LTE Data Service Overview

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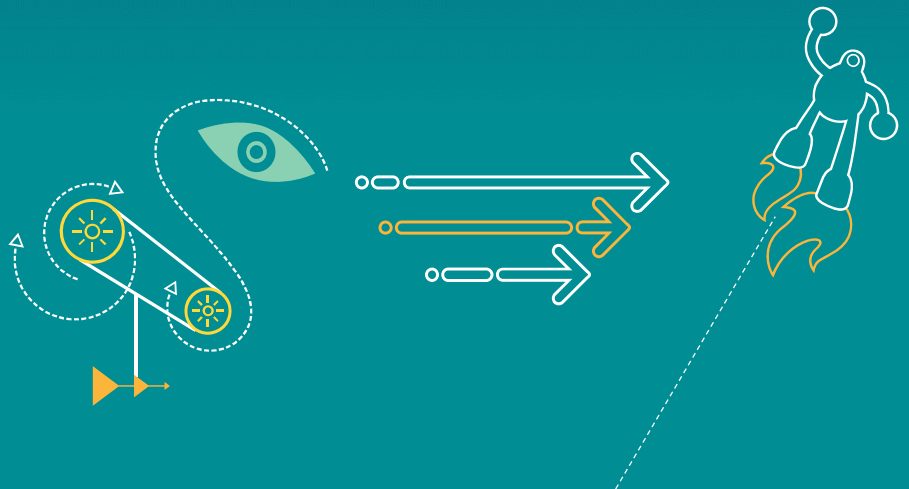

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Qualcomm Technologies, Inc.
5775 Morehouse Drive
San Diego, CA 92121
U.S.A.

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Revision History

Revision	Date	Description
A	July 2009	Initial release
B	March 2010	Numerous changes were made to this document; it should be read in it entirety
C	September 2010	Updated slide 17; added slides 19, 20, and 21 dual address bearer information; updated title on slide 29; added slide 30
D	January 2012	Numerous changes were made to this document; it should be read in it entirety
E	September 2015	Numerous changes were made to this document; it should be read in it entirety

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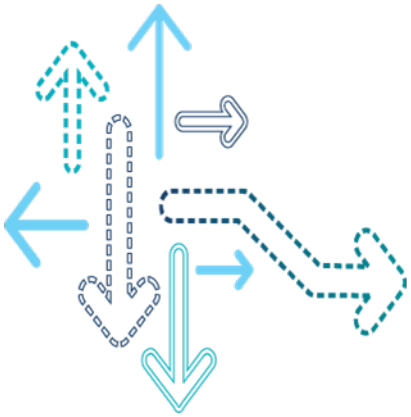
Introduction



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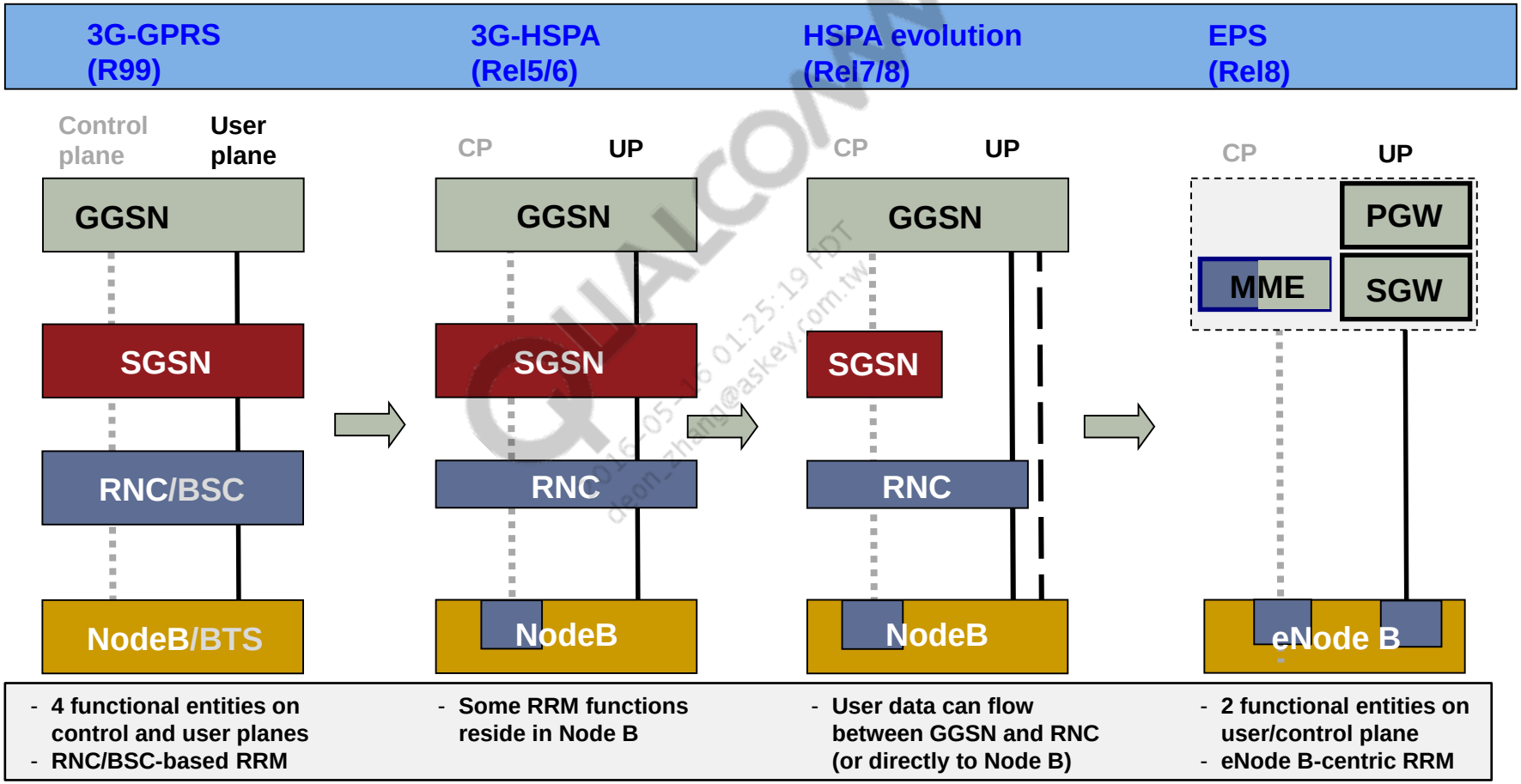
3GPP Network Architecture Evolution



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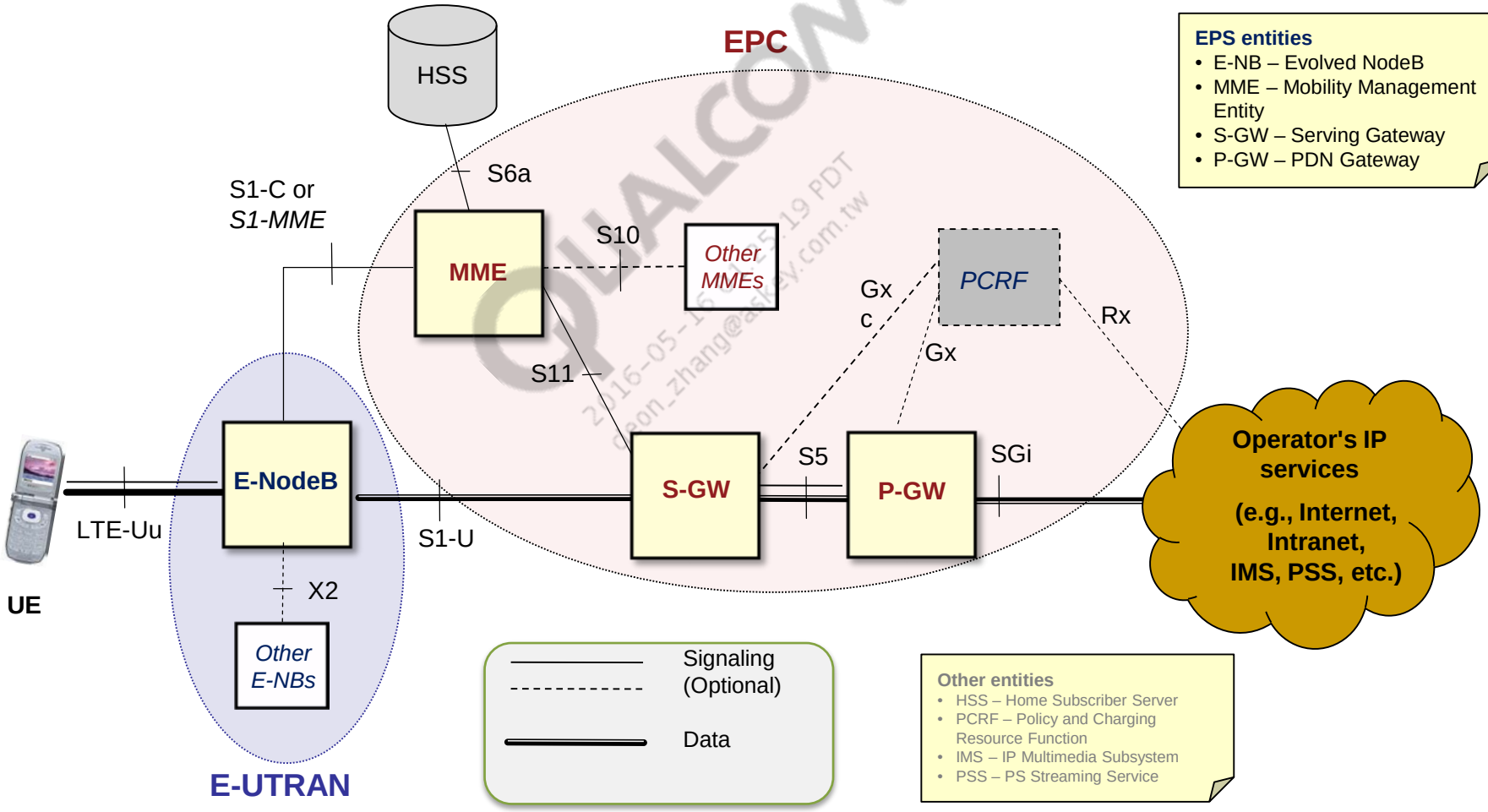
Overall EPS Architecture

- Basic EPS entities and interfaces



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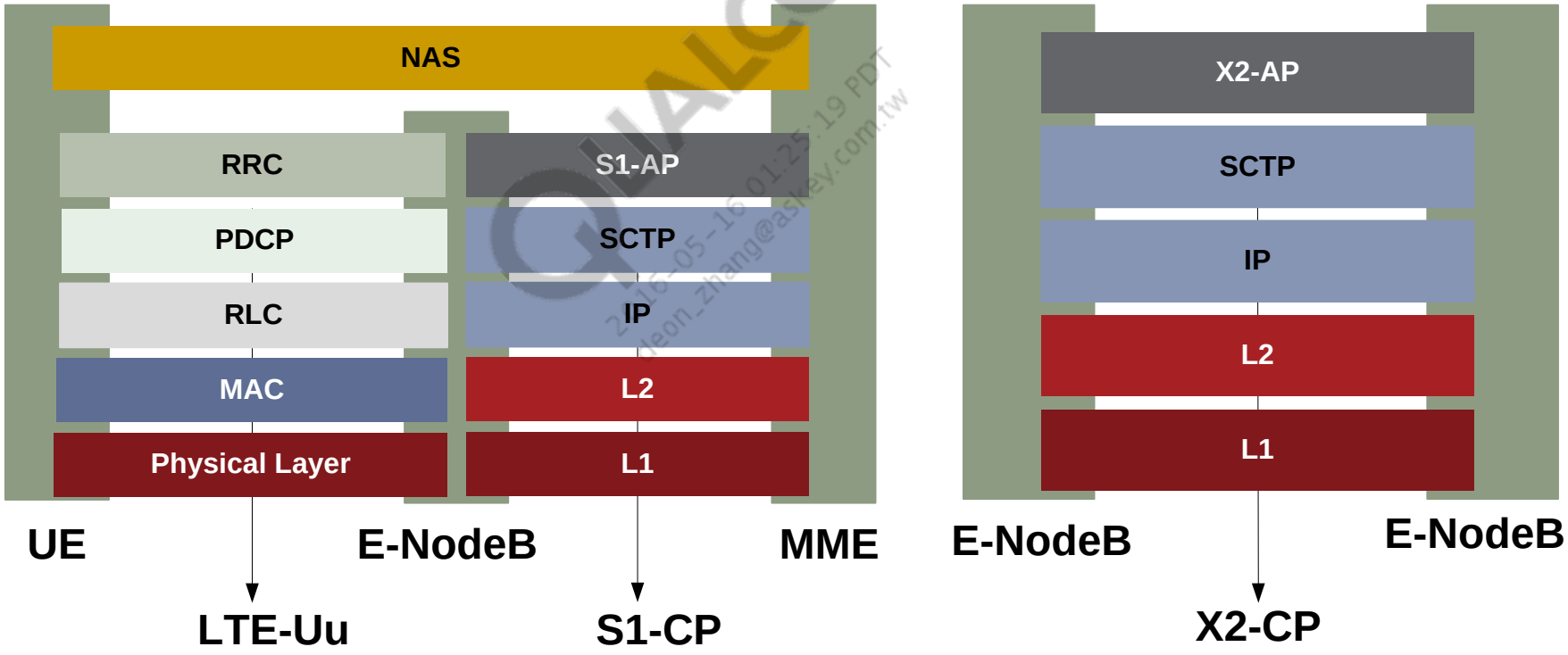
E-UTRAN Protocol Stack – Control Plane

- S1-CP – Interface between E-UTRAN and EPC signaling
- X2-CP – Interface between eNBs used for cell reselection and intra-LTE handover signaling



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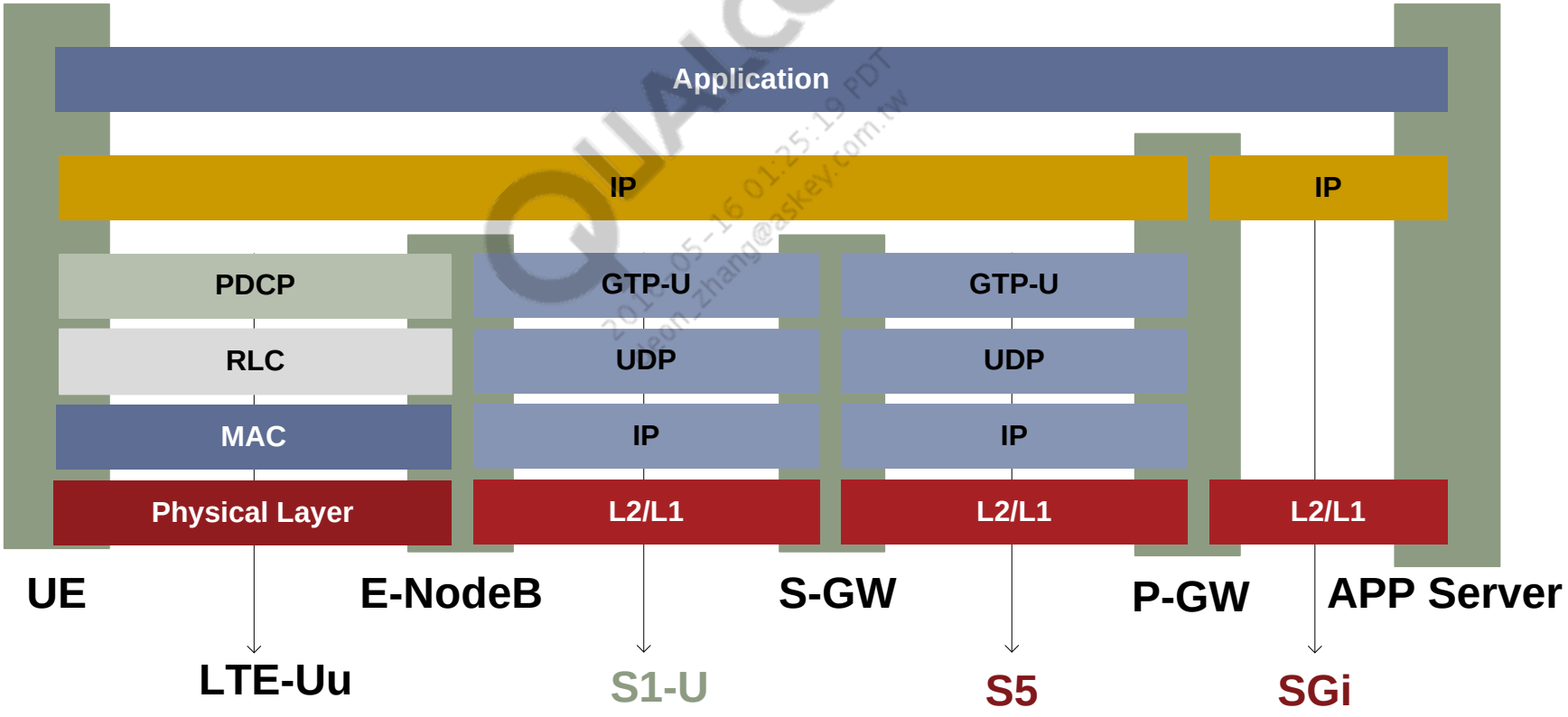
E-UTRAN Protocol Stack – User Plane

- S1-U – Interface between E-UTRAN and EPC for user data
- S5 – Interface between S-GW and P-GW for user data
- SGi – Access from/toward IP networks



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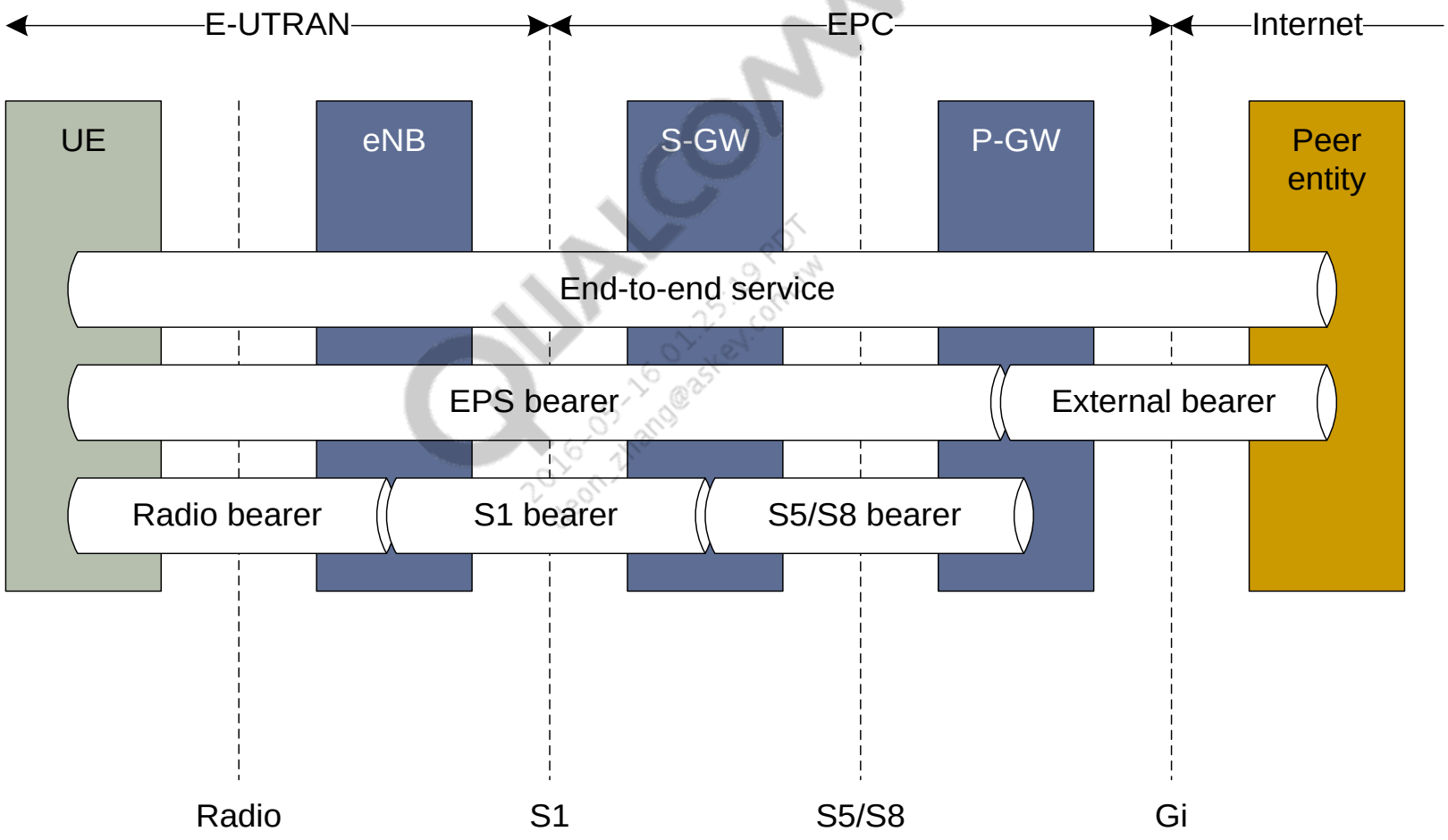
EPS Bearer Service Architecture



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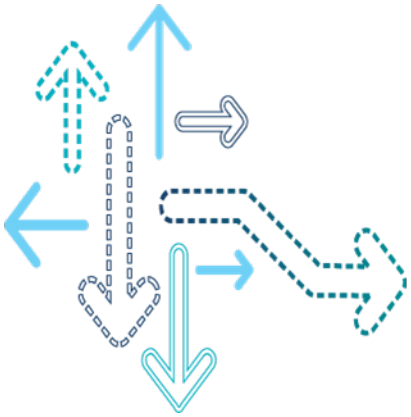
Main Concepts



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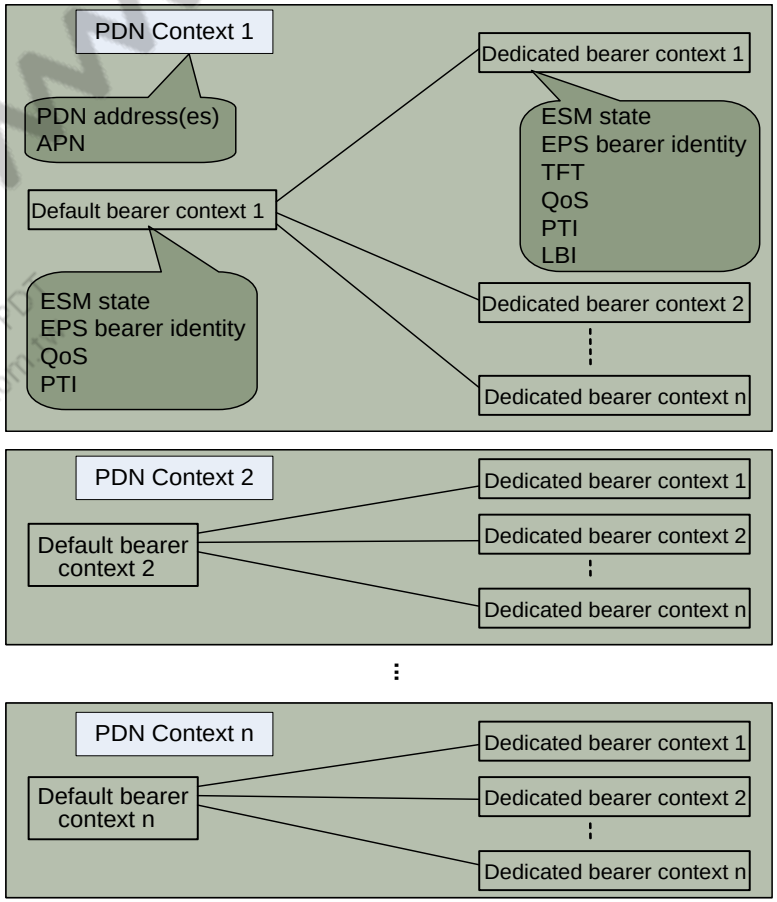
PDN Context Bearer Model

- PDN Context
  - IP connectivity to a given PDN
  - One default bearer plus zero or more dedicated bearers
- Default Bearer Context – Primary PDP Context
  - Non-GBR bearer established when PDN context is created
  - Best-effort traffic
- Dedicated Bearer Context – Secondary PDP Context
  - Can be GBR or Non-GBR
  - Associated with a TFT



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LTE Bearer Management Procedures

- PDN connectivity/default bearer procedures
  - Default bearer activation during attach procedure
  - Additional PDN connectivity
  - Default Bearer Activation
  - Bearer Modification
  - Bearer Deactivation
  - ESM Information
- Dedicated bearer/QoS procedures
  - Dedicated Bearer Activation
  - Bearer Modification
  - Bearer Resource Allocation
  - Bearer Resource Modification
  - Bearer Deactivation

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IP Address Allocation

- IPv4
  - Support of address allocation as part of NAS signaling is mandatory
  - DHCPv4 can optionally be used if both UE and PDN GW support it
    - UE requests DHCPv4 use in PCO
    - Network returns 0.0.0.0 address to indicate that DHCPv4 should be used
- IPv6
  - Stateless address autoconfiguration used for address allocation
    - Network returns IID to use for link local address construction in NAS signaling
    - UE subsequently uses Router Solicitation/Router Advertisements to obtain global prefix
  - An entire 64-bit prefix is assigned to UE
    - No need for Duplicate Address Detection
    - Optional support for shorter than 64-bit prefix using DHCPv6 prefix delegation
- IPv4 + IPv6
  - A single bearer may support both IPv4 and IPv6, provided the PDN supports it
  - UE indicates IP stack capability during bearer activation; PDN GW may subsequently modify the PDN Context's IP type

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Dual Address Bearers

- A single default bearer may support both IPv4 and IPv6
- For backward compatibility, network may be configured to use single IP-type bearers
  - Whether dual or single IP-type bearers are used is network-driven
- UE indicates IP stack capability in PDN Connectivity Request
- Network returns supported addresses in Activate Default EPS Bearer Context Request, depending on network configuration and user subscription
  - Network can return both addresses
  - Network can return only the supported address with ESM Cause IE in message indicating reason for not returning the other address type
  - Reason can be IPv4-only supported or IPv6 only supported; UE must not subsequently request connectivity to same APN for the denied IP type
  - Reason can be single address bearer only supported; UE can send another PDN connectivity request to same APN for the denied IP type

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EPS Bearer QoS Model

- Bearer QoS Parameters
  - QCI (QoS Class Identifier)
    - Scalar that specifies the packet forwarding treatment in eNodeB
    - Standardized set with corresponding standard characteristics is defined
    - Replaces UMTS Traffic Class, Traffic Handling Priority, Transfer Delay, etc.
  - ARP (Allocation and Retention Priority)
    - Used to select a bearer to deactivate to support a new bearer, if needed
    - NW-only parameter
  - GBR (Guaranteed Bit Rate), MBR (Maximum Bit Rate)
    - Only specified for GBR bearers
  - APN-AMBR (Aggregate Maximum Bit Rate)
    - Only applies to non-GBR bearers
    - Optionally returned to UE
  - UE-AMBR
    - NW-only parameter

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LTE – WCDMA/GERAN interworking

- One-to-one mapping between LTE bearers and GW PDP contexts.
- Default bearer ↔ Primary PDP context
- Dedicated bearer ↔ Secondary PDP context
- EPS bearer ID ↔ NSAPI
- PDP address, APN, TFT are retained.
- NW-MME provides UTRAN/GERAN parameters during EPS bearer establishment: R99 QoS, LLC SAPI, radio priority, packet flow identifier, transaction identifier and BCM (if available).
- If the above-mentioned parameters are not specified, the EPS bearer is not transferable to GW. It is locally deactivated after transition to GW. See *General Packet Radio Service (GPRS) Enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) Access* (3GPP TS 24.301, 6.1.4).

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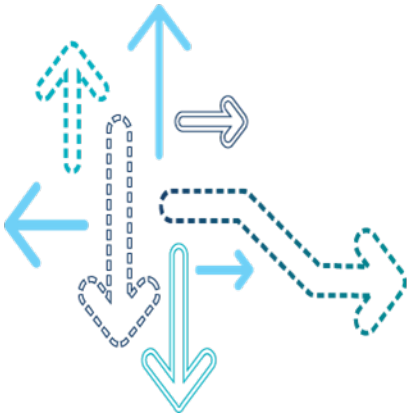
Architecture and High-Level Design



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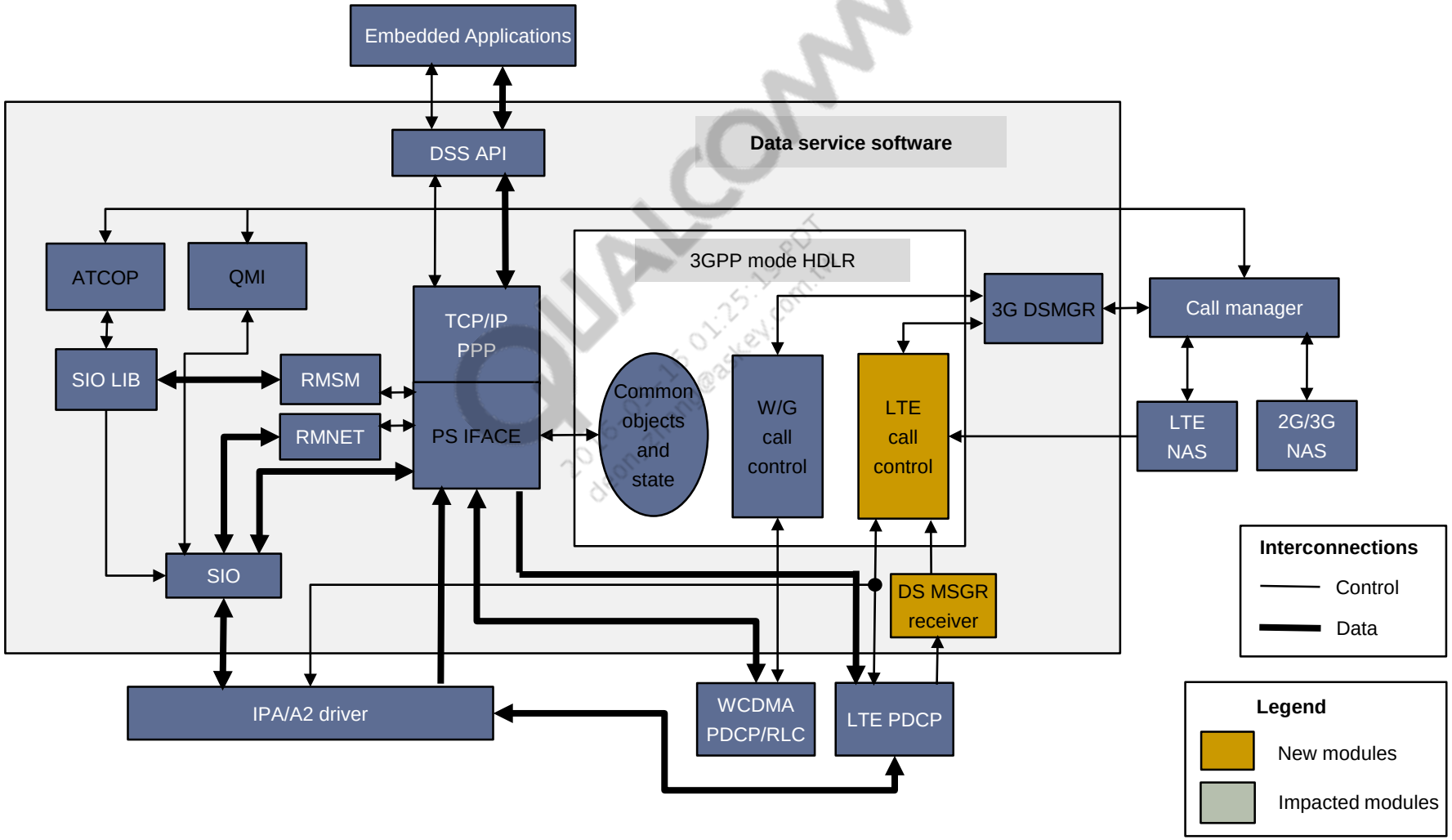
Architecture Diagram



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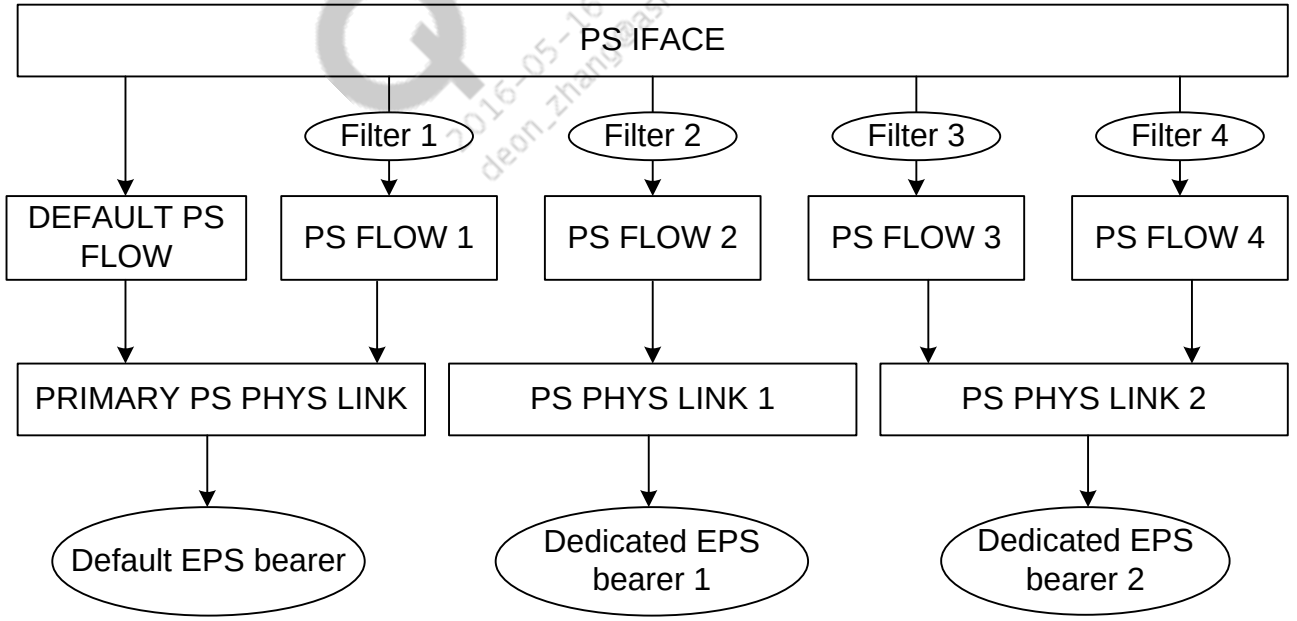
Common PS Objects

- PS IFACE objects
  - Represent a network interface in the protocol stack/PDN connection
- PS PHYS LINK objects
  - Represent bearers/both default and dedicated
- PS FLOW objects
  - Represent application flows



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New Components

- LTE call control/Mode handler
  - Manages LTE-specific procedures
    - Kick-start appropriate LTE procedures based on application request
    - Interact with CM/NAS/LTE protocol stack
  - Manages 3GPP PS IFACE, PHYS LINK, and FLOW objects
    - Bringing up network interfaces
    - Address configuration
    - Filter installation for QoS
    - Interface selection for application requests
  - Sets up data path between data stack and LTE protocol stack
- DS MSGR receiver
  - Provides interface for receiving message router-based messages
    - Used for receive-side interface with LTE PDCP and LTE NAS
    - Enables serialized processing of message router messages in DS task context

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EPS Bearer Support on MDM9x00/9x15

- Maximum number of bearers supported = 8 (default plus dedicated)
- Total IP addresses supported = 8
  - Two reserved for default EPS bearer (one for IPv4 and one for IPv6)
  - The other six IP addresses can be used for either dual IP bearers or single IP bearers, as required by the carrier
  - Some examples are as follows:
    - Four dual IP PDN connections, or
    - Eight single IP PDN connections, or
    - Three dual IP and 2 single IP
    - We cannot support three dual IP and three single IP bearers, as the total IP addresses required to support this configuration is 9 (3 x 2 + 3)

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Default Bearer Establishment During Attach

- Overview
  - Modem brings up default PDN during LTE attach without involving AP/TE
    - Dedicated Um PS IFACEs are used for default PDN connectivity
  - Embedded applications/tethered device can subsequently begin to use this connection using existing APIs
  - Local configuration is used for determining APN to use for attach
- Always On behavior
  - Modem preserves connectivity to attach PDN for duration of attachment to LTE
  - When application/TE requests connection release, modem maintains this PDN connection
  - If network releases attach PDN connection at any time, if other PDN connection(s) are active, UE preserves the last remaining PDN connection

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Default Bearer Establishment During Attach (cont.)

- Configuration of profile to use for attach
  - Use EFS file /data/ds_dsd_attach_profile.txt can to configure the Attach profile preference
  - Sample configuration:

```
/data/ds_dsd_attach_profile.txt
-------------------------
Attach_Profile_ID:1;
```

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Default Bearer Establishment During Attach (cont.)

- Selection of parameters to use for PDN connectivity request
  - Profile is chosen using mechanism described earlier
  - APN – From selected profile; if no APN is specified in profile then none is requested
  - PDP type – IP type from selected profile
  - PAP/CHAP authentication parameters – From selected profile
  - DNS server addresses – Always requested based on profile PDP type
    - IPv4 address is requested using both IPCP CONFIG REQ packet and IPv4 DNS container
  - P-CSCF server address – From selected profile
    - IPv4 address is requested if profile is IPv4 or IPv4v6 PDP type
    - IPv6 address is requested if profile is IPv6 or IPv4v6 PDP type
  - ESM Information transfer flag – Set if PAP/CHAP authentication parameters need to be requested or if non-NULL APN is being requested
    - APN and PCO are then requested by NW using ESM Information Request procedure

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Default Bearer Establishment During Attach (cont.)

- LTE – WCDMA/GERAN interworking aspects
  - IRAT from WCDMA/GERAN to LTE
    - If there is no active PDN connection in W/G, then device performs attach (after network rejects TAU request) and establishes connectivity to default PDN
    - If there is an active PDN connection in W/G, then if connectivity to default PDN does not exist then default PDN connection is not automatically established
    - Modem will maintain the last active PDN connection while on LTE
  - IRAT from LTE to WCDMA/GERAN
    - If default PDN connection is not in use then it is terminated after moving to W/G
- Auto-connect default PDN
  - NV item “auto-connect default PDN” provides an alternative behavior
  - On IRAT from WCDMA/GERAN to LTE, modem automatically establishes connectivity to default PDN
  - Modem-only maintains default PDN connection while on LTE (when application/TE releases PDN connection)

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Default Bearer Establishment During Attach (cont.)

- LTE – eHRPD interworking aspects
  - IRAT from eHRPD to LTE
    - Modem always establishes connectivity to default PDN during attach on LTE
    - If default PDN connection is active on eHRPD, then Handover attach is performed
    - Otherwise, Initial attach is performed
    - Modem will maintain the last active PDN connection while on LTE
  - IRAT from LTE to eHRPD
    - If default PDN connection is not in use, then it is terminated after moving to eHRPD
    - If default PDN connection is in use, then it is handed-off to eHRPD

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Dual Address Bearers Design

- Overview
  - Application/TE request connectivity to specific IP type (IPv4 or IPv6)
  - Modem requests dual IP connectivity based on profile configuration, even if application only requests single IP type connectivity
    - Separate Um PS IFACEs used for IPv4 and IPv6
    - Both IFACEs are bound to shared default PS PHYS LINK representing the shared default bearer
    - Both IFACEs are reserved when APP/TE requests connectivity to a dual IP type APN
  - Modem requests PDN disconnection when both IP addresses are not in use by applications
  - Implementation allows simultaneous use of IPv4 and IPv6 addresses by different clients
    - For example, tethered device uses IPv4 address while embedded applications use IPv6 address
  - For QMI/RMNET-based data calls, dual IP type over single RMNET instance is supported through allowing submission of two requests, one per IP type
  - Design supports deferred IPv4 address assignment using DHCPv4 to conserve IPv4 addresses

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Dual Address Bearers Design (cont.)

- Selection of parameters to use for PDN connectivity request
  - Profile is selected by application/TE
  - APN – Override parameters if specified in request are used, otherwise APN specified in selected profile are used
  - PDP type – See Dual Address Bearers Design slide
  - PAP/CHAP auth params – Override parameters if specified in request are used, otherwise those specified in selected profile are used
  - DNS server addresses – Always requested based on profile PDP type
  - Use of DHCPv4 for address allocation – From selected profile
  - P-CSCF server address – From selected profile

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Data Path

- Overview
  - Data stack interfaces with LTE PDCP at the lower edge, in the UL
  - In the DL, PDCP sends packets to IPA for deciphering; data stack interfaces with IPA driver to receive data
  - Data Path Manager (DPM) manages all the functionality related to IPA registration/deregistration, bridging/unbridging, and all common data path related functionalities
  - Direct bridging of data from DL PDCP to USB/apps processor via IPA
  - IPA hardware performs filtering of DL data to send packets destined for modem applications to Data stack
    - For example, ICMPv6 packets, DHCP
  - Filtered DL data is sent up the appropriate IFACE based on IP type
  - After IRAT to/from WCDMA/GPRS, any buffered data pending to be transmitted to source RAT L2 is delivered to the target RAT L2

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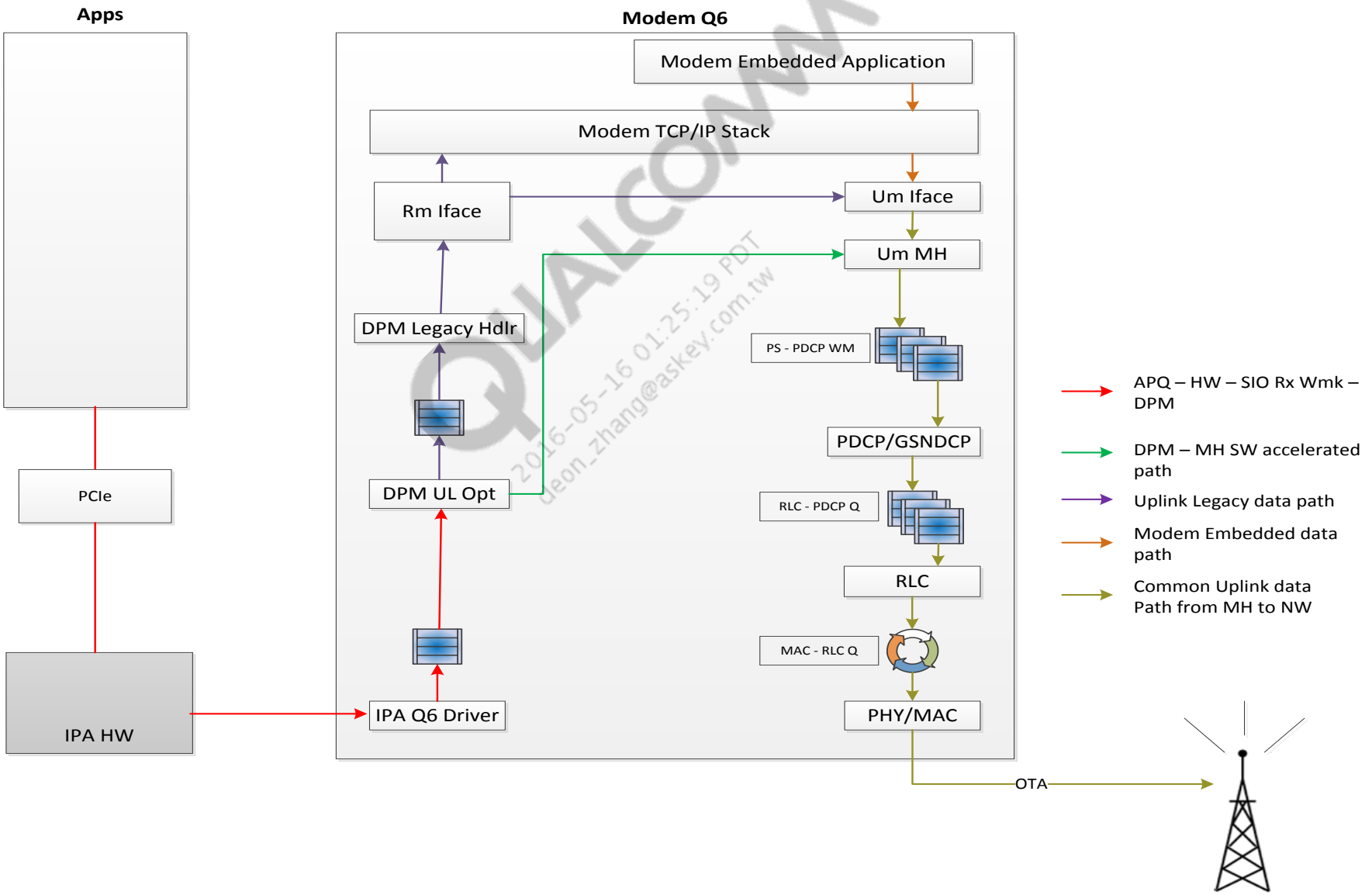
3GPP/LTE Uplink Data Path



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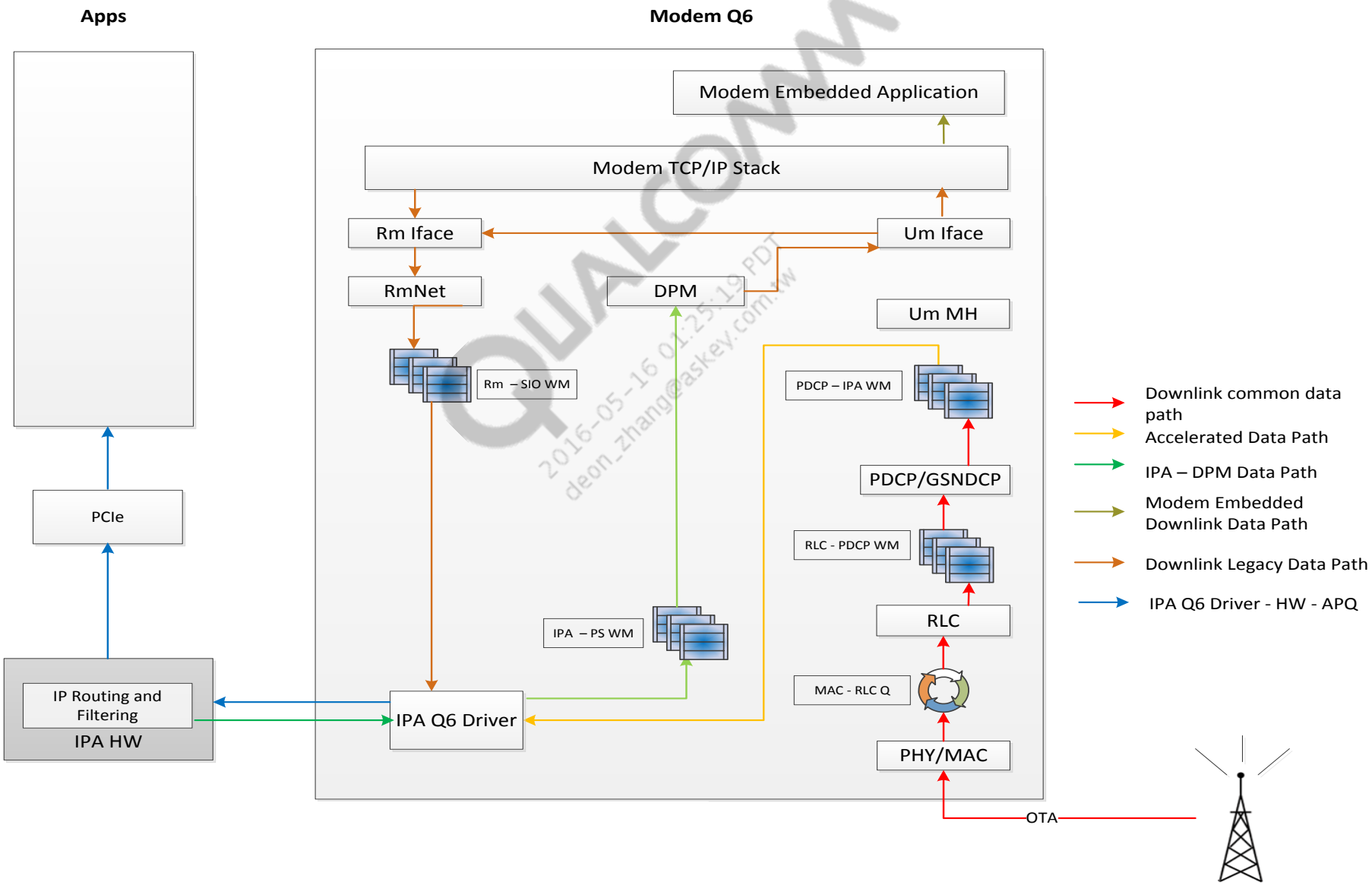
3GPP/LTE Downlink Data Path



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Dormancy

- Overview
  - EPS bearers are preserved when DRBs are released
  - When UL data is received, data stack requests reestablishment of DRBs
  - While DRB reestablishment is pending, UL flow is disabled
  - UL flow is reenabled once DRBs are reestablished
    - Note: All DRBs are released/reestablished together
- Failure handling
  - Data stack retries DRB establishment when reestablishment fails after dormancy
  - Default behavior is to retry DRB reestablishment after a random backoff time in the range 100 ms to 400 ms
  - The maximum number of retries to be attempted is controlled through NV item “Max RAB Re-estab Retry Count”
  - After maximum number of retries, buffered data is discarded.

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QoS

- Overview
  - Multiple PS flows are created per Bearer Context/PS PHYS LINK, each representing a UE/network-initiated SDF (i.e., flow)
  - Each UE-initiated SDF is represented by a separate PS flow
    - Even if bearer is dual IP type
  - Network-initiated QoS is represented by a separate PS flow per bearer
    - For dual IP bearers, a separate flow object used per IFACE for representing network-initiated QoS

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QoS (cont.)

- Filtering limitations
  - Support maximum of eight filters per flow
  - No support for filtering based on:
    - SPI
  - No support for filters with following combinations of filter components:
    - SPI and any one or more of {Flow label, TOS, port number(s), port range(s), next protocol}
    - Flow label and any one or more of {TOS, port number(s), port range(s), next protocol}
    - TOS and any one or more of {port number(s), port range(s), next protocol}
    - UDP, TCP, ICMP are only supported protocols in the next header.
    - Zero is not supported for TOS/Traffic value.
  - Note that the above are also not supported for DL filters
    - Even if network provides these unsupported components/component combinations in DL filters only, request will be rejected
  - No support for TFT on default bearer
    - Bearer modification request to install TFT on default bearer will be rejected
  - No enforcement of UL APN-AMBR

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LTE < -- > WCDMA QoS Continuity

- Bearer Conversion
  - One to one mapping between EPS Bearer and PDP Context
    - EPS Bearer ID = NSAPI
    - TFT is retained as it is
  - UMTS QoS parameters are provided by NW in NAS signaling
  - For bearer activated in UTRAN/GERAN, EPS QoS parameters need to be derived by UE
    - Conversion rules specified to derive QCI from Traffic Class, Traffic Handling Priority and Transfer Delay
    - GBR and MBR are retained, for conversational and streaming classes
  - For bearer activated in EUTRAN Mode, UMTS QoS parameters need to be derived by UE
    - Conversion rules specified to derive Traffic Class, Traffic Handling Priority and Transfer Delay from QCI; see *General Packet Radio Service (GPRS) Enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) Access* (3GPP TS 23.401)
  - If QoS modification is needed when moving to target RAT, NW will use appropriate procedures to modify QoS or delete bearers as needed

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BCM

- The Bearer Control Mode (BCM) for E-UTRAN access is always UE/NW. Hence, explicit signalling between the UE and the network to determine BCM for E-UTRAN is not needed.
- GERAN/UTRAN/E-UTRAN capable UEs negotiate the BCM of a PDN Connection applicable for GERAN/UTRAN access during E-UTRAN Initial Attach and during UE Requested PDN Connectivity procedure.
- The selected BCM, valid for GERAN/UTRAN, is provided back to the UE in PCO IE in the E-UTRAN Attach Accept or PDN Connectivity Accept message. The selected BCM is also stored in the PDN GW and the UE, and applied by UE upon moving to GERAN or UTRAN access unless explicitly informed by PDN GW of a change in BCM via PCO IE.

BCM Mode Supported
01 - UE ONLY
02 - UE/NW

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Inter-RAT– Silent Redial

- During inter-RAT transitions between LTE and WCDMA/GPRS, data calls that are locally rejected on source RAT will be redialed by Data Services mode handler on target RAT
  - Data Services supports silent redial in WCDMA to LTE transition for the default PDN connection
- Use case
  - User triggers a call on WCDMA
  - UE is redirected to LTE during RRC connection establishment
  - This leaves the user-initiated call in pending state during inter RAT
  - On the new RAT LTE, DS receives the GET_PDN_CONN_REQ_IND
  - DS redials the pending call to bring up def PDN connection on LTE
- Alternative use cases
  - UE is out of service when call is placed and then finds LTE service

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Throttling

- Throttling algorithm supported per operator-specific data retry requirements
- 3GPP TS 24.301 standard – Rel10 throttling is supported
- Throttling can be configured for any of the following causes:
  - When UE receives any EMM cause code
  - When UE receives ‘Attach reject’
  - When UE receives ‘Service reject’
  - When UE does not receive any response for ‘Attach accept or Service Request’ and NAS retry timers expiry
  - When UE receives ‘PDN connectivity reject’
  - When UE receives ‘BEARER RESOURCE ALLOCATION REJECT’
  - When UE receives ‘BEARER RESOURCE ALLOCATION REJECT’
- Throttling algorithms supported are as follows:
  - Throttle until power recycle or UICC card replace based on EMM cause codes
  - Throttle based on failure count and timers based on EMM and ESM cause codes
  - PLMN-based throttling
  - PDN-based throttling

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References

Documents	
Standards	
Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall Description; Stage 2	3GPP TS 36.200
Nonaccess-Stratum (NAS) Protocol for Evolved Packet System (EPS); Stage 3	3GPP TS 24.301
Quality of Service Concept and Architecture	3GPP TS 23.107
General Packet Radio Service (GPRS) Enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) Access	3GPP TS 23.401

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deon_zhang@asker.com.tw

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References (cont.)

Acronyms	
Term	**Definition**
eNB	Evolved Node B
EPC	evolved packet core
EPS	evolved packet system (E-UTRAN + EPC)
E-UTRA	Evolved Universal Terrestrial Radio Access
E-UTRAN	Evolved Universal Terrestrial Radio Access Network
GERAN	GSM/EDGE Radio Access Network
LTE	long term evolution
MIB	master information block
MME	Mobility Management Element
NAS	nonaccess stratum
PDCP	packet data convergence protocol
PDN	Packet Data Network
P-GW	Packet Data Network Gateway
RLC	radio link control
SAE	system architecture evolution
S-GW	Serving Gateway

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deon_zhang@askey.com.tw

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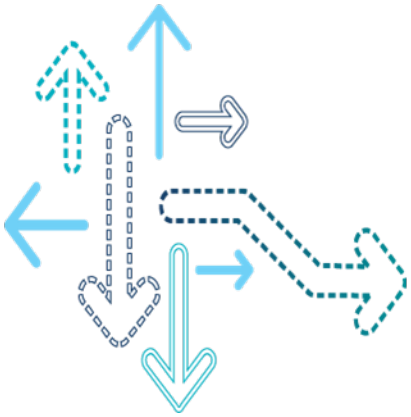

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