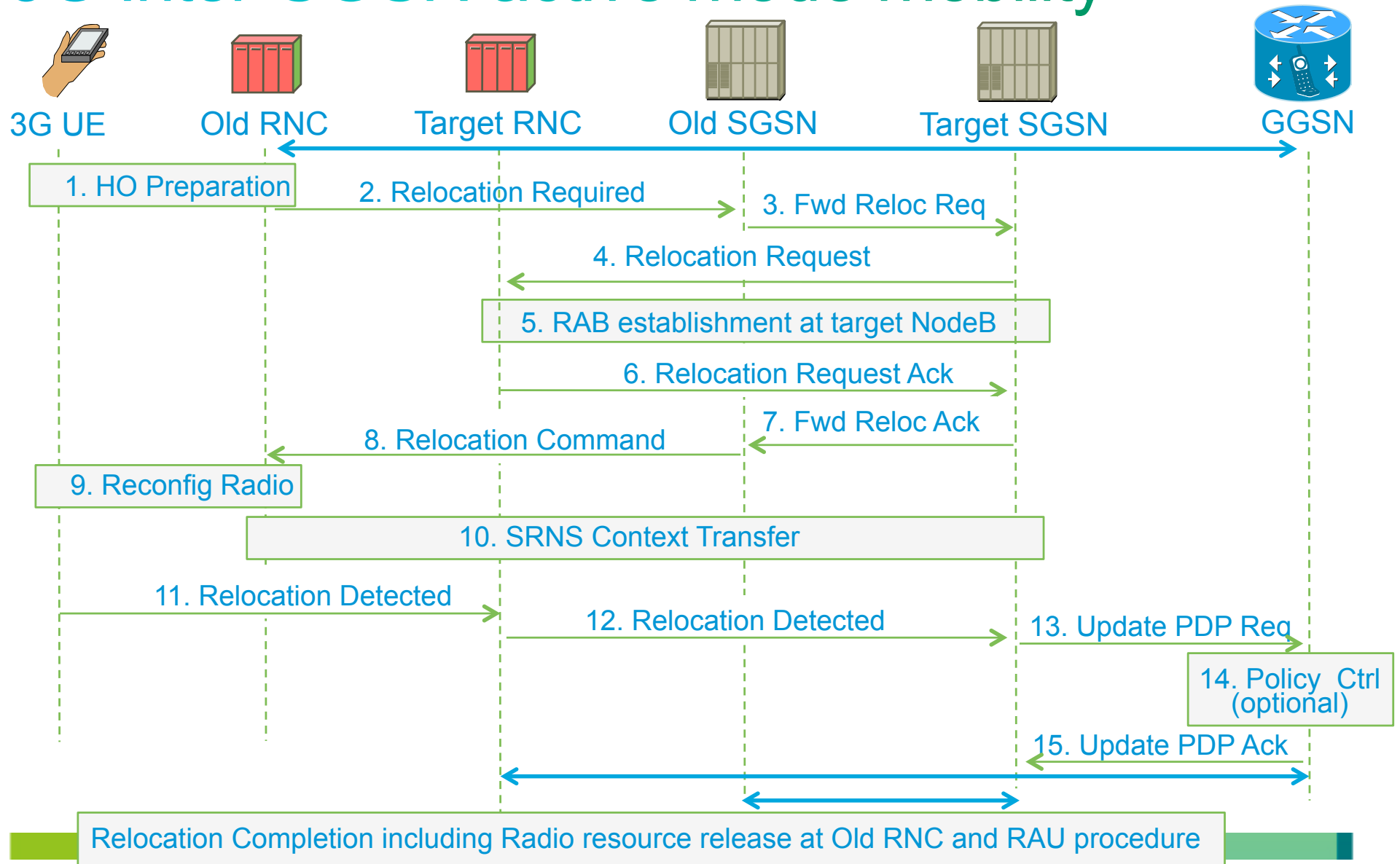
3G initial Attach



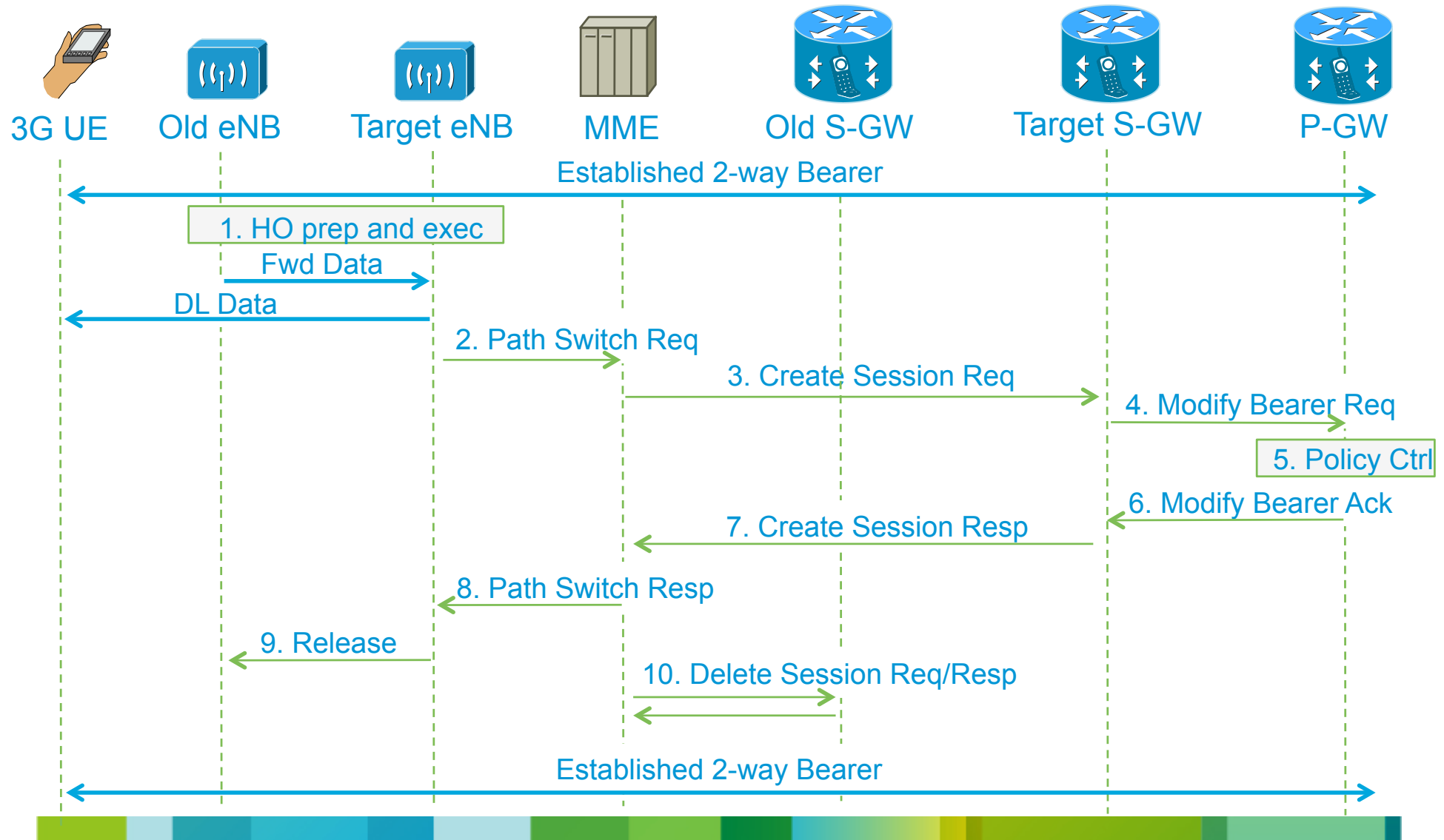
LTE Network Attach



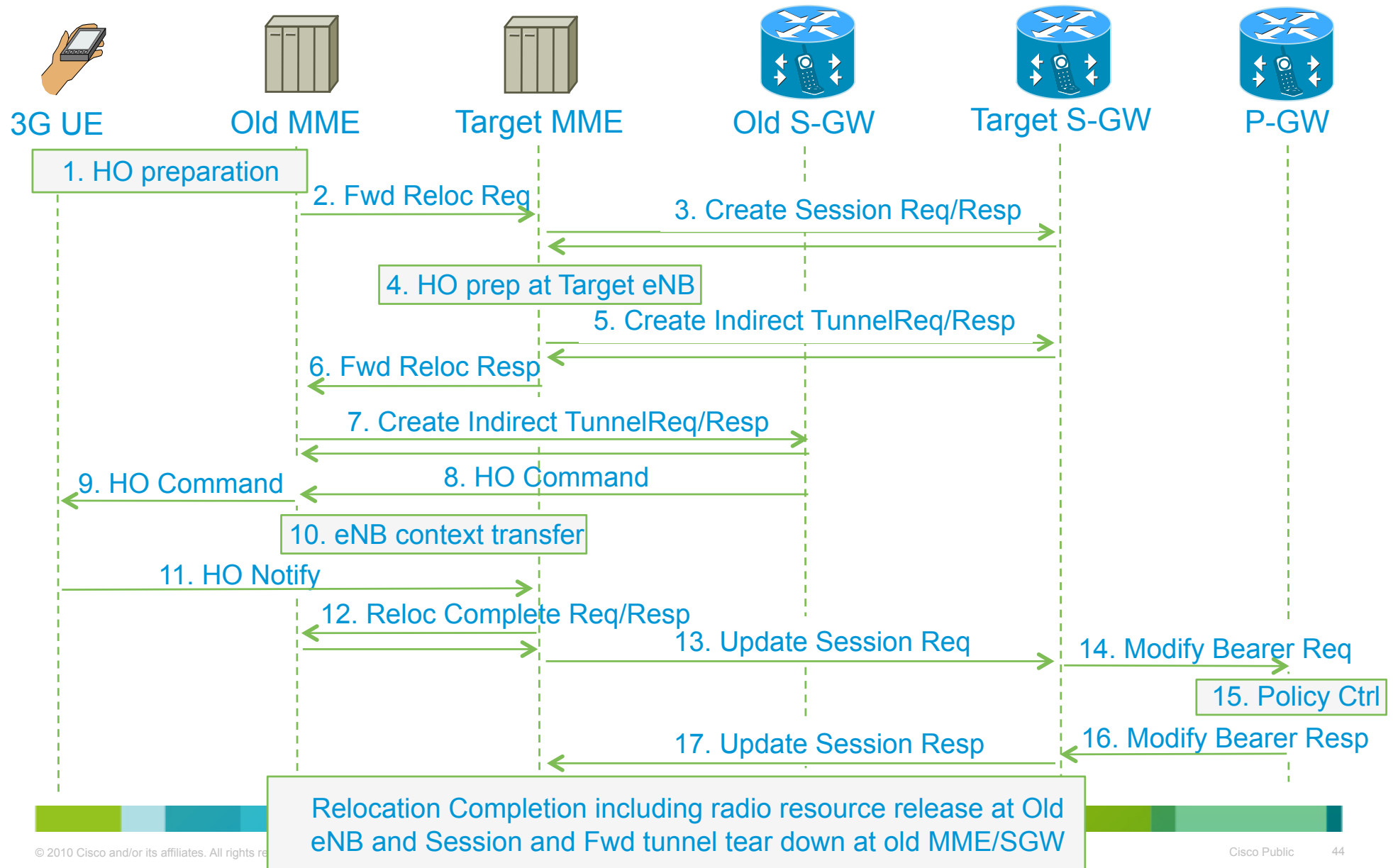
3G Inter-SGSN active mode mobility



LTE X2-based HO with S-GW change



LTE S1-based HO with S-GW change

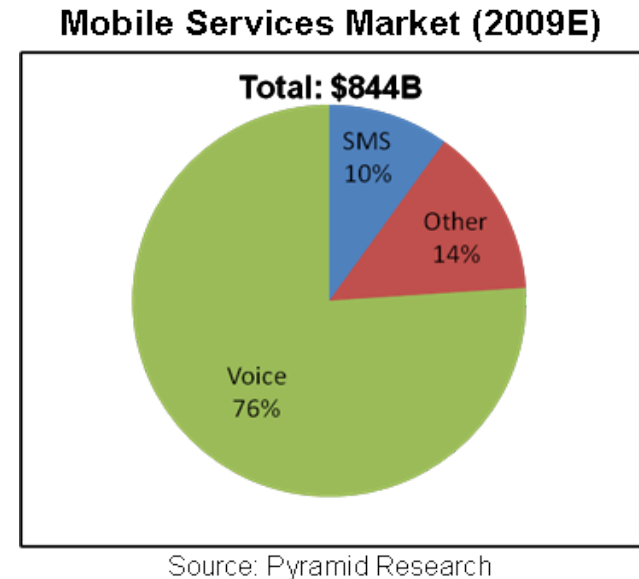


Services in LTE



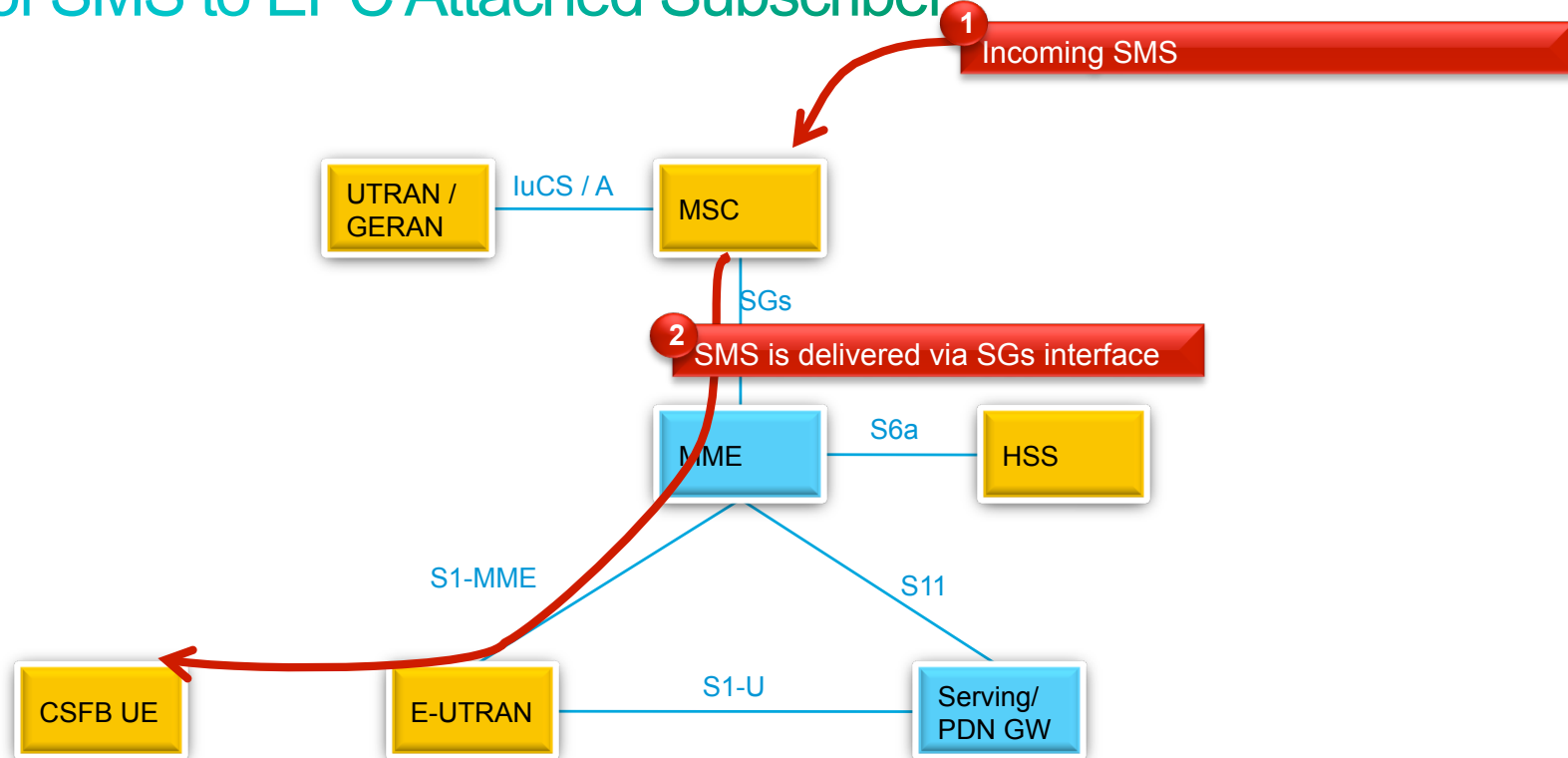
Legacy Services in LTE

- The EPS architecture (3GPP Rel 8) is the first 3GPP all-IP architecture
- Voice and SMS are still the cash cows for mobile operators
 - Migration is critical
 - User experience must be preserved
- CSFB is the interim solution recommended by NGMN
- IMS is the target solution for Telephony and Multimedia Services
- OneVoice IMS profile 'simplifies' implementation for VoLTE
- NGMN and OneVoice initiatives reduce risk of industry fragmentation
- SMS typically required before voice due to EU regulatory requirements for data roaming services



Circuit Switched Fallback

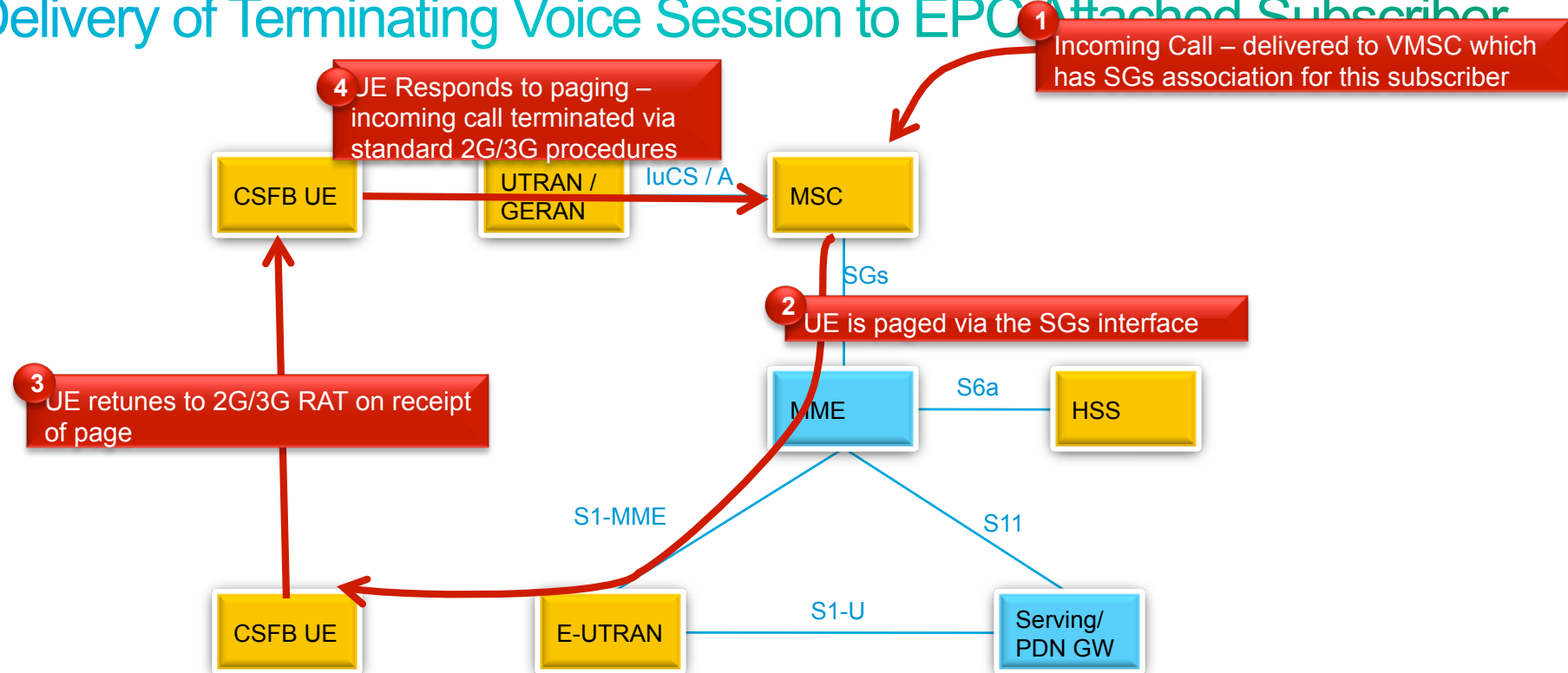
Delivery of SMS to EPC Attached Subscriber



- During EPC attach, CSFB UE's are also attached over SGs to MSC
- MME maintains mapping of TA to LA to determine appropriate MSC to establish SGs association with
- SMS can be delivered/sent without FallBack to legacy radio (SGs interface includes SMS payload capability)

Circuit Switched Fallback

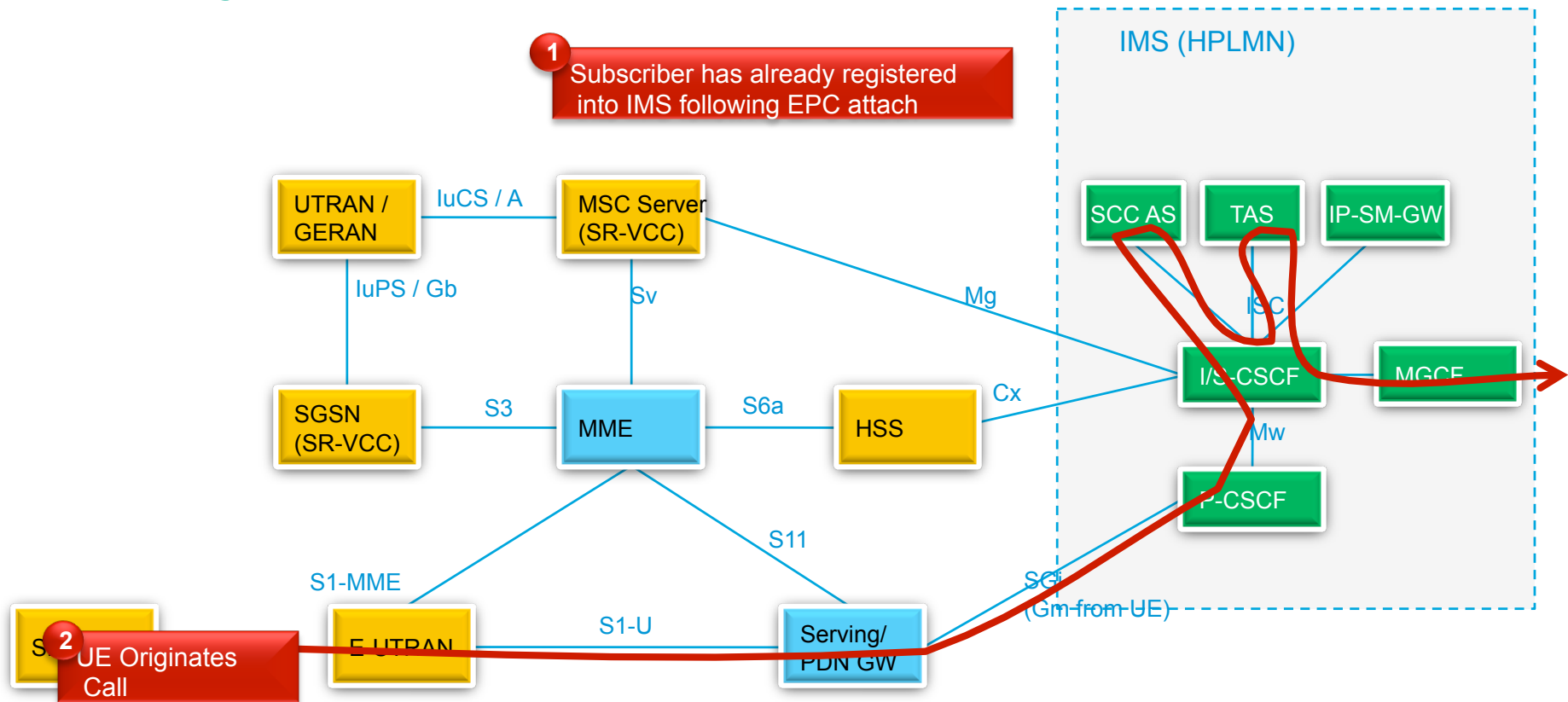
Delivery of Terminating Voice Session to EPC Attached Subscriber



- Additional complexity / upgrades required on CS core to support use-case where the MSC sending Page is different to MSC receiving Page response (i.e. TA to LA mapping is inaccurate due to cell breathing or other circumstances)
- This capability (Roaming Retry) requires upgrades on GMSC, VMSC and HLR. Introduces further termination latency.

Voice over IMS

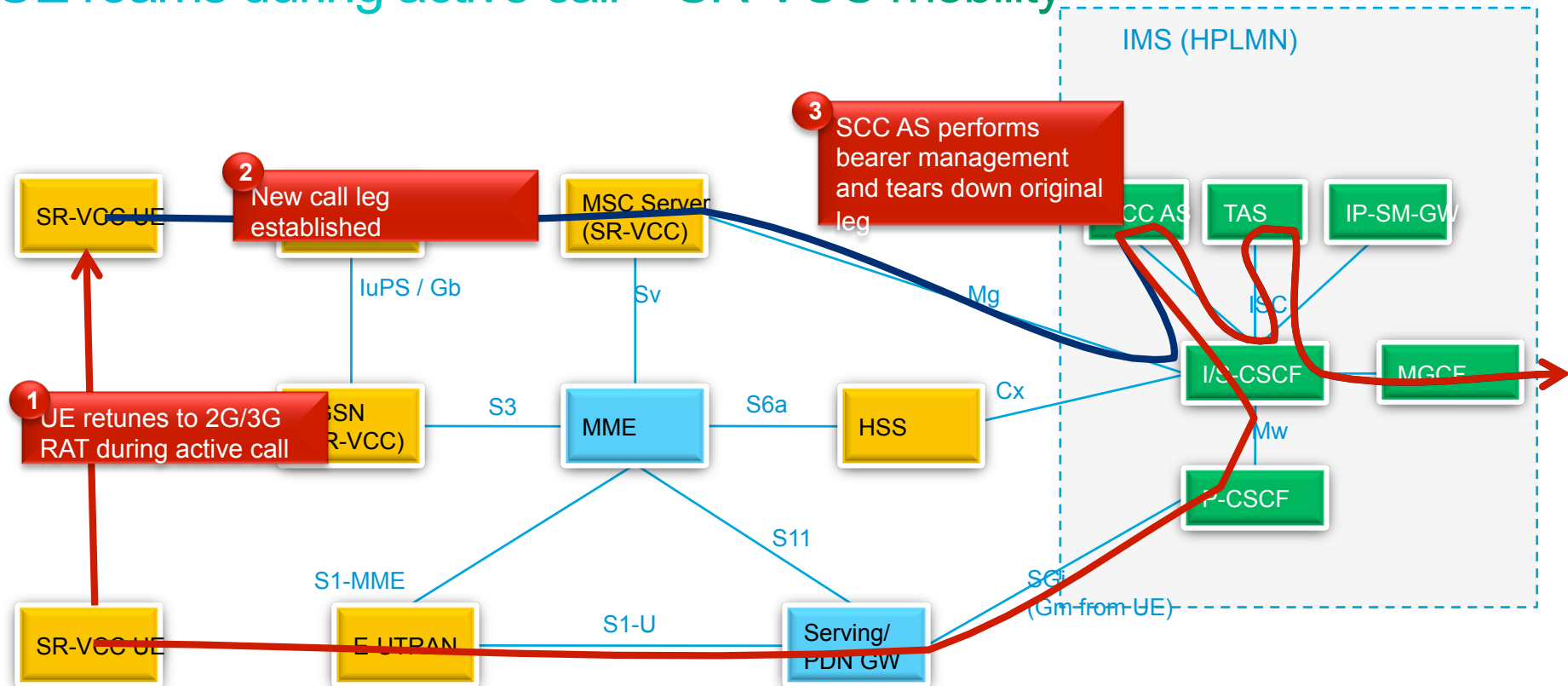
Mobile Origination



- To enable mid-call mobility, S-CSCF anchors call at SCC AS
- TAS provides end-user services (e.g. IR.92)
- MGCF provides breakout to PSTN or other CS networks

Voice over IMS

UE roams during active call – SR-VCC mobility



- SCC AS performs leg management – hides mobility events from other IMS application servers
- SR-VCC only works in one direction – LTE → 2G/3G
- Requires upgrades on legacy MSC infrastructure

High-Level CSFB and VoIMS Comparison

	CSFB	VoIMS
End-User Services	Re-use legacy implementation	OneVoice (IR.92) provides baseline. All operator proprietary services and extensions must be ported to IMS.
Regulatory	Re-use legacy implementation	National regulatory services must be implemented in IMS.
Service Differentiation	Restricted to only services deliverable from legacy core.	IR.92 services can be blended with other IMS services such as presence, RCS, rich messaging.
End-user Experience	Significant post-dial delay. Retuning from CS back to LTE may take some time – impact to data services.	No retuning required to access CS equivalent services. Still industry concerns regarding SR-VCC latency.
Complexity	Medium – CS core requires upgrades for SGs interface and also to support Roaming Retry.	High – Significant new network infrastructure required. SR-VCC extremely complex. Intensive service porting to ensure full legacy parity.
Cost	Unknown – upgrades must come from existing CS vendors. Believed that legacy vendors are using this to their advantage to seek premium.	High – large investment required for new infrastructure. However, diverse range of vendors opens door for innovative deals/ solutions.

Thank you.

