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LTE Policy and Charging Control (PCC)

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This document will describe Policy and Charging Control (PCC) rules and PCC procedures to be performed based on these rules. It will review PCC procedures required for using Internet and voice services on LTE networks, and also how "Policy Control" is performed depending on different PCC rules applied.

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Abbreviations

AAA	AA-Answer
AAR	AA-Request
AMBR	Aggregated Maximum Bit Rate
APN	Access Point Name
ARP	Allocation and Retention Priority
CCA	Credit-Control-Answer
CCR	Credit-Control-Request
DL	Downlink
DPI	Deep Packet Inspection
EMM	EPS Mobility Management
eNB	Evolved Node B
EPS	Evolved Packet System
ESM	EPS Session Management
GBR	Guaranteed Bit Rate
HSS	Home Subscriber Server
IMS	IP Multimedia Subsystem
IP	Internet Protocol
LBI	Linked EPS Bearer Identity
LTE	Long Term Evolution
MBR	Maximum Bit Rate
MME	Mobility Management Entity
P2P	Peer-to-Peer
PCC	Policy and Charging Control
PCEF	Policy and Charging Enforcement Function
PCO	Protocol Configuration Options
PCRF	Policy and Charging Rule Function
P-CSCF	Proxy Call Session Control Function
PDN	Packet Data Network
P-GW	Packet Data Network Gateway
QCI	QoS Class Identifier
QoS	Quality of Service
RAA	Re-Auth-Answer
RAR	Re-Auth-Request
RTP	Real Time Transport Protocol
SAE-GW	System Architecture Evolution Gateway
SDF	Service Data Flow
S-GW	Serving Gateway
SIP	Session Initiation Protocol
SPR	Subscriber Profile Repository
TFT	Traffic Flow Template
UDP	User Datagram Protocol
UE	User Equipment
UL	Uplink
VoLTE	Voice over LTE

I. Introduction

To use LTE services, a user must purchase an LTE device, sign up for an account with his mobile operator, and then select the service types and plan he wants. Then, to support and manage the selected services, the operator configures a subscription profile based on his subscription information. When the user uses LTE services, an EPS session is established (or modified) to each Access Point Name (APN) associated with different services selected. In the meantime, the network determines a policy on how network resources are to be allocated and how services are to be charged when an EPS session is established or modified. Then, it applies the policy to the EPS session while the session remains active. This procedure is called Policy and Charging Control (PCC), and is mainly taken care of by entities like Policy and Charging Control Function (PCRF) and Policy and Charging Enforcement Function (PCEF)[1].

When an EPS session is established or modified, PCRF determines a PCC rule for each Service Data Flow (SDF) based on the operator's policy (e.g. QoS policy, gate status, charging methods, etc.). PCEF (P-GW) detects an SDF, and applies a PCC rule that is specific to the particular SDF to the user packets in it. It also binds the SDF QoS and bearer QoS, and applies the bearer QoS to the EPS bearer(s). That is, EPS bearer contexts are set or modified at EPS entities (UE, eNB, S-GW, P-GW, and MME).

Establishment, modification and termination of an EPS session are performed in accordance with the PCC procedure. EPS session modification procedure may include establishment, modification or termination of an EPS bearer. During this procedure, EPS bearer contexts between UE and MME are processed by EPS Session Management (ESM) function in NAS layer.

This document discusses PCC rules and procedures, and is organized as follows: Chapter II defines PCC rules, and describes how PCC rules are provisioned over the Gx interface for different service types. Chapter III explains PCC procedures required for EPS session establishment and modification, along with ESM procedures. Chapter IV explores how IP packet flows are handled when policy control is applied, and Chapter V summarizes information related to policy control held by EPS entities.

II. PCC Rules

PCRF determines a PCC rule for each SDF, and forwards them to PCEF (P-GW) over the Gx interface. P-GW then has the forwarded PCC rules enforced for each SDF. After enforcing the PCC rules, when IP packets arrive, it detects SDFs that each packet belongs to, and applies a PCC rule to each packet according to their SDF. 3GPP TS 29.212 [1] defines PCC rules as follows:

- **Purpose**: The purpose of the PCC rule is to detect a packet belonging to a SDF, identify the service the SDF contributes to, provide applicable charging parameters for the SDF, and provide policy control for the SDF.
- **Apply to**: Different SDFs. PCEF (P-GW) classifies IP packets by matching them against the packet filters (SDF templates), and the matching PCC rules are applied to the packets.

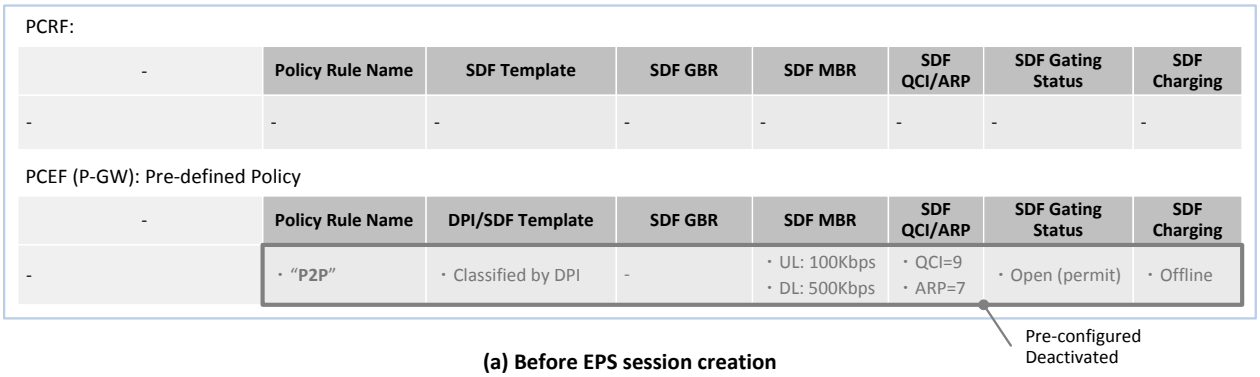
[1] PCRF cooperates also with other entities than PCEF (P-GW) for PCC. However, we will focus on PCRF that determines PCC rules, and PCEF (P-GW) that enforces the rules to EPS bearer in this document.

- **Type**: Dynamic PCC rules or pre-defined PCC rules. Dynamic PCC rules are dynamically provisioned by PCRF to P-GW when an EPS session is established or modified. Pre-defined ones are preconfigured in P-GW, and thus can be activated or deactivated by PCRF.
- **Elements**: A PCC rule consists of a policy rule name, service ID, SDF template, gate status, QoS parameters, charging parameters etc.,[2] and varies depending on the operator's policy.

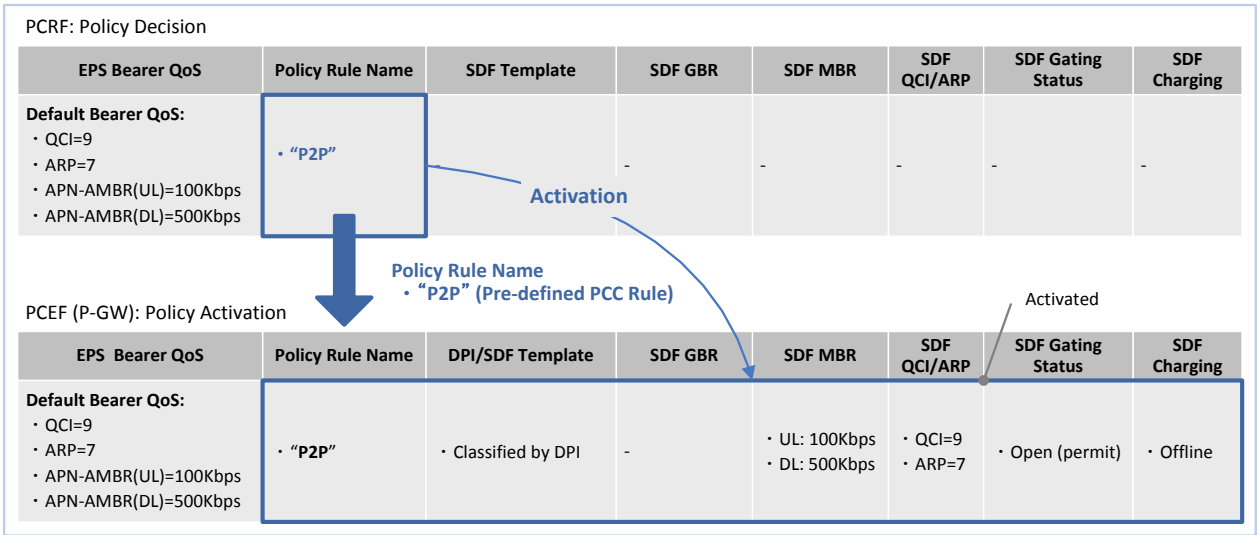
Below, we will see how PCC rules in different types (pre-defined and dynamic) are delivered over the Gx interface, and are enforced in P-GW. Section 2.1 describes the delivery of pre-defined PCC rules and Section 2.2 explains that of dynamic PCC rules.

2.1 Pre-defined PCC Rule

Some operators apply a policy that limits the bit rate of traffic not served by themselves, for example P2P. So, we will explain pre-defined PCC rules by using P2P as an example. Figure 1 illustrates how a pre-defined PCC rule is configured in P-GW.



(a) Before EPS session creation



(b) After EPS session creation

Figure 1. Example of Pre-defined PCC Rule: P2P Traffic

[2] See 3GPP TS 29.212 [1] for more details.

In the figure, "**P2P**", a pre-defined rule, is pre-configured and deactivated in P-GW. Here, because this rule is pre-defined, once PCRF decides on it, it just needs to give the P-GW the name of the policy rule (i.e. **P2P**), instead of sending all the elements of the rule. Upon receiving "**P2P**" rule name, the P-GW activates the "**P2P**" rule that has been deactivated, and enforces it.

2.2 Dynamic PCC Rule

Dynamic PCC rules are used whenever there is an event. Figure 2 shows how a dynamic PCC rule is configured in P-GW when a user uses Internet and voice services. The figure assumes the followings, and shows all the dynamic PCC rules to be covered in this document.

- Operator policy – Internet services are accessible to the extent allowed by the network resources, and the data rates of voice services are guaranteed.
- APN – Internet and voice services are accessed through different APNs, e.g. Internet and IMS, respectively.
- PCC rule name – Internet service: "**Internet**", voice service: "**Voice-C**" (SIP signaling)/"**Voice-U**" (voice packet)

PCRF:

-	Policy Rule Name	SDF Template	SDF GBR	SDF MBR	SDF QCI/ARP	SDF Gating Status	SDF Charging
-	-	-	-	-	-	-	-

PCEF (P-GW):

-	Policy Rule Name	SDF Template	SDF GBR	SDF MBR	SDF QCI/ARP	SDF Gating Status	SDF Charging
-	-	-	-	-	-	-	-

(a) Before EPS session creation

PCRF: Policy Decision

EPS Bearer QoS	Policy Rule Name	SDF Template	SDF GBR	SDF MBR	SDF QCI/ARP	SDF Gating Status	SDF Charging
Default Bearer (APN: Internet) ・QCI=9 ・ARP=7 ・APN-AMBR(UL)=Unlimited ・APN-AMBR(DL)=Unlimited	・**"Internet"**	・UL: (UE IP, *.*.*.*) ・DL: (*,UE IP, *.*.*)	-	・UL: Unlimited ・DL: Unlimited	・QCI=9 ・ARP=7	・Open (permit)	・Offline
Default Bearer (APN: IMS) ・QCI=5 ・ARP=6 ・APN-AMBR(UL)=100Kbps ・APN-AMBR(DL)=100Kbps	・**"Voice-C"**	・UL: (UE IP, *, SIP, *, UDP) ・DL: (*, UE IP, SIP, *, UDP)	-	・UL: 100Kbps ・DL: 100Kbps	・QCI=5 ・ARP=6	・Open (permit)	・Offline
Dedicated Bearer (APN: IMS) ・QCI=1 ・ARP=7 ・GBR/MBR(UL)=88Kbps ・GBR/MBR(DL)=88Kbps	・**"Voice-U"**	・UL: (UE IP, *, RTP, *, UDP) ・DL: (*, UE IP, RTP, *, UDP)	・UL: 88Kbps ・DL: 88Kbps	・UL: 88Kbps ・DL: 88Kbps	・QCI=1 ・ARP=7	・Open (permit)	・Offline

PCC Rule
・"Internet" (Dynamic PCC Rule)
・"Voice-C" (Dynamic PCC Rule)
・"Voice-U" (Dynamic PCC Rule)

Dynamic Provisioning

PCEF (P-GW): Policy Install

Default Bearer QoS	Policy Rule Name	SDF Template	SDF GBR	SDF MBR	SDF QCI/ARP	SDF Gating Status	SDF Charging
Default Bearer (APN: Internet) ・QCI=9 ・ARP=7 ・APN-AMBR(UL)=Unlimited ・APN-AMBR(DL)=Unlimited	・**"Internet"**	・UL: (UE IP, *.*.*.*) ・DL: (*,UE IP, *.*.*)	-	・UL: Unlimited ・DL: Unlimited	・QCI=9 ・ARP=7	・Open (permit)	・Offline
Default Bearer (APN: IMS) ・QCI=5 ・ARP=6 ・APN-AMBR(UL)=100Kbps ・APN-AMBR(DL)=100Kbps	・**"Voice-C"**	・UL: (UE IP, *, SIP, *, UDP) ・DL: (*, UE IP, SIP, *, UDP)	-	・UL: 100Kbps ・DL: 100Kbps	・QCI=5 ・ARP=6	・Open (permit)	・Offline
Dedicated Bearer (APN: IMS) ・QCI=1 ・ARP=7 ・GBR/MBR(UL)=88Kbps ・GBR/MBR(DL)=88Kbps	・**"Voice-U"**	・UL: (UE IP, *, RTP, *, UDP) ・DL: (*, UE IP, RTP, *, UDP)	・UL: 88Kbps ・DL: 88Kbps	・UL: 88Kbps ・DL: 88Kbps	・QCI=1 ・ARP=7	・Open (permit)	・Offline

(b) After EPS session creation

Figure 2. Example of Dynamic PCC Rule: Internet/Voice Service

"**Internet**" rule applies to all packets that access the Internet. It supports unlimited MBR (UL/DL), allowing maximum available bit rate for the Internet access. This rule applies to the default bearer accessing the Internet. APN-AMBR (UL/DL) is set unlimited, and data travels at maximum rate if there is no other user being served. But, the more users are served, the lower rate is supported.

"**Voice-C**" rule applies to SIP signaling packets. It applies to the default bearer that accesses the IMS network, supporting APN-AMBR (UL/DL) of 100 Kbps.

"**Voice-U**" rule applies to media packets, which are user voice packets, and supports GBR. During an active voice session, the network resources are allocated to ensure that packets are delivered at UL/DL 88 Kbps all the time. Also, a dedicated bearer is established, allowing packet delivery at GBR (UL/DL) 88 Kbps.

Every time an EPS session is established or modified, PCRF dynamically determines a PCC rule including the rule name (e.g. "**Internet**", "**Voice-C**" or "**Voice-U**") and the policy parameters specific to the particular rule depending on the service type selected. Next, it provisions them to P-GW through the Gx interface. Then the P-GW enforces the received policy parameters to IP packets after mapping them to bearer QoS parameters.

Once a user accesses the Internet and IMS network through initial attach procedure, the user's default bearers are kept connected unless he is detached from the LTE network. So, basically, "**Internet**" and "**Voice-C**" rules are kept active in the P-GW. On the other hand, a dedicated bearer on IMS APN is established upon detection of a voice call, and terminated as soon as the call ends.

III. PCC Procedures

We have discussed PCC rules in Chapter II. Now in Chapter III, we will explore PCC procedures by reviewing EPS session establishment and modification procedures. In LTE, voice services use a PDN (IMS network) different from one used in Internet services, and thus they have their own default bearer. Voice signaling messages are delivered through a default bearer using SIP protocol while media packets (user voice packets) are delivered through a dedicated bearer using RTP protocol.

Procedures for initial attach by an Internet service user and EPS session establishment were already discussed in our LTE Initial Attach document [2]. So, we will look into how PCC works during EPS session establishment/modification procedure for a user accessing IMS to make a voice call.
In order to make a voice call in an LTE network, attach to LTE and IMS registration are required in advance. Once an EPS session for voice service is established through LTE attach, a default bearer needed for attach to IMS network is created in the LTE network. During this procedure, a PCC rule for voice service signaling ("**Voice-C**") is applied to the bearer. Through this bearer, SIP signaling messages are delivered, and IMS authentication/registration between user and IMS network is carried out.
Then later when there is a voice call, the IMS network detects it and informs PCRF of the call. The PCRF determines a PCC rule ("**Voice-U**") and forwards it to P-GW. The P-GW creates a dedicated bearer for voice packet delivery, and the voice packets are delivered through the dedicated bearer.

3.1 Voice Session Establishment: Default Bearer Establishment and IMS Registration

Figure 3 shows how an EPS session is established for a user who initially attaches through IMS APN. For the purposes of the figure, we assumed the EPS session establishment is initiated by the user's turning on UE. As initial attach procedure using EPS Mobility Management (EMM) messages has already been explained in our previous document [2], we will briefly go over the session establishment using EPS Session Management (ESM) messages this time[3].

[3] NAS layer consists of ESM sublayer and EMM sublayer. ESM sublayer is an upper layer of EMM sublayer, and ESM messages are carried in EMM messages.

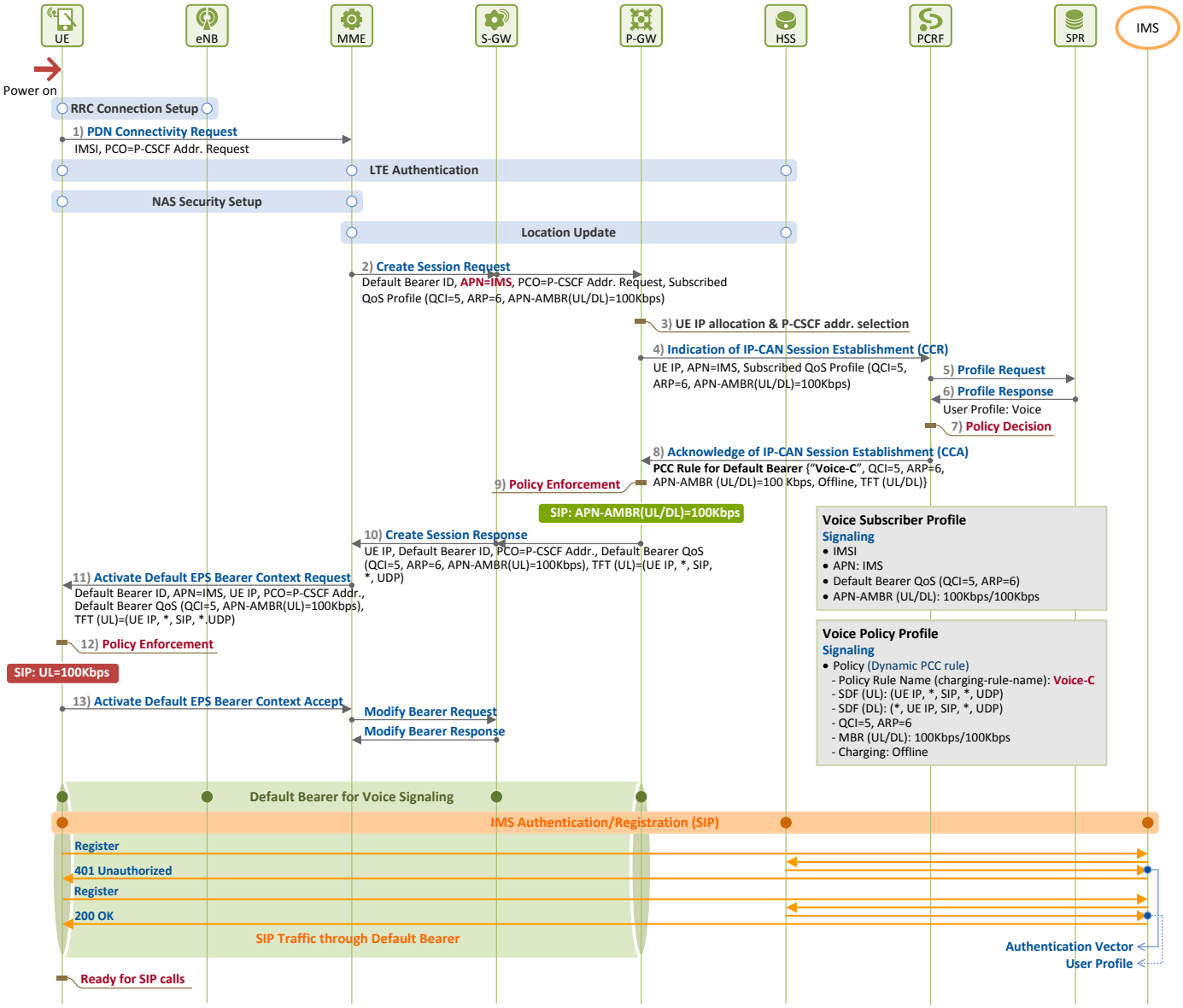


Figure 3. Voice Session and Default Bearer Establishment

1) [UE → MME] PDN Connectivity Request

UE requests for access to IMS network by sending a **PDN Connectivity Request** message to MME. The Protocol Configuration Options (PCO) field in this ESM message is used to ask for Proxy Call Session Control Function (P-CSCF) address. The message is included in an **Attach Request** message, an EMM message, and then sent to MME.

2) [MME → S-GW → P-GW] Request for Voice Session Creation

MME obtains an APN and subscription QoS profile from the subscription profile received from HSS during "Location Update". From APN, MME recognizes it has to create a default bearer for voice service and allocates an ID for the default bearer (for SIP signaling). The subscription profile contains QoS parameters (QCI = 5, ARP = 6, APN-AMBR = 100 Kbps), which are to be applied to the default bearer. MME prepares a **Create Session Request** message containing default bearer ID, APN, PCO and Subscribed QoS Profile, and forwards it to P-GW. At this time, PCO field received from UE is transparently delivered to P-GW.

3) **[P-GW] UE IP and P-CSCF Address Allocation**

P-GW allocates an UE IP for IMS APN, and selects the address of P-CSCF, an IMS control node.

4) **[P-GW → PCRF] Notification of EPS Session Establishment**

P-GW forwards the user's subscription QoS profile to PCRF by sending a **Credit-Control-Request (CCR)** message, asking for authorization.

5) **~ 6) [PCRF, SPR] User Profile Acquisition**

PCRF may obtain the user's subscription profile from SPR, and use it to determine a PCC policy for voice service.

7) **[PCRF] Policy Decision**

Based on the subscription profile, PCRF decides a policy for the EPS session. As it was for SIP signaling in this example, "**Voice-C**" is selected as a PCC rule.

- **"Voice-C" rule:** QCI = 5, ARP = 6, APN-AMBR (UL/DL) = 100 Kbps, Charging Rule: Offline, SIP Packet Filter

8) **[P-GW ← PCRF] PCC Rule Provision**

PCRF forwards the PCC rule (**"Voice-C"**) to P-GW over the Gx interface.

9) **[P-GW] Policy Enforcement**

Upon receipt of the PCC rule (**"Voice-C"**), P-GW enforces policy parameters, and maps SDF QoS parameters to default bearer QoS parameters[4].

- **P-GW (SDF)**: QCI = 5, ARP = 6, MBR (UL/DL) = 100 Kbps/100 Kbps, SDF Template (UL/DL) = (UE IP, *, SIP, *, UDP) /(*, UE IP, SIP, *, UDP)
- **P-GW (Default Bearer)**: QCI = 5, ARP = 6, APN=AMBR (UL/DL) = 100 Kbps/100 Kbps, TFT (UL/DL) = (UE IP, *, SIP, *, UDP)/(*, UE IP, SIP, *, UDP)

10) **[MME ← S-GW ← P-GW] Response for Voice Session Creation**

As a response to the request made in Step 2), P-GW sends a **Create Session Response** message to MME. This message contains approved QoS profiles and UL policy parameters to be forwarded to UE (e.g. APN-AMBR (UL), TFT (UL)).

11) **[UE ← MME] Request for Default Bearer Context Activation**

MME requests UE for activation of the default bearer context by sending an **Activate Default EPS Bearer Context Request** message. This ESM message, containing APN, UE IP, P-CSCF address, and policy parameters sent by P-GW, is embedded in an EMM message, **Attach Accept** message.

12) **[UE] Policy Enforcement: Default Bearer Context Activation**

UE enforces UL policy and activates the default bearer context.

- **UE**: QCI = 5, APN-AMBR (UL) = 100 Kbps, TFT (UL) = (UE IP, *, SIP, *, UDP)

13) **[UE → MME] Notification of Default Bearer Context Activation**

UE notifies MME that the default bearer context required for delivering of SIP signaling messages has been activated, by sending an **Activate Default EPS Bearer Context Accept** message.

Once the default bearer for SIP signaling is established, IMS authentication/registration procedure is

[4] See LTE QoS technical document [3].

performed through the bearer. IMS procedure using SIP protocol is beyond the scope of this document, and will be discussed later in the VoLTE technical document [4]. Once IMS registration is completed, UE is ready to send/receive voice calls.

3.2 Voice Session Modification: Dedicated Bearer Establishment

Once LTE attachment and IMS registration are completed, UE is ready to start a voice call. However, as voice packets require real-time delivery, QoS provided by the default bearer established for SIP signaling cannot satisfy the voice packet QoS. For this reason, now a new bearer that can provide satisfying voice packet QoS is needed. So, for every voice call, a dedicated bearer for voice packets is established, through a voice session modification procedure.

Figure 4 shows how a dedicated bearer is created and, as a result of the creation, how a voice session is modified according to a new PCC rule upon detection of a voice call. In the figure, when the originating UE requests for a voice call, PCRF knows from the SIP signaling (**Session Progress** message) that a voice call is requested. Then it determines a PCC rule, "**Voice-U**" rule (QCI = 1, ARP = 7, GBR/MBR = 88 Kbps), and forwards it to P-GW, which then creates a GBR-type dedicated bearer. From then on, when the originating UE receives a **200 OK** SIP message generated by the terminating UE through the default bearer, it forwards voice packets through the dedicated bearer.

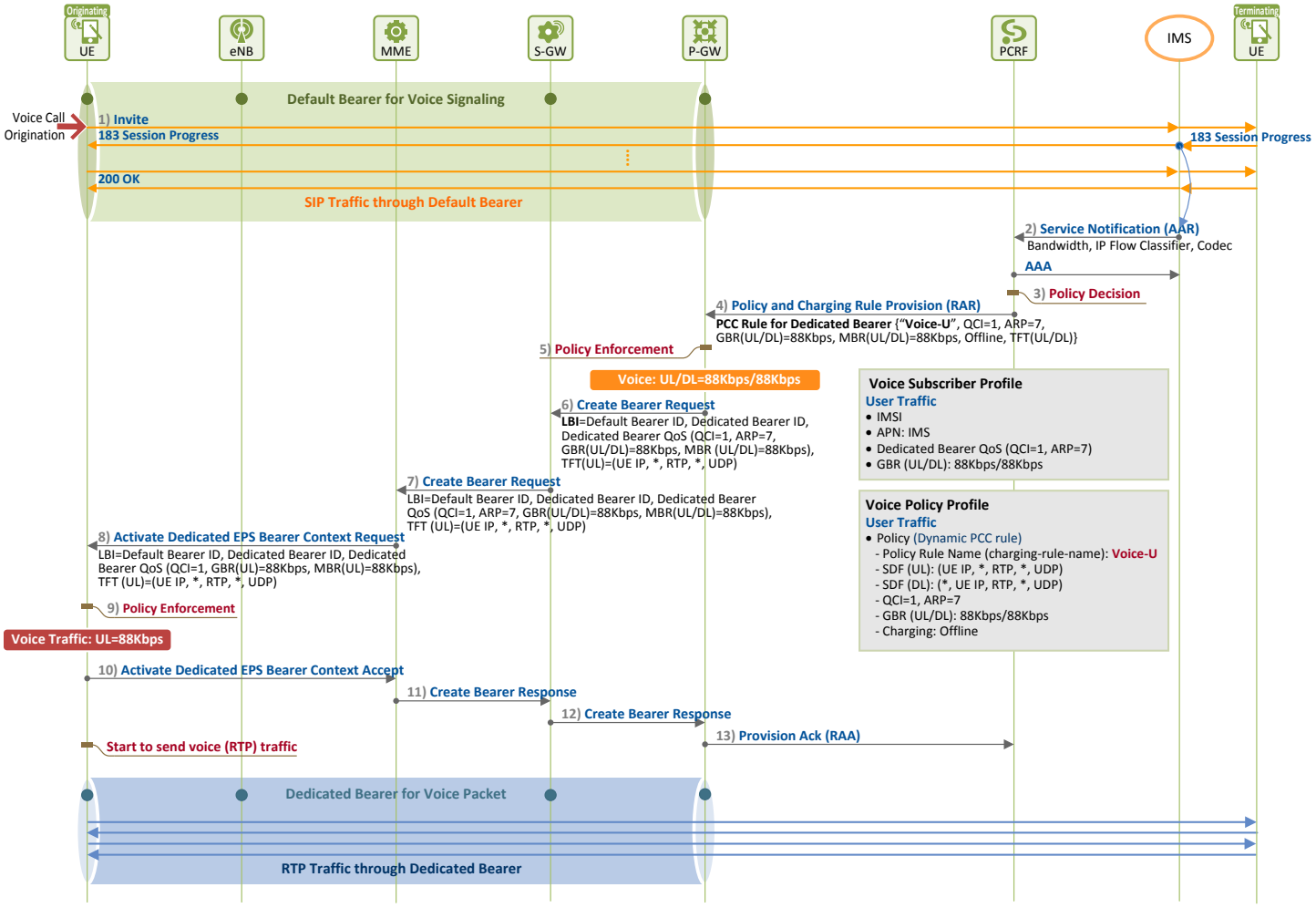


Figure 4. Voice Session Modification and Dedicated Bearer Establishment

1) **[UE → P-CSCF] Voice Call Generation**

An originating UE requests for a voice call by sending an **Invite** message to the IMS network. Detailed procedures performed in the IMS network are out of the scope of this document, and hence will be not discussed here.

2) **[PCRF ← P-CSCF] Service Information Delivery**

Upon receiving the SIP message, the IMS network (P-CSCF) knows a voice call has been requested. So, it sends an **AAR (AA-Request)** message to PCRF, forwarding service information. The **AAR** message contains media information such as maximum/minimum bandwidth, IP flow identifier, Codec, etc.

3) **[PCRF] Policy Decision**

Based on the service information received from P-CSCF, PCRF determines a policy for the EPS session by selecting a PCC rule and bearer. For a PCC rule, it selects "**Voice-U**" rule that supports voice packets. For QoS class of the bearer, it selects QCI=1. As voice packet QoS cannot be supported by the QoS class of the existing default bearer, a new dedicated bearer with different QoS class is established, thereby modifying the EPS session.

- **"Voice-U" rule:** QCI = 1, ARP = 7, GBR (UL/DL) = 88 Kbps/88 Kbps, MBR (UL/DL) = 88 Kbps/88 Kbps, Charging Rule: Offline, RTP Packet Filter

4) **[P-GW ← PCRF] PCC Rule Provision**

PCRF delivers the PCC rule (**"Voice-U"**) to P-GW over the Gx interface.

5) **[P-GW] Policy Enforcement**

Upon receiving the PCC rule (**"Voice-U"**), P-GW configures QoS and charging policy parameters, and maps SDF QoS parameters to the dedicated bearer QoS parameters.

- **P-GW (SDF)**: QCI = 1, ARP = 7, GBR (UL/DL) = 88 Kbps/88 Kbps, MBR (UL/DL) = 88 Kbps/88 Kbps, SDF Template (UL/DL)=(UE IP, *, RTP, *, UDP) /(*, UE IP, RTP, *, UDP)
- **P-GW (Dedicated Bearer)**: QCI = 1, ARP = 7, GBR (UL/DL) = 88 Kbps/88 Kbps, MBR (UL/DL) = 88 Kbps/88 Kbps, TFT (UL/DL) = (UE IP, *, RTP, *, UDP)/(*, UE IP, RTP, *, UDP)

6) **~ 7) [MME ← S-GW ← P-GW] Request for Dedicated Bearer Creation**

P-GW sends MME a **Create Bearer Request** message, requesting for creation of a dedicated bearer. The **Create Bearer Request** message contains a Linked EPS Bearer Identity (LBI), dedicated bearer ID, dedicated bearer QoS and UL TFT information. Dedicated bearer related messages contain a LBI, which is indicated as the default bearer ID of the EPS session that each dedicated bearer belongs to, and plays a role to link all bearers which belong to the same session. In the figure above, it is expressed as the default bearer ID of voice session.

8) **[UE ← MME] Request for Activation of Dedicated Bearer Context**

MME requests for activation of the dedicated bearer context by sending UE an **Activate Dedicated EPS Bearer Context Request** message. In this message, policy parameters sent by P-GW are contained.

9) **[UE] Policy Enforcement: Activation of Dedicated Bearer Context**

UE enforces the UL policy, and activates the dedicated bearer context.

- **UE**: QCI = 1, GBR (UL) = 88 Kbps, MBR (UL) = 88K bps, TFT (UL) = (UE IP, *, RTP, *, UDP)

10) [UE → MME] Notification of Dedicated Bearer Context Activation

UE notifies MME that the dedicated bearer context for voice packets has been activated by sending an **Activate Dedicated EPS Bearer Context Accept** message.

11) ~ 12) [MME → S-GW → P-GW] Notification of Dedicated Bearer Creation

MME notifies P-GW that the dedicated bearer has been created.

13) [P-GW → PCRF] Notification of Applied PCC Rule

P-GW notifies PCRF that the PCC rule has been enforced.

After the dedicated bearer is established, when the Originating UE receives a **200 OK** message upon completion of SIP signaling through the default bearer, voice packets (RTR packets) are delivered through the dedicated bearer.

IV. How Policy Control Affects the Way IP Packet Flows are Handled

We will explore how policy control affects the way IP packet flows are handled over EPS sessions. Figure 5 illustrates IP packet flows over EPS sessions that were generated by a UE (S-GW and P-GW are integrated as SAE-GW). In the figure 5(a), Internet traffic (i.e. web flow) is delivered to/from the Internet PDN through the default bearer created for Internet service. In case of voice traffic, SIP signaling flow is delivered to/from IMS PDN (P-CSCF) through the default bearer created for voice service while voice media flow is delivered to/from a callee through the dedicated bearer created for voice service.

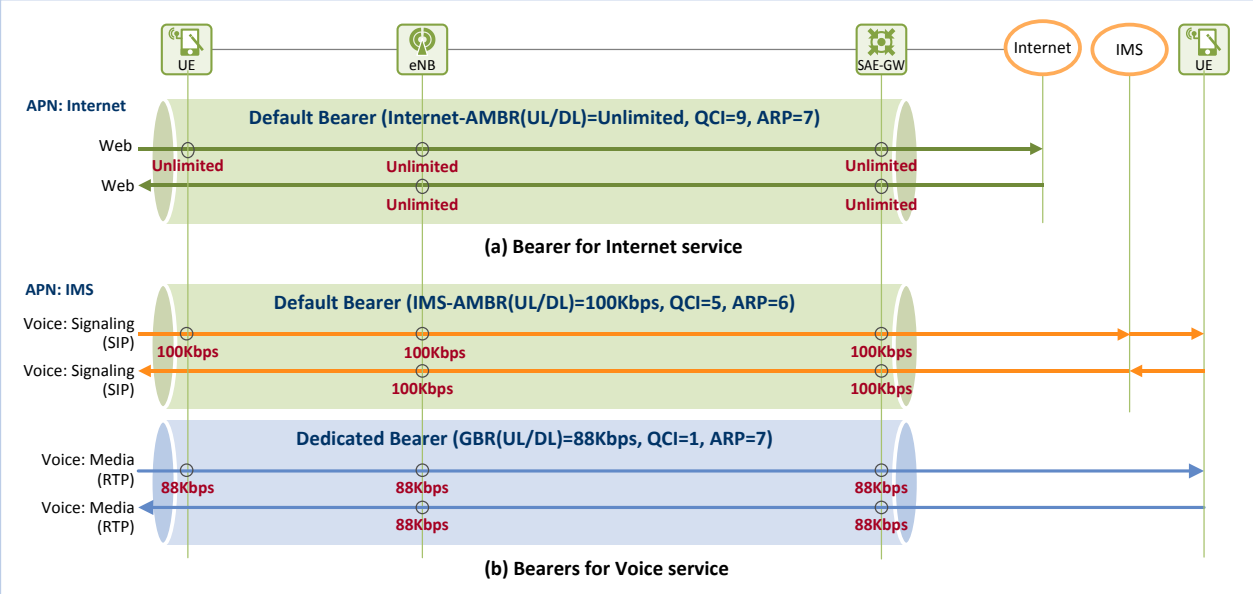


Figure 5. IP Packet Flows over EPS sessions

Figure 6 shows an example of policy control applied to the IP packet flows in Figure 5. In the figure, policy parameters listed in Figure 2 are enforced at P-GW. P-GW detects SDFs in DL/UL, and performs policy control on every IP packets in each SDF. In the EPS bearer, EPS bearer QoS parameters have been set.

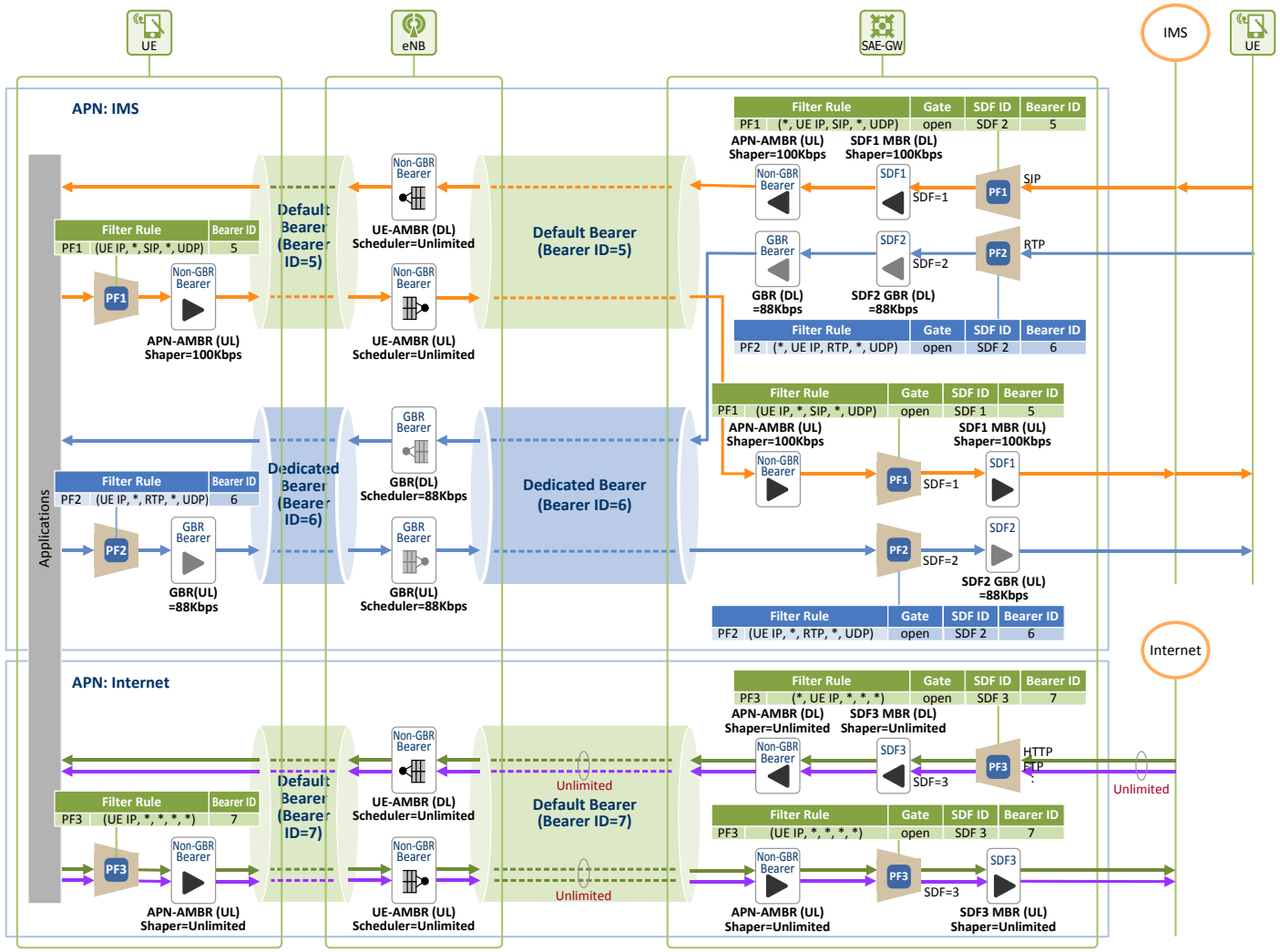


Figure 6. Example of Applied Policy Control

Downlink

IP packet flows arrive at P-GW. Traffic coming from the Internet and IMS network is permitted according to the gate status set in P-GW.

- SIP traffic (APN: IMS) is i) detected as SDF1 by a packet filter (PF1) at P-GW, ii) shaped at MBR (100 Kbps), iii) mapped to the default bearer, and iv) shaped at APN-AMBR (100 Kbps). At eNB, the traffic is scheduled with the rate of UE-AMBR (unlimited) and delivered to UE.
- Voice traffic (APN: IMS) is i) detected as SDF2 by PF2 at P-GW, ii) secured with GBR, iii) mapped to the dedicated bearer, and iv) again secured with GBR. At eNB, the traffic is scheduled with GBR and delivered to UE.
- Internet traffic (APN: Internet) is i) detected as SDF3 by PF3 at P-GW, ii) shaped at Unlimited rate, iii) mapped to the default bearer, and iv) shaped at APN-AMBR (unlimited). At eNB, the traffic is scheduled with UE-AMBR (unlimited), and delivered to UE.

Uplink

IP packet flows arrive at UE from user applications. UL IP packets are mapped to appropriate bearers by UL packet filters (UL TFT; PF1, PF2, PF3), and QoS of each bearer is applied to the packets. Then, they are

forwarded to P-GW, which detects SDFs using packet filters (SDF template; PF1, PF2, PF3), and forwards them to their destinations after applying SDF QoS.

- SIP traffic is i) mapped by PF1 at UE to the default bearer connected to IMS APN, ii) shaped at APN-AMBR (100 Kbps), and iii) then sent to eNB. At P-GW, it is i) shaped at APN-AMBR (100 Kbps) again, ii) detected by PF1 as SDF1, iii) shaped at SDF MBR (100 Kbps), and iv) then forwarded to the IMS network.
- Voice traffic is i) mapped by PF2 at UE to the dedicated bearer connected to IMS APN, and ii) sent to eNB at GBR as scheduled by the eNB. Once at P-GW, it is i) detected by PF2 as SDF2, and ii) forwarded at SDF GBR (88 Kbps).
- Internet traffic is i) mapped by PF3 at UE to the default bearer connected to the Internet APN, ii) shaped at APN-AMBR (unlimited), and iii) sent to eNB. Once at P-GW, it is i) shaped at UL APN-AMBR (unlimited) again, ii) detected by PF3 as SDF3, iii) shaped at SDF MBR (unlimited), and iv) forwarded to the Internet.

V. EPS Entity Information

Below we will see how EPS entity information in each APN is changed after PCC rules are enforced for Internet traffic and voice traffic.

5.1 Internet Service

Figure 7 shows the information that is kept by EPS entities as a result of applying a PCC rule to Internet service traffic. PCRF selects a PCC rule, "**Internet**", during initial access to the Internet, and forwards it to P-GW. Then P-GW uses the rule to enforce QoS parameters for the EPS default bearer for Internet service. The default bearer is kept active unless UE is detached.

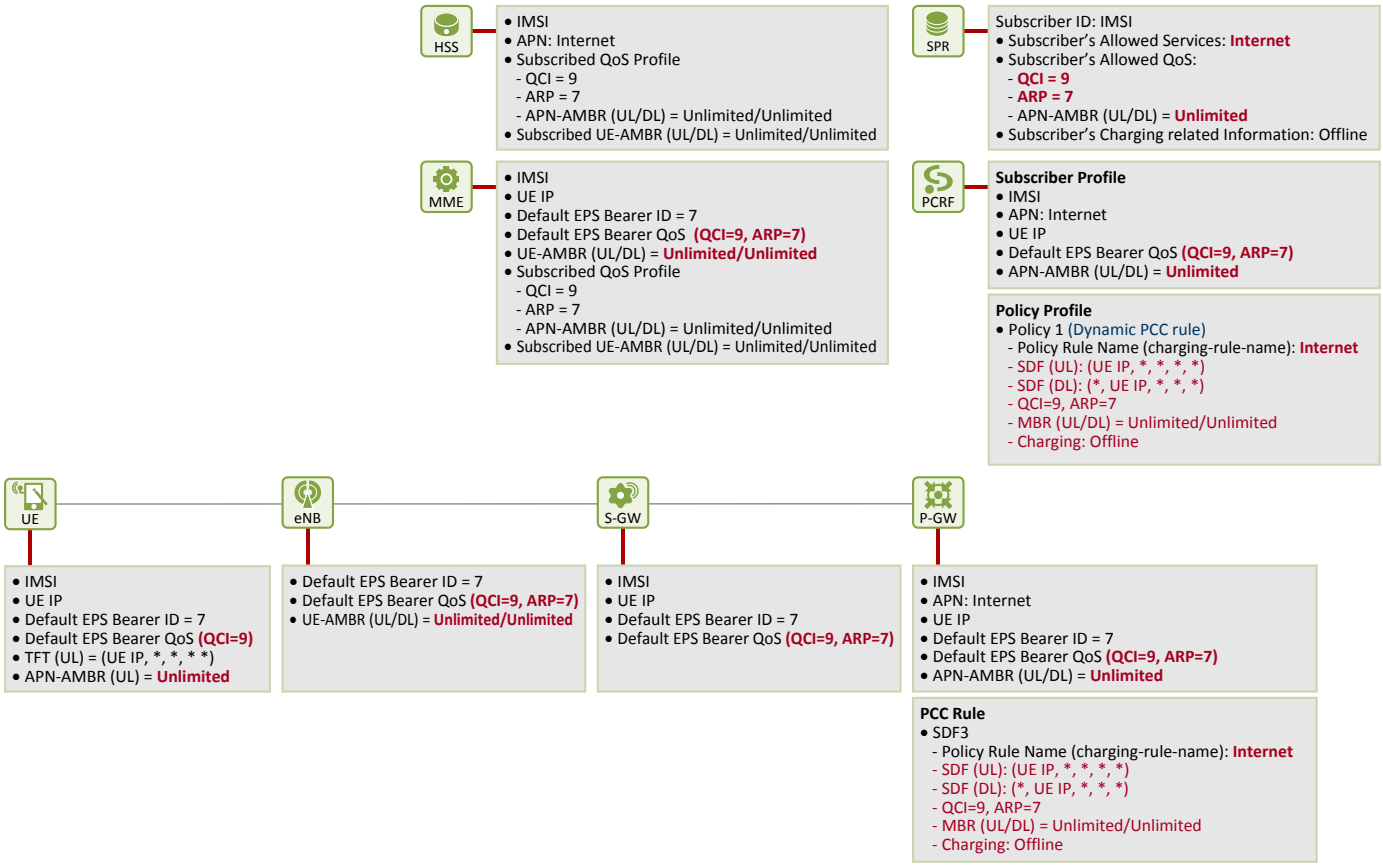


Figure 7. EPS entity information after applying PCC rule: Internet service

5.2 Voice Service

Figure 8 shows the information kept by EPS entities as a result of applying a PCC rule to voice service traffic. In this example, a voice call is detected as soon as the default bearer is established upon UE's initial attach to IMS network. During initial attach to IMS network, PCRF selects a PCC rule, "**Voice-C**", and P-GW enforces QoS parameters for EPS default bearer for SIP signaling. Since a voice call was detected shortly after, PCRF selected "**Voice-U**" rule, and P-GW enforced QoS parameters for the EPS dedicated bearer.

Once the voice call is ended, P-CSCF notifies PCRF. Then PCRF initiates an EPS session modification procedure, having the dedicated bearer terminated, and dedicated bearer contexts deleted at UE, eNB, S-GW and P-GW. However, the default bearer for SIP signaling remains active even after the voice call ended unless UE is detached from the LTE network.

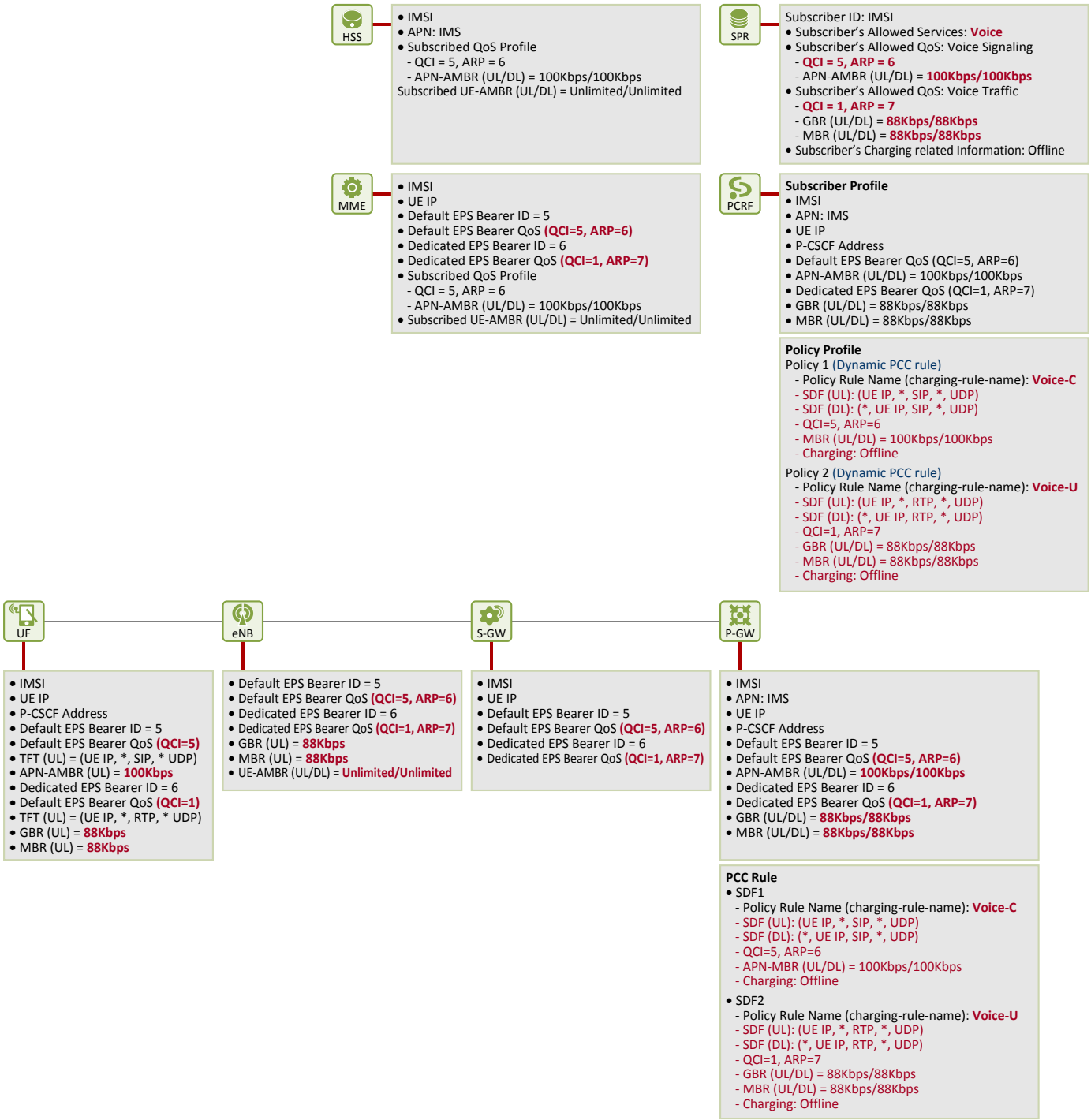


Figure 8. EPS entity information after applying PCC rule: Voice service

VI. Closing

So far, we have explained how PCRF decides a PCC rule and how the rule is enforced at P-GW when a user uses Internet and voice services in an LTE network, and analyzed the PCC procedure. We have also learned how P-GW controls EPS bearers based on PCC rules, and looked into an example showing how policy control affects the way IP packet flows are handled.

This document has covered PCC rules, with more focus on QoS rules, and briefly reviewed charging rules as a form of offline charging only. The next document [5] is about charging, and will discuss charging information and procedures relating to offline charging.

References

[1] 3GPP TS 29.212, “Policy and Charging Control over Gx Reference Point”

[2] Netmanias Technical Document, “LTE EMM Procedure 1. Initial Attach – Part 2. Call Flow of Initial Attach”, January 2014, http://www.netmanias.com/en/?m=view&id=techdocs&no=6102

[3] Netmanias Technical Document, “LTE QoS: SDF and EPS Bearer QoS”, September 2013, http://www.netmanias.com/en/?m=view&id=techdocs&no=5908

[4] Netmanias Technical Document, “Initial Attach procedure for VoLTE”, TBD

[5] Netmanias Technical Document, “LTE Charging: Offline”, TBD

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

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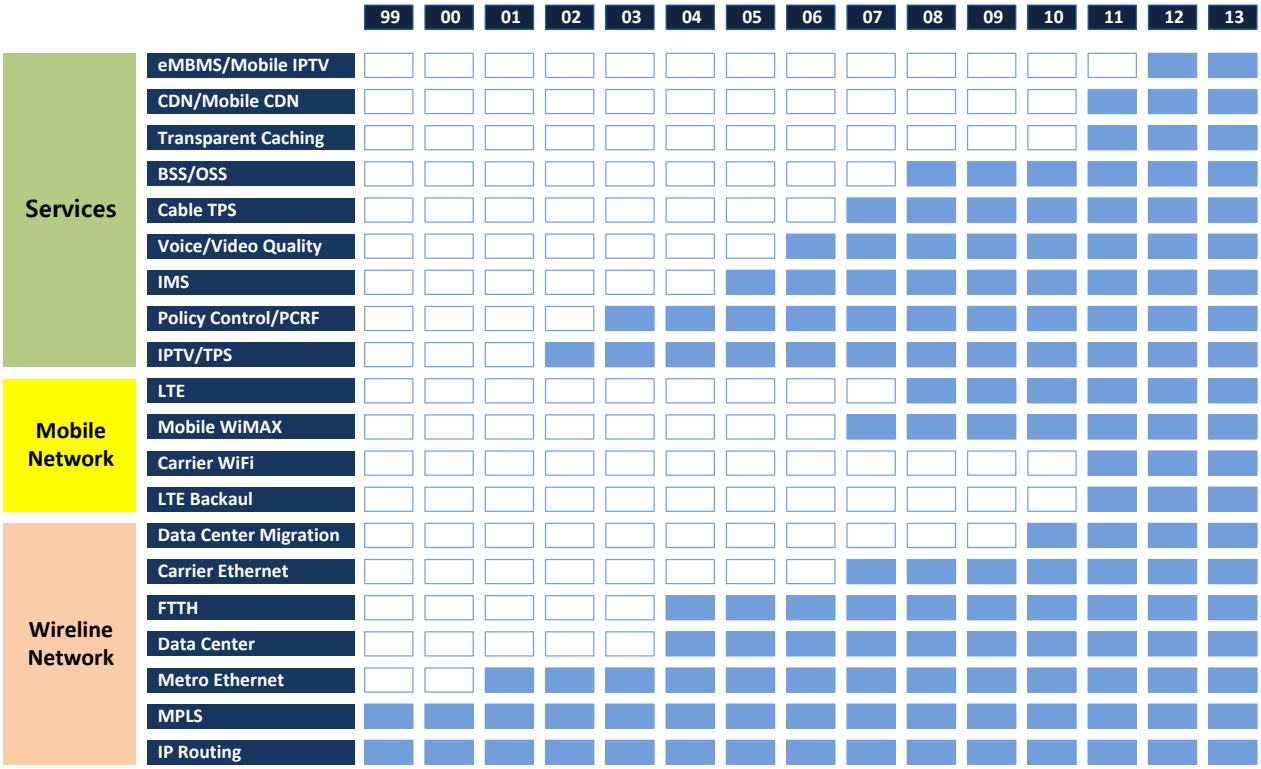

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