QoS Mechanism in EPS

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Abstract:
To adapt to the development of mobile communication technologies in the next 10-year timeframe and better meet an ever-increasing demand for data services, 3GPP has started the Long Term Evolution (LTE) and System Architecture Evolution (SAE) study projects. In view of the high-speed and bursty feature of future data services, the Evolved Packet System (EPS) makes quite a few enhancements and improvements in Quality of Service (QoS). By introducing such technologies as default bearer and aggregate resource scheduling, the EPS truly realizes the objective of "Always Online" for users, improves data rates and thus enhances user experience ultimately. Furthermore, an appropriate mapping between the EPS QoS Class Identifier (QCI) parameter and Universal Mobile Telecommunication System (UMTS) QoS parameter is designed regarding future interoperability scenario between UMTS Terrestrial Radio Access Network (UTRAN) and Evolved UTRAN (E-UTRAN).

At present, one of the major challenges confronted by the mobile communication system is to deliver various types of multimedia services including data, voice, image and video with guaranteed Quality of Service (QoS)[1]. To guarantee QoS of various multimedia services, 3GPP clearly defines the end-to-end QoS architecture for Universal Mobile Telecommunication System (UMTS), and introduces several bearer and processing mechanisms to ensure UMTS can make full of its technical advantages to offer differentiated services for users.

To keep the competitive advantages of 3GPP systems in the next 10-year timeframe and better support the ever-increasing demand of users for data services, 3GPP launched the Long Term Evolution (LTE) and System Architecture Evolution (SAE) study projects[2] in 2004. The SAE project aims at optimizing and enhancing system performance in terms of network architecture, and the evolved network is called Evolved Packet System (EPS).

The QoS mechanism for EPS has made quite a few enhancements and improvements on the basis of UMTS.

Firstly, in view of the high-speed and bursty feature of future data services, the EPS introduces the concept of default bearer to effectively enhance user experience, reduce service setup latency and truly realize "Always Online". A default bearer with a constant data rate is established for a user when the user attaches to a network in order to ensure the user's basic service requirements are met.

Secondly, the LTE uses shared channel mechanism to replace the dedicated channel in Radio Access Network (RAN), and adopts more flexible dynamic scheduling technology. Correspondingly, the EPS gives up complicated QoS negotiation mechanism for UMTS.

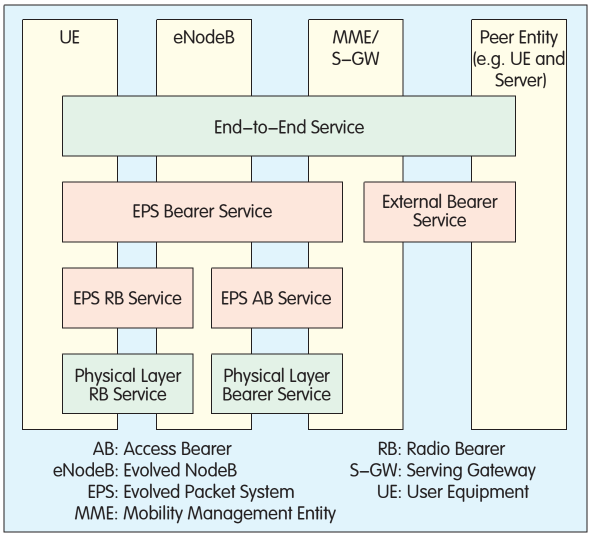
In addition, the EPS networks are required to enable various Radio Access Technologies (RATs), such as GSM, Wideband Code Division Multiple Access (WCDMA), LTE, CDMA2000 and Worldwide Interoperability for Microwave Access (WiMAX), to access a uniform packet-domain core network. Accordingly, the EPS must also support end-to-end QoS guarantee for users crossing different access networks, that is, User Equipment (UE) crossing access networks can fulfill mapping between the QoS parameters in order to ensure seamless user experience[3].

1 Evolution of QoS in 3GPP Mobile Networks

With the convergence of wireless communication technologies and IP technologies, the mobile communication networks have evolved from GSM network to General Packet Radio Service (GPRS) network and to present UMTS network capable of offering high-speed real-time data services. Following the evolution footsteps of mobile networks, the QoS mechanism also gradually comes to maturity in order to provide satisfying services for users based on various service features.

The GSM network is based on Circuit Switch (CS), and QoS is guaranteed once a circuit connection is established. Accordingly, QoS guarantee is quite simple and QoS parameters are basically not transferred in the GSM network.

The introduction of the IP bearer makes the GPRS network based Packet-Switched (PS) have far more complicated QoS guarantee mechanism than the GSM network. GPRS defines the



▲Figure 1. EPS bearer service architecture.

following QoS parameters: latency level, reliability, maximum data traffic, priority, average data traffic, and retransmission request. These QoS parameters are required to be transferred between UE and such network-side entities as the Serving GPRS Support Node (SGSN) and Gateway GRRS Support Node (GGSN).

End-to-end QoS hierarchical architecture is introduced in R99. This architecture involves all Network Elements (NEs), including UE, radio access network entities and core network entities, and requires consistent QoS parameter processing on different interfaces. The end-to-end QoS hierarchical architecture introduced in UMTS is a great leap forward on the road of QoS evolution for mobile communication networks[4]. Furthermore, the core network IP bearer in R99 adopts the QoS technologies defined by IETF, including Integrated Services (IntServ)/Resource Reservation Protocol (RSVP), Multi-Protocol Label Switch (MPLS), Differentiated Services (DiffServ), Traffic Engineering (TE) and constraint-based routing. R99, for the first time, clearly defines four service types with different QoS: Conversational, Streaming, Interactive and Background.

To fulfill end-to-end QoS guarantee for IP Multimedia System (IMS) services, 3GPP proposed an IP-connection based Policy Decision Function (PDF) in R5/R6[5]. In the subsequent R7, the PDF and Flow Based Charging (FBC) specified in R6 were then combined, and the Policy and Charging Control (PCC) subsystem is added between the service control layer and the access/bearer layer to implement resource admission control function.

Considering the strong bursty feature of future data services, R8 introduces EPS dedicated and default bearers to effectively minimize bearer setup latency and truly realize "Always Online" for users[6]. In addition, the complicated QoS negotiation mechanism is eliminated in the bearing processes (bearer setup/modification/deletion) in the EPS network due to the channel sharing mechanism on LTE RAN.

2 QoS Mechanism in EPS

A bearer is the basic level of QoS control granularity in R8 EPS, that is, all data traffic on the same bearer are granted identical QoS guarantee and various types of QoS guarantee are provided for different bearers. The bearer mechanism for EPS is different from that for UMTS in the following aspects:

(1) EPS bearers are used to replace Packet Data Protocol (PDP) contexts. An EPS bearer can be deemed as a logical circuit between UE and Packet Data Network Gateway (PDN-GW).

(2) A default bearer is set up according to the subscribed default QoS class in the process of a user's initial attachment to the network, that is, each UE has at least one active bearer to shorten latency taking place during service initiation.

(3) The PDP context setup procedure initiated by terminal changes into the data bearer setup procedure triggered by the network side; the triggering conditions are various, including interaction between Policy and Charging Rules Function (PCRF) entities in IMS session, Mobility Management Entity (MME) indication during initial attachment, and UE request, so as to facilitate QoS and policy control of the services initiated by the network side in the future.

(4) EPS QoS mechanism is implemented based on the QCI parameter, which can be used to supersede over a dozen of parameters in UMTS, that is, the evolved NodeB (eNodeB) can deduce all parameter features from QCI.

2.1 EPS Bearer Service Architecture

EPS establishes and adopts the bearer service with clearly defined attributes and functions from the start to the end of a service to realize end-to-end QoS. Figure 1 shows the hierarchical structure of the EPS bearer service:

The EPS bearer service architecture, as shown in Figure 1, has the similar hierarchical and region-based QoS framework with that in UMTS network, that is, the bearer service of each layer is offered through the bearer service of the layer immediately below it[7-8].

The end-to-end QoS service consists of the external bearer service and the EPS bearer service. The former is used to carry out services between the UMTS core network and external network nodes; and the latter is further subdivided into the EPS Radio Bearer (RB) service and the EPS Access Bearer (AB) service.

The EPS RB service implements the transport of EPS bearer service data units between eNodeB and UE according to requested QoS. Moreover, it supports IP header compression and user plane encryption functions, and provides mapping and multiplexing information for UEs.

EPS AB services implement the transport of EPS bearer service data units between MME and eNodeB based on requested QoS, and provide QoS guarantee for end-to-end IP traffic flow convergence[9].

2.2 Concept of EPS Bearer

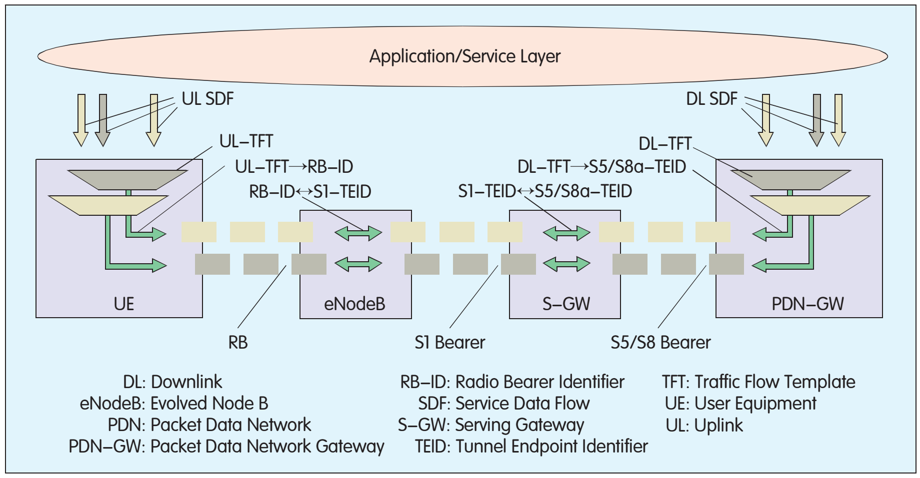
EPS defines a Packet Data Network (PDN) connection service as an IP connection between a UE and an external PDN of the Public Land Mobile Network (PLMN). The PDN connection service is able to support the transmission of one or more Service Data Flows (SDFs).

When the S5/S8 interface between a Serving Gateway (S-GW) and a PDN

Gateway (PDN–GW) is based on GPRS Tunnel Protocols (GTP), the PDN connection service in EPS will be delivered by EPS bearers. When the S5/S8 interface is based on Proxy Mobile IP (PMIP), the PDN connection service will be delivered through both EPS bearers and the IP bearers between S–GW and PDN–GW. An EPS bearer solely identifies a set of one SDF, corresponding to a set of multiple SDFs with the same bearer level QoS. Each SDF corresponds to a packet filter in the Traffic Flow Template (TFT), which means every EPS bearer is associated with an Uplink TFT (UL–TFT) of UE and a Downlink TFT (DL–TFT) of PDN–GW.

In Figure 2, the GTP–based uplink EPS bearer is taken as an example to analyze its establishment process and principles. First, a UE binds an uplink SDF to form an EPS bearer through a UL–TFT. If the UL–TFT contains more than one uplink packet filters, multiple SDFs can multiplex the same EPS bearer. Sequentially, the UE creates bindings between SDFs and RBs to set up a one–to–one mapping between UL–TFT and RBs; the eNodeB creates bindings between RBs and S1 bearers to set up a one–to–one mapping between them; and the S–GW creates bindings between S1 and S5/S8 bearers to set up a one–to–one mapping between them. Finally, the data carried over EPS, through concatenation of RB, S1 and S5/S8 bearers, enable UE to support the PDN connection service among external PDNs.

In EPS, a bearer always exists in the lifetime of the PDN connection service in order to provide UE with "Always Online" IP connections, and this bearer is called the default bearer. The QoS parameters of the default bearer are the subscription data obtained from the Home Subscriber Server (HSS), and their values can be modified through PCRF interactions or local configurations. Other EPS bearers in connection with the same PDN are called dedicated bearers, and their setup or modification can be triggered by the network side only. In addition, the bearer level QoS parameter values are always allocated by the packet core network. During the setup or modification of an EPS bearer, if the dedicated network resources related to the EPS



▲Figure 2. GTP–based EPS bearer.

bearer–associated Guaranteed Bit Rate (GBR) are allocated in a fixed mode, this EPS bearer is a GBR bearer; otherwise, it is a non–GBR bearer. Dedicated bearers can be either GBR or non–GBR bearers, but the default bearer must be a non–GBR bearer.

2.3 Bearer Level QoS Parameters

In EPS, the bearer level QoS parameters include Quality Class Identifier (QCI), Allocation and Retention Priority (ARP), GBR, Maximum Bit Rate (MBR) and Aggregated Maximum Bite Rate (AMBR). Where QCI and AMBR are newly added into EPS, while other parameters are inherited from UMTS.

Both GBR and non–GBR bearers contain QCI and ARP. As an order of magnitude, QCI refers to access point parameters used to control bearer level packet transfer, e.g. scheduling weights, admission thresholds, queue management thresholds, and link layer protocol configuration. ARP is used to determine whether to accept or reject the requests of establishing or modifying bearers in case of limited resources, and which bearer needs to be discarded in case of special resource limit (e.g., at handover). After a bearer is successfully established, ARP shall not have any impact on the bearer level packet transfer and processing.

Besides QCI and APR, every GBR bearer is also associated with GBR and MBR. GBR bearers are mainly used to carry voice, video and real–time gaming services through dedicated bearers or static scheduling. The GBR represents the bit rate that can be expected to be provided by a GBR bearer, while the MBR indicates the upper limit of GBR bearer.

Non–GBR bearers are mainly used to carry various data services. To improve bandwidth utilization, EPS introduces the concept of aggregated, and defines the AMBR. AMBR is an IP Connectivity Access Network (IP–CAN) session level QoS parameter of every PDN connection. Multiple EPS bearers for the same PDN connection share the same AMBR value. Each non–GBR bearer can potentially make use of the whole AMBR if other EPS bearers do not transfer any services. Therefore, an AMBR actually restricts the total bit rate of all the bearers sharing this AMBR.

AMBR can be classified into UE–AMBR and Access Point Name (APN)–AMBR based on different scenarios. UE–AMBR, saved in HSS as UE's subscription data, is used to indicate the UE parameter attributes regarding different types of PDN access, and transfer from HSS to MME through the network registration procedure. When a UE establishes the first data connection to a PDN, the corresponding uplink and downlink UE–AMBRs can be established through the default bearer, and sent to the eNodeB entity for control and execution. APN–AMBR is an APN subscription parameter in HSS. It restricts the aggregated maximum bit rate that can be expected to be provide by all the PDN connections in the same APN. Where, downlink APN–AMBR is controlled by the PDN–GW, and uplink

▼Table 1. Standardized QCI Characteristics

QCI	Resource Type	Priority	PDB	PLR	Typical Service
1	GBR	2	100 ms	10^{-2}	Conversational Voice
2		4	150 ms	10^{-3}	Conversational Video (Live Streaming)
3		5	300 ms	10^{-6}	Non–Conversational Video (Buffered Streaming)
4		3	50 ms	10^{-3}	Real–Time Gaming
5	Non–GBR	1	100 ms	10^{-6}	IMS Signaling
6		7	100 ms	10^{-3}	Voice, Video (Live Streaming), and Interactive Gaming
7		6	300 ms	10^{-6}	Video (Buffered Streaming) and TCP–Based Services (e.g. WWW, E–mail, Chatting, Ftp, P2P File Sharing and Progressive Video)
8		8			
9		9			

GBR: Guaranteed Bite Rate P2P: Peer–to–Peer QCI: QoS Class Identifier
IMS: IP Multimedia Subsystem PDB: Packet Delay Budget TCP: Transmission Control Protocol
Non–GBR: Non–Guaranteed Bite Rate PLR: Packet Loss Rate

APN–AMBR is controlled by the UE or PDN–GW.

2.4 Standardized QCI Characteristics

As one of the most important QoS parameters for EPS bearer, QCI represents the QoS features that EPS should offer for the SDF. Each SDF is associated with only one QCI. If more than one SDFs related to the same IP–CAN session have identical QCI and ARP, they can be considered as one individual service set, which is called an SDF set. Table 1 lists standardized QCI characteristics defined in EPS. Operators may pre–configure all QCI Characteristics in eNodeB based on their actual conditions. These parameters determine the allocation of bearer resources on the RAN side.

The standardized QCI characteristics in Table 1 describe the packet transport characteristics of one SDF set:

(1) Resource Type

It determines whether the dedicated network resources related to service/bearer GBR can be constantly allocated. The GBR SDF set requires dynamic PCC, while the non–GBR SDF set may only adopt static PCC.

(2) Priority

It is used to differentiate SDF connections of identical UE or those of different UE. Each QCI is associated with one priority; 1 refers to the highest priority.

(3) Packet Delay Budget (PDB)

PDB refers to possible latency of data packets transported between UE and PDN–GW. It is used to support configurations of time sequence and link layer functions. PDB is identical in both uplink and downlink for the same QCI.

(4) Packet Loss Rate (PLR)

PLR is defined as the rate of SDUs not successfully transported to the upper layer to the total number of SDUs processed by the link layer of the transmitting end. Therefore, PLR actually reflects the upper threshold of data packet loss rate in non–congested cases. PLR is also identical in both uplink and downlink for the same QCI.

3 Mapping Between EPS QCI and UMTS QoS Parameters

The evolution from UMTS to EPS is a step–by–step course. LTE networks may exist as hot spots during its primary commercialization, so LTE network coverage will be smaller than UMTS coverage. In this case, it is possible for UE to perform frequently interoperations, such as handover and cell reselection, between UMTS and EPS.

Since EPS and UMTS adopt different QoS mechanisms, most attention should be paid to the mapping relation between QCI parameters of EPS bearers and QoS parameters of Pre–R8 PDP contexts.

The parameter mapping between these two sets of QoS mechanism must comply with the following rules:

(1) One EPS bearer should have a one–to–one mapping relation with one PDP context.

(2) ARP, an EPS bearer parameter, should have a one–to–one mapping relation with ARP of the Pre–R8 bearer. Different from UMTS, EPS allows two or more PDP contexts to have different ARP values.

(3) GBR and MBR of GBR–based EPS should have a one–to–one mapping relation with those of PDP contexts in Pre–R8 "conversational" or "streaming" class services.

(4) In the case of E–UTRAN–to–UTRAN handover, the latency in transport and SDU error rate in Pre–R8 system are respectively deduced from PDB and PLR in EPS, while in UTRAN–to–E–UTRAN handover, these two parameters in Pre–R8 system are ignored.

Table 2 lists the one–to–one mapping relation between EPS QCIs and QoS parameters in Pre–R8 system including traffic class, traffic handling priority, signaling indication, and source

▼Table 2. Mapping between EPS QCIs and UMTS QoS parameters

QCI	Traffic Class	Traffic Handling Priority	Signaling Indication	Source Statistics Descriptor
1	Conversational Class	N/A	N/A	Speech
2	Conversational Class	N/A	N/A	Unknown
3	Streaming Class	N/A	N/A	Unknown
4	Streaming Class	N/A	N/A	Unknown
5	Interactive Class	1	Yes	N/A
6	Interactive Class	1	No	N/A
7	Interactive Class	2	No	N/A
8	Interactive Class	3	No	N/A
9	Background Class	N/A	N/A	N/A

EPS: Evolved Packet System QCI: QoS Class Identifier UMTS: Universal Mobile Telecommunications System
N/A: Not Available QoS: Quality of Service

statistics descriptor.

4 Conclusion

With the acceleration of migration to full-IP network, the EPS proposed by the LTE/SAE project is supporting full IP networks, that is, providing truly pure packet system. Furthermore, R8 adds requirements for flat architecture, shorter connection setup latency and support of multiple access technologies, which introduces a lot of new features into EPS QoS mechanism. This article elaborates on the EPS bearer, bearer service architecture as well as related QoS parameters and characteristics, contributing to understanding the background of implementations of EPS applications.

This article also gives an elementary description of the mapping between EPS QCIs and UMTS QoS parameters in the event of UE handover between UTRAN and E-UTRAN. However, 3GPP only brings forward a preliminary concept at present, which calls for further research to address implementation details, for example, the definition of the entity for implementing QoS mapping translation, the processing principle of IPv4/IPv6 dual-stack bearer, the AMBR implementation during handover, and PCRF's selection of QCIs during handover. And some issues may even have to be addressed in R9. Moreover, it is worthwhile to further research how to ensure QoS mapping between non-3GPP and EPS networks.

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Biographies

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Roundup

ZTE Announces First EV-DO Revision B on CDMA2000 System

ZTE Corporation (ZTE), a leading global provider of telecommunications equipment and network solutions, announced, on February 24, 2009, another technological breakthrough by achieving the world's first EV-DO Revision B (Rev.B) VoIP Call on its CDMA2000 system, marking the first time in the industry that a CDMA vendor achieves an impressive 9.3 Mb/s download rate and 5.4 Mb/s upload rate. This remarkable feat once again demonstrates ZTE's leading position in the CDMA industry.

The company has completed the first stage of achieving EV-DO Rev.B and adopted 3-carrier bundling technology, with each carrier having a bandwidth of 1.25 MHz. Compared with mature commercial EV-DO Rev.A, what ZTE's EV-DO Rev.B does is only upgrading EV-DO Rev.A's software, with no additional hardware equipment required. Both ZTE's EV-DO Rev.A and Rev.B adopt identical baseband chipset.

ZTE plans to commercialize its EV-DO Rev.B system in Q3 2009, reaffirming its leading position in EV-DO technology development. In future, EV-DO Rev.B can bundle up to a maximum of 15 carriers, with a download rate of 73.5 Mb/s and an upload rate of 27 Mb/s. The unique features of EV-DO Rev.B include allocating flexible bandwidth and offering better QoS, hence enhancing user experience.

There are now more than 105 million EV-DO users worldwide. To date, ZTE has established 70 EV-DO networks in more than 60 countries, including China, the United States, Czech, Poland, India and Indonesia.

ZTE has been creating waves in the global CDMA market with global CDMA subscriber capacity reaching 200 million. It ranks first in terms of global base station shipment as well as taking the number one spot in China's CDMA sector by virtue of having one third of the domestic market share. The continuous success of ZTE in the CDMA market is attributed to a corporate policy of constantly introducing technical innovation, offering low TCO for its All-IP CDMA2000 solutions, and quick customer response.