PCC (Policy and Charging Control) In Mobile Data

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By implementing policy and charging control (PCC) procedures in their mobile data network, mobile service providers are able to :

- guarantee bandwidth for higher revenue services
- allow market segmentation,
- assure fair usage of the network,
- stop or reduce service flows that degrade network performance,
- guarantee optimum end-user experience
- ensure appropriate online or offline charging of the service flows based on user subscription data

With PCC procedures, the following scenarios become possible : faire usage, anti-bill shock, parental control, roaming data pass, etc.

Mobile data networks are connection oriented. The user establishes a connectivity called a PDP context (2G/3G) or a bearer (4G) to send/receive IP packets. The service provider applies PCC on the different IP flows exchanged over the connectivity. A policy server called PCRF (Policy and Charging Rules Function) provides customer-based PCC rules to the PCEF (Policy and Charging Enforcement Function) which enforces them. Each PCC rule :

- Identifies an IP service flow based on a quintet (source IP address, destination IP address, source port number, destination port number, type of transport) or based on highler level description (e.g., application).
- Authorizes or blocks the IP flow
- If authorized, indicates which QoS should apply to the IP flow
- Informs about how to charge the IP flow, which the charging method (i.e.., online, offline) and the charging criteria (volume, duration, volume and duration).

Policy control is related to authorizing/blocking an IP flow and if authorized, the QoS that should apply to the flow. Charging control relates to the charging of the IP flow.

The goal of this tutorial is to present the PCC principles, concepts, architecture and interfaces.

1 PCC : Access Independent Architecture

PCC architecture as defined by 3GPP in TS 23.203 may apply to any IP-based access network which interfaces with IP worlds. Examples of IP-based access networks are xDSL, cable access, WiMax, GPRS (with GERAN/UTRAN radio access), EPS, FTTx, etc. In this context, the used vocabulary is :

- IP-CAN means IP Connectivity Access Network. It represents a generic IP-based access network.

- IP-CAN bearer represents an IP transmission path of defined capacity, delay and bit error rate, etc. Default bearer and dedicated bearers in EPS and primary and secondary PDP contexts in GPRS are examples of IP-CAN bearers.
- IP-CAN session describes the association between a UE represented by an IPv4 and/or an IPv6 address, and a PDN represented by a PDN ID (e.g. an APN). An IP-CAN session incorporates one or more IP-CAN bearers. Support for multiple IP-CAN bearers per IP-CAN session is IP-CAN specific. An IP-CAN session exists as long as UE IP addresses are established and announced to the IP network.
- IP flow represents a unidirectional flow of IP packets with the same source IP address and port number and the same destination IP address and port number and the same transport protocol.

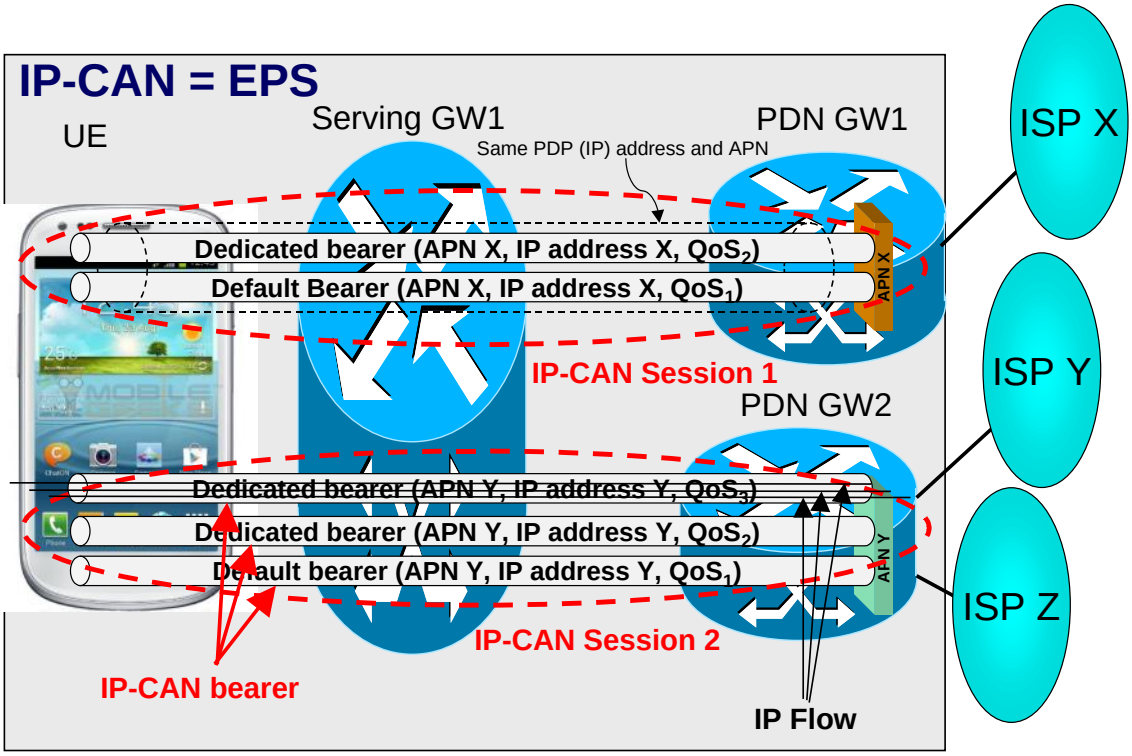

Figure 1: IP-CAN, IP-CAN Session, IP-CAN Bearer and IP Flow

In the figure 1, the IP-CAN is EPS (Evolved Packet System).
Each IP-CAN Session represents an active APN. An IP address is assigned for each active APN. In the above example, IP-CAN Session1 is associated with Internet APN; IP-CAN Session 2 relates to IMS APN.
Each active APN consists at least of a default bearer which corresponds to an IP-CAN Bearer. Additional IP-bearers may also be associated with the active APN; these are dedicated bearers. In the case of IP-CAN Session2, the default bearer is permanent and only carries SIP signaling flows; the two dedicated bearers are used to transport the audio and video components of a videtelephony call. Since these two components require different QoS, they need different dedicated bearers to support them.
IP Flows are transported over IP-CAN bearers (default or dedicated bearer).

2 PCC : A definition

Policy control refers to the binding, gating control, QoS control and event reporting functions :

- Binding is the generation of an association between a service data flow and the IP-CAN bearer transporting that service data flow;
- Gating control is the capability to block or to allow IP packets belonging to IP flow(s) for a certain service.
- QoS control allows the PCRF to provide the PCEF with the authorized QoS for the IP flow(s). The authorized QoS may, for example, include the authorized QoS class and the authorized bit rates. The PCEF performs bit rate enforcement to ensure that a certain service session does not exceed its authorized QoS.
- Event reporting allows the notification of and reaction to application events to trigger new behaviour in the user plane as well as the reporting of events related to the resources in the GW(PCEF);
- IP-CAN bearer establishment : for IP-CANs that support network initiated procedures for IP-CAN bearer establishment.

Charging Control includes means for both offline and online charging. The PCRF makes the decision on whether online or offline charging or none of them shall apply for a certain IP flow, and the PCEF enforces that decision by collecting charging data and interacting with the charging systems.
With online charging, the charging information can affect, in real-time, the services being used and therefore a direct interaction of the charging mechanism with the control of network resource usage is required. The online credit management allows an operator to control access to services based on credit status. For example, there has to be enough credit left with the subscription in order for the service session to start or an ongoing service session to continue. The OCS may authorize access to individual services or to a group of services by granting credits for authorized IP flows. Usage of resources is granted in different forms. The OCS may, for example, grant credit in the form of certain amount of time, traffic volume or chargeable events. If a user is not authorized to access a certain service, for example, in case the pre-paid account is empty, then the OCS may deny credit requests and additionally instruct the PCEF to redirect the service request to a specified destination that allows the user to re-fill the subscription.
With offline charging, the charging information is collected by the network for later processing and billing.
Online and offline charging may be used at the same time. For example, even for billed (offline charged) subscriptions, the online charging system may be used for functionality such as Advice of Charge. Conversely, for prepaid subscribers, the offline charging data generation may be used for accounting and statistics.

The whole PCC architecture relies on identifyng IP flows at the PCEF level. Packet analysis can be divided into 3 different levels :

- Shallow Packet Inspection (SPI)
- Deep Packet Inspection (DPI)
- Heuristic analysis Deep Packet Inspection (H-DPI).

SPI uses header information such as source and destination IP addresses, ports and the transport protocol for analysing and investigation of the packets.
DPI inspects packets headers as well as payload by using protocol based analysis on layer 7 such as finding out what sites the user is browsing by looking at the HTTP request URI in HTTP GET messages. It provides application awareness, capability to analyse network usage and improving network performance.

H-DPI examines packet transaction based on the detected behavioral patterns. This makes it possible to even analyse traffic when it has been encrypted. Behavioral patterns are kept in a database which is used for matching packet flows and they contain observations of flow rate, typical length of packets, uplink/downlink packet rates, parallel connections etc.
GGSN/PGW DPI functionality or stanlone DPI engine performs packet inspection and packet analysis in all 3 different levels (SPI, DPI, H-DPI). It can identify different types of traffic which is useable for traffic shaping purposes under different network load conditions.
The DPI functionnality of GGSN/PGW/PCEF or of independent DPI module performs packet inspection at the three levels (SPI, DPI, H-DPI).
PCC architecture from 3GPP Release 11 enables DPI and H-DPI with dynamic rules supplied by PCRF to PCEF/TDF (Traffic Detection Function) over the Gx/Sd interface. Before Release 11, only predefined rules with non-standardized format, hosted at PCEF are considered to enable DPI and H-DPI.

3 PCC Architecture

3.1 PCC Entities

The PCC functionality is comprised by the functions of the Policy and Charging Enforcement Function (PCEF), the Policy and Charging Rules Function (PCRF), the Application Function (AF), the Traffic Detection Function (TDF), the Online Charging System (OCS), the Offline Charging System (OFCS) and the Subscription Profile Repository (SPR) or the User Data Repository (UDR). UDR replaces SPR when the UDC (User Data Convergence) architecture as defined in TS 23.335 is applied to store PCC related subscription data. In this deployment scenario Ud interface between PCRF and UDR is used to access subscription data in the UDR. When UDC architecture is used, SPR and Sp can be replaced by UDR and Ud respectively. In Figure 2, the AF is instantiated with IMS (IP Multimedia Subsystem)..

The Policy Charging and Rules Function (**PCRF**) provides network control regarding service data flow detection, gating (allowing or blocking packets), QoS control and flow-based charging towards the PCEF. The PCRF ensures that the PCEF user plane traffic treatment is in accordance with the user's subscription profile which it receives from SPR over Sp/Ud interface.

The Policy and Charging Enforcement Function (**PCEF**) is the functional entity which includes policy enforcement along with flow based charging functionalities. The PCEF enforces policy decisions (e.g. gating, maximum bit rate policing) received from the PCRF and also provides the PCRF with user- and access-specific information over the Gx interface. The PCEF may also perform measurements of user-plane traffic (e.g. user-plane traffic volume and/or time duration of a session). It reports usage of resources to the OFCS and interacts with the OCS for credit management. The PCEF can also provide usage reports to the PCRF if policy decisions based on consumed volume or time are desired.

The Application Function (**AF**) (eg. P-CSCF for IMS solution) interacts with applications or services that require dynamic PCC. The AF extracts session information from the application signaling and provides it to the PCRF over the Rx interface.

The Online Charging System (**OCS**) is a credit management system for online Charging (e.g., prepaid). OCS consists of three functions, OCF, ABMF and RF.
The PCEF interacts with the OCF (Online Charging Function) to check out credit and report credit status. In 3GPP Release 10, an interface (Sy) between OCF and PCRF has also been introduced to enable policy control based on subscriber spending limits.

The Account Balance Management Function (ABMF) is the location of the subscriber's account balance within the OCS. The Rating Function (RF) determines the value of the network resource usage based on Charging events given by OCF.

The Offline Charging System (**OFCS**) is used for offline charging. It receives charging events from the PCEF and generates Charging Data Records (CDRs) that can be transferred to the billing system.

The application detection and control feature comprise the request to detect the specified application traffic, report to the PCRF on the start/stop of application traffic and to apply the specified enforcement actions. The application detection and control shall be implemented either by a standalone Traffic Detection Function (**TDF**) or by PCEF enhanced with TDF capabilities (i.e. TDF is encompassed in PCEF). The TDF shall perform gating, redirection and bandwidth limitation for the detected applications, if required.

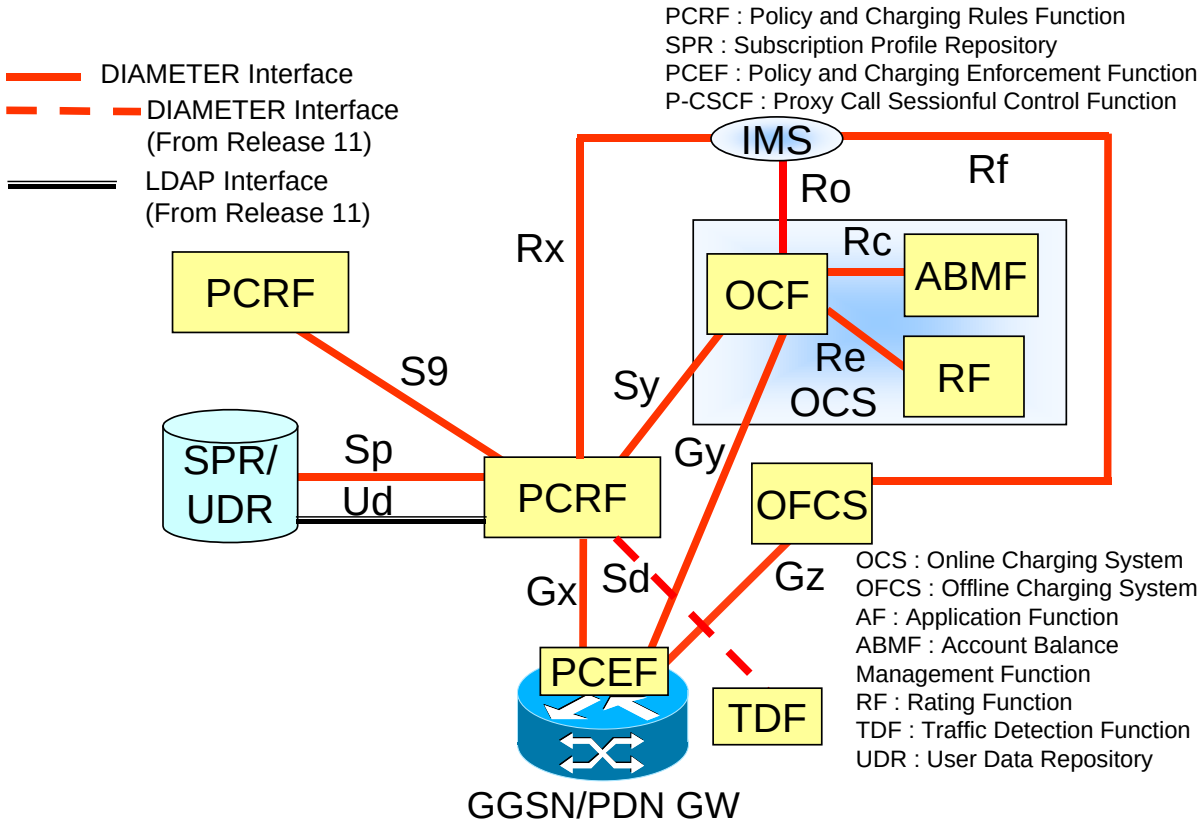

Figure 2 : PCC Architecture

3.2 PCC Interfaces

The DIAMETER-based interfaces of the PCC architecture are :

- Gx (GPRS/EPS) : The Gx interface is located between the Policy and Charging Rules Function (PCRF) and the Policy and Charging Enforcement Function (PCEF). PCEF may be embedded in a GGSN or PDN GW. The Gx interface is used for provisioning and removal of PCC (Policy and Charging Control) rules from the PCRF to the PCEF and the transmission of traffic plane events from the PCEF to the PCRF. The Gx interface can also be used for application's traffic detection and control.
- Sd (EPS) : The Sd interface is between the PCRF and the TDF (Traffic Detection Function) and is used for application's traffic detection and control.

- Gy (GPRS/EPS) : The Gy interface resides between the OCS and the PCEF (e.g., GGSN, PDN GW) and allows online credit control for service data flow based charging.
- Gz (GPRS/EPS) : The Gz interface resides between the PCEF and the OFCS and enables transport of service data flow based offline charging information.
- S9 (EPS) : In the roaming case, a PCRF in the home network controls the policies to be applied. This is done via a PCRF in the visited network over S9 which hence is a roaming interface between PCRFs.
- Rx (EPS) : Rx interface is between the PCRF and the AF (e.g., P-CSCF), for transport of application level session information from the AF to the PCRF and delivery of IP bearer events in the opposite direction.
- Rf (IMS) : Rf is the interface between IMS entities and CDF (Charge Data Fuction) for offline charging.
- Ro (IMS) : Ro is the interface between IMS entities and Online Charging System (OCS) for online charging.
- Rc (IMS) : The Rc interface allows the interaction between the Online Charging Function (OCF) and the Account Balance Management Function (ABMF) to access the subscribers account balance.
- Re (IMS) : The Re interface allows the interaction between the Online Charging Function (OCF) and the Rating Function (RF) to rate the service the user wants to access to.
- Sp (GPRS/EPS) : Sp is the interface between the PCRF and the SPR (Subscription Profile Repository) to enable the PCRF obtaining subscription information required for PCC rules generation.
- Sy (GPRS/EPS): Sy is used between the PCRF and the OCS to enable transport of indications about charging related events from the OCS to the PCRF.

4 PCC Rule : A definition

The purpose of the PCC rule is to:
- Detect a packet belonging to a service data flow.
  - The service data flow filters within the PCC rule are used for the selection of downlink IP CAN bearers.
  - The service data flow filters within the PCC rule are used for the enforcement that uplink IP flows are transported in the correct IP CAN bearer.
- Identify the service the service data flow (i.e., IP flow) contributes to.
- Provide applicable charging parameters for a service data flow.
- Provide policy control for a service data flow.

4.1 PCC Rules Types

There are two different types of PCC rules :
- Dynamic PCC rules. Dynamically provisioned by the PCRF to the PCEF via the Gx interface. These PCC rules may be either predefined or dynamically generated in the PCRF. Dynamic PCC rules can be installed, modified and removed at any time.
- Predefined PCC rules. Preconfigured in the PCEF. Predefined PCC rules can be activated or deactivated by the PCRF at any time. Predefined PCC rules within the PCEF may be grouped allowing the PCRF to dynamically activate a set of PCC rules over the Gx reference point.

NOTE: The operator may define a predefined PCC rule, to be activated by the PCEF. Such a predefined rule is not explicitly known in the PCRF.

For dynamic PCC rules, the following operations are available:
- Installation: to provision a PCC rules that has not been already provisioned.

- Modification: to modify a PCC rule already installed.
- Removal: to remove a PCC rule already installed.

For predefined PCC rules, the following operations are available:

- Activation: to allow the PCC rule being active.
- Deactivation: to disallow the PCC rule.

4.2 PCC Rules Provisioning

The PCRF shall indicate, via the Gx reference point, PCC rules to be applied at the PCEF. This may be using one of the following procedures:

- PULL procedure (Provisioning solicited by the PCEF): In response to a request for PCC rules being made by the PCEF, as described in the preceding section, the PCRF shall provision PCC rules in the CC-Answer; or
- PUSH procedure (Unsolicited provisioning): The PCRF may decide to provision PCC rules without obtaining a request from the PCEF, e.g. in response to information provided to the PCRF via the Rx reference point, or in response to an internal trigger within the PCRF. To provision PCC rules without a request from the PCEF, the PCRF shall include these PCC rules in an RA-Request message. No CCR/CCA messages are triggered by this RA-Request.

Figure 3 lists the commands exchanged over the DIAMETER-based Gx interface.

Type de message	Description	Direction
CCR	Credit Control Request	PCEF→PCRF
CCA	Credit Control Answer	PCEF←PCRF
RAR	Re-Auth Request	PCEF←PCRF
RAA	Re-Auth Answer	PCEF→PCRF

Figure 3 : Commands of Gx interface

The Gx interface (between the PCRF and the PCEF) provisions the PCC rules to the service flows. The above Table lists the message types and the delivery direction for the Gx Interface.

When a bearer session is established (e.g.,, the GPRS Primary PDP context is activated), the PCEF sends an INITIAL_REQUEST CCR command to the PCRF. This is the pull procedure. This message contains the service information such as the type of radio access technology, the UE's IP address, the QoS profile negotiated, and the APN. The PCRF determines the PCC rules and then sends them to the PCEF by using the CCA command. Both the PCRF and the PCEF maintain information for the Gx session. When an existing bearer session is modified (e.g., the GPRS PDP context is updated with new QoS), the PCEF sends an UPDATE_REQUEST CCR command to the PCRF. This command contains the new service information. The PCRF determines the new PCC rules and then sends them to the PCEF by using the CCA command. Note that these CCR/CCA commands carry the same session ID to uniquely identify the Gx session (for the purpose of requesting PCC rules. When the primary PDP context is release, the PCEF the PCEF sends an TERMINATE_REQUEST CCR command to the PCRF which acknowledges it by CCA command. Then the Gx session related to the monitoring of that PDP context is released between them.

The Re-Auth Request (RAR) command is used when the push procedure applies and is also used to inform the PCEF to re-authorize the existing PCC rules. The Re-Auth Answer (RAA) command acknowledges the RAR command.

References

3GPP TS 32.203. Policy and charging control architecture
3GPP TS.29.212. Policy and Charging Control over Gx reference point .
3GPP TS.29.214. Policy and Charging Control over Rx reference point .
3GPP TS.29.213. Policy and Charging Control signalling flows and Quality of Service (QoS) parameter mapping.
3GPP TS 32.240;Telecommunication management; Charging management; Charging architecture and principles.
3GPP TS 32.299. Telecommunication management; Charging management; Diameter charging applications .
RFC 3588, P. Calhoun et al., Diameter Base Protocol, Sept 2003.
Magnus Olsson et al. « ePC and 4G Packet Network », Academic Press, 2013.