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LTE QoS: SDF and EPS Bearer QoS

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This document will describe LTE QoS at service level and at bearer level. First, the concept of Service Date Flow (SDF) and EPS bearer, traffic flows at these two levels, will be explained, followed by a description of their relationship. Then, it will explain the concept of QoS at each level, and cover different types and characteristics of SDF QoS parameters and EPS bearer QoS parameters. Finally, explanation on how QoS parameters are provisioned to Evolved Packet System (EPS) entities and applied to user traffic, and how they work in UL and DL traffic will be given.

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Abbreviations

AMBR	Aggregated Maximum Bit Rate
APN	Access Point Name
ARP	Allocation and Retention Priority
DL	Downlink
DRB	Data Radio Bearer
EBI	EPS Bearer Identity
eNB	Evolved Node B
EPS	Evolved Packet System
E-RAB	E-UTRAN Radio Access Bearer
E-UTRAN	Evolved Universal Terrestrial Radio Access Network
GBR	Guaranteed Bit Rate
HSS	Home Subscriber Server
IP	Internet Protocol
IP-CAN	IP Connectivity Access Network
LTE	Long Term Evolution
MBR	Maximum Bit Rate
MME	Mobility Management Entity
PCC	Policy and Charging Control
PCRF	Policy and Charging Rules Function
PDN	Packet Data Network
PF	Packet Filter
P-GW	PDN GW
QCI	QoS Class Identifier
QoS	Quality of Service
SDF	Service Data Flow
S-GW	Serving GW
SPR	Subscriber Profile Repository
TFT	Traffic Flow Template
UE	User Equipment
UL	Uplink

I. Introduction

An LTE service provider should be able to make services with different QoS requirements available to its users with different subscription levels. So, the service provider needs to be aware of subscription levels of each user (e.g. premium, best effort, etc.) and requested service types (e.g. Internet, voice, etc.) in order to assign radio and network resources to the traffic of each user and manage them properly.

For this reason, the LTE network first classifies user traffic (IP flows) into different SDFs having different QoS classes based on the type of the service that is being provided through the SDFs, and then applies different QoS rules to each SDF. Since SDFs are delivered through EPS bearers in the LTE network, EPS bearer QoS has to be controlled in a way that SDF QoS is maintained.

In this document, QoS mechanisms for SDFs and EPS bearers are explained as QoS mechanisms in LTE, and examples showing how they work are provided. This document is organized as follows: Chapter II defines an SDF and EPS bearer and Chapter III describes QoS parameters for SDFs and EPS bearers. Chapter IV covers QoS provisioning and QoS enforcement, describing by which entity QoS parameters are provisioned and where they are enforced. In Chapter V, some examples showing how the LTE QoS works are provided and explained based on the concept of QoS discussed in Chapters II and III.

II. SDF and EPS Bearer

Figure 1 illustrates SDFs and EPS bearers, and their relationship. In an LTE network, user traffic (IP flows or IP packets) is classified into SDF traffic (hereinafter referred to as “SDF”) and EPS bearer traffic (hereinafter referred to as “EPS bearer”). An SDF refers to a group of IP flows associated with a service that a user is using, while an EPS bearer refers to IP flows of aggregated SDFs that have the same QoS class.

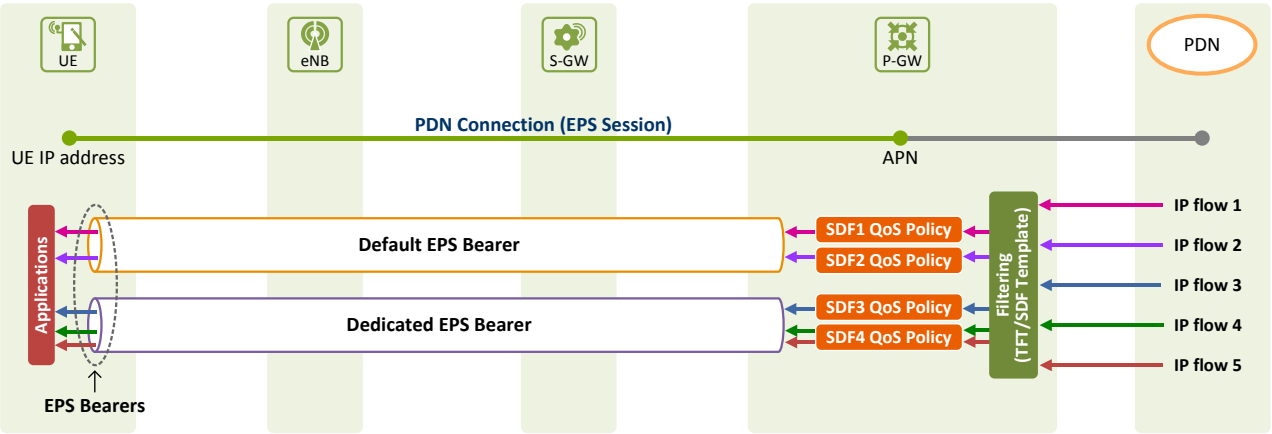


Figure 1. SDFs and EPS Bearers

The SDF and EPS bearer are detected by matching the IP flows against the packet filters (SDF templates for SDFs or traffic flow templates (TFTs) for EPS bearers). These packet filters are pre-configured by network operators in accordance with their policy, and each of them typically consists of 5-tuple (Source IP address, Destination IP address, Source port number, Destination port number, and Protocol ID).
In other words, in the LTE network, IP flows with the same service characteristics that match the packet filters

of a SDF template are designated a SDF. SDFs that match the packet filters of a TFT are mapped to an EPS bearer, to be finally delivered to a UE. SDFs with the same QoS class are delivered, as aggregated, through an EPS bearer, whereas ones with different QoS class are delivered through different EPS bearers.

SDF

User traffic using different services (or applications) has different QoS class. A SDF is an IP flow or an aggregation of IP flows of user traffic classified by the type of the service in use. Different SDFs have different QoS class and hence an SDF serves as a unit by which QoS rules[1] are applied in accordance with Policy and Charging (PCC) procedure in the LTE network (See "LTE PCC" technical document for detailed PCC procedure). In Figure 1, IP flows heading to a UE are classified into different SDFs according to their service type by using the SDF template. Then, appropriate QoS policies (e.g. priority, bandwidth control, etc.) are applied to these SDFs before they are delivered to the UE. As QoS is provided by EPS bearers when the SDFs are delivered over the LTE network, each SDF is mapped by the P-GW to an EPS bearer that satisfies its QoS requirement, and then delivered to the UE.

EPS Bearer

There are two types of EPS bearers: default and dedicated (See [1]). When a UE attaches to the LTE network, an IP address to be used in a PDN (Packet Data Network) is assigned, connecting to a PDN[2], and a default EPS bearer is established all at the same time. When a user who has been using a service through a default bearer (e.g. Internet) attempts to use a service which requires higher QoS that the current default bearer cannot provide (e.g. VoD), a dedicated bearer is established on demand[3]. Thus, the dedicated bearer is established with QoS different from the one already sent in the existing bearer. A UE can be connected to more than one PDN, which has one mandatory default EPS bearer and none to many optional EPS bearers. The number of EPS bearers a UE can have cannot exceed 11 (See [1]).

Once the default bearer is established at the initial attach of a UE to the network, the establishment lasts even while no service is being used and until the UE detaches from the network. The default bearer is established one per each PDN. When a UE initially attaches to the network, the network (MME) needs information about how to establish a default bearer, such as which QoS to use and to which PDN to connect. This information is already provisioned to an HSS as subscription information. So, the MME can simply download the subscription information (default APN, EPS subscribed QoS profile, etc.), select a P-GW to connect a PDN from based on the APN, and activate a default bearer associated to the PDN based on the subscribed QoS profile.

SDFs and EPS Bearers in Figure 1

Figure 1 shows EPS bearers and SDFs when downlink IP flows are delivered to a UE through EPS. The IP flows arriving at a P-GW through a PDN are filtered to SDFs by using SDF templates (kind of packet filters). In the figure, IP flows 1, 2 and 3 are filtered to SDFs 1, 2 and 3, respectively while IP flows 4 and 5 are filtered to SDF 4. Different QoS policies are applied to each SDF and then the SDFs are mapped to EPS bearers as classified by using Traffic Flow Template (TFT). SDFs 1 and 2 are mapped to the default bearer and SDFs 3 and 4 are

[1] QoS rules are based on the policy of operators.
[2] A PDN connection is also called an EPS session.
[3] A dedicated bearer can be activated when a default bearer is activated.

mapped to the dedicated bearer, all destined to the UE. Upon arrival at the UE, the IP flows are all sent to their destination applications.

Terms relating to EPS bearers and SDFs shown in Figure 1 are listed in Table 1. Out of the IP Connectivity Access Networks (IP-CANs) covered in 3GPP standards, this document discusses EPS only. So, all IP-CANs are referred to as EPS herein (e.g. IP-CAN Bearer = EPS Bearer).

Table 1. Terms relating to SDFs and EPS Bearers

Terms	Description
PDN Connection	• IP connection between UE and PDN (An LTE network identifies a PDN by its APN and assigns a PDN address (IP address) to UE.)
EPS Session	• Used to refer to a PDN Connection • Must have at least one EPS bearer. Remains activated as long as UE stays connected to PDN network
EPS Bearer	• Transmission path set between UE and P-GW to deliver user traffic (IP packets) with specified QoS • Each EPS bearer is activated with QoS parameters that indicate the characteristics of the transmission path. • Refers to EPS bearer traffic in this document
Default Bearer	• The first EPS bearer activated when an EPS session (PDN connection) is created. Stays activated until the EPS session is terminated • Always set as non-GBR type (See Chapter III)
Dedicated Bearer	• Additional EPS bearer activated on demand after an EPS session (PDN connection) is created • Can be either GBR or non-GBR type (See Chapter III)
Service Data Flow (SDF)	• An IP flow or an aggregation of IP flows of user traffic classified by the service type. Classified by using SDF templates • Different QoS is applied to each SDF. Each SDF is subject to different QoS rules[4] determined by PCRF (See “LTE PCC” technical document for more information). • Each SDF is delivered through an EPS bearer that can satisfy its QoS. • A SDF that matches the packet filters of a TFT is mapped to an EPS bearer, and multiple SDFs with the same QCI are mapped and delivered to one EPS bearer.

III. QoS Parameters for SDF and EPS Bearer

In Chapter II, we have learned that user traffic is classified by using packet filters into either SDFs or EPS bearers, and SDF QoS and EPS bearer QoS are respectively applied to the SDFs and the EPS bearers. In Chapter III, we will study QoS parameters for SDFs and for EPS bearers and explain their relationship.

In an LTE network, QoS parameters are defined at service level and at bearer level. SDF QoS parameters are service-level QoS parameters while EPS bearer QoS parameters are bearer-level QoS parameters. Service level and bearer level are also called as SDF level and SDF aggregate level. An SDF aggregate refers to a group of SDFs which have the same QCI (QoS Class Identifier) and ARP (Allocation and Retention Priority) values and

[4] QoS rule means a set of information enabling the detection of a service data flow and defining its associated QoS parameters.

belong to one EPS session. Both QCI and ARP are the basic QoS parameters applied to all SDFs and EPS bearers. The QCI is particularly important because it serves as a reference that indicates the performance characteristics of SDFs and EPS bearers. In addition to these two basic parameters, there are other QoS parameters, such as GBR, MBR and AMBR that specify the bandwidth (or bit rate) characteristics of SDFs and EPS bearers. SDF and EPS bearer QoS parameters are as follows:

- **SDF QoS parameters**: QCI, ARP, GBR and MBR
- **EPS bearer QoS parameters**: QCI, ARP, GBR, MBR, APN-AMBR and UE-AMBR

SDF QoS Parameters

QCI and ARP are applied to all SDFs. The QCI, in an integer from 1 to 9, indicates nine different QoS performance characteristics of each IP packet, such as resource type (GBR or Non-GBR), priority (1 ~ 9), packet delay budget (50 ms ~ 300 ms), and packet error loss rate (10^{-2} ~ 10^{-6}) [2].
Maximum Bit Rate (MBR) and Guaranteed Bit Rate (GBR) are also the SDF QoS parameters, and they indicate the bandwidths (or bit rates) of SDFs. MBR specifies the maximum bit rate of an SDF. If the network traffic is not congested, user traffic travelling as SDF can be delivered at most at the specified MBR. However, GBR is the guaranteed bit rate of an SDF. This means the SDF is guaranteed with a specified GBR no matter what. So, even when the network traffic is congested, user traffic travelling as SDF is delivered at least at the guaranteed GBR.

There are two types of SDFs: GBR SDF and non-GBR SDF. In case of a GBR SDF, dedicated network resources are assigned according to the resource type specified by its QCI. However, in case of a non-GBR SDF, dedicated network resources are not assigned (See Table 3 for comparison between GBR and non-GBR types). A GBR SDF is assigned a GBR and an MBR, whereas a non- GBR SDF is assigned an MBR only. QoS parameters for these two SDFs are as follows:

- **GBR SDF QoS parameters**: QCI, ARP, GBR (UL/DL) and MBR (UL/DL)
- **Non-GBR SDF QoS parameters**: QCI, ARP and MBR (UL/DL)

A SDF that matches the packets filters of a TFT (DL TFT) is mapped to an EPS bearer in a P-GW, and delivered to a UE through its mapped EPS bearer. An aggregate of SDFs with the same QCI and ARP is mapped to one EPS bearer.

EPS Bearer QoS Parameters

QCI and ARP are applied to all EPS bearers. An EPS bearer is classified as a GBR bearer or a non-GBR bearer depending on the resource type specified by its QCI (See Table 3 for comparison between GBR and non-GBR types). A default bearer must be non-GBR while a dedicated bearer can be either GBR or non-GBR.
Other than QCI and ARP, there are other QoS parameters for EPS bearers: MBR and GBR indicating the bandwidth (or bit rate) of an EPS bearer, and AMBR (Aggregated Maximum Bit Rate) indicating the total bandwidth of multiple EPS bearers. MBR and GBR are the maximum and the guaranteed bandwidths of an EPS bearer respectively, and AMBR is the maximum total bandwidth of multiple EPS bearers.

A GBR EPS bearer is assigned a GBR and an MBR, which means dedicated network resources are allocated (i.e.

a bandwidth in an amount of the specified GBR is guaranteed and a bandwidth in an amount of the specified MBR is available) to the bearer. However, a non-GBR EPS bearer is assigned an AMBR, which means dedicated network resources are not allocated to the bearer, but a maximum bandwidth to share with other non-GBR bearers is allocated. There are two types of AMBR: APN-AMBR, the maximum bandwidth that can be shared by all non-GBR bearers in a PDN, and UE-AMBR, the maximum bandwidth that can be shared in a UE. A UE can be connected to more than one PDN, in which case the total APN-AMBR of all PDNs cannot exceed the UE-AMBR. QoS parameters for the two types of EPS bearers are as follows:

- **GBR bearer QoS parameters**: QCI, ARP, GBR(UL/DL) and MBR(UL/DL)
- **Non-GBR bearer QoS parameters**: QCI, ARP, APN-AMBR(UL/DL) and UE-AMBR(UL/DL)

SDF and EPS Bearer QoS Parameters

Figure 2 illustrates QoS parameters applied to SDFs and EPS bearers.

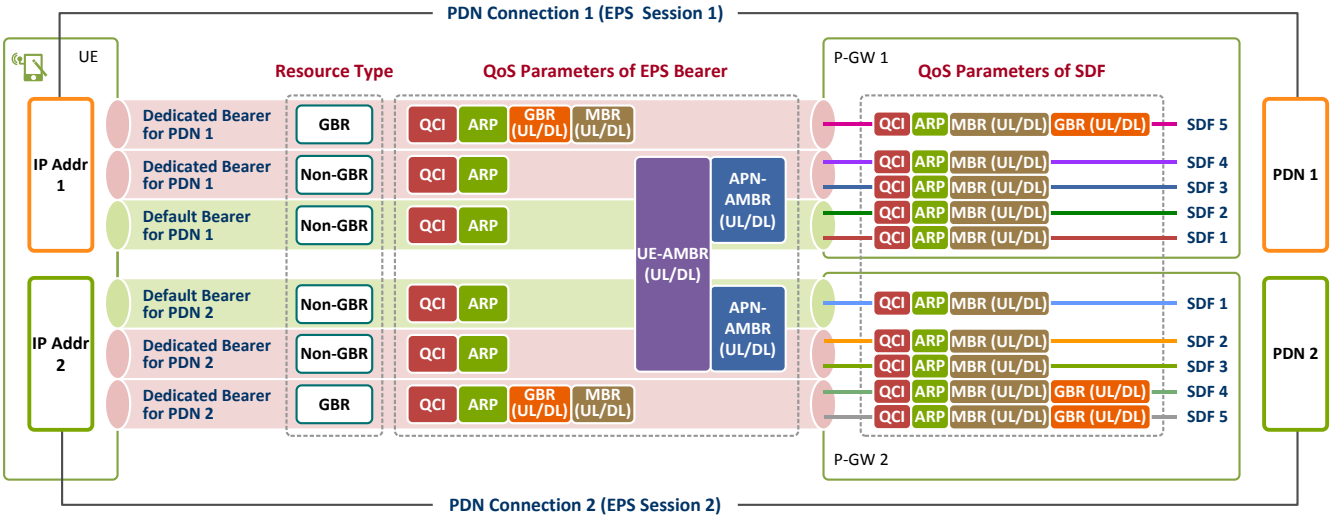


Figure 2. QoS Parameters for SDF and EPS Bearer

In Figure 2, the UE is connected to two PDNs. The UE has two IP addresses: IP address 1 assigned by P-GW 1 for use in PDN 1, and IP address 2 assigned by P-GW 2 for use in PDN 2. And it has one default bearer and two dedicated bearers established for each PDN. User traffic IP flows are filtered into SDFs in the P-GW by using SDF templates. There are two groups of SDFs 1~5 each received from PDN 1 and PDN 2. For these SDFs, network resources are allocated and packet forwarding is treated according to the QoS rules set in the P-GW. And the SDFs are then mapped to EPS bearers based on their specified QCI and ARP. In case of PDN 1 in the figure, SDFs 1 and 2 are mapped to the default bearer, SDFs 3 and 4 are mapped to the non-GBR dedicated bearer, and SDF 5 is mapped to the GBR dedicated bearer, all heading to the UE, their final destination. Such traffic mapped from SDF to EPS bearer is defined by using Traffic Filter Template (TFT). All the user traffic is subject to the EPS bearer QoS while being delivered through the EPS bearers.

All non-GBR bearers associated with a PDN are controlled by the maximum APN-AMBR they share while the ones associated with a UE are controlled by the maximum UE-AMBR they share.

Table 2. QoS Parameters for SDF and EPS Bearer

Terms	Description
QCI	• Indicates different QoS performance characteristics. • Standardized QoS characteristics values are defined as QCI=1 ~ 9 (See 3GPP TS 23.203 [3] table 6.1.7). • QoS characteristics represented by QCI value: resource type (GBR or non-GBR), priority (1~9), packet delay budget (50ms ~ 300ms), and packet error loss rate (10^{-2} ~ 10^{-6}) • Controls packet forwarding treatment (e.g. scheduling weights, admission thresholds, queue management thresholds, link layer protocol configuration, etc.) at network nodes (eNB, S-GW and P-GW). • Pre-configured in operators' network node (e.g. eNB)
ARP	• ARP parameters: Priority Level, Pre-emption Capability and Pre-emption Vulnerability - Priority Level (1~15): defines relative importance of a resource request, with 1 being the highest. - Pre-emption Capability (yes or no): defines whether a SDF can get resources already assigned to another SDF/bearer with a lower priority level. - Pre-emption Vulnerability (yes or no): defines whether a SDF can lose the resources already assigned to it in order to establish a SDF/bearer with a higher priority level. • Used for controlling call admission. Indicates a priority value used to decide whether to refuse to activate a new SDF/EPS bearer or remove the existing SDF/EPS bearer when a new SDF/EPS bearer needs to be activated or fixed in a network with limited resources. • Considered only when deciding whether to activate a new SDF/bearer or not. Once successfully established, ARP has no impact on packet forwarding treatment.
GBR (UL/DL)	• Applied to a GBR SDF/bearer. Indicates a minimum bandwidth (bit rate) to be guaranteed for the SDF/bearer.
MBR(UL/DL)	• Applied to a GBR/Non-GBR SDF and GBR bearer. Indicates a maximum bandwidth (bit rate) allowed for the SDF/bearer. • Any traffic in excess of the specified MBR is discarded through rate policing.
APN-AMBR(UL/DL)	• Defined per PDN. Indicates a maximum bandwidth (bit rate) allowed for all the non-GBR bearers associated with a PDN connected to a UE. • Applied only to the aggregated bandwidth of non-GBR bearers.
UE-AMBR(UL/DL)	• Defined per UE. Indicates a maximum bandwidth (bit rate) allowed for all the non-GBR bearers associated with a UE. • Applied only to the aggregated bandwidth of non-GBR bearers. • Subscription information provide by an HSS ($UE\text{-}AMBR_{HSS}$). Still, can be modified by an MME with the APN-AMBR of all PDNs within a UE to the extent permitted (within a range of values provided by the HSS, $UE\text{-}AMBR_{HSS}$). (UE-AMBR = $\sum$ APN-AMBR(s) for all PDNs)

Table 3. GBR vs. Non-GBR

Terms	Description
GBR SDF/Bearer	• Dedicated network resources are assigned to these types of SDFs/bearers for guaranteed GBR. • The network always reserves the bandwidth specified as GBR for GBR SDFs/bearers even when there is no traffic.
Non-GBR SDF/Bearer	• Dedicated network resources are not assigned to these types of SDFs/bearers. • Traffic is delivered on a best-effort basis depending of the degree of congestion in the network.

IV. QoS Provisioning and Enforcement

Section 4.1 discusses QoS provisioning that decides by which entity the QoS parameter values set in EPS entities are provided. And Section 4.2 covers QoS enforcement that determines to which EPS entities the SDF and EPS bearer QoS parameters defined in Chapter III are set and to which user traffic the parameters are applied.

4.1 QoS Provisioning

Figure 3 shows by which entity the QoS parameters set in EPS entities are provided.

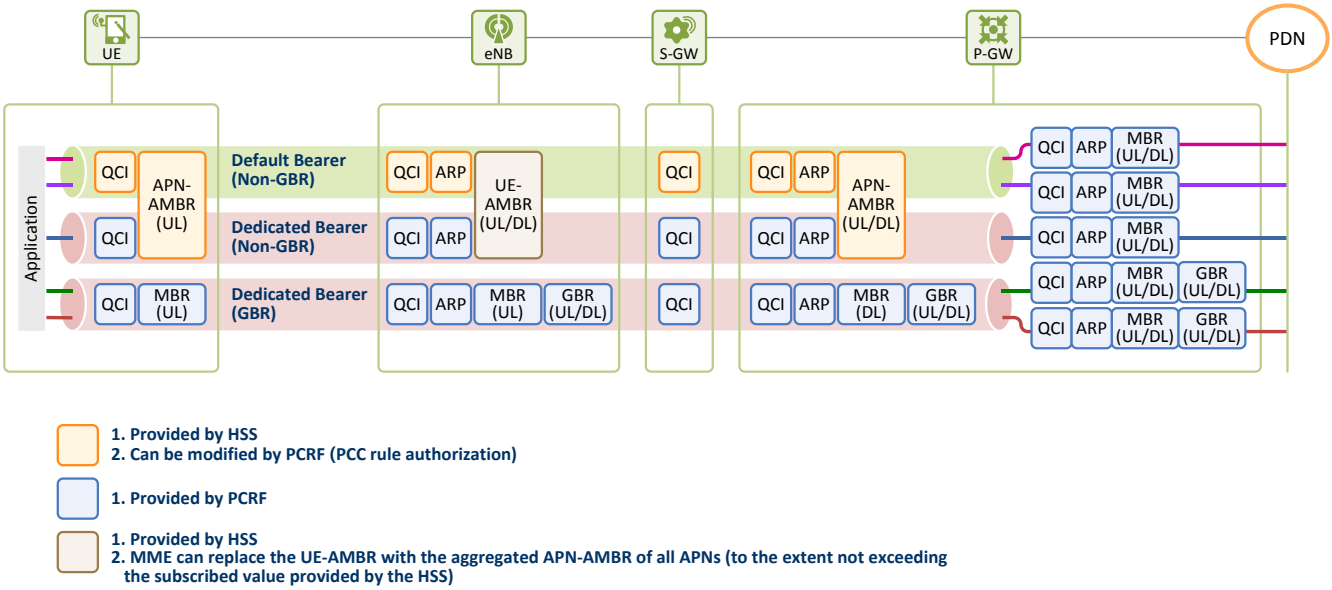


Figure 3. QoS Provisioning

SDF QoS Provisioning

All the QoS parameters for SDFs are provisioned by Policy and Charging Rules Function (PCRF).

EPS Bearer QoS Provisioning

QoS parameters applied to a default bearer are provisioned to an HSS as subscription information by a

network operator. And then, when the default bearer is activated, an MME downloads the QoS profile for the bearer from the HSS and sends it to EPS entities appropriately. QoS parameters for the default bearer provided by the HSS can be modified when QoS rules are authorized by PDRF upon creation of an EPS session. UE-AMBR controlled by an eNB is provided by the HSS, but can be modified by the MME. In such case, the MME can replace the existing UE-AMBR with the aggregated APN-AMBR of all active PDNs, to the extent that the new value does not exceed the value provided by the HSS, UE-$AMBR_{HSS}$.

QoS parameters applied to a dedicated bearer are provisioned by PCRF. The PCRF determines QoS parameters for the bearer based on the subscription information it received from Subscriber Profile Repository (SPR) when the bearer is activated.

4.2 QoS Enforcement

During QoS enforcement, detection of user traffic (IP flows i.e., SDF and EPS bearer) is performed and then QoS rules are applied to each of the detected SDFs and EPS bearers accordingly.
Figure 4 is an illustration showing to which EPS entities the SDF and EPS bearer QoS parameters are set and enforced. EPS bearer QoS parameters enforced to an S-GW are same as in a P-GW except for APN-AMBR. However, only QCIs are displayed in this figure for illustrative purposes.

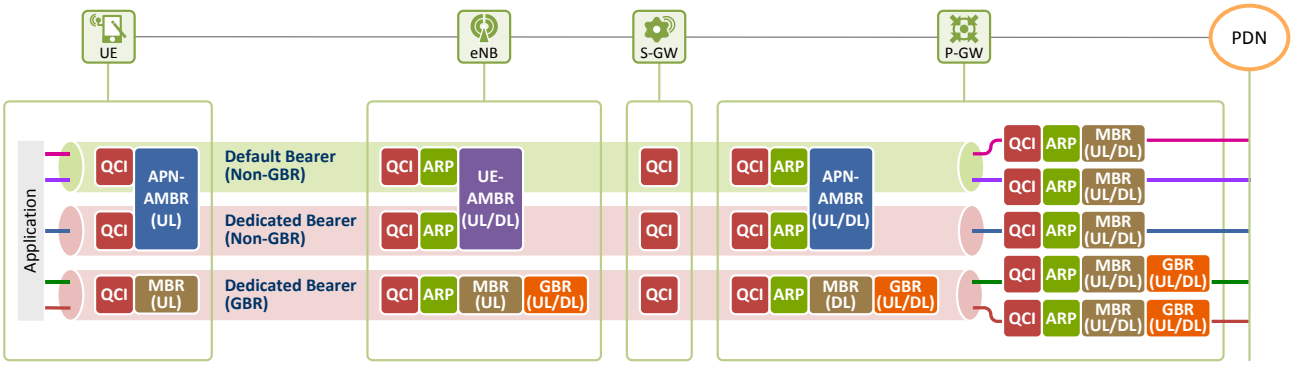


Figure 4. QoS Enforcement

SDF QoS Enforcement

SDF QoS parameters (i.e. QCI, ARP, MBR and GBR) are installed in a P-GW. Table 4 shows to which EPS entity the SDF QoS parameters are enforced. IP flows arriving at a P-GW are filtered into different SDFs by using SDF templates, then these SDFs are controlled by SDF QoS parameters installed in the P-GW.

Table 4. SDF QoS Enforcement

SDF QoS Parameter	Enforcement
QCI	Applied to all SDFs by P-GW
ARP	Applied to all SDFs by P-GW
MBR	Applied to all SDFs by P-GW
GBR	Applied to only GBR SDFs by P-GW

EPS Bearer QoS Enforcement

QoS parameters for EPS bearers are enforced in EPS entities (UE, eNB, S-GW and P-GW) that deliver user traffic between UE and P-GW. Table 5 illustrates to which EPS entity each of the QoS parameters is enforced.
APN-AMBR is applied to all the non-GBR EPS bearers activated in a PDN, by UE and P-GW, the two endpoints of the bearers. The APN-AMBR is applied only for UL traffic in a UE, but for both UL and DL traffic in a P-GW. Whereas UE-AMBR is applied to all the non-GBR EPS bearers activated in a UE, by eNB from which all PDN traffic is sent. That is, APN-AMBR is applied only to the PDN identified by its associated APN, while UE-AMBR is applied to a UE, and thus to all PDNs associated with the UE.
MBR is applied only to GBR bearers, and only for UL traffic in a UE and an eNB, but only for DL traffic in an S-Gw and a P-GW. GBR is also applied only to GBR EPS bearers and for UL and DL traffic in all entities except for a UE.

Table 5. EPS Bearer QoS Enforcement

EPS Bearer QoS Parameter	Enforcement
QCI	Applied to all bearers by all entities (UE, eNB, S-GW and P-GW)
ARP	Applied to all bearers by entities (eNB, S-GW and P-GW) except for UE
MBR	Applied to only GBR bearers - UL: Applied to only non-GBR bearers by UE and eNB - DL: Applied to only non-GBR bearers by S-GW and P-GW
GBR	Applied to only GBR bearers by entities (eNB, S-GW and P-GW) except for UE
APN-AMBR	Applied to only non-GBR bearers - UL: Applied to only non-GBR bearers by UE and P-GW - DL: Applied to only non-GBR bearers by P-GW
UE-AMBR	Applied to only non-GBR bearers by eNB

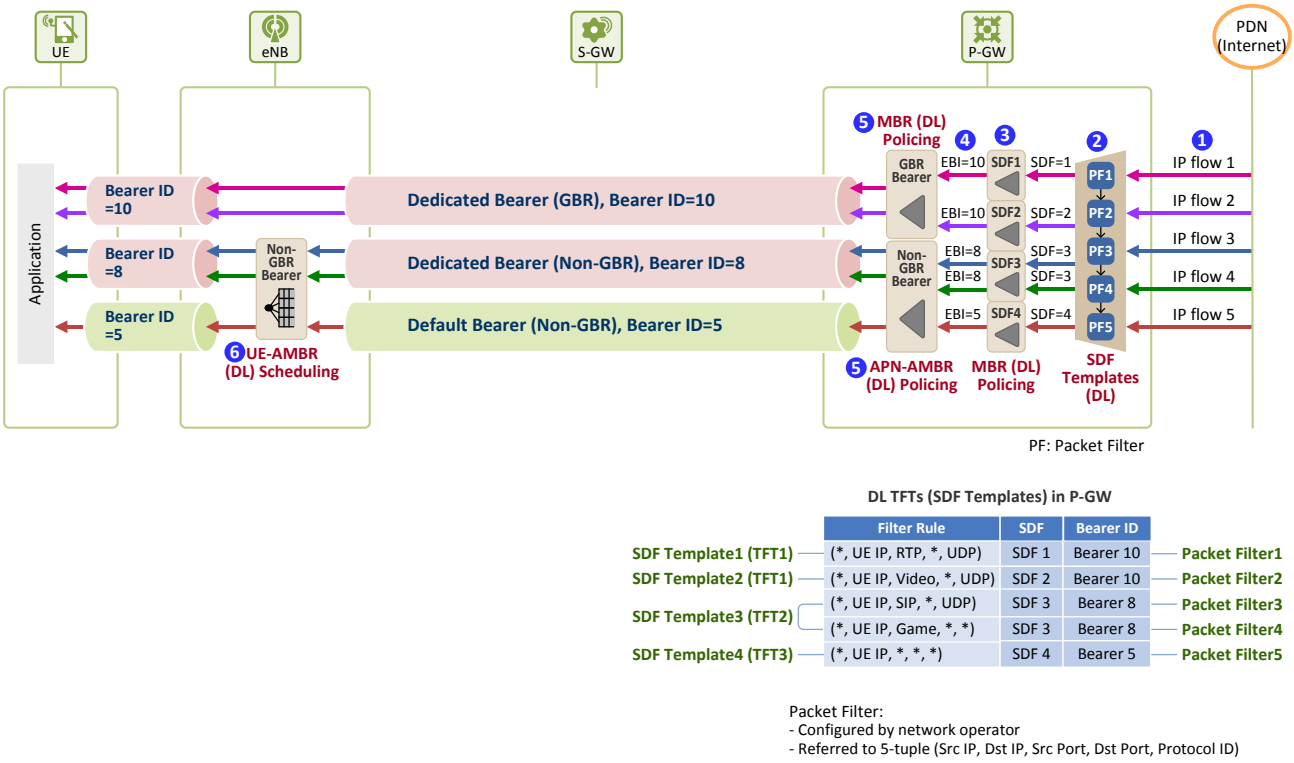
V. An Example for SDF and EPS Bearer QoS

In Chapter V, LTE QoS examples are provided based on the concept of the SDF and EPS bearer QoS discussed in Chapters II and III. Through the examples, a description of how the SDF QoS and EPS bearer QoS mechanisms work and what they do in each EPS entity will be given. The scenario used for the purposes of this chapter is as follows:

- UE connected to one PDN (Internet)
- UE communicating with the Internet through three bearers, i.e. one default bearer, one non-GBR dedicated bearer, and one GBR dedicated bearer.
- Their bearer IDs (EPS bearer ID (EBI)) are 5, 8 and 10, respectively.

5.1 QoS Operation in Downlink

Figure 5 shows an example of LTE QoS operation in DL. Their operation in each entity, mainly in UE, eNB and P-GW, is described in details below. The traffic control applicable herein includes traffic policing and shaping. Figure 5 and Figure 6 show examples of applying traffic policing.



DL TFTs (SDF Templates) in P-GW

	Filter Rule	SDF	Bearer ID	
SDF Template1 (TFT1)	(*, UE IP, RTP, *, UDP)	SDF 1	Bearer 10	Packet Filter1
SDF Template2 (TFT1)	(*, UE IP, Video, *, UDP)	SDF 2	Bearer 10	Packet Filter2
SDF Template3 (TFT2)	(*, UE IP, SIP, *, UDP)	SDF 3	Bearer 8	Packet Filter3
	(*, UE IP, Game, *, *)	SDF 3	Bearer 8	Packet Filter4
SDF Template4 (TFT3)	(*, UE IP, *, *, *)	SDF 4	Bearer 5	Packet Filter5

Packet Filter:
- Configured by network operator
- Referred to 5-tuple (Src IP, Dst IP, Src Port, Dst Port, Protocol ID)

Figure 5. An Example for LTE QoS (Downlink)

1 [P-GW] DL IP Flows Arrival

IP flows arrived at a P-GW. The flows 1 ~5 are voice data (RTP), video streaming, voice signaling (SIP), two-way game, and best effort type Internet traffic, respectively.

2 [P-GW] IP Packet Filtering (SDF Templates)

Upon arrival at the P-GW, the IP flows are filtered through IP packet filters (SDF templates) into different SDFs. Here, 5-tuple (Source IP address, Destination IP address, Source port number, Destination port number, Protocol ID) values are used as filtering rules for this purpose. IP flow 1 is classified as GBR SDF 1, IP flow 2 is classified as GBR SDF 2, IP flows 3 and 4 are classified as non-GBR SDF 3, and IP flow 5 is classified as non-GBR SDF 4.

3 [P-GW] SDF QoS Enforcement: MBR Rate Policing

MBR rate policing is performed against each SDF, and any traffic exceeding the specified DL MBR is discarded.

4 [P-GW] SDF – EPS Bearer Mapping: IP Packet Filtering (Traffic Flow Templates; TFT)

SDFs are filtered by using IP packet filters (TFT) into different EPS bearers. SDF 1 and SDF 2 are mapped to the GBR dedicated bearer (EBI=10), SDF 3 is mapped to the non-GBR dedicated bearer (EBI=8), and finally SDF 4 is mapped to the non-GBR default bearer (EBI=5).

5 [P-GW] EPS Bearer QoS Enforcement: MBR/APN-AMBR Rate Policing

EPS bearer QoS is applied to each bearer. For GBR bearers, MBR rate policing is performed using DL MBR value, and any IP packets exceeding the specified DL MBR are discarded. For non-GBR bearers, APN-AMBR

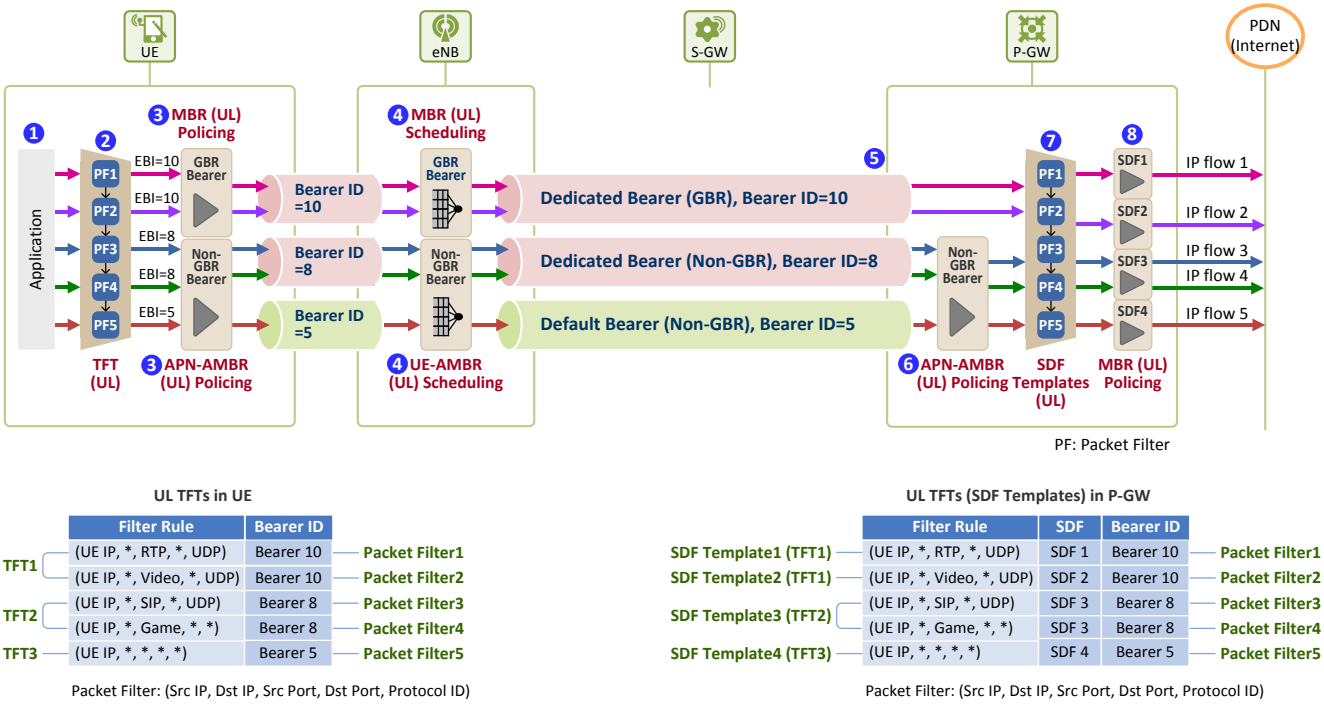
rate policing is performed. That is, for all the IP flows heading to EBI 8 and EBI 5, rate policing with is performed and any IP packets exceeding the specified DL APN-AMBR are discarded.

6 [eNB] EPS Bearer QoS Enforcement: UE-AMBR Scheduling

The eNB performs UE-AMBR rate policing against the non-GBR bearers and also scheduling over radio link. That is, for all the IP flows heading to EBI 8 and EBI 5, DL UE-AMBR rate policing is performed. In Figure 5, because there is one PDN, DL UE-AMBR has the same value as DL APN-AMBR.

5.2 QoS Operation in Uplink

Figure 6 shows an example of LTE QoS operation in UL. Unlike in DL, controlling of MBR and APN-AMBR is performed both in the UE and the P-GW.



UL TFTs in UE

	Filter Rule	Bearer ID	
TFT1	(UE IP, *, RTP, *, UDP)	Bearer 10	Packet Filter1
	(UE IP, *, Video, *, UDP)	Bearer 10	Packet Filter2
TFT2	(UE IP, *, SIP, *, UDP)	Bearer 8	Packet Filter3
	(UE IP, *, Game, *, *)	Bearer 8	Packet Filter4
TFT3	(UE IP, *, *, *, *)	Bearer 5	Packet Filter5

Packet Filter: (Src IP, Dst IP, Src Port, Dst Port, Protocol ID)

UL TFTs (SDF Templates) in P-GW

	Filter Rule	SDF	Bearer ID	
SDF Template1 (TFT1)	(UE IP, *, RTP, *, UDP)	SDF 1	Bearer 10	Packet Filter1
SDF Template2 (TFT1)	(UE IP, *, Video, *, UDP)	SDF 2	Bearer 10	Packet Filter2
SDF Template3 (TFT2)	(UE IP, *, SIP, *, UDP)	SDF 3	Bearer 8	Packet Filter3
	(UE IP, *, Game, *, *)	SDF 3	Bearer 8	Packet Filter4
SDF Template4 (TFT3)	(UE IP, *, *, *, *)	SDF 4	Bearer 5	Packet Filter5

Packet Filter: (Src IP, Dst IP, Src Port, Dst Port, Protocol ID)

Figure 6. An Example for LTE QoS (Uplink)

1 [UE] UL IP Flows Arrival

IP flows from user applications arrive at a UE. Here, the applications are the same as in DL.

2 [UE] IP Packet Filtering (TFT)

IP flows in UL are filtered by using IP packet filters (TFT) into EPS bearers appropriately. A 5-tuple in IP and TCP/UDP headers is used as the filtering rule for this purpose. IP flows 1 and 2 are mapped to the GBR dedicated bearer (EBI=10), IP flows 3 and 4 are mapped to the non-GBR dedicated bearer (EBI=8), and finally IP flow 5 is mapped to the default bearer (EBI=5).

3 [UE] EPS Bearer QoS Enforcement: MBR/APN-AMBR Rate Policing

EPS bearer QoS is applied to each EPS bearer. For the IP flows to the GBR dedicated bearer (EBI=10), rate policing is performed using UL MBR, and for all the IP flows to the non-GBR dedicated bearers (EBI=8 and

EBI=5), rate policing is performed using UL APN-AMBR.

4 [eNB] EPS Bearer QoS Enforcement: MBR/UE-AMBR Rate Policing

The eNB performs rate policing/scheduling using UL MBR for the GBR bearer (EBI=10), and rate policing/scheduling using UL UE-AMBR for non-GBR bearers (EBI=8 and EBI=5). Because there is one PDN, UL UE-AMBR has the same value as UL APN-AMBR.

5 [P-GW] Bearer Traffic Arrival

Bearer traffic arrives at a P-GW through a S-GW.

6 [P-GW] EPS Bearer QoS Enforcement: APN-AMBR Rate Policing

APN-AMBR rate policing is performed against all IP flows received through non-GBR bearers (EBI=8 and EBI=5), and any IP packets exceeding the specified UL APN-AMBR are discarded.

7 [P-GW] IP Packet Filtering (SDF Templates)

EPS bearers are filtered through IP packet filters (SDF templates) into different SDFs. IP flows 1 and 2 from the GBR dedicated bearer (EBI=10) are mapped to SDFs 1 and 2, IP flows 3 and 4 from non-GBR dedicated bearer (EBI=8) are mapped to SDFs 3 and 4, and finally IP flows 5 from the default bearer (EBI=5) is mapped to SDF 5.

8 [P-GW] SDF QoS Enforcement: MBR Rate Policing

MBR rate policing is performed against each SDF), and any IP packets exceeding the specified UL MBR are discarded.

VI. Closing

We have studied LTE QoS mechanisms at service level and at bearer level. We have learned that user IP traffic flows at service level are classified into SDFs, to which different QoS classes are defined, and that user IP traffic flows at bearer level are classified into EPS bearers, each of which is an aggregation of SDFs with the same QoS class (QCI and ARP). We discussed the relationship between SDFs and EPS bearers and the way they are mapped to each other.

MAC layer in an eNB assigns radio resources to UEs and performs packet scheduling based on their EPS bearer QoS parameters. eNB packet scheduling was not covered in this document. Detailed procedure of deciding and authorizing QoS parameter values will be later described in the “LTE PCC” technical document.

References

[1] Netmanias Technical Document, “LTE Identification III: EPS Session/Bearer Identifiers”, August 2013, http://www.netmanias.com/en/?m=view&id=techdocs&no=5907

[2] 3GPP TS23.203, “Policy and charging control architecture”.

[3] NMC Consulting Group Confidential Internal Report, “E2E LTE Network Design”, August 2010.

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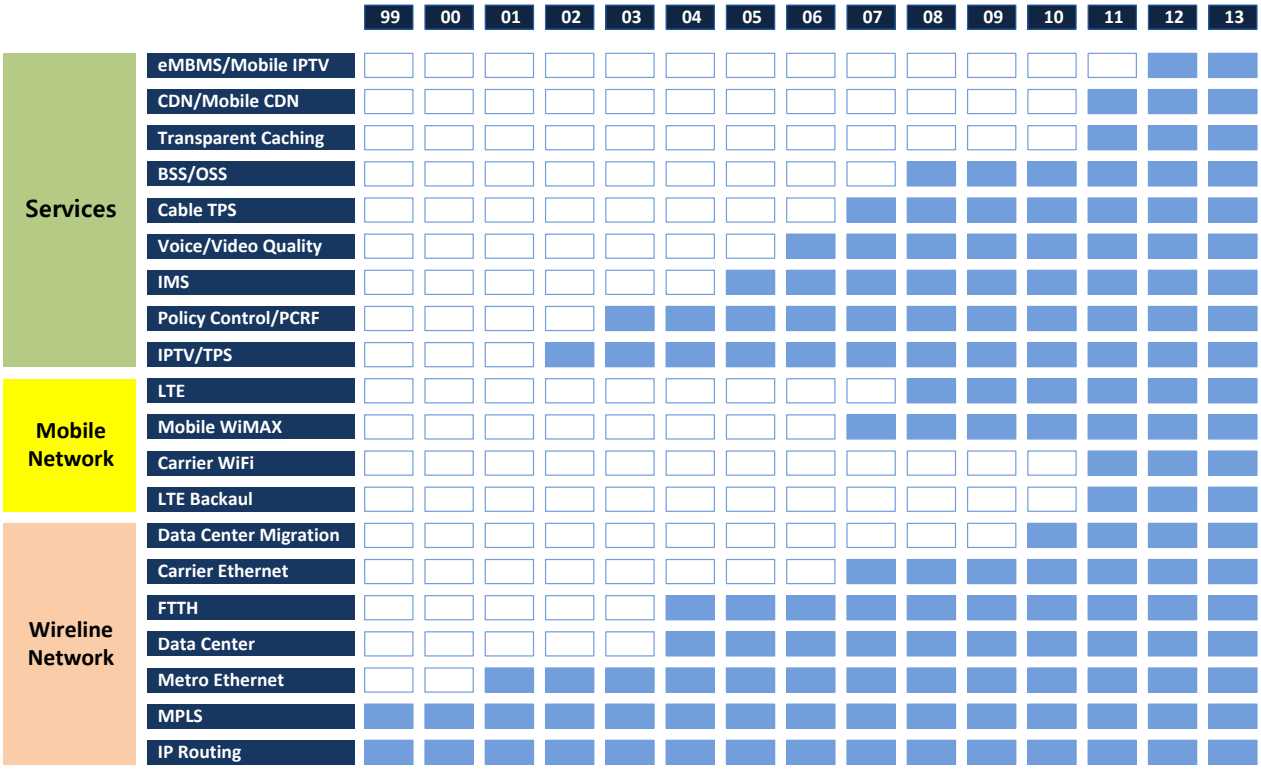

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