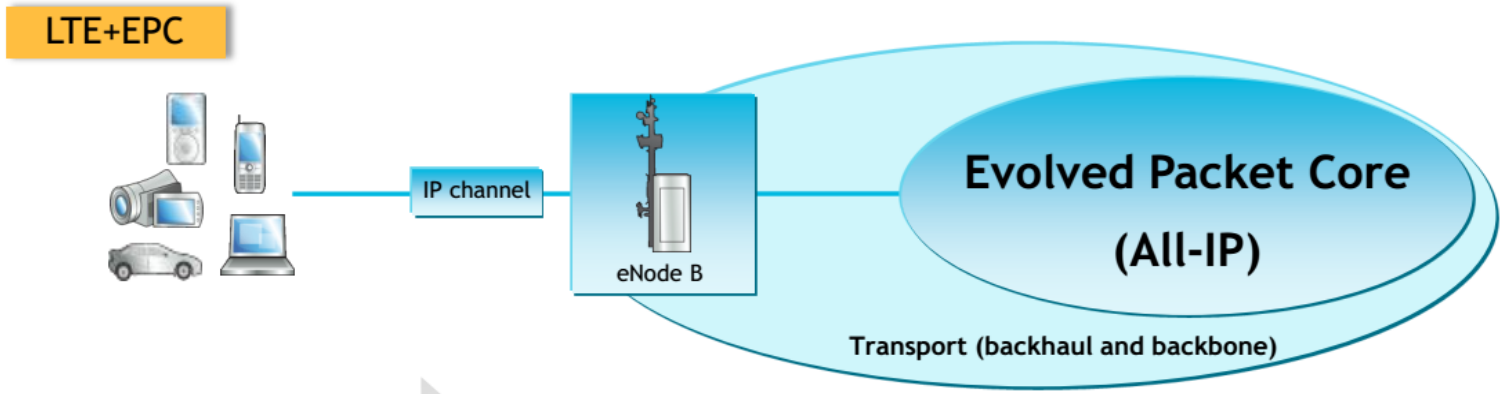
Virtual Evolved Packet Core (VEPC) Placement in the Metro Core-Backhual-Aggregation Ring

BY
ABHISHEK GUPTA
FRIDAY GROUP MEETING
OCTOBER 20, 2017

UCDAVIS

LTE: All-IP, simplified network architecture



What is EPC ?

New, all-IP mobile core network introduced with LTE

- End-to-end IP (All-IP)
- Clear delineation of control plane and data plane
- Simplified architecture: flat-IP architecture with a single core

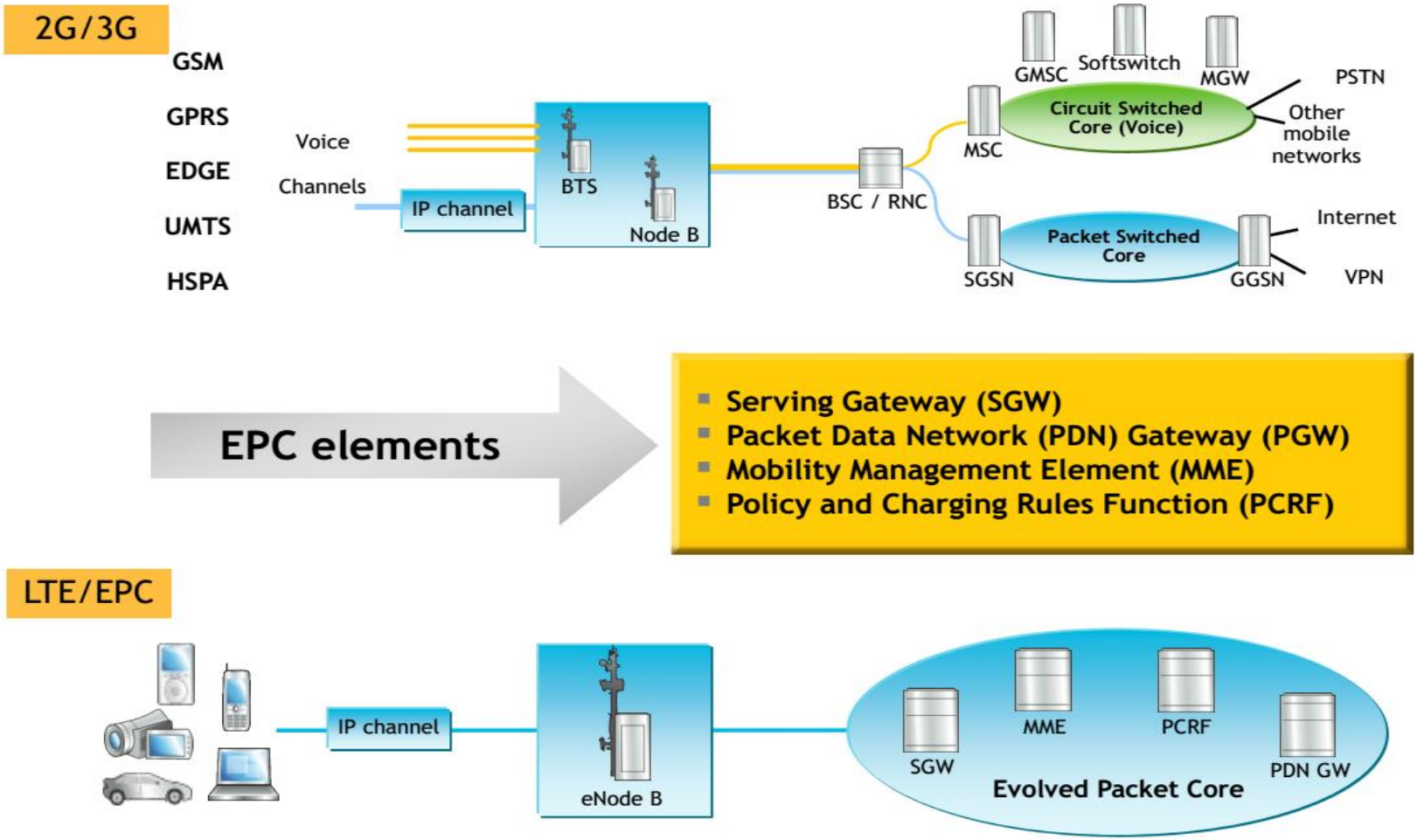
- **EPC was previously called SAE (System Architecture Evolution)**
- **eNodeB is also called E-UTRAN**
- **Evolved Packet System = EPC + E-UTRAN**

- "The EPC is a **multi-access core network** based on the Internet Protocol (IP) that enables operators to deploy and operate **one common packet core** network **for 3GPP radio access** (LTE, 3G, and 2G), **non-3GPP radio access** (HRPD, WLAN, and WiMAX), **and fixed access** (Ethernet, DSL, cable, and fiber).
- The EPC is defined around the three important paradigms of mobility, policy management, and security."

Source: IEEE Communications Magazine V47 N2 February 2009 REF: http://www.comsoc.org/livepubs//ci1/public/2009/feb/pdf/ciguest_bogineni.pdf

[1] Introduction to Evolved Packet Core (EPC) – EPC elements, protocols and procedures – Alcatel Lucent

Evolved Packet Core (EPC)



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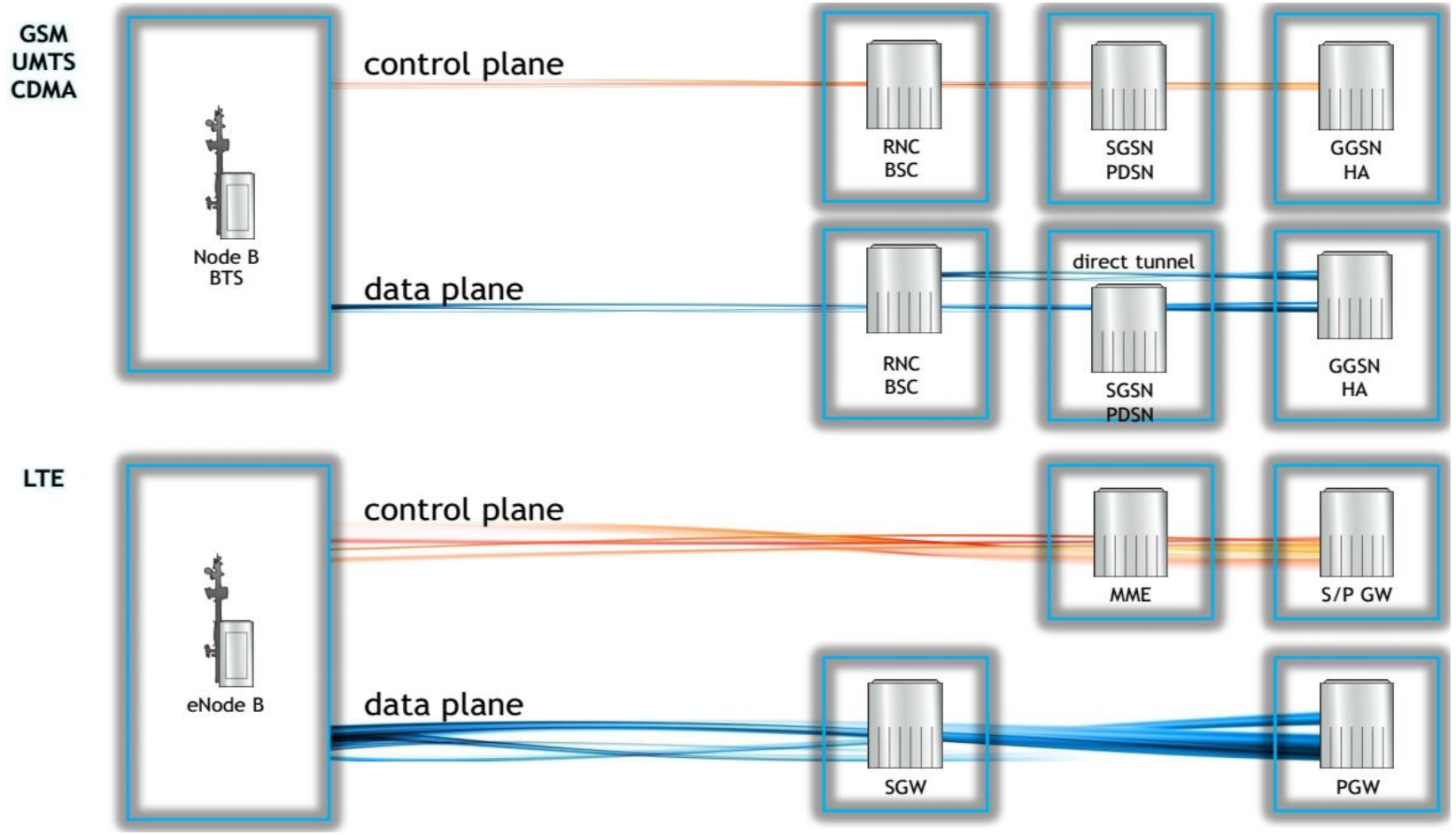
“Flat IP” = less hierarchy = lower latency



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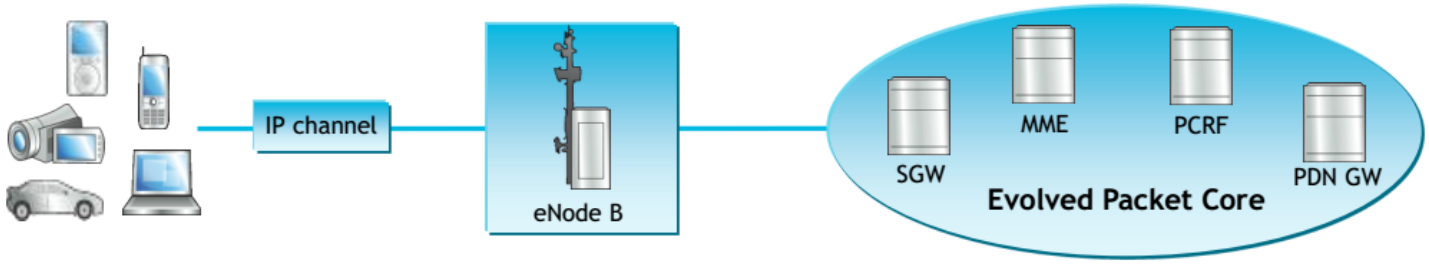
EPC elements

LTE/EPC



EPC elements

- **Serving Gateway**
  - Serving a large number of eNodeBs, focus on scalability and security
- **Packet Data Network (PDN) Gateway**
  - IP management ("IP anchor"), connection to external data networks; focus on highly scalable data connectivity and QoS enforcement
- **Mobility Management Element (MME)**
  - Control-plane element, responsible for high volume mobility management and connection management (thousands of eNodeBs)
- **Policy and Charging Rules Function (PCRF)**
  - Network-wide control of flows: detection, gating, QoS and flow-based charging, authorizes network-wide use of QoS resources (manages millions on service data flows)

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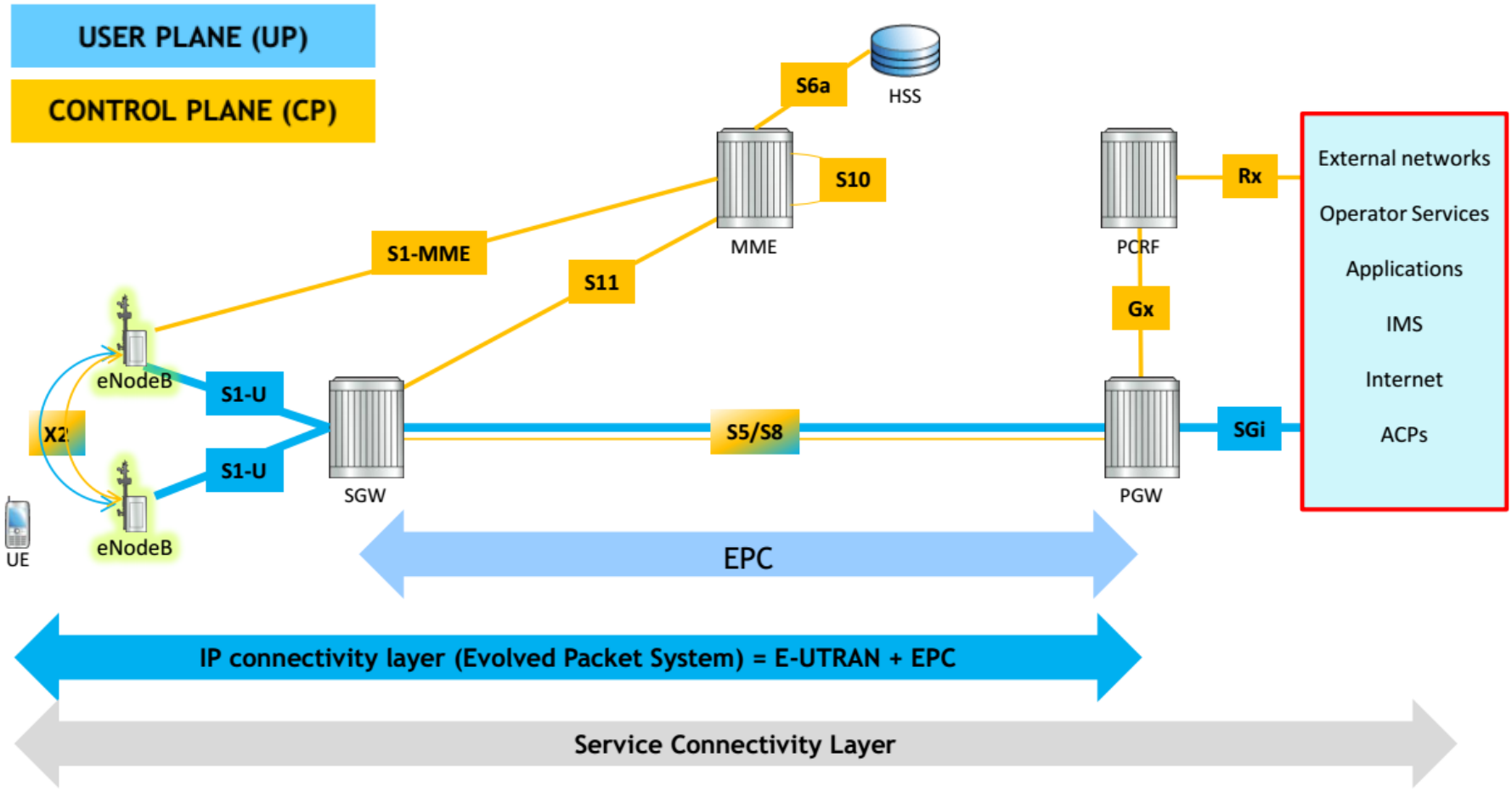
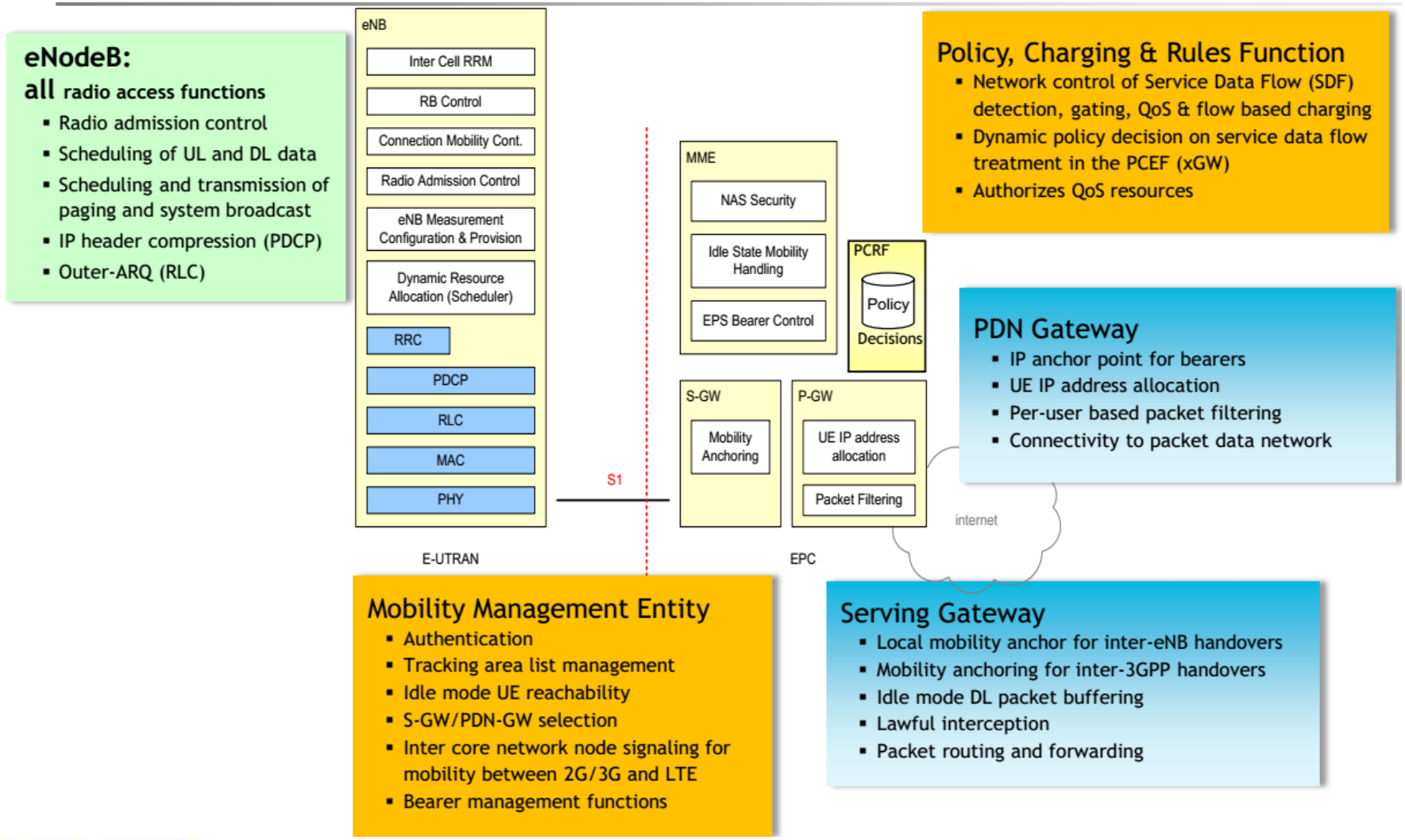
EPC Architecture



EPC elements and functions



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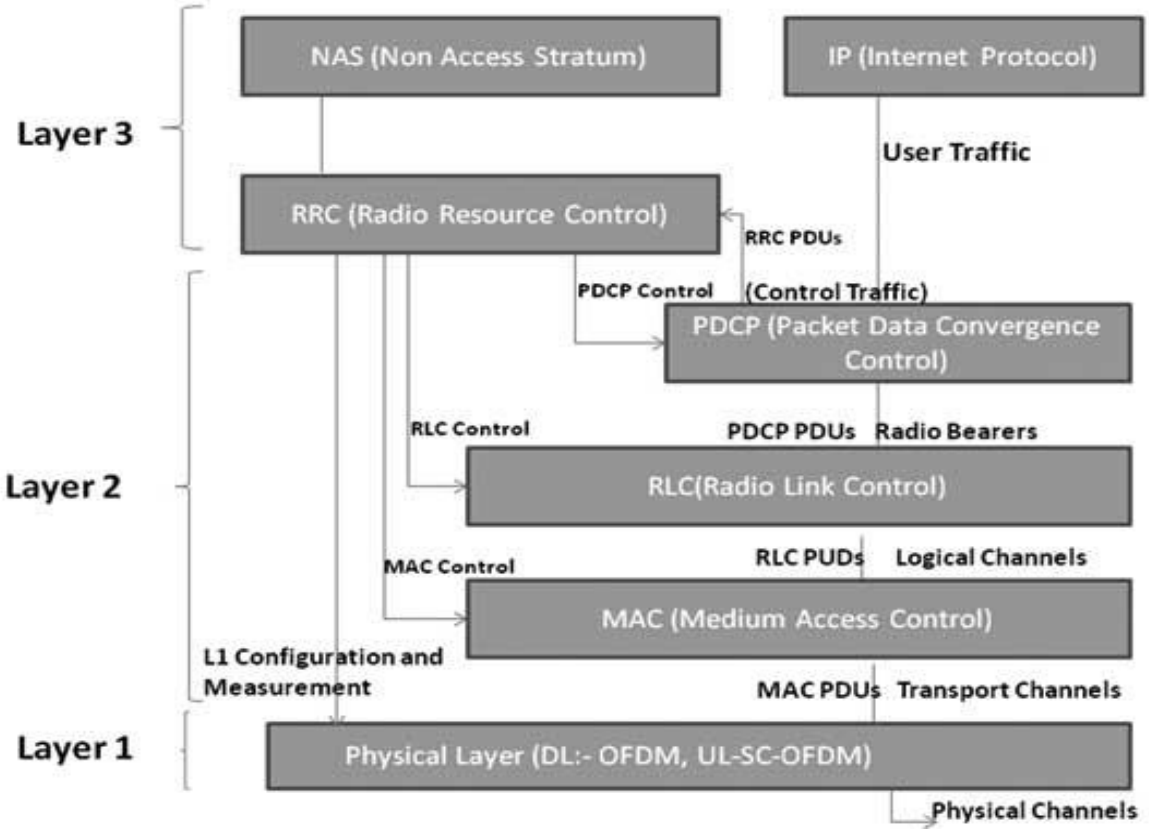
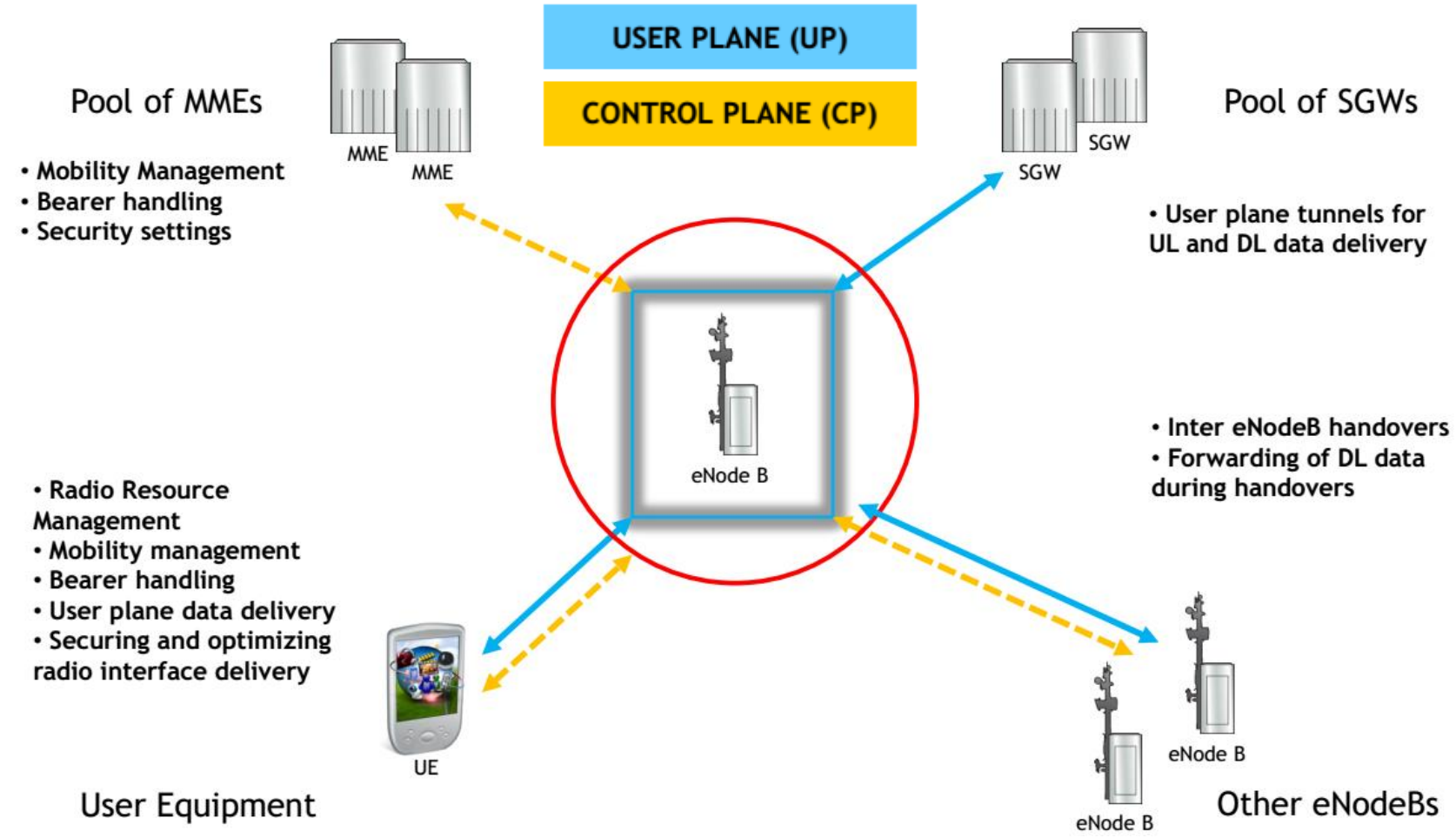
LTE Protocol Stack



EPC FUNCTIONAL ELEMENTS

eNodeB – Interactions with EPC elements



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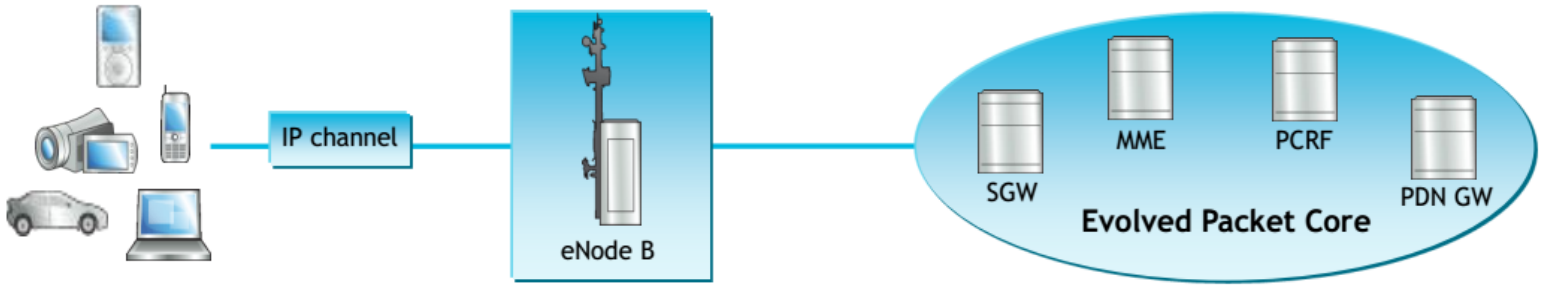
Mobility Management Entity (MME)

- MME is **control plane element** that manages network access and mobility

MME controls how UE interacts with the network via non-access stratum (NAS) signalling

- Authenticates UEs and controls access to network connections
- Controls attributes of established access (e.g., assignment of network resources)
- Maintains EPS Mobility Management (EMM) states for all UE's to support paging, roaming and handover
- Manages ECM (EPS Connection Management) states



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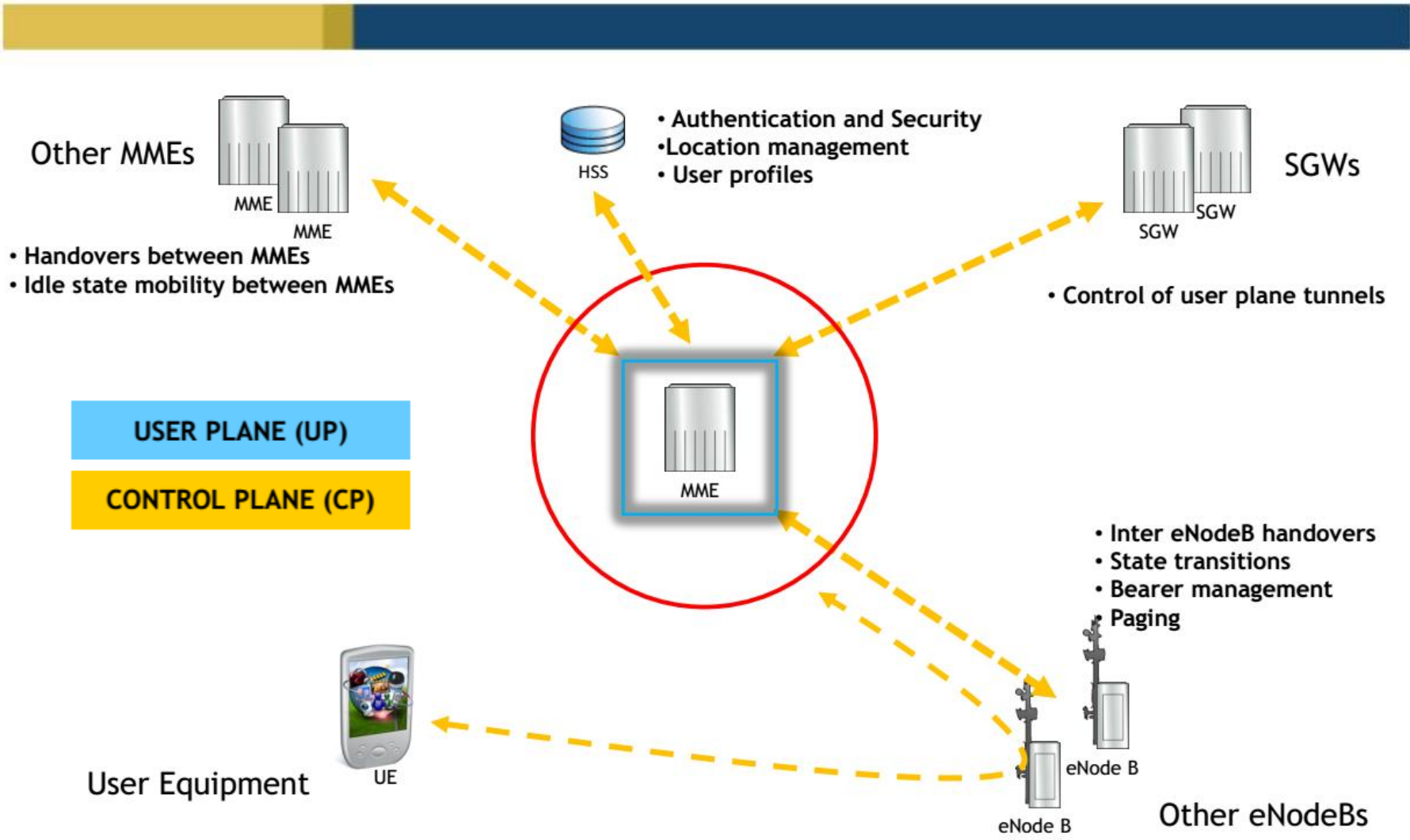
MME: interaction with other elements



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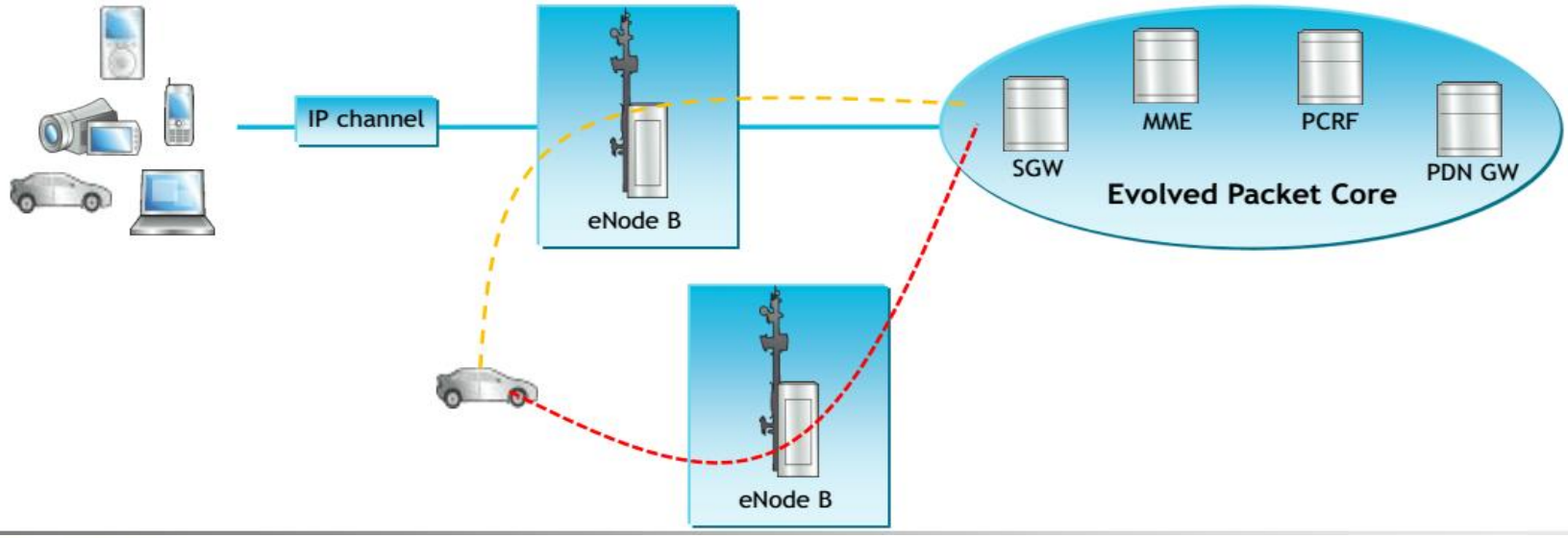
Serving Gateway (SGW) and Packet Data Network Gateway (PGW)

SGW is local mobility anchor

- Terminates (S1-U) interface towards E-UTRAN
- Local anchor point for inter-eNB handover and inter-3GPP mobility
- Support ECM-idle mode DL packet buffering and network-initiated service request
- IP routing and forwarding functions

PGW is IP anchor for bearers

- Terminates (SGi) interface towards the PDN
- Provides UE IP address management (allocation)
- Provide Policy and Charging Enforcement Function (PCEF)
- Per-SDF based packet filtering
- Interface to Online and Offline Charging Systems



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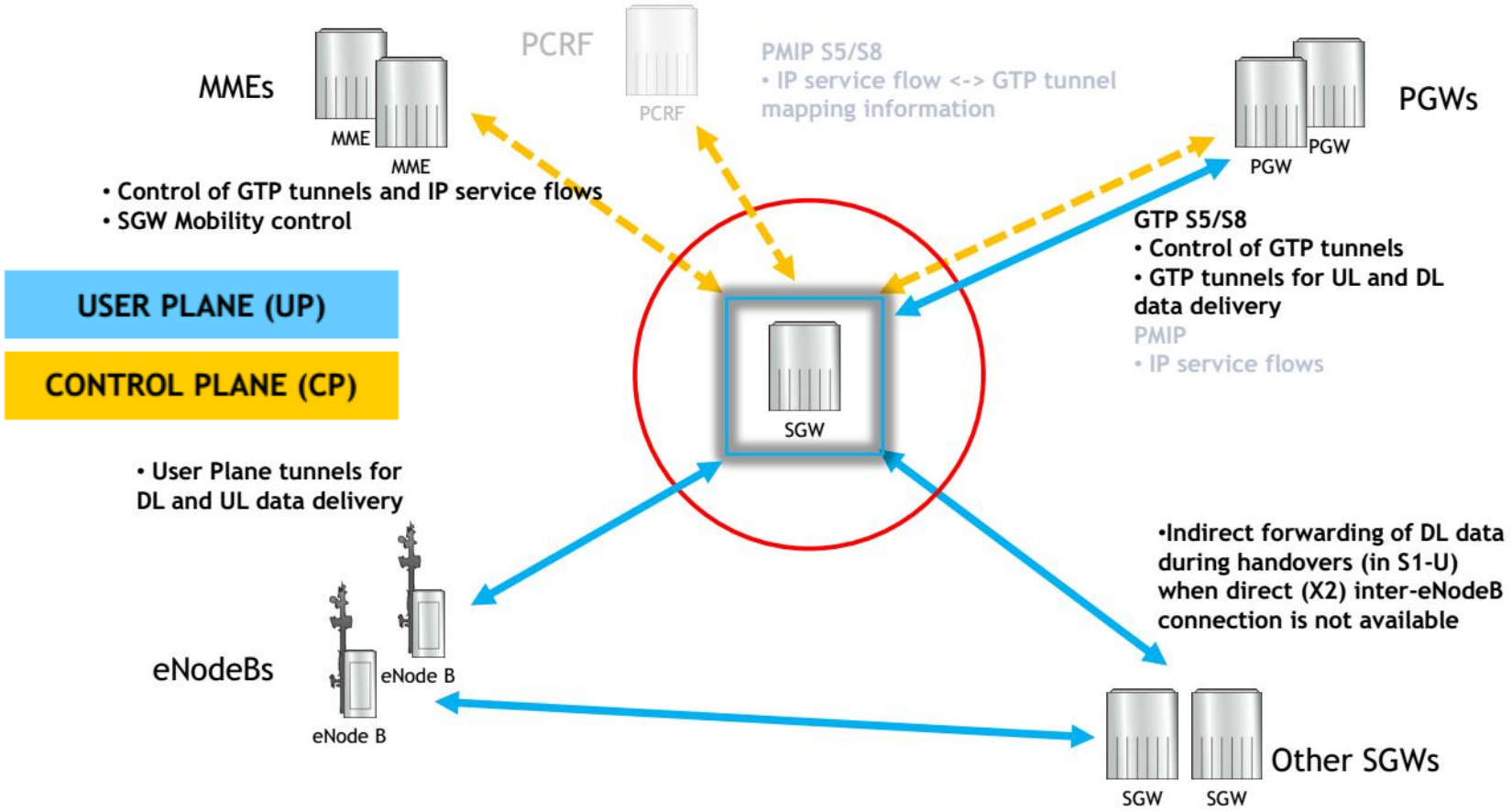
SGW – Interactions with other functional elements



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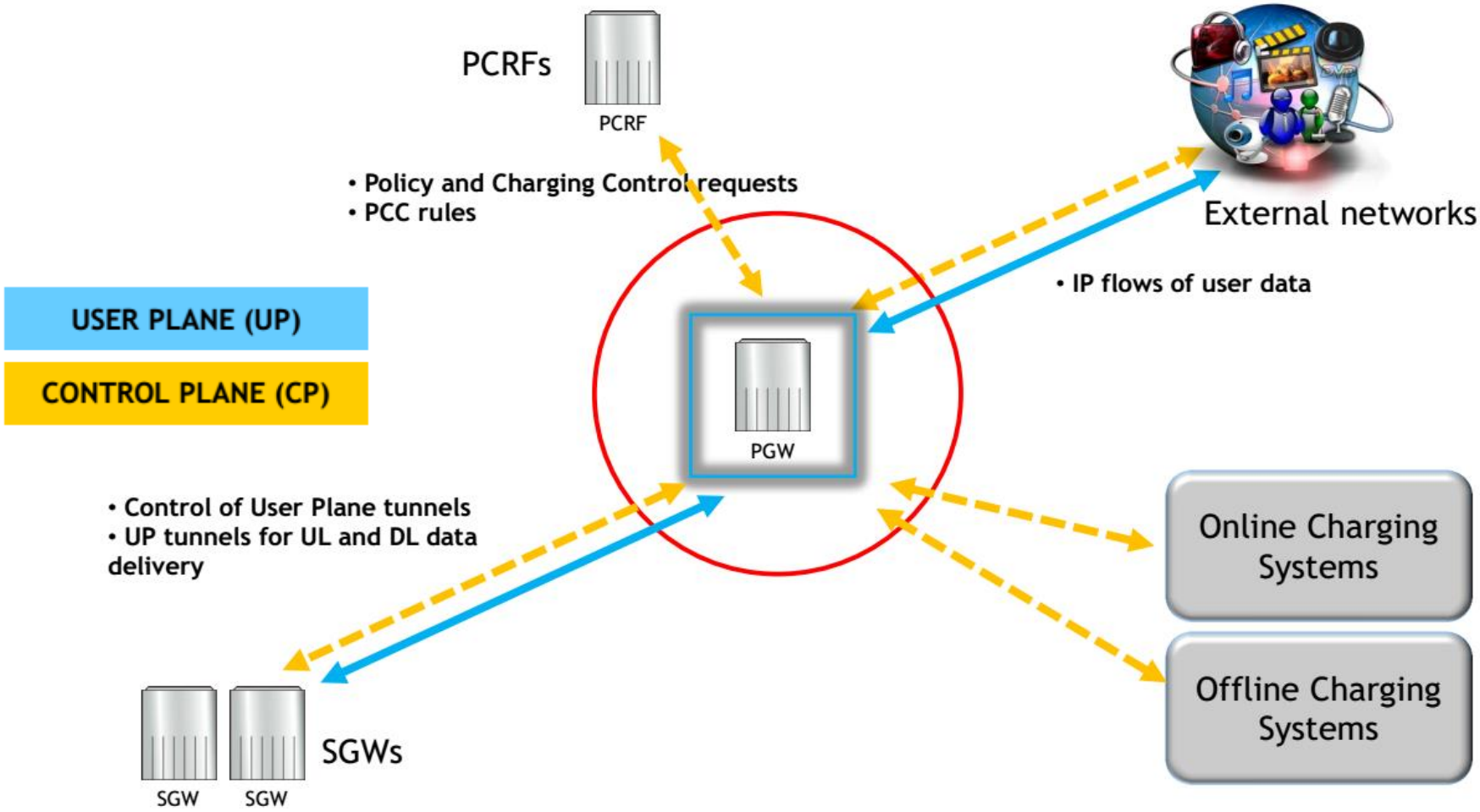
PGW – Interactions with other functional elements



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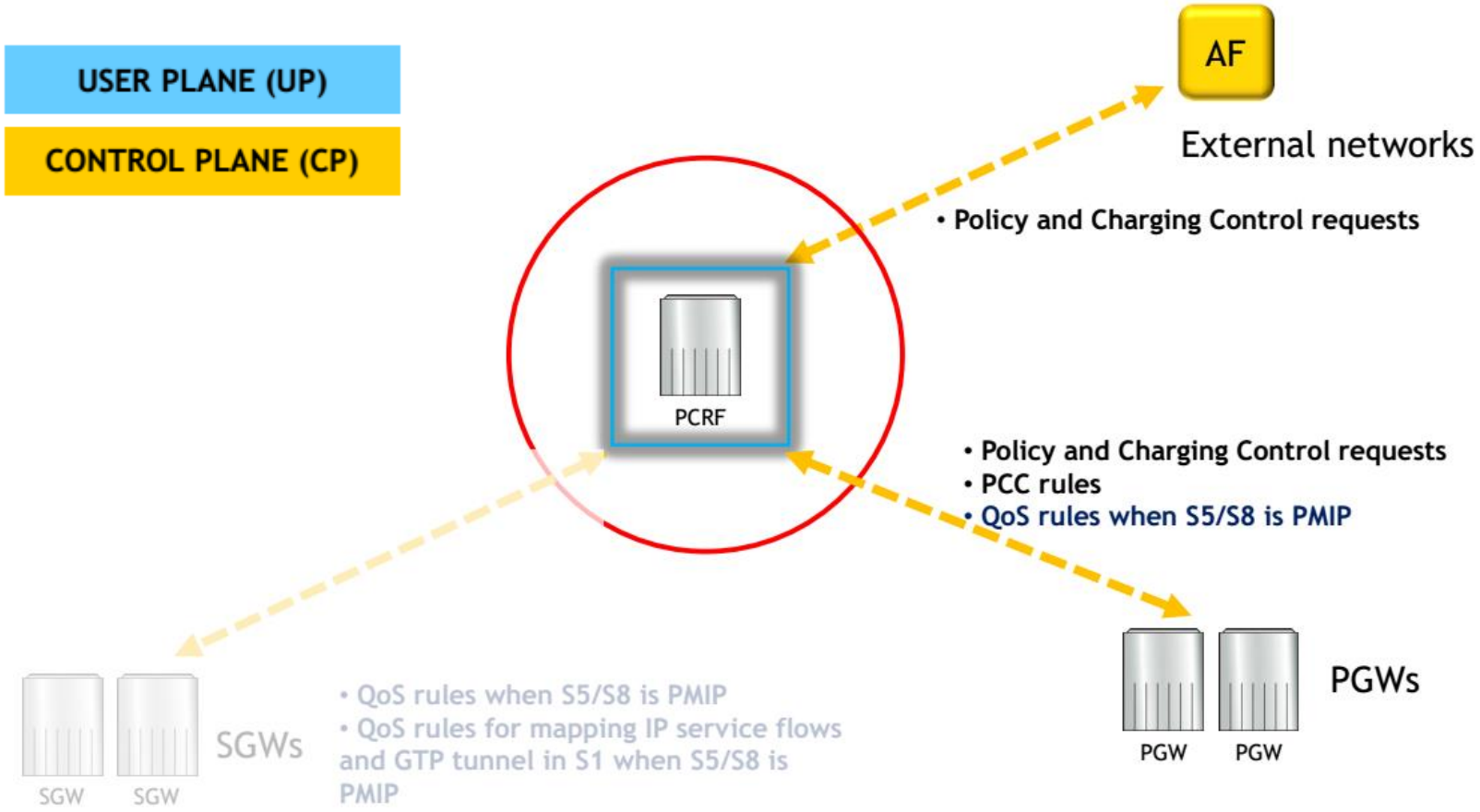
PCRF – Interactions with other functional elements



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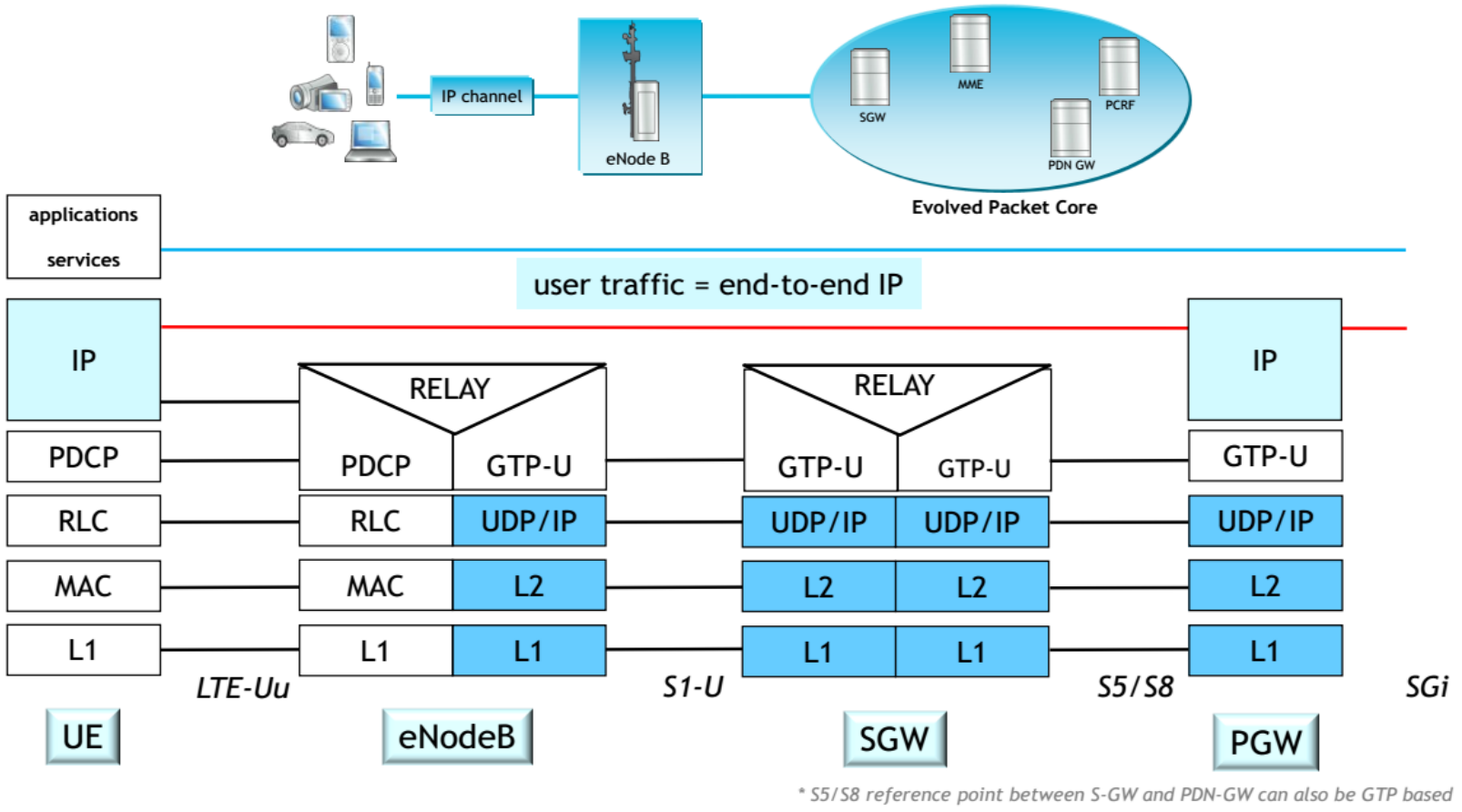
End-to-end protocol stack (User Plane)



Key role of S-GWs and PDN-GWs = to manage the user plane (bearer traffic)

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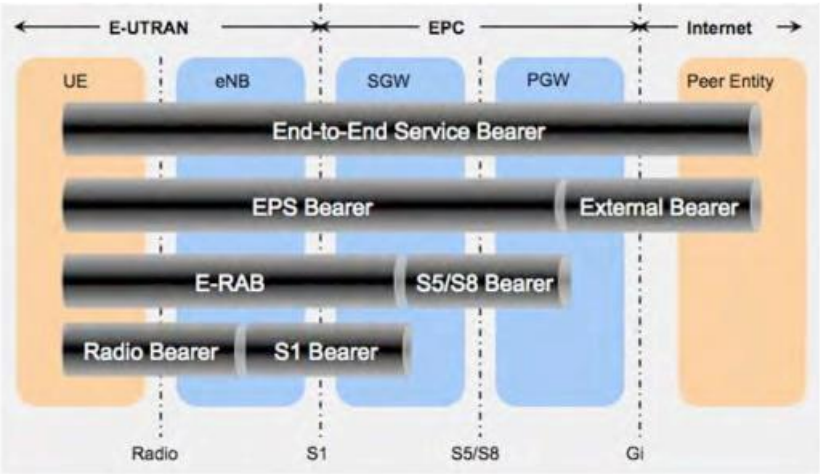
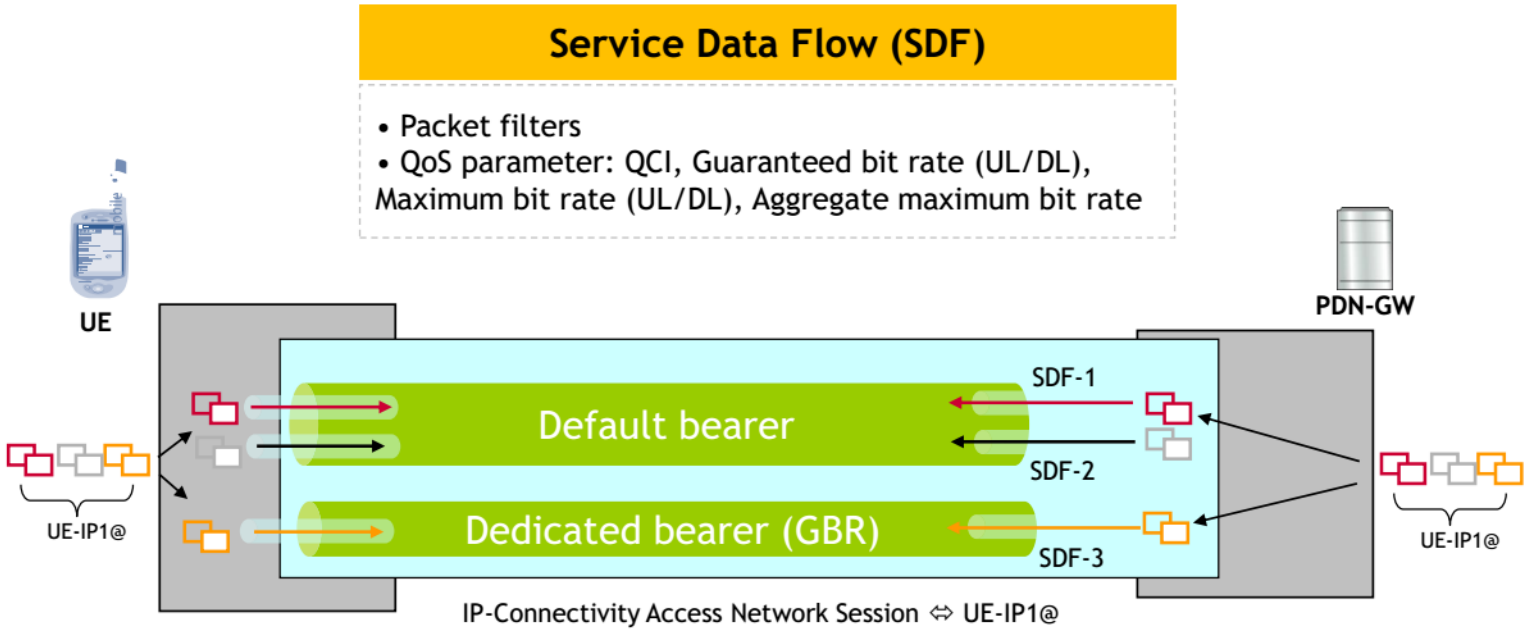
EPS Bearer

- Each EPS bearer context represents a GTP tunnel between UE and PGW
- Can be a default bearer context or a dedicated bearer context
- Default EPS bearer context is activated when UE requests a connection to PGW during EPS attach procedure
- Additionally, the network can activate one or several dedicated EPS bearer contexts in parallel



[2] Protocol Signaling Procedures in LTE -Radisys

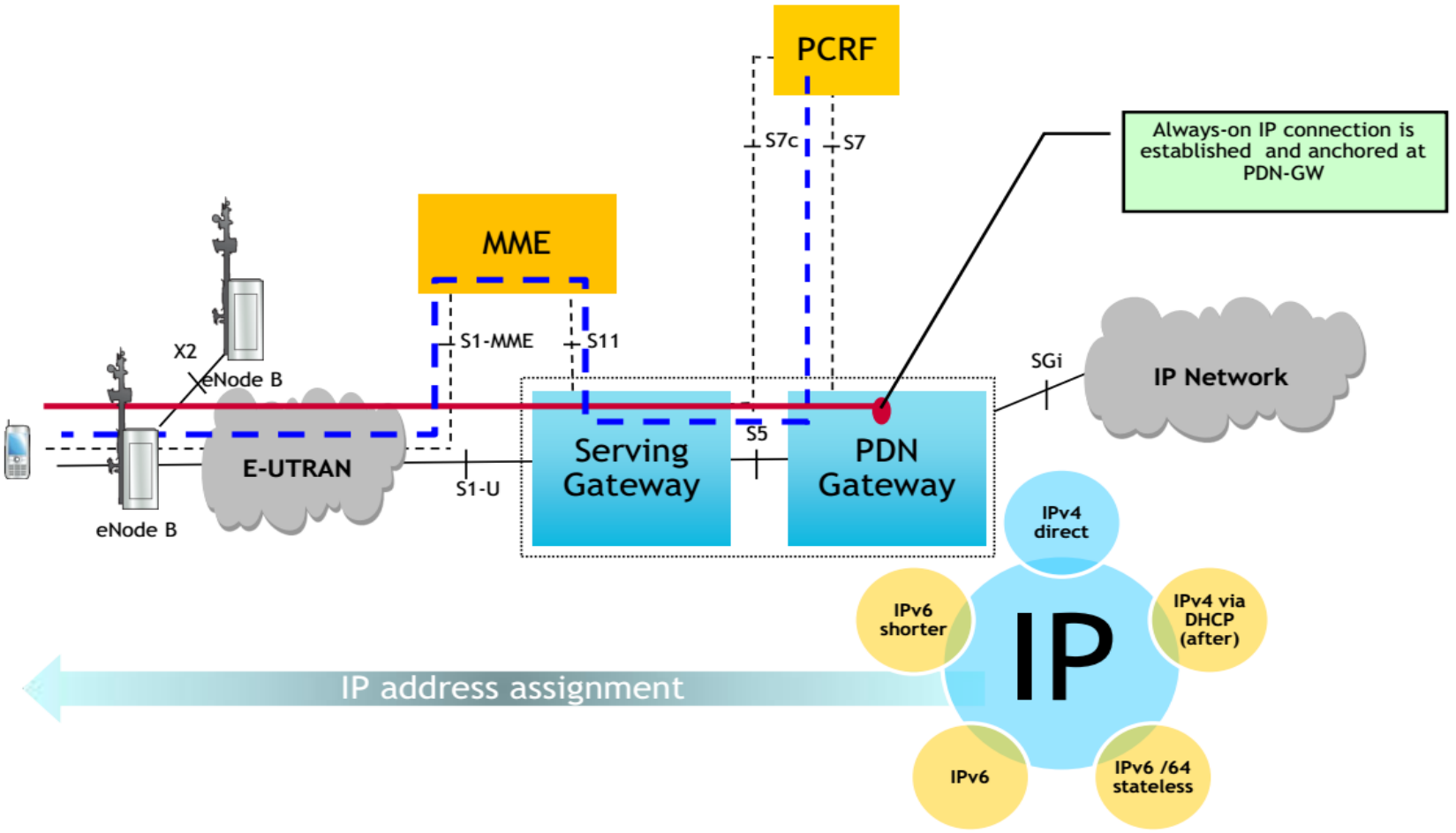
Service level policy control



- The PGW needs to support fine-granularity of QoS and charging enforcement functions beyond transport / bearer level
  - Multiple Service Data Flow (SDF) can be aggregated onto a single EPS bearer
  - Uplink and downlink packet filters are defined for each bearer, and QoS enforcements are applied

EPS PROCEDURES

Network attachment and IP address assignment



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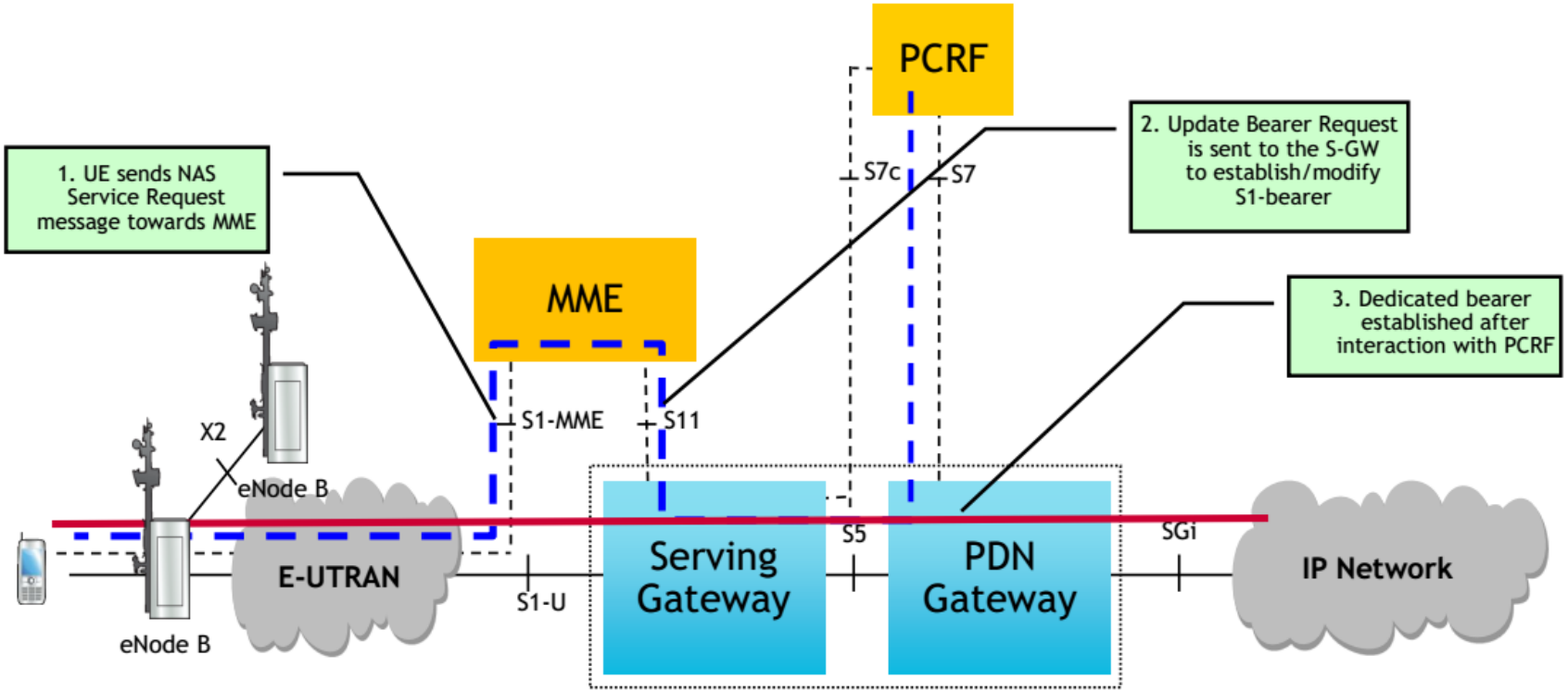
UE and service requests



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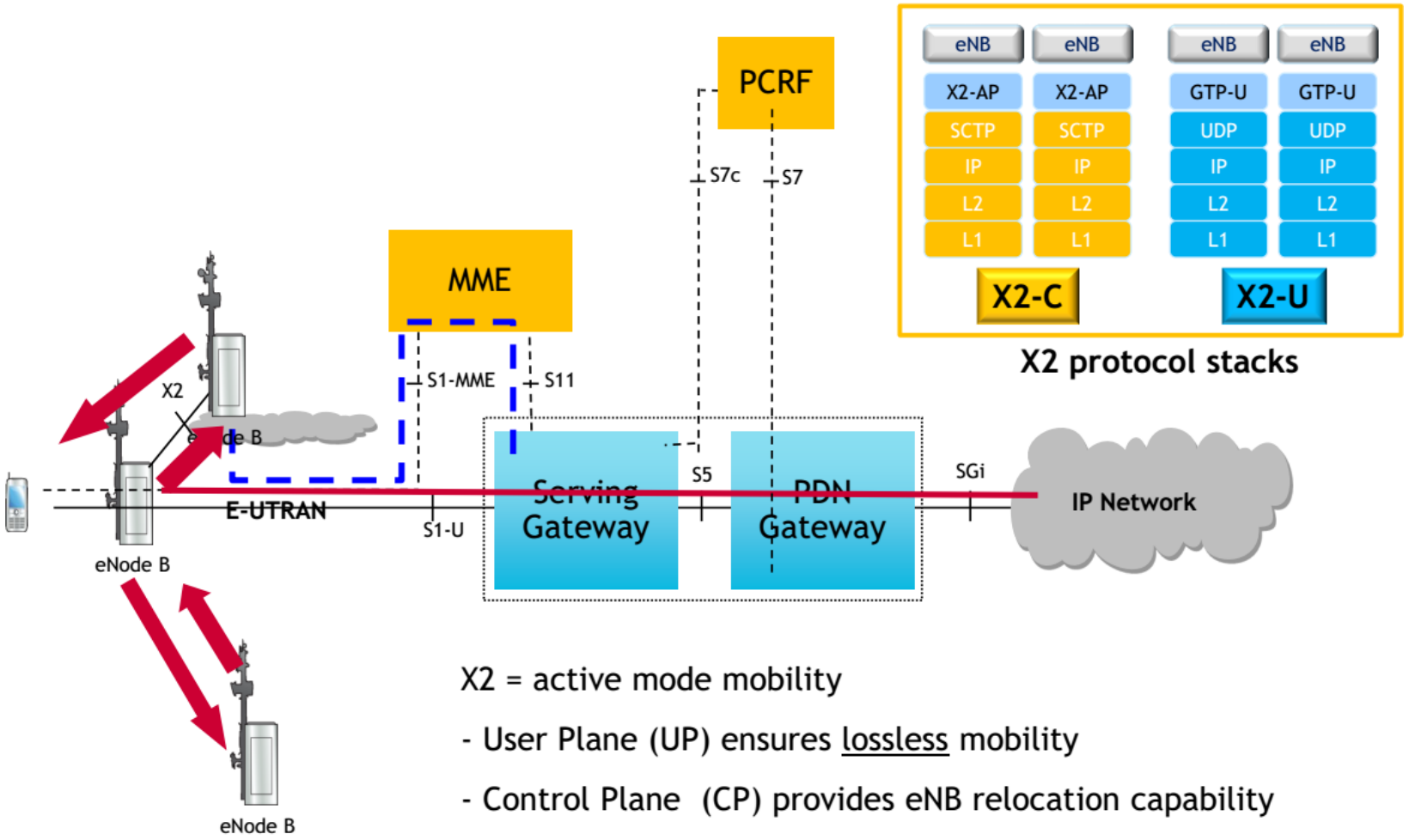
Handover and X2 routing



X2 = active mode mobility

- User Plane (UP) ensures lossless mobility
- Control Plane (CP) provides eNB relocation capability

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NAS (Non-Access Stratum)

- NAS protocols control EPC procedures
- Non-Access Stratum (NAS) resides between the UE and the MME in the control plane
- NAS is responsible for call processing and session management functions of creation, deletion, modification and management of default and dedicated radio bearers
- NAS procedures are grouped in 2
  - EPS Mobility Management (EMM), and
  - EPS Session Management (ESM)

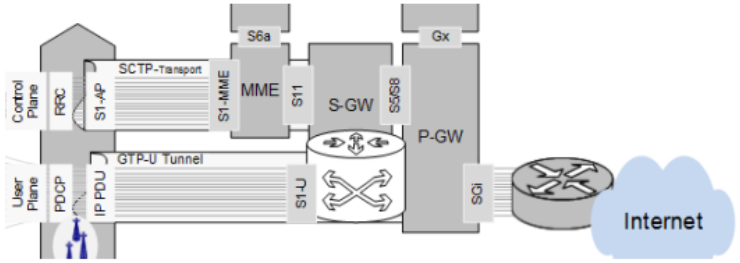

Fig. 1. Traditional cellular EPC with logical interfaces

EPS Mobility Management (EMM)

- EMM protocol provides procedures for mobility control when UE uses E-UTRAN and control of security for NAS protocols

- EMM procedures:
  - EMM common procedures (authentication etc.)
  - EMM specific procedures (attach etc.)
  - EMM connection management procedures
    - Service request
    - Paging procedure
    - Transport of NAS messages
    - Generic transport of NAS messages

EPS Session Management (ESM)

- ESM protocol provides procedures for the handling of EPS bearer contexts
- Together with the bearer control provided by Access Stratum, it provides the control of user plane bearers
- Transmission of ESM messages is suspended during EMM procedures except for the attach procedure
- Types of ESM procedures:
  - EPS bearer contexts procedures
  - Transaction related procedures

EPC Procedures Summary

Event Type	MME	HSS	S-GW	P-GW	PCRF
Attaches	10	2	3	2	1
Additional Default Bearer Setups	4	0	3	2	1
Dedicated Bearer Setups	2	0	2	2	1
Idle-to-Connected Transitions	3	0	1	0	0
Conntected-to-Idle	3	0	1	0	0
X2-based Handovers	2	0	1	0	0
S1-based Handovers	8	0	3	0	0
Tracking Area Updates	2	0	0	0	0
Total	34	2	14	6	3

TABLE I. TRANSACTION PER NAS EVENT BY EPC ELEMENT

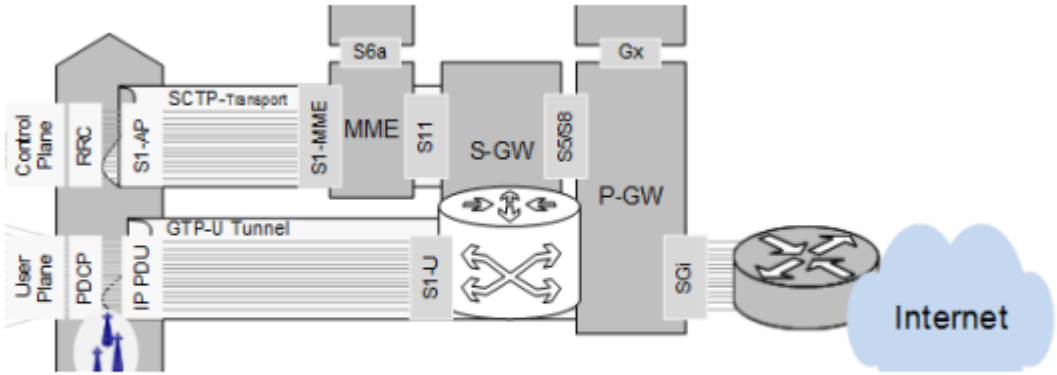

Fig. 1. Traditional cellular EPC with logical interfaces

[3] Understanding the bottlenecks in Virtualizing Cellular Core Network Functions – Intel Labs, Connectem, AT&T Labs

Network Attach Procedure

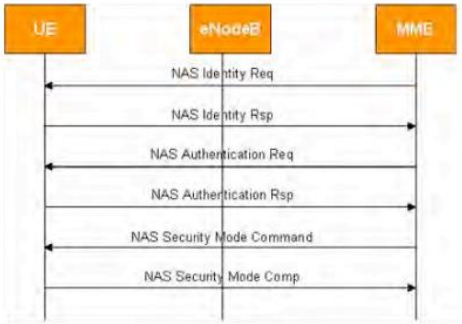

Figure 10. *NAS Common Procedures*

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Chained Requests (Control Plane)

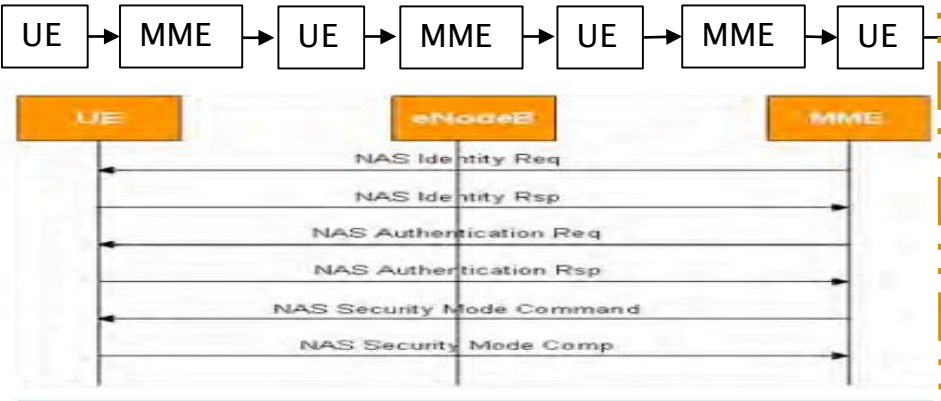

Figure 10. *NAS Common Procedures*

UE → MME → UE → MME → UE → MME → UE → MME → HSS → MME → PGW → MME → SGW → MME → UE → MME

Control Plane Service Chain with EPC elements only

MME → HSS → MME → PGW → MME → SGW → MME

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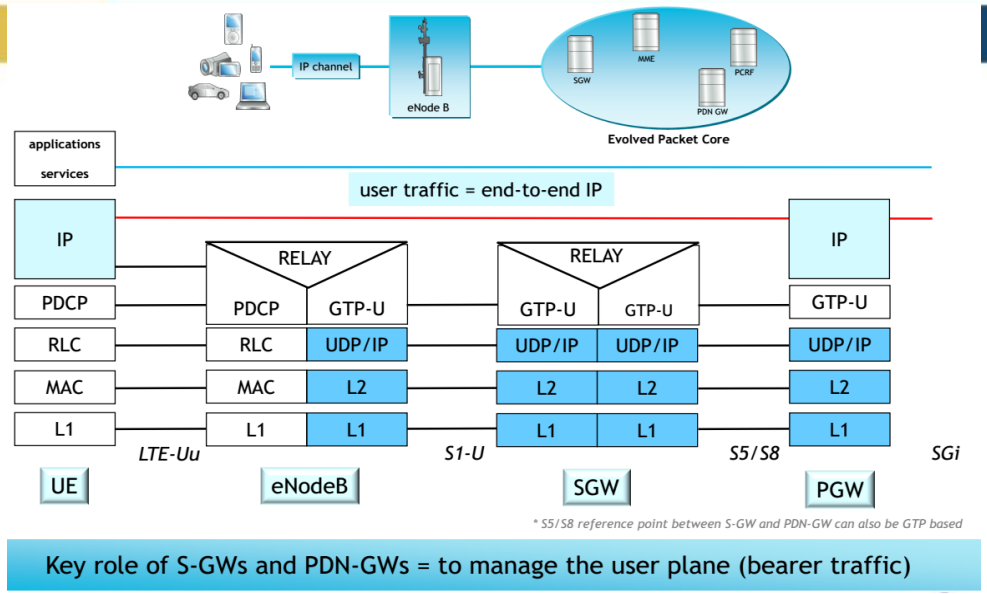
Chained Requests (Control Plane + Data Plane)



Downlink Chain

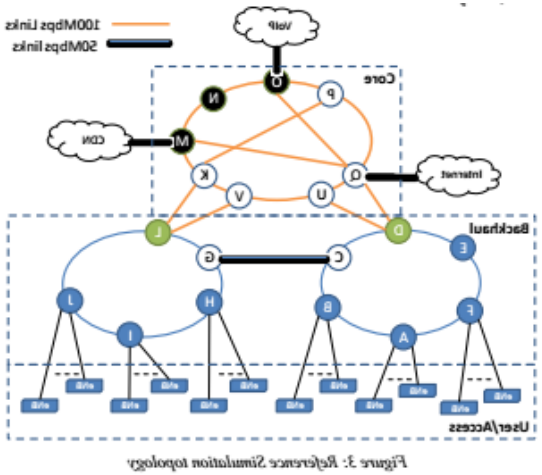
MME → HSS → MME → PGW → MME → SGW → MME → PGW → SGW

Uplink Chain

MME → HSS → MME → PGW → MME → SGW → MME → SGW → PGW

Problem Statement

- To reduce the bandwidth consumption in a cellular core network while placing service chained requests while adhering to latency requirements
- Inputs
  - Aggregate traffic flows from a aggregation point to PGW (both uplink and downlink)
  - Latency constraints for communication between each EPC element



Further details

- Which EPS procedures to consider?
- Maybe include CPU constraints? Or give CPU capacity as an output?
- What insights would be most interesting?
  - Do all EPC elements require replication?
  - Which locations are most suitable for replication?

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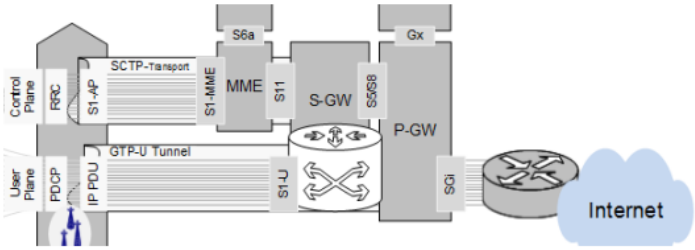

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