QoS Interoperability and Policy Management Recommendations

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Executive Summary

As mobile networks race toward converged 3G networks, demands for converged services and service roaming will intensify. Both involve providing services across network boundaries. It is currently very challenging to provide such services for two main reasons. The first is that networks have not been fully converged. The second is that even if all networks are totally IP-based, each operator has to have full control of its own network, thus making it extremely difficult, if not impossible, to control end-to-end traffic quality. Regarding roaming, all mobile data traffic is now backhauled to the home network and there are few standard mechanisms and practices to provide end-to-end services between networks. This white paper outlines and recommends a policy-based mechanism for exchange service and network information such as QoS (Quality of Service) for providing end-to-end and real-time services.

Policy management framework (PMF) is a key underlying technology for roaming service and QoS control. In this paper, we introduce a policy management framework based on 3GPP Rel-7 policy and charging control (PCC) architecture, as well as some basic concepts concerning policy management and QoS. This paper also briefly covers standardization progress in various standards forums. As of this writing, there are definitions still to be made in order to harmonize the policy functions and interfaces between different standards. The recommendation of this paper is to use the PMF to provide a platform for managing QoS and other network parameters between roaming partners.

Quality of Service has been defined in many different ways with different requirements. This paper refers to QoS in terms of 3GPP Release 99's definition in which four traffic classes are defined: conversational, streaming, interactive and background. The paper provides extensive discussion on QoS concept and practices in the radio network such as Multi-RAB (Radio Access Bearer), RAB combination, traffic handling priority (THP), radio network admission, and congestion controls. Roaming-related QoS mechanisms such as GRX (Global Roaming eXchange) and IPX (IP eXchange) are also introduced.

While it is recognized that each operator can choose to follow the recommendations in ways that meet their own business requirements and network conditions, 3G Americas recommends the following actions for service providers:

Recommendation 1: Mobile service providers shall deploy a policy management framework based on 3GPP Rel-7 PCC architecture for subscriber services and network resources control.

Recommendation 2: Mobile service providers should use the policy management framework as a standard mechanism to exchange policies related to end-to-end services between mobile operators. Although more technical details of this policy-based mechanism still need to be defined at the operational level, these recommendations are reflective of this working group's desire to have a standard and deployable mechanism for roaming services.

Recommendation 3: Mobile service providers should establish a minimum set of QoS feature parity in the Packet Core and Transport network based on 3GPP Rel-7 Policy Charging Control in order to support policy management, QoS and charging functions. A minimum set of QoS parameters should provide the basic parameters for policy exchange in real-time roaming services.

Recommendation 4: Mobile service providers should establish a minimum set of QoS feature parity in the Radio Access Network in order to support real-time/time-sensitive services such as VideoShare and VoIP.

1. Introduction

Traditionally, policy management has been mainly focused on network management. In recent years, however, policy management has been gaining increasing importance in the telecom network for managing and controlling services as wireless networks migrate towards an all-IP environment. There are two sets of service management issues that operators face: the first is how to manage IP-based services in an all-IP environment, and the second is how to manage end-to-end services that traverse across different network domains. This white paper will evaluate and recommend solutions with regard to the latter issue of how to policy enable QoS interoperability across operator domains to offer “home-like” services for roamers.

1.1. Problem Statement and Scope

Intense competition in the telecom market has put a premium on converged services. This creates a great need to provide services across network boundaries (such as fixed and mobile convergence applications). However, it is very challenging to provide such services for two main reasons: first, networks have not been fully converged. Second, even if all networks are totally IP-based, each operator has to have full control of its own network thus making it extremely difficult, if not impossible, to control end-to-end traffic quality.

Another aspect of this convergence story is roaming. It involves not only user plane traffic routing, but also services that people need to use when they roam. Currently, most of the services used by subscribers are routed back to the home network, and there is no mechanism in commercial use for the roamer to be provided services using the visited network while maintaining his/her service continuity. In addition, a mechanism to exchange QoS and policy information is needed, and that is the subject of this white paper.

In this paper, we assume a policy management framework has been deployed in each domain of networks and policies can be negotiated between the home and the visited network based on Service Level Agreements (SLAs).

1.2. Definitions

Policy is a very generic and widely interpreted word with many different definitions and meanings. In this paper, we define policies as a set of rules that a network operator can define and enforce in a telecom network. These policies can be exchanged and applied both within an operator domain and across different operator domains. There are three logical elements in a policy framework: a policy decision element (PDP in IETF terminology and PCRF in 3GPP Release 7), a central policy repository and policy enforcement elements (PEP in IETF and PCEF in 3GPP).

3GPP defined E2E QoS in 3GPP R99. Quality of Service is defined by four classes: Conversational, Streaming, Interactive and Background. For more information, see 3GPP TS23.107.

Traffic Class	Conversational Class Real-Time	Streaming Class Real-Time	Interactive Class Best Effort	Background Class Best Effort
Fundamental characteristics	Preserve time relation (variation) between entities of the stream Conversational pattern	Preserve time (variation) between entities of the stream	Request response pattern Preserve payload content	Destination is not expecting the data within a certain time Preserve payload content.
Example Application	Voice	Steaming video	Web browsing	Background download of emails.

Table 1: Traffic Class Characteristics

Examples of use cases:

- Conversational traffic class
  - VoIP call
  - Video call
  - Multimedia gaming
- Streaming traffic class
  - Streaming video
  - Audio Streaming
- Interactive traffic class
  - Web browsing
  - Interactive gaming
  - Instant messaging
- Background traffic class
  - Downloading of e-mails
  - FTP download

1.3. Drivers and use cases

1.3.1. Roaming service control

One of the most challenging issues in the telecom network is roaming. It involves not only user plane traffic routing, but also services that subscribers need to use when they roam. Currently, most of the services get routed back to the home network and there is no mechanism for roamers to get services using a visited network while maintaining their service continuity.

1.3.2. Local breakout for real-time services (e.g. IMS Video Share Calling)

Although current PCC (Policy and Charging Control) specification does not clearly define the architecture for local breakout, 3G Americas considers this functionality to be very important for services over IP-converged networks. A PCRF to PCRF (Policy and Charging Rules Function) communication is desirable between the visited and home network to provide home network service policies while the user is roaming and the services are being delivered via a local breakout.

1.4. Current roaming implementations

1.4.1. GRX (Global Roaming eXchange)

The GPRS Roaming Exchange (GRX) was created as a platform for enabling mobile data roaming.

GRX networks have evolved from purely the exchange 2.5G and 3G packet switched roaming services to additionally facilitate inter-working of MMS. In the GRX model the operator can replace the need for multiple connections, with other operators, with a single (or few) logical connections to a GRX.

GRX networks interconnect with other GRX networks to form a Global Roaming Network for mobile data roaming.

The roaming model for GPRS is to route traffic from the visited SGSN (Serving GPRS Support Node) to the home GGSN (Gateway GPRS Support Node) across the GRX network. Therefore, a subscriber will egress his or her service provider's GGSN when roaming. This backhauling mechanism across the GRX can introduce latency and jitter.

1.4.2. DiffServ (defined in GSMA IR.34)

In order to address the latency and jitter introduced by the GRX, the GSM Association (GSMA) developed a mapping between 3GPP QoS/CoS and DiffServ Control Points (DSCP). This mapping was defined in GSMA document IREG 34 (IR.34).

Traffic Class	**DiffServ PHB**	**Max Delay**	**Max Jitter**	**Packet loss**	**Service example**
Conversational	EF 10110	20 ms	5 ms	0.5%	VoIP
Streaming	AF4 100010	40 ms	5 ms	0.5%	audio video streaming
Interactive	AF3 011010	250 - 350 ms	--	0.1%	browsing
Background	BE 000000	400 ms	--	0.1%	email

Table 2: Performance of the four classes of Traffic Classes

Even though real-time classes are defined in IR.34, backhauling real-time services back to the home network is not very efficient and not recommended. To this end, the standards are moving toward local-breakout architectures allowing the user plane and control plane to be routed across the optimal route and egress the visited network much like it does today in the circuit switched architecture.

1.4.3. IPX (IP eXchange)

In order to facilitate IMS (IP Multimedia Subsystem) roaming, the GRX is evolving into the IP eXchange (IPX). IPX will support secure control plane traffic – SIP/SDP (Session Initiation Protocol/Service Delivery Platform) as well as the QoS enabled user plane – RTP (Real Time Transport Protocol).

GPRS Roaming Exchange **IPI Framework**

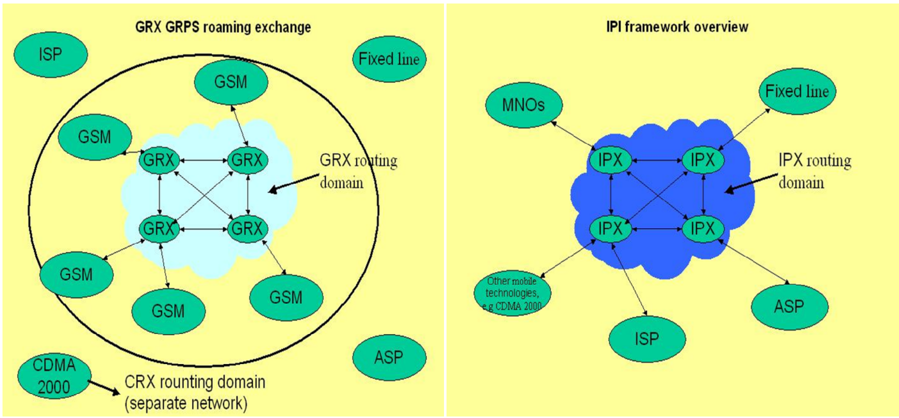

Figure 1: The Evolution of the GRX Model to the IPX Model

The IPX provides interconnection between different Service Providers - i.e. mobile and fixed operators, other service providers such as ISPs (Internet Service Providers), ASPs (Application Service Providers), and later possibly Content Providers and other stakeholders - in a scaleable and secure way with special focus on guaranteed QoS.

IPX Providers manage the exchange of traffic and associated basic control information. The IPX Provider can offer both technical and commercial interconnect capability via a single agreement with the Service Provider.

One mechanism is to use SIP to convey QoS information. One can also leverage subscriber profile for QoS information exchange. The goal would be to use policy management mechanism to exchange QoS and other service policy information as we suggested in this paper. The detailed mechanisms will require further studies and possible standardizations, and are currently beyond the scope of this white paper.

1.5. QoS architecture: interfaces and protocols

1.5.1. Standardized QoS Radio Access capabilities

Currently, there are four QoS classes defined in 3GPP for a UMTS/HSPA network. These are:

- Conversational Class
- Streaming Class
- Interactive Class
- Background Class

The main distinguishing factor between these classes is their sensitivity to delay.

Conversational class is intended for real-time traffic, which is very delay-sensitive but can stand bit errors and packet losses. Good examples of where Conversational class should be used are voice and video telephony. The services allow speech and video codecs to conceal errors. The short delay is the most essential feature for the users (human) of the service.

Streaming class is very similar to the conversational class with the exception that more delay is tolerated. The increased delay provides larger variety of means for achieving lower error rate. Streaming class is suitable for the case where one end of the connection is human and the other is a machine.

Interactive class is intended for the traffic, which allows delay variation while requiring reasonably low response time. An example of Interactive class would be Web browsing, where the channel can be unused for long periods of time, but when a user makes a request for a new page, the response time should be reasonably low. Due to less stringent delay requirements, the error rates can be improved by having better channel coding and applying retransmissions.

Background class is a class described by its name. It will get service with lowest priority when there are resources to be utilized. Background class is a cheap and suitable for applications such as email.

These QoS classes are used for UMTS bearer services and the Radio Access Bearer (RAB) services.

Traffic class	Conversational class Conversational RT	Streaming class Streaming RT	Interactive class Interactive best effort	Background Background best effort
Fundamental characteristics	-Preserve time relation (variation) between information entities of the stream Conversational pattern (stringent and low delay) - Bandwidth guaranteed	-Preserve time relation (variation) between information entities of the stream - Bandwidth guaranteed - One way transport to downlink direction	-Request response pattern -Preserve payload content	-Destination is not expecting the data within a certain time -Preserve payload content
Example of the application	-voice	-streaming video	-Web browsing	-background download of emails

Table 3: Traffic Class characteristics and applications

1.5.2. Requirements for supporting QoS for Real-Time Services

There are three key capabilities in order to support QoS for real-time services: 1) multi-RAB support, 2) Secondary PDP context support, 3) real-time RABS (e.g. streaming and conversational), and 4) QoS control via 3GPP Rel-7 Policy Control Framework.

1.5.2.1. Multi-RAB support

To support real-time Radio Access Bearers (RABs), a carrier must support multi-RAB. Multi-RAB support is the capability for a User Equipment / Terminal to establish more than one PDP (Policy Decision Point) context simultaneously. Each PDP context maps to a single RAB; therefore, to support more than one PDP context, multiple RABS must be supported. Section 3.3 goes into more detail from a radio perspective.

1.5.2.2. Secondary PDP context support

3GPP supports two categories of PDP contexts: 1) primary and 2) secondary PDP contexts. It is the position of this paper that real-time RABS should be supported via secondary PDP contexts. One example of how real-time RABS may be deployed is Video Share service. In this example, a primary PDP context is established at UE power-on. The UE's IMS client is assigned an IP address and registers with IMS. This primary PDP context is always on and connected. However, when a user wants to establish a video share, the UE will signal the IMS to establish a bearer to another UE via SIP. The attributes of the bearer will be negotiated and the UE will establish a secondary PDP context mapped to the appropriate real-time RAB. In this example, the streaming RAB would be invoked for the duration of the session. Figure 6 provides a diagram of this use case.

1.5.2.3. Real-time RAB support

3GPP defines real-time RABs as streaming and conversational. Interactive RABS are defined as interactive and background. In order to support real-time services with deterministic quality, real-time RABs should be developed.

1.5.2.4. Policy Management Framework

Lastly, in order to support real-time services and manage the QoS, the packet core gateway node must be upgraded to support dynamic QoS control based on 3GPP Rel-7 PCC. This capability includes policy and charging enforcement and decision making. The PCC provides the mechanisms to grant QoS and gate the flow. Just as importantly, the PCC also provides the mechanisms to release the resources when the real-time flow is complete. The packet core gateway will evolve to support Policy Charging Enforcement Function. This is a key enabler which interfaces into the larger Policy Management Framework via Gx diameter.

2. Policy and QoS standards work

2.1.1. 3GPP

There are four predominant standards bodies currently working on standards relevant to the policy framework architecture.

- ITU-T - Standards support both wireless and wire line technologies.
- 3GPP - Standards support wireless related access technologies, notably UMTS.
- 3GPP2 - Standards support wireless related access technologies, notably CDMA.
- TISPAN - Standards support wire line broadband access related technologies, notably DSL.

In addition to these, the IETF has had a significant influence on these standards, especially related to the Diameter protocol.

The 3GPP standards organization has defined Policy Charging Control (PCC) architecture in 3GPP Rel-7, which specifies service based local policy and Flow based charging functionality into one merged model called PCC. This model provides more efficient real-time control of the service flows in the gateways.

PCC architecture is built on the work achieved in 3GPP Release 6 on flow-based charging, which includes how policy can be provided with the 3GPP Release 6 FBC reference points (Gx, Gy, and Rx) in the context of multiple service data flows on one single bearer.

3GPP PCC technical specification (TS 23.203) has been base-lined. In addition, the interfaces involved with the charging rules function and charging coordination has been base-lined in 3GPP which involves combining the interfaces for charging (FBC), bearer control, and QoS authorization into a single pair of interfaces. The functionality provided by 3GPP is also being looked at by ITU-T in their work on Next Generation Networks.

2.1.2. Harmonization of Policy and Enforcement with other standards bodies

Standards specifications from various standards bodies are at varying stages of completion. ITU-T, DSL Forum, and TISPAN all have related policy function specifications with different degrees of maturity. It is outside of the scope of this paper to discuss details of these specifications in progress and it is expected that in the future, these specifications from different standard bodies will be harmonized based on the IETF model.

3. Technical considerations

3.1. Policy architecture

3.1.1. Policy Management Framework (PMF)

In order to be able to manage both network and services, a centralized policy management framework is recommended to be deployed within each operator domain. The PMF will provide a platform for centrally management all policies not only related to network management, but also services that ride on these network resources. The general requirement of this policy management framework is that it shall manage policies in a unified and consistent manner so that a network operator has the ability to provision, validate, and correlate policies in a centralized framework, which will improve efficiency (one mechanism to provide policies) and consistency (to reduce duplication and conflicts). Furthermore, the PMF will be an independent horizontal enabler providing ubiquitous services for all future services that will need policy control and management functions. It will support service and network management and control within an operator's network. It will also be the policy framework to support roaming and in wireless/wireline/Internet three-way convergence scenarios.

PMF will support many different types of services across a broad service spectrum. Examples of these service types could be:

- Integrate services (e.g. voice and data services)
- Presence and Location
- Instant Messaging / Chat
- VoIP
- Convergence (e.g. service across different types of networks).

3.1.2. Design principles and architecture

The design of a PMF has to consider the operating environment for a mobile operator in terms of the new services that will be enabled by the deployment of 3G network. We also have to be mindful of the current deployed systems and how to optimize network resources. The following architectural principles and design guidelines were recently developed and are now recommended by 3G Americas:

- The PMF should be a unified and independent network enabler.
- The PMF shall be access technologies agnostic.
- The PMF shall support SLA (Service Level Agreement) management.
- The PMF shall support both IP and non-IP flow based services.
- The PMF shall support an interface with a PMF in other operator domains.
- The PDP (Policy Decision Point) and PEP (Policy Enforcement Point) functions should be separated so the PDP function can be centralized. This separation will also allow for a centralized policy repository.
- Flexibility is highly desirable for the PMF system to be interoperable with various enforcement elements.
- Any middle elements between PDP and PEP should be avoided. If possible, collapse functions into single logical elements to avoid unnecessary signaling between functional elements.
- The system must support policy-based content filtering and other application-level policy control.
- The PMF system shall support policy decisions based on both subscription and dynamic service policies (such as location, device type, user presence, and time of the day).
- The PMF shall be able to handle charging rules and interact with charging functions, specifically:
    1. The PMF shall support charging control (FBC) and QoS control (SBLP - Service Based Local Policy) independently for a PDN (Process Data Network) access.
    2. PMF shall support various charging models such as volume based charging, time based charging, volume and time based charging, and event based charging.
    3. The PMF policy interface shall support flow based charging to provide the ability to do differential accounting/charging for traffic flows belonging to different services.
- The PMF policy interface shall support both push-and-pull based model for policy authorization.
- The PMF shall be able to manage both network security and data service security.
- The PMF shall provide migration mechanisms for converging the localized policy function into this centralized management framework.

3.1.3. Policy exchange between operator domains

Policy management has become one of the best tools in managing converged services because the policies that control resources can be negotiated and exchanged.

There are three main scenarios in deploying converged services:

1. Backhaul all services to home network and use PSTN (Public Switched Telephone Network) for voice interconnects. This is the current situation for inter-domain communication such as roaming and converged services.

2. Use IMS: the service parameters (such as QoS) are exchanged using a SDP (Service Delivery Platform).

3. Use a PMF to exchange service polices between the home network and visited network. 3G Americas recommends defining an interface to link PMFs between operators' networks and use the PMF to exchange policies such as QoS parameters to provide end-to-end services. It is further recommended that local policies will take precedence if there are conflicts between home policies and visited policies that are being exchanged.

3.1.4. 3GPP Release 7 standard interfaces and protocols

3GPP Release 7 combined policy and charging functions and specified a policy and charging control mechanism for mobile networks. It is an all-IP flow-based mechanism based on policy rules (filters). Policy, as it relates to PCC (Policy and Charging Control), describes the set of rules that a network may apply when authorizing the use of network resources or how users are charged for those network resources. If the user is roaming, the serving network may apply local policy to the set of application authorized resources. This may restrict the allowed set of resources compared to those authorized by the application function (AF). Because the serving network knows nothing about the resource requirements of the requesting application in the user endpoint, granting fewer resources than requested by an application may result in unacceptable application performance. If requested resources are not allowed by the local serving network policy, the result should be a denial of service to the application.

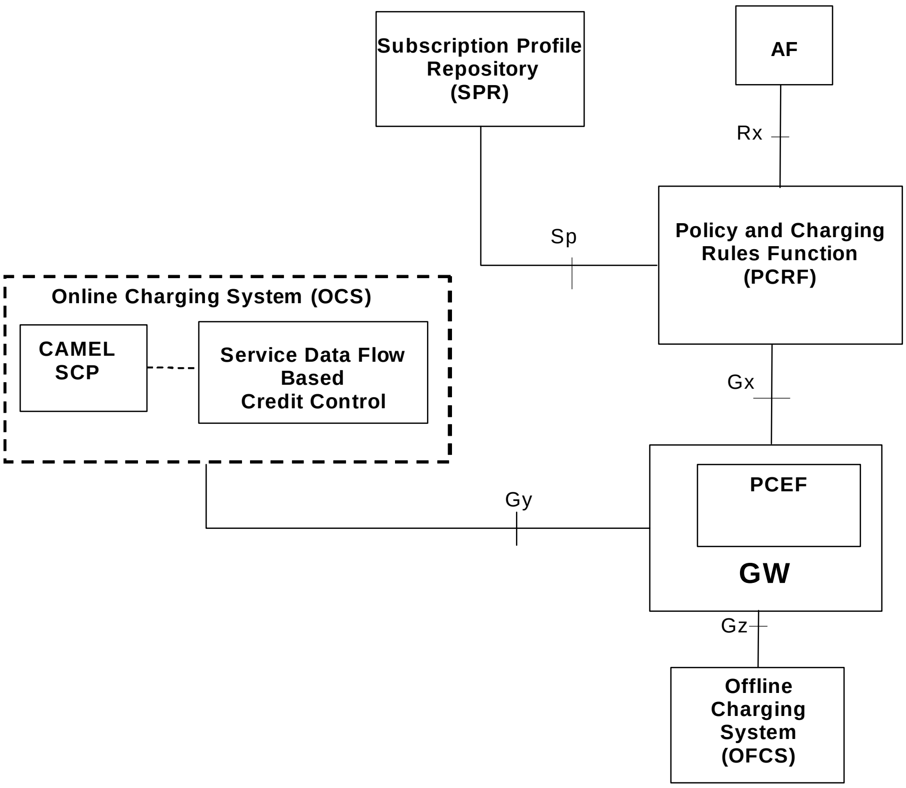

Figure 2: 3GPP PCC logical architecture

There are two functional elements related to PCC policy. The first piece is the policy decision point (PDP). The policy decision point maintains the rules for network operations for the segment of the network for which it has responsibility. The PDP will filter resource requests against the policy rules and make decisions about network operations. For example, a network may have a policy that no user may use more than 20 Kbps during peak voice call hours of 4 PM to 6 PM. A user may be allowed to use 100 Kbps via their home network subscription. When the user makes a request for 100 Kbps resources in the serving network, the Authorizing Application will authorize the requested bandwidth. However, the policy decision function will filter this authorization against the current policy and deny the resource request. If the application requires 100 Kbps per second to function correctly, the session should be denied based on current local policy rules.

The policy decision is sent to a policy enforcement point (PEP). In the PCC architecture, the traffic plane function is the PEP. It is responsible for enforcing the decisions of the PDP, and in the previous example, it would be responsible for notifying the application in the endpoint of service denial.

Policy control comprises functionalities for:

- Gating control, i.e. the blocking or allowing of packets, belonging to a service data flow, to pass through to the desired endpoint,
- Event reporting, i.e. the notification of and reaction to application events to trigger new behavior in the user plane as well as the reporting of events related to the resources in the GW,
- QoS control, i.e. the authorization and enforcement of the maximum QoS that is authorized for a service data flow or an IP-CAN (IP-Connectivity Access Network) bearer.

In case of an aggregation of multiple service data flows (e.g. for GPRS, a PDP context), the combination of the authorized QoS information of the individual service data flows is provided as the authorized QoS for this aggregate. The enforcement of the authorized QoS of the IP-CAN bearer may lead to a downgrading of the requested bearer QoS by the GW as part of IP-CAN bearer establishment or modification. If the Policy and Charging Rules Function (PCRF) provides authorized QoS for both, the IP-CAN bearer and PCC rule(s), the enforcement of authorized QoS of the individual PCC rules shall take place first.

QoS authorization information may be dynamically provisioned by the PCRF or predefined as a default policy in the GW. In case the PCRF provides PCC rules dynamically, authorized QoS information for the IP-CAN bearer (combined QoS) may be provided. For predefined PCC rules within the PCEF, the authorized QoS information shall take affect when the PCC rule is activated. The GW shall combine the different sets of authorized QoS information, i.e. the information received from the PCRF and the information corresponding to the predefined PCC rules.

For policy control, the AF interacts with the PCRF and the PCRF interacts with the GW as instructed by the AF. For certain events related to policy control, the AF shall be able to provide instructions to the PCRF to act on its own, i.e. based on the service information currently available. The following events are subject to instructions from the AF:

- The authorization of the IP-CAN session modification
- The revoke of authorization
- The gate control
- The forwarding of IP-CAN bearer events

Reference points for the 3GPP Rel-7 PCC architecture utilize and enhance the interfaces used in 3GPP Release 6 FBC. In 3GPP Rel-7, the following interfaces are defined:

- **Rx** between PCRF and AF
- **Gx** between GW and PCRF
- **Gy** between GW and OCS
- **Sp** between SPR and PCRF
- **Gz** between PCEF and OFCS

Rx: In Rel-6 (3GPP Release 6) Rx interface is defined between CRF and AF, so Rx in Rel-7 is a single reference point between AF and PCRF which will allow for all Rel-6 capabilities of the Gq and Rx reference points plus all identified enhancements of Rel-7, which will be backward compatible with Rel-6. For example, Rel-7 PCRF can support interacting with Rel-6 AFs and Rel-7 (3GPP Rel-7) AFs can support interacting with a Rel-6 PDF and/or Rel-6 CRF. The Rel-7 Rx reference point is realized by combining relevant parts of Rx and Gq reference points within a single protocol as most of the information transferred between the AF and the CRF/PDF are common.

Gx: Rel-7 Gx is introduced to evolve the charging rules defined in Rel-6 to support gating functionality. The Rel-6 Gx reference point enables the use of service data flow-based charging rules such as counting the number of packets belonging to a rate category in the IP-Connectivity network. This functionality is required for both offline and online charging. In Rel-5 and Rel-6, the Go reference point enables service-based local policy (SBLP) and QoS interworking information to be transferred from PDF to PEP. But in this architecture, the Go reference point can be realized together with the Gx reference point with a single protocol, using a single message sequence to communicate both SBLP decisions and charging rules. The Gx reference point lies between the GW and PCRF.

Sp: The Sp reference point lies between the SPR and the PCRF. The Sp reference point allows the PCRF to request subscription information related to the IP-CAN transport level policies from the SPR based on a subscriber ID and possible further IP-CAN session attributes.

Gy: The Gy reference point resides between the OCS and the PCEF. The Gy reference point allows online credit control for service data flow-based charging. The functionalities required across the Gy reference point use existing functionalities and mechanisms, based on RFC 4006.

Gz: Gz reference point resides between the PCEF and the OFCS. The Gz reference point enables transport of service data flow based offline charging information.

Diameter is the chosen protocol that is used across the above mentioned interfaces in the 3GPP PCC framework.

3.2. IPv6 Impacts on QoS/Policy Control

IPv4 and IPv6 dual stack devices and packet core networks are expected to be deployed by operators during the same timeframe that QoS/Policy is rolled out. One of many main drivers for IPv6 deployment is the inevitable depletion of IPv4 address space by the IANA (Internet Assigned Numbers Authority) and RIR's (Regional Internet Registry e.g. ARIN, American Registry for Internet Numbers) as soon as 2009/10. Therefore, understanding the impact of dual stack IPv4/IPv6 is critical. For example, during the transition to IPv6, multiple primary PDP contexts may be required to support IPv4 and IPv6 flows. The effect of multiple primary PDP contexts being used simultaneously decreases the capability to support real-time services via secondary PDP contexts.

The principle architectural recommendation is to support IPv6 while in the home network for all services. When roaming, the preference should be IPv6 first with a fallback to IPv4.

3.3. Radio QoS considerations

Radio resource management plays a vital role in the end-to-end wireless Quality of Services (QoS) delivery. A sophisticated radio resource management function with a QoS aware, policy driven radio access bearer (RAB) not only can increase the wireless capacity distribution efficiencies, but also can provide better user experiences.

As in Figure 3 below, wireless QoS consists of 5 layers of QoS scheme each performing its specific functions:

1. End-to-end (E2E) QoS: The end-to-end QoS on the application level uses the bearer services of the underling networks.

2. UMTS QoS: QoS carried out on the UMTS bearers that UMTS operators offer to the end user. UMTS QoS consists of two sections of network QoS, Radio Access Bearer QoS and Core Network QoS.

3. Radio Access Bearer QoS: RAB QoS enables differentiated transport bearers to ensure priority delivery of applications.

4. Radio Bearer QoS: RB QoS carries out the function of radio physical layer resource management and resource distributions that takes RAB QoS attributes as the priority scheduling inputs.

5. Iu (Interface unit) QoS: Iu connects the UMTS core network gateway with the edge node to provide the contracted UMTS bearer services. Next generation Ethernet based Iu interface will have its own QoS which can be mapped into RB QoS as well.

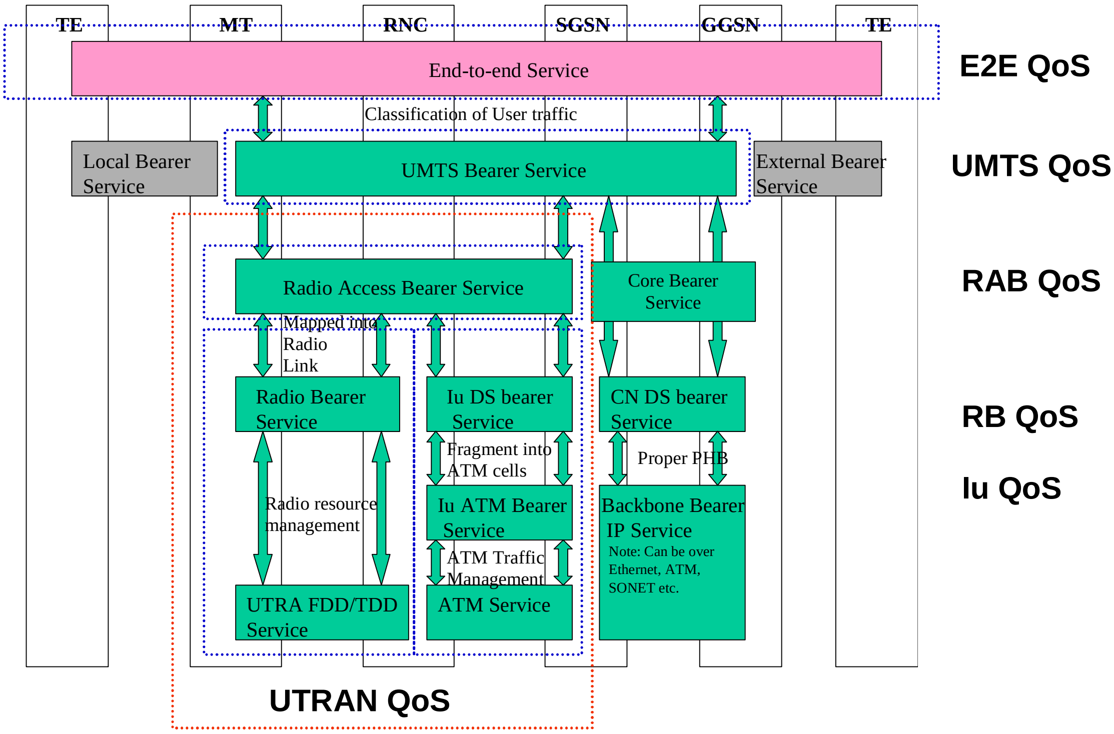

Figure 3: Three segments of Wireless QoS

Because of the radio link's dynamic nature, many factors shall be considered by radio resource management function besides QoS at the IP layer.

As in Figure 4 below, the radio resource management function performs capacity management functions and priority delivery based on the following parameters:

- QoS attributes
- Radio conditions such as:
  - Radio power amplifier power margin
  - Code channel availability
  - Traffic load
  - Signal strength and interferences
- In the future, RAN policy rules.

The objective of the RAN resource management in the normal operating conditions is to maximize the air interface capacity and the cell's overall throughputs while maintaining quality of service delivery for high priority application delivery.

In the emergency operating condition, RAN management shall ensure the critical application delivery such as E911 calls and data sessions while maintaining normal traffic only when capacity allows.

RAN resource management shall also support following QoS driven definitions:

- Provide a finite set of QoS definitions, as in Figure 3
- Map between application requirements and HSDPA classes with a GGSN
- Be compatible with current QoS schemes
- Support SIP session based QoS and allow multiple QoS data streams per IP address
- Manage QoS and radio resources to yield efficient capacity utilization

- Modify QoS attributes during the active session.

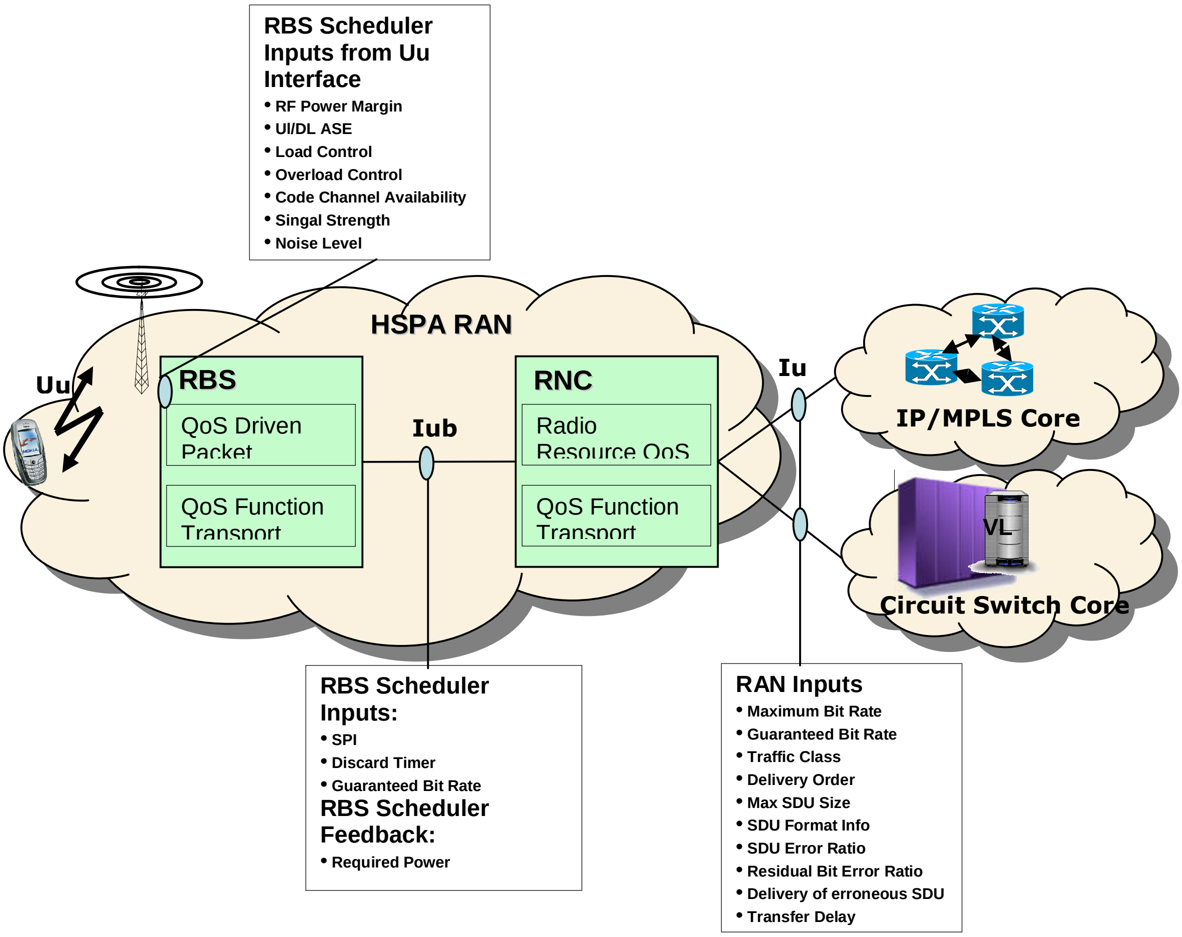

Figure 4: RAN Resource Management and QoS

Bearer QoS	Priority	Timing Objective	Traffic Pattern	Typical Applications
Conversational	Preserve Time Relation	Real Time Low Delay	Generally Duplex, Symmetrical Service	CS Voice CS Video PS VoIP PS Video conferencing
Streaming	Preserve Time Relation	Real Time Low Jitter	Typically Simplex Traffic	Video streaming Audio streaming PTT AV broadcast /multicast
Interactive	Preserve Data	Best Effort	Duplex Typically Asymmetrical	Web browsing Database Retrieval On-line gaming Remote terminal (TELNET)
Background	Preserve Data	Best Effort	Simplex / Duplex Non-timed constrained	Emails FTP Telemetry SMS

Table 4: Four QoS classes

3.3.1. Multi-RAB

Radio access bearers (RABs) are specific data flow conduits that identify the service the AS (Access Stratum) provides to the NAS (Non Access Stratum) for transfer of user data between the UE (User Equipment) and the CN (Core Network). In UMTS, there is a one-to-one mapping of RABs to PDPs. So multi-RAB capability gives the possibility to have two or more simultaneous RABs to support simultaneous communication over the radio access network with multiple service access points.
Both Rel '99 and HSDPA multi-RABs are described in 3GPP TS 34.108 and 3GPP TR 25.993. The RAB combinations have been planned with an associated 3.4 Kbps SRB (Signaling Radio Bearer).

For Rel '99 multi-RABs, the radio bearers are multiplexed on MAC-d level into one single dedicated transport channel (DCH), with a maximum rate of 8, 16, 64, 128 or 384 Kbps for both downlink and uplink. The maximum bit rate is shared by the two RABs, meaning the sum of the instantaneous bit rates on the bearers transmitted in a TTI (Transmission Time Interval) is less than or equal to the maximum bit rate on the DCH. The transport channel is shared, and also has lower transport formats in order to adapt to lower data rates when there is less data to transmit.

Multi-PS RAB are required to support radio QoS. For HSDPA Multi-RABs, there is no multiplexing on the MAC-d level for the downlink. Instead, the radio bearers are carried as different MAC-d flows down to the RBS, where the data is put into separate priority queues for scheduling on the HS-DSCH (Downlink Shared Channel used in HSDPA). The available HS-DSCH bandwidth is shared between the various flows. The uplink radio bearers will continue to be Rel '99, and follow the mapping described previously.

In addition, support of real-time services will be realized with the introduction of streaming, guaranteeing bit rate radio access bearers on HSDPA. UTRAN (UMTS Terrestial Radio Access Network) does not differentiate between primary and secondary PDPs (Policy Decision Point), and the RAB combinations can be catering to either all primaries or a combination of primary and secondary PDPs, depending on the end-to-end service definition.

All the multi-RAB combinations are realized according to the typical radio parameter sets described for the UL and DL radio bearers in 3GPP TS 34.108 and 3GPP TR 25.993. Each PS RAB typically has a separate user activity supervision algorithm, whereby channel switching occurs.

3.3.2. RAB combinations

RAB Combination allows the radio bearer management to combine different classes of PDP context to provide different services simultaneously, e.g. VoIP and video streaming. Specific RAB combinations will be too many to list. Following are examples of RAB combination types:

- Up to 3 HSDPA PDPs with I/B QoS (DCH Upstream) + CS 12.2K AMR Voice
- Up to 3 DCH/DCH UL/DL PDPs with I/B QoS + CS 12.2K AMR Voice
- Up to 2 PDP with I/B QoS + 1 PDP with Streaming QOS (DCH/HS-DSCH) + CS 12.2K AMR Voice

Note 1: Typical streaming rates supported on HSDPA DL and R99 DCH UL will be 16, 32, 64 and 128kbps.

Note 2: R99 DCH I/B QoS RABs will support all combinations of 8, 16, 64, 128 and 384 kbps speeds on UL and DL.

3.3.2.1. APN Provisioning and RAB limitations

Use of specific APNs (Access Point Name) for providing specific packet data services on UMTS leads to a profusion of multi-RAB combinations. Some of these are in support of always-on applications, which typically have a high heartbeat frequency, while some are not. This arrangement leads to complicated testing requirements and user service experience incompatibility while roaming. A separate APN strategy also results in a large number of simultaneous PDPs leading to each PDP requiring independent Keep Alive Signaling, inefficiencies in RAN and increased UE battery drain.

Most of the issues described above are not valid in a GPRS network due to the inherent radio bearer capabilities. So operators need to plan ahead with their service and APN strategies while migrating and/or growing the 3G network. The APN issue will be exacerbated in the near term by the presence of IPv4 and IPv6 applications, and a dual-stack-capable device.

Depending on whether the legacy applications have been transitioned to IPv6 or not, both Service Aware APNs should support real-time secondary RABs and multiple primaries. Although it is beneficial to support secondary PDP contexts, there are costs and other issues associated with secondary PDPs and operators need to weight their business requirements, cost justifications, and implementation complexity considerations in deciding on their own deployment plan and schedules.

Single APN use for QoS (one Primary and multiple Secondaries)

PROS

- Only one APN needs to be configured on the terminal side (no complex multiple APNs settings)
- Only one Primary PDP (Packet Data Protocol) Context is allocated for each user
- Each application can request certain QoS with secondary PDP Context (QoS aware terminal)
- When Secondary PDP Contexts are used then existing connection for IMS can be used for applications
- This concept works both for SIP and non-SIP based applications
- Operator HelpDesk receives less support calls (OPEX savings)
- Flexi ISN (Initial Sequence Number) supports single APN concept

CONS

- NRT (Near Real Time) traffic uses the same QoS if NRT applications are used simultaneously
- QoS aware terminal is needed

Multiple APNs in device

PROS

- Simultaneous NRT applications has own QoS
- QoS differentiation between applications

CONS

- Requires Multiple Primary PDP Contexts support from terminal
- Multiple PDP Contexts concept requires also multiple IP addresses/user
- Each Primary PDP Context requires own IMS connection because each primary PDP Context has own IP address
- Multiple Primary PDP Contexts requires complex multiple APN setups from the user
- Operator HelpDesk receives more support calls when multiple APNs are needed to setup in the terminal (high OPEX)
- Terminals support usually maximum 5 APNs settings simultaneously
- Terminals support maximum 3-4 simultaneous Primary PDP Contexts

Significant cost-saving opportunities exist if IPv4 / IPv6 APNs are combined or services are provisioned exclusively depending on UE capability. This can be realized by upgrading all key legacy applications to a dual stack on the device user interface. Such an implementation will require 5-tuple (Header Inspection) in the GGSN to identify how on IPv4 and IPv6 packets are routed, but will significantly reduce the requirements for multiple PDPs and consequently multi-RABs.

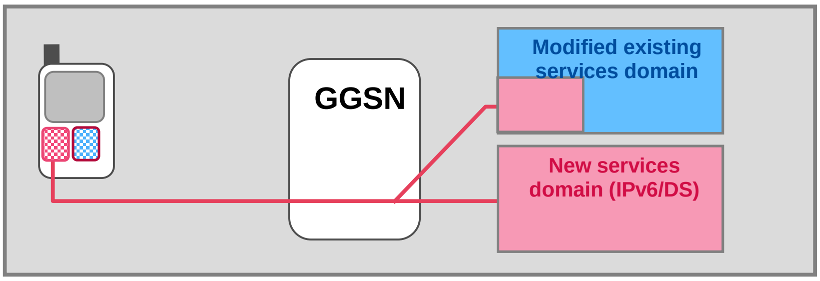

Figure 5: Modified and Existing Services Domain

To further reduce RAB/PDP complexity, a Service Aware APN Architecture may be used, as shown in Figure 5.

3.3.2.2. Signaling of RAB Id for active PDP contexts

Presently Data Service Request Type is sent to the Network without any indication of which PDP context is active in pre-3GPP Rel-7 devices. This results in the network needing to re-establish all RABs, even dormant ones, while there is real data flow on only one. This has a number of undesirable side effects, especially when there are several PDP contexts present. The network is obliged to attempt to reactivate all PDP contexts when a Service request type data is requested. Dormant PDP contexts will be unnecessarily activated, consuming UE and RNC resources. This procedure is wasteful on resources when PDP contexts are released in the network due to inactivity. If the network is in a congested situation, it will not know which PDP context to prioritise for re-establishment.

The above issues can be solved if the UE signals indication of PDP context activity in the Service Request message of service type=data. It is recommended that operators plan to deploy this principle in pre-3GPP Rel-7 devices and core network elements to maximize radio and packet network efficiency. A scheme has been standardized in 3GPP to mitigate the problem. As per C1-060347 CR 24.008, the UE will be required to signal indication of PDP context activity in the Service Request message of service type=data.

3.3.3. Traffic Handling Priority (THP)

THP treats the relative priority for the handling of all SDUs (Service Data Unit) belonging to the UMTA Interactive Class bearer compared with all other SDUs of the same class bearers. THP along with other QoS attributes such as traffic class, ARP (Allocation and Retention Priority), GBR (Guaranteed Bit Rate), SI (scheduling information) shall be used in the RNC QoS scheduler mapping function to derive a scheduling priority index, discard timer and GBR. In the Node-B scheduling process, RABs are mapped based on SPI with an operator definable weight on each of 15 SPIs (Scheduling Priority Indicator).

Node-B shall use these different SPI levels with appropriate scheduling algorithms (e.g. maximum C/I, Proportional Fair, minimum GBR, etc) to differentiate individual HSDPA flows, taking into account both radio conditions, resources and call priorities.
Both the RNC mapping table and Node-B HSDPA scheduling priority mapping sets shall be configurable Operation and Maintenance parameters. They shall have the same life span as the RAB assignment.

3.3.4. RAB Modifier Process

PDP modification process applies to both primary and secondary PDPs. Primary PDP modification mainly addresses non-QoS aware UEs. Secondary PDP modification can be used to change the QoS characteristics initially assigned to the secondary context.

The latter can be manifest by dynamically modifying the THP or ARP parameters of the PDP according to the service being used. The core network will initiate the RAB modify process by ordering the RNC.

RAB negotiation or Iu fallback procedures are required for real-time services if the originally requested guaranteed RABs could not be assigned by the network due to congestion or other reasons.

In the case of RAB negotiation, SGSN gives the RNC alternative MBR/GBR values at RAB assignment and the RNC can then request a change of the MBR/GBR based on values given at RAB assignment during the connection.

With Iu (Interface unit) fallback, the SGSN makes a new RAB assignment attempt with different QoS attributes in response to a RAB assignment failure.

In addition to the above procedures, UE may initiate PDP context modification to request a different MBR, GBR or QoS class.

3.3.5. Radio Network Admission and Congestion Control

The main check is done by the RNC QoS Call Admission Control (CAC) manager based on QoS class associated with the RAB combinations, as well as other QoS attributes like THP and ARP to determine the relative priority level during admission and congestion processes. The RNC CAC manager also checks the available network resources (channel codes), capacity/hardware resources, and Air interface resources (cell load, available power) to estimate the load associated with new request. Freeing resources is based on priorities and request class. In general, GBR requests can free up resources from non GBR and from GBR with lower priority. Non GBR may free up resources from other non GBR with same or lower priority. The pre-emption order followed will first down switch interactive/ background users to minimum non shrinkable rate according to ARP parameter. This will be followed by release of services, also in order of ARP.

ARP is one of the attributes that defines UMTS bearer priority. This ARP attribute is an operator assignable subscription attribute that can be used to decide ARP allocation policy for the user differentiation. ARP does not need to be negotiated with the mobile terminal. Therefore the operator can decide ARP allocation policy for the user differentiation.

There are three levels of ARP, 1- high, 2-medium, and 3-low. ARP applies to all traffic classes. This IE specifies the relative importance compared with other RABs for allocation and retention of the radio access bearer.

For PDP context activation, the ARP field in QoS profile has the value of 1, 2 or 3. However in RAB Assignment Request, the ARP field is made of four fields: Priority level (1 to 14), Pre-emption capability (shall not trigger pre-emption, may trigger pre-emption), Pre-emption Vulnerability (not pre-emptable, pre-emptable) and Queuing allowance (queuing not allowed, queuing allowed). SGSN will populate the ARP fields contained in the RAB parameter IE with correct priority levels for the RANAP

(Radio Access Network Application Part) messages sent to RNC. RNC receives 4 attributes that make up the ARP field in QoS from RAB assignment request, in principle RNC needs to determine the call priority using all of them. ARP has precedence over traffic class during call admission control. An ARP=1 bearer shall have higher priority than ARP=2 bearer even it is conversational or streaming. During congestion ARP value will be taken into account first in order to downgrade a bearer. In addition, for interactive class, the THP and (optionally) ARP parameters are mapped to SPI in RNC to determine scheduling priority per TTI.

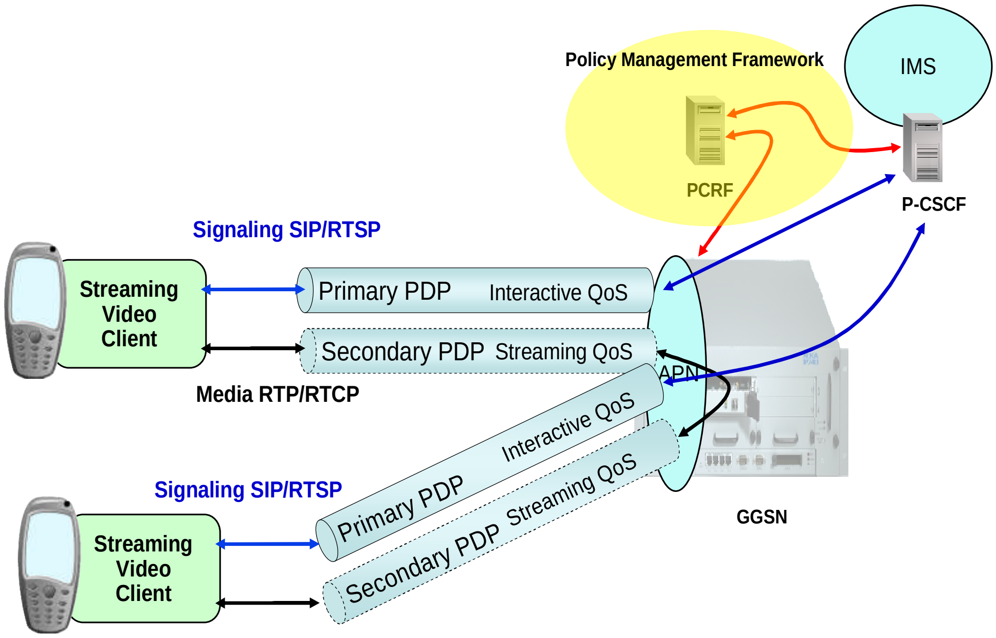

Figure 6: UE Considerations to support QoS

Real-time QoS Device Use Case – See Figure 6.

Streaming QOS- See Figure 6.

- Application requests flow specific QoS profile via QoS API
- Terminal uses an existing Primary PDP context for SIP/RTSP signaling and opens a Streaming QoS Secondary PDP Context for RTP/RTCP
- If network rejects the Secondary PDP Context activation or deactivates it later, Fallback is to use one Primary PDP context for both SIP/RTSP and RTP/RTCP. See Figure 6.
- In case network downgrades the negotiated QoS, UE reaction is application dependent (e.g. continue with downgraded QoS or deactivate the context)

Streaming QOS application to POC – See Figure 7.

- PoC SIP signaling will use Interactive context with subscribed QoS (network default) values
- Secondary streaming context is requested for PoC media flows with explicit values for QoS parameters
- PoC SIP Signaling requires always-on PDP context (Network shall not deactivate the context)
- VSC (video sharing) same but higher bit rates

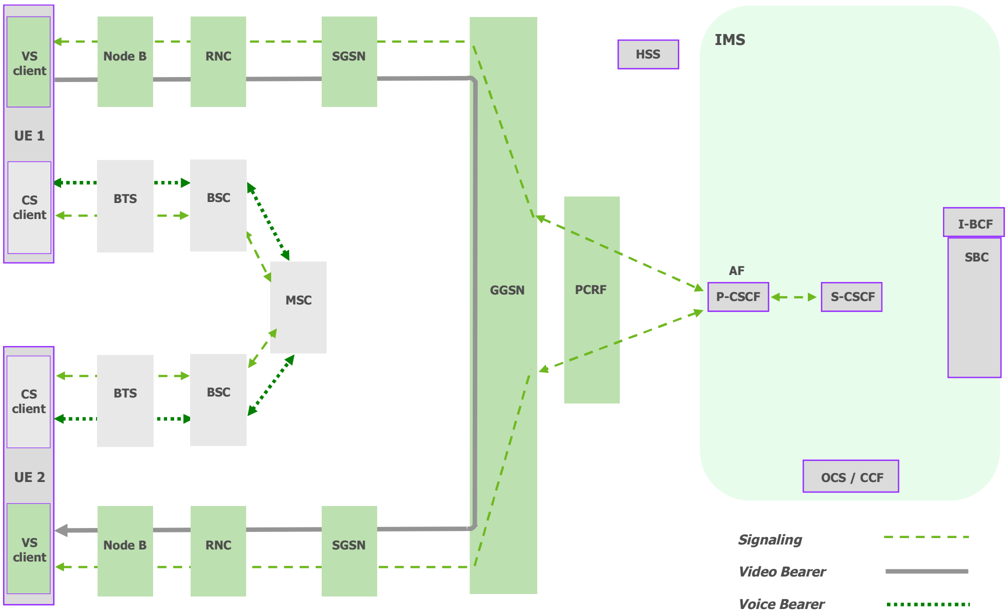

Figure 7: Streaming QoS application example

3.3.6. Complex QoS / QoS Aware Devices

QoS-aware user equipment will support QoS in the following areas:

- QoS-aware application client – ability to request QoS parameters (from OS middleware through e.g. a QoS API)
- QoS-aware middleware / operating system – ability to pass QoS requests and responses from application to cellular engine.
  - o OS needs to handle Multiple PDP contexts and secondary PDP contexts
- QoS-enabled cellular engine – ability to establish PDP context including secondary PDP contexts and negotiate QoS

QoS-aware user equipment will not perform the IP Bearer Service Manger (IP BS Mgr) function.

- Only GGSN will perform diffuser edge function
- UE will not perform diffuser edge function

POC Signalling

QoS parameter	UE requested value
Traffic Class	Interactive or Subscribed
Traffic handling priority	Subscribed
Maximum bit rate DL (kbps)	Subscribed
Maximum bit rate UL (kbps)	Subscribed
Guaranteed bit rate DL (kbps)	Subscribed
Guaranteed bit rate UL (kbps)	Subscribed
Transfer delay (ms)	Subscribed
Maximum SDU size (octets)	Subscribed
Delivery order	Subscribed
Delivery of erroneous SDUs	Subscribed
SDU error ratio	Subscribed
Residual BER	Subscribed

Table 5: POC Signaling

POC Media

QoS parameter	UE requested value
Traffic Class	**Streaming**
Traffic handling priority	Subscribed
Maximum bitrate DL (kbps)	<Terminal max capability in DL> **e.g. 176 kbps**
Maximum bitrate UL (kbps)	<Terminal max capability in UL> **e.g. 112 kbps**
Guaranteed bitrate DL (kbps)	**8 kbps** with IPv4 (9 kbps with IPv6) *
Guaranteed bitrate UL (kbps)	**8 kbps** with IPv4 (9 kbps with IPv6) *
Transfer delay (ms)	**600**
Maximum SDU size (octets)	600
Delivery order	No
Delivery of erroneous SDUs	No
SDU error ratio	10^{-4}
Residual BER	10^{-5}

Table 6: POC Media

3.3.7. Simple QoS

Simple QoS does not support real-time QoS, but rather interactive RABs with static QoS profiles. Simple QoS provides better than best effort for non QoS aware devices. For example, providing different tiers of performance and bandwidth to the ubiquitous internet could leverage simple QoS. Because the internet is “best effort” and the services are “internet grade,” there is little value to provide E2E QoS via real-time RABs.

Many times simple QoS is defined statically and does not change. The QoS is statically provisioned in the HLR. The QoS is enforced on the primary PDP context and no secondary PDP contexts are used.

3.3.8. QOS / Multiple APN support in Devices – overall analysis

- Device test software support for QOS has been available for some time.
- Tokens are no longer required for QoS. The recommended approach is to support a token-less method which was defined in 3GPP Rel-7
- Globally it does not appear to have been fully deployed. Last year no operators were using it although some operators were in test.
- Many test issues associated with failure cases
- Provisioning and IT issues
- UMTS complexity with RABs
- 2G / 3G transition issues
- Not a standalone capability – tied to applications/ OS etc.
- QOS can be supported in devices but depends on a detailed end-to-end plan with applications and appropriate testing

3.4. Policy enabled charging for Roamers

Charging for roamers is beyond the scope of this white paper because charging between carriers is more of a business issues than a technical issue. However, we can not stress enough the importance of charging in the roaming arrangements. We would assume that charging parameters and rules can be handled in the same way as QoS by the policy framework.

4. Summary

As wireless networks evolve to all-IP networks, it is critical for mobile service providers to continue to provide value to the subscribers while maintaining control over resources. Two key enabling architectures have been introduced: Policy Management Framework and QoS (Packet Core/Transport and RAN). 3G Americas recognizes that each operator must determine the final implementation of their QoS and Policy based on their own business requirements and network conditions.

Detailed recommendations and technical considerations have been provided throughout the whitepaper. In conclusion, 3G America recommends the following three actions:

Firstly, 3G Americas recommends service providers implement a policy management framework based on 3GPP Rel-7 Policy Charging Control. Policy management framework becomes a key enabling technology for roaming service and dynamic QoS control. The Policy Management Framework is critical for roaming and policy negotiation.

Secondly, 3G Americas recommends service providers establish a minimum set of QoS feature parity in the Packet Core and Transport based on 3GPP Rel-7 Policy Charging Control in order to support QoS and Charging. To get to QoS feature parity in the Packet Core, 3G Americas has the following recommendations for mobile service providers: 1) gateway support for policy enforcement based on 3GPP Rel-7 Policy Control Charging e.g. GGSN, PDG, 2) QoS enabled transport e.g. IPX, and 3) support for local-breakout based on policy and SLAs.

Lastly, 3G Americas recommends service providers establish a minimum set of QoS feature parity in the Radio Access Network in order to support real-time / time sensitive services e.g. video share. To get to QoS feature parity in the RAN, 3G Americas has provide the following considerations: 1) multi-RAB support for HSPA bearers, 2) agreed-upon set of RAB combinations, 3) traffic handling priority (THP) support, and 4) scheduler support for QoS / CAC.

5. Acknowledgements

The mission of 3G Americas is to promote and facilitate the seamless deployment throughout the Americas of GSM and its evolution to 3G and beyond. 3G Americas' Board of Governors members include Alcatel-Lucent, Andrew Corporation, AT&T, Cable & Wireless, Ericsson, Gemalto, HP, Motorola, Nortel Networks, Nokia, Openwave, Research in Motion (RIM), Rogers, T-Mobile USA, Telcel, Telefónica, and Texas Instruments.

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6. Acronym/Glossary

AF	Application Function
APN	Access Point Name
APN	Access Point Name
ARIN	American Registry for Internet Numbers
ARP	Allocation & retention Priority
ASP	Application Service Provider
CAC	Call Admission Control
CoS	Class of Service
DSCP	DiffServ Control Points
FBC	Flow Based Charging
GBR	Guaranteed bit rate attribute in QoS profile
GGSN	Gateway GPRS Support Node
HLR	Home Location Register
HSDPA	High Speed Downlink Packet Data Access
HS-DSCH	Downlink Shared Channel used in HSDPA
HS-DSCH	High-Speed Downlink Shared Channel
IANA	Internet Assigned Numbers Authority
IMS	IP Multimedia Subsystem
IP-CAN	IP Connectivity Access Network
IP-CAN	Industry Pack Module with two channels of CAN - Controller Area Network
ISN	Initial Sequence Number
ISP	Internet Service Provider
Iu	Interface unit
MACD	Moving Average Convergence / Divergence
MBR	Maximum bit rate attribute in QoS profile
NAS Layer	Non Access Stratum layer
NRT	Near Real Time
OCF	Online Charging System
OCFS	Offline Charging System
PCC rule	A set of information enabling the detection of a service data flow and providing parameters for policy control and/or charging control.
PCEF	Policy and Charging Enforcement Function
PCRF	Policy and Charging Rules Function
PDN	Process Data Network
PDP	Policy Decision Point
PDP Context	Packet Data Protocol context is a data structure present on both the SGSN and the GGSN which contains the subscriber's session information when the UE has an active session
PDP	Programmed Data Processor
PEP	Extension Mechanism for HTTP
Policy	Policies are “a set of rules to administer, manage, and control access to network resources [RFC3060]”

PDP	Policy Decision Point. A logical entity that makes policy decisions for itself or for other network elements that request such decisions
PEP	Policy Enforcement Point. A logical entity that enforces policy decisions
PS (with RAB)	Packet Switched (with Radio Access Bearers)
PSTN	Public Switched Telephone Network (PSTN)
QoS	Quality of Service - A set of attributes used to differentiate the quality of service flows. QoS affects latency, jitter (variable delay), and packet loss.
RAB	Radio Access Bearer. The RAB functionality provides the CN with a set of services between the core network and the UE
RB	Radio Bearer. The allocation/de-allocation function located in the RNC translates the connection element set up requests into physical radio channel allocation according to the QoS of the radio access bearer
RANAP	Radio Access Network Application Part
RIR	Regional Internet Registry
RTP	Real-time Transport Protocol
RTCP	Real-time Control Protocol
RTSP	Real-time Streaming Protocol
SBLP	Service Based Local Policy
SCP	Service Control Point
SDP	Service Delivery Platform
SDU	Service Data Unit
SLA	Service Level Agreement. The documented result of a negotiation between a customer/ consumer and a provider of a service that specifies the levels of availability, serviceability, performance, operation or other attributes of the service.
SGSN	Serving GPRS Support Node
SIP	Session Initiation Protocol
SLA	Service Level Agreement
SPI	Scheduling Priority Indicator
SPR	Subscription Profile Repository
SRB	Signaling Radio Bearer
THP	Traffic handling Priority
TTI	Transmission Time Interval
TTI	Trusted Time Infrastructure
UE	User Equipment. The UE contains both the mobile equipment domain and the smart card based user services identity module (USIM) domains
UTRAN	UMTS Terrestrial Radio Access Network

7. References

[1] 3GPP TS 23.203: "Policy and Charging Control Architecture", V7.3.0

[2] 3GPP TS 32.240: "Telecommunication management; charging management; Charging architecture and principles"

[3] 3GPP TS 23.207: "End-to-end Quality of Service (QoS) concept and architecture"

[4] 3GPP TS 29.214: “Policy and Charging Control over Rx reference point”

[5] 3GPP TS 29.212: “Policy and Charging Control over Gx reference point”

[6] 3GPP TS 29.213: “Policy and charging control signaling flows and Quality of Service (QoS) parameter mapping”

[7] 3GPP TS 23.228: “IP Multimedia Subsystem (IMS); Stage 2”

[8] 3GPP TS 34.108: “Common test environments for User Equipment (UE); Conformance testing”

[9] 3GPP TR 25.993: “Typical examples of Radio Access Bearers (RABs) and Radio Bearers (RBs) supported by Universal Terrestrial Radio Access (UTRA)”

[10] 3GPP TSG-CT1 Meeting #41 - Tdoc C1-060347, CR 24.008-1053 PDP Context Activity Indication for Service Request (Service Type = Data)