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A Survey on Optimized QOS Provisioning for NGMN

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ABSTRACT: In this review paper, basic mechanisms of providing QOS and its implementation over the long-term evolution (LTE) mobile network are introduced. Explosive growth in wireless subscribers, increasing deployment of multiplay applications for mobile platforms and demand for superior user experience are driving the need for quality of service (QoS) in mobile broadband networks. Long term evolution (LTE) is the next generation wireless communication network which is an all-IP based system. Nowadays, more and more kinds of services are being transmitted on wireless communication network with different requirements. So, to satisfy the quality of service (QoS) of multi-service requirements is one of the key challenges that need to be dealt in the LTE system.

KEYWORDS: LTE; QoS

I. INTRODUCTION

Ongoing world-wide adoption of mobile devices has created an unprecedented demand for access to e-commerce, social media and entertainment applications anywhere, at any time. This has not only increased the amount of mobile broadband data transported by the carrier networks but also transformed its composition – mobile traffic that was traditionally voice-only is now dominated by video and data due to applications such as live video streaming, Netflix, Facebook, Twitter and mobile browsing. This trend continues to increase as the variety and number of applications and services increase and the subscriber base grows. Heterogeneous, multimedia traffic is characterized by different bandwidth, latency and jitter requirements. Large-scale events such as major sporting events and natural disasters add another level of complexity to the mobile traffic. The next-generation carrier networks must incorporate a high degree of intelligence to transport different types of traffic to provide an excellent end-user experience, while maximizing revenue per user. This can be achieved through QoS techniques which enable these networks to isolate and manage traffic based on a number of attributes such as traffic types, their relative priorities, and source and destination. As the wireless carriers deploy more and more LTE and LTE-Advanced (LTE-A) networks, comprehensive QoS schemes must be implemented to support next-generation services and applications on LTE networks. The LTE technology, which is based on the ubiquitous and inexpensive IP/Ethernet protocols, leverages the IP QoS principles and defines a comprehensive QoS framework to address traffic management aspects of next-generation LTE networks.

With the rapid development of mobile communication technologies, the Third Generation Partnership Project (3GPP) has introduced LTE specifications as the next cellular networks to satisfy the ever-growing demand for mobile communication requirements. In 3GPP release 8, LTE provides high peak data rates of 100Mb/s on the downlink and 50Mb/s on the uplink for 20MHZ bandwidth. In order to improve spectral efficiency, LTE adopted Orthogonal Frequency Division Multiple Access (OFDMA) as the downlink access technology and adopted Single-Carrier Frequency Division Multiple Access (SC-FDMA) for uplinks [1]. With the growing usage of the mobile equipment, it is clear that more and more services will be transmitted through wireless networks, such as video application with different resolution, conversational voice, real time game and FTP.

These growing applications bring some problems for wireless networks since those services generally have different QoS requirements. For example, besides the huge bandwidth requirement, the real-time video needs some other QoS requirements: such as delay, jitter and data rate. If a video packet does not arrive within delay constraint, it will be considered lost. Video packet loss incurs distortion[2]. Usually, FTP service has no strictly QoS constraints. In 3GPP

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release 8, we can see the evolved packet system (EPS). The EPS consists of evolved packet core (EPC) and evolved universal terrestrial radio access (E-UTRAN). It is also referred to as LTE [3]. The EPC consists of mobile management entity (MME)/serving gateway (S-GW). The only node in LTE is the evolved node B (eNB), so called base station. The eNBs are connected with each other through X2 interface distributed the network coverage area, and with EPC through S1 interface. An eNB may be served by more than one MME. LTE has improved and enhanced 3G air interface. In LTE air interface, user plane protocol stack is in charge for LTE downlink data transmission.

II. FACTORS DRIVING THE NEED FOR QOS IN WIRELESS BROADBAND NETWORKS

Mobile broadband subscriptions reached over 1.4 billion in 2012 and it is projected to reach 6.5 billion by 20181. Of this user base, the number of LTE subscribers is projected to reach over 1.1 billion by 2016[9], as shown in **Figure 1**. Correspondingly, the demand for user-experience and differentiated service levels continues to increase. In order to retain users and maximize average revenue per user (ARPU), mobile carriers should offer differentiated quality service packages based on user needs. Therefore, QoS is a fundamental component of the LTE network for satisfactory delivery of Internet applications to subscribers and management of network resources. To achieve this, the LTE network elements must incorporate techniques to manage diverse traffic characteristics of the applications and services.

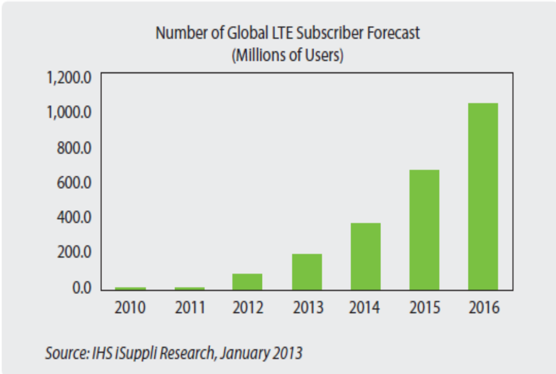

Figure 1: LTE Subscriber Forecast

The major market drivers that are driving the need for comprehensive QoS in today's wireless networks are listed below.

A. Services and applications

a. Voice over Internet Protocol (VoIP) over mobile

VoIP is a technology for delivery of voice communication over IP networks such as the Internet. Voice traffic channels require low bandwidth, but to support quality live communication, packets should be transmitted with minimum latency and jitter. Packets associated with voice traffic must be given very high priority and assigned to a guaranteed bandwidth channel to ensure the packet delivery within an acceptable delay limit. Even within voice traffic, differentiated, high-priority service must be provided for important calls such as emergency (911) calls (i.e., based on destination) and critical communication among emergency service personnel (i.e., based on source and/or destination).

b. Video streaming

Real-time, user-generated and on-demand video streaming applications such as YouTube and Hulu (as shown in **Figure 1**) are a huge factor requiring QoS in carrier networks. For quality voice and video streaming, the network has to satisfy high bandwidth and stringent latency requirements. Streaming can be person-to-person, real-time video sharing or content-to-person, and each has different QoS needs[10]. For example, real-time video sharing has far more stringent latency requirements than content-to-person streaming. Real-time video sharing also requires that bandwidth on both uplink and downlink bandwidths is high. The network should be able to provide the QoS based on the type of streaming application.

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c. **Content download**

A significant amount of mobile bandwidth is used for downloading movies, pictures and music. Unlike real-time video, this can be a batch-mode transaction. The network needs to use best-effort scheduling for the transaction and make sure that lost packets are retransmitted using protocols such as TCP.

d. **Miscellaneous services and applications**

There are hundreds of gaming and social media applications available for mobile platforms that require differentiated QoS[11]. Multiplayer gaming requires fast, real-time responses while Facebook communication can be best-effort but needs sufficient bandwidth for uploading a video or photo.

B. Events causing mobile traffic surge

QoS is critical to effectively manage peak-demand scenarios when a large number of users access the same application. Common examples are prescheduled events such as sports or unscheduled events happening around the globe. For example, during the men's cycling road race at the 2012 Summer Olympics, the unexpected amount of viewer mobile activity (tweets, live streaming, etc.) flooded the mobile network, preventing timely updates to TV broadcasters. Hurricane Sandy in 2012 is another example of an unexpected event. It is critical that the wireless network instantaneously adapts to support these event-specific traffic bandwidth and latency requirements and support special features including tracing enablement of emergency traffic such as 911 calls[12].

C. Monetization of mobile networks

In addition to the above-mentioned services, monetization is a key factor that is driving the need for QoS in mobile networks. Present-day mobile operators face enormous pressure to maximize their return on investment (ROI)[13] while keeping up with the rapid variations in application characteristics, and diversity in subscriber needs and preferences. They need to implement techniques to increase the ARPU and utilize the deployed bandwidth more efficiently.

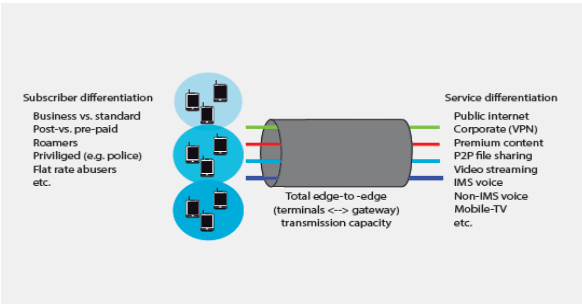

Figure 2: Service and Subscriber Differentiation

To increase ARPU, the network operator should differentiate its subscribers based on their needs and offer differentiated or even user-customizable service packages with specific Service Level Agreements (SLAs)[14] as shown in **Figure 2**. LTE SLAs need to incorporate latency-related guarantees to establish pricing tiers based on end-user experience. Optimum utilization of bandwidth requires the ability to prioritize subscribers and services without over-provisioning for worst-case traffic scenarios.

III. Overview of QoS in LTE networks

QoS is a framework of open standards widely used in communications networks to ensure priority, performance and guaranteed throughput. QoS enables network managers to isolate traffic into flows based on attributes such as traffic type (voice, video and control) or application needs (throughput, latency and jitter) and transport them accordingly. QoS addresses the subscriber SLAs by allocating dedicated bandwidth for critical users and applications, providing deterministic jitter and latency (required by real-time applications), improving network congestion and smoothening traffic flows. Let us discuss how these QoS techniques can be implemented in the LTE networks.

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A. LTE network architecture overview

Figure 3 illustrates a typical LTE network. Unlike other mobile broadband technologies such as GSM, which are circuit-switched, LTE is based on IP. It supports a variety of legacy access technologies including 2G GSM, 3G UMTS, WCDMA, CDMA2000 and Wi-Fi[15]. Different services are carried over the radio interface to the evolved base station, i.e., eNodeB (ENB), which connects with radio user equipment (UE) on one side and with the core network, i.e., evolved packet core (EPC), on the other side. EPC is connected to the external IP networks such as IP multimedia core network systems (IMS). LTE architecture is flat since the traditional control functions are collapsed into EPC and the radio network controller (RNC) functions (in a 3G network) are incorporated into the LTE eNodeB. This simplifies the network infrastructure, reduces the number of network nodes by removing multiple hops and protocol translations, and makes the network fast and cost-effective. LTE architecture enables peer-to-peer (eNodeB to eNodeB) connections, which lowers latency and improves round-trip delay times. LTE offers throughput rates beyond 100Mbit/s and short latency of around 20 ms. To support this complex functionality, more intelligence must be built into the eNodeB than in its predecessor (3G NodeB). LTE has the concept of user-plane (user applications) and control-plane (network control traffic). Comprehensive QoS is achieved by applying QoS techniques to the user-plane as well as the control-plane in the LTE network. Application of the QoS concepts to the LTE network is outlined below.

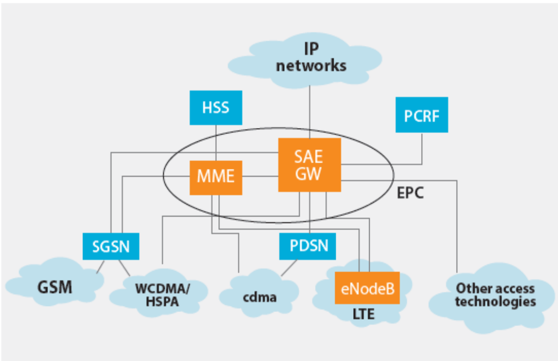

Figure 3: Simplified View of LTE Network Architecture

B. LTE QoS concept

The 3rd Generation Partnership Project (3GPP) is a standards body that develops standard specifications for telecommunications networks to enable multivendor interoperability and enable roaming capabilities. LTE networks use IP over Ethernet transport, which leverages DiffServ for traffic management. 3GPP has defined the QoS framework for LTE networks, based on the EPS bearer model.

C. Bearer model

A bearer is a traffic separation element that enables differentiated treatment of traffic based on its QoS requirements and provides a logical path between a UE and gateway[16]. All flows mapped to a single bearer receive the same packet-forwarding treatment (e.g., scheduling policy, queue management policy, rate shaping policy, link layer configuration, etc.) between UE and the gateway.

A bearer can be classified based on its QoS requirements as default or dedicated bearer, as shown in **Figure 4**. When a mobile device first attaches to an LTE network, it will be assigned a default bearer, which will be associated with the UE's IP address. Default bearer does not have bit rate guarantee and offers only best-effort service. Dedicated bearer acts as another bearer on top of the default bearer and provides a dedicated tunnel to give appropriate treatment to specific services. It will be associated with the IP address of the corresponding default bearer.

A dedicated bearer is further classified as a guaranteed bit rate (GBR) EPS bearer or a non-GBR bearer. GBR has dedicated network resources and is needed for real-time voice and video applications. A non-GBR bearer does not have dedicated bandwidth and is used for best-effort traffic such as file downloads.

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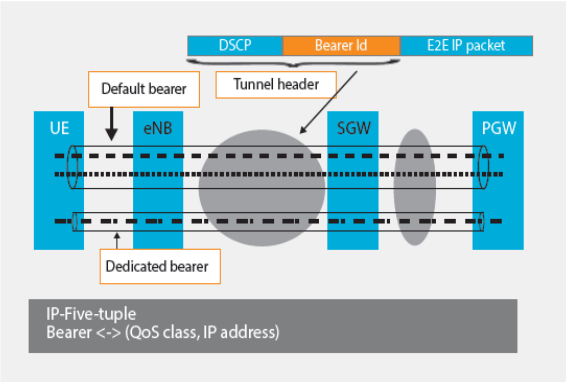

Figure 4: Default and Dedicated Bearers

D. LTE QoS parameters

Allocation and retention priority (ARP): ARP specifies the forwarding treatment for the control-plane traffic that the bearers receive. ARP enables bearer establishment or modification and enables a connection setup or release. For example, ARP can be used by the EPS to decide which bearer should be released during resource limitations or traffic congestion.

Maximum bit rate (MBR): MBR is applicable only for real-time services and is defined for GBR bearers. MBR is the bit rate that the traffic on the bearer may not exceed.

Guaranteed bit rate (GBR): GBR, similar to MBR, is defined for GBR bearers only. It specifies the bit rate that the network guarantees (e.g., through the use of an admission control function) for that bearer. In 3GPP Release 8 and beyond, the MBR must be set equal to the GBR, that is, the guaranteed rate is also the maximum rate that is allowed by the system.

E. Policy control and assignment of QoS rules to flows

UE always has a default bearer, but the default bearer may not be sufficient to support multiplay services. The network operator controls the mapping of packet flows onto the dedicated bearer and determines the QoS level of the dedicated bearer through policies. These policies are provisioned into the network policy and charging resource function (PCRF), also known as the policy controller, implemented in the PDN gateway. The policy controller typically filters packet flows using these five parameters: source IP address, destination IP address, source port number , destination port number, protocol identification (i.e., TCP or UDP) – referred to as IP five-tuple[17]. PCRF determines the QoS requirements based on three criteria:

- Application requirement
- Subscription information
- Policy of the operator

Based on the decision made by PCRF, a dedicated EPS bearer may be established, as shown in **Figure 6.**

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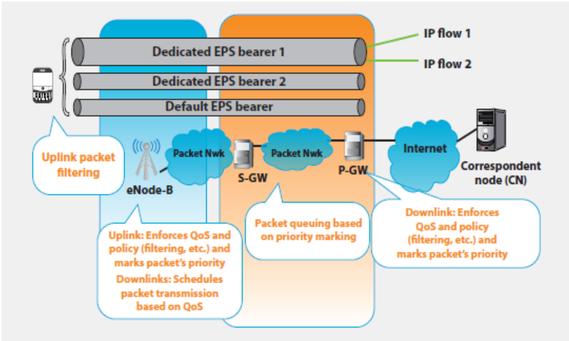

Figure 5: QoS Assignment on EPS Bearers

Each IP packet entering the system is provided with a tunnel header (as shown in **Figure 4**) which contains the bearer identifier so that the network nodes can treat it with appropriate QoS. These QoS parameters for user-plane and control-plane are preserved in the LTE transport network using appropriate transport layer protocols. **Figure 6** below illustrates the protocol stack implemented in the LTE transport network. For example, the GTP protocol between eNodeB and S-GW is transferred over UDP/IP as shown in the figure. An all-IP-based packet network is used between radio access network, core network and within EPC[19].

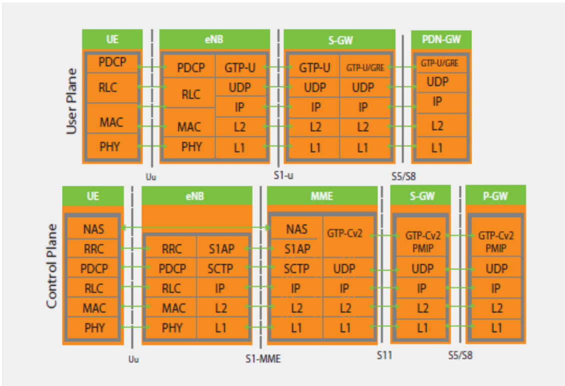

Figure 6: LTE User-Plane and Control-Plane Protocol Stacks

IV. PSEUDO CODE IMPLEMENTATION OF QOS IN LTE NETWORKS

This section will outline the functions that the network elements need to implement for achieving end-to-end QoS in LTE networks.

QoS identification and marking: IP packets belonging to a flow are identified and marked through classification of the packet. This is necessary for coordinating end-to-end QoS. Common methods of identifying flows include access control lists and policy-based routing using routing tables. Marking ensures the flow characteristics are carried through portions or the entire network.

Policing: Policing is used to make sure that a flow does not exceed the agreed-upon configured rate. The policing mechanisms are required to guarantee a minimum share of service to all types of traffic characterized by average/sustained throughput, peak throughput, etc. Non-compliant traffic is either delayed within limits or dropped based on the drop policies. Single rate two color marker (srTCM) and two rate three color marker (trTCM) are examples of policing algorithms[20].

Traffic management and shaping: Traffic management ensures that bandwidth is available to pass through certain types of traffic such as mission-critical traffic. It manages the overall bandwidth so that the negotiated bandwidth needs for different services are satisfied. For example, it ensures guaranteed bandwidth for VoIP and control traffic, minimum guaranteed bandwidth for file transfers, emails, etc. Traffic management algorithms such as weighted random early

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detection (WRED) and random early detection (RED) are used for congestion monitoring. Shaping is used for limiting the bandwidth of a flow and avoiding overflow situations.

Administration of QoS policy and management: These are realized via provisioning and accounting algorithms in the operations, administration, and management domain.

Queuing and scheduling: Scheduling ensures that important traffic is not dropped in the event of heavy oversubscription. Since IP traffic is usually carried over Ethernet in LTE networks, the DiffServ protocol feature of Ethernet is used to provide QoS. The DiffServ standard provides for up to six queues and the IP traffic will be mapped to one of the DiffServ classes, as shown in **Figure 7**. DiffServ class can also be determined by the DSCP field in the IP layer in the tunnel header, as shown earlier in **Figure 3**. Scheduling is based on algorithms such as strict priority (SP) without starvation avoidance, weighted round robin (WRR), weighted fair queuing (WFQ) and deficit weighted round robin (DWRR) or smoothed deficit weighted round robin (SDWRR)[26].

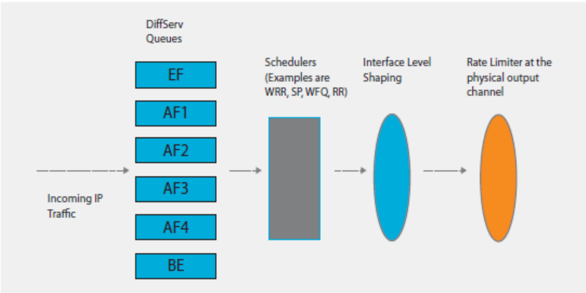

Figure 7: DiffServ 6 Class of Services

Intelligent SoC platforms are a critical component in an LTE network infrastructure to achieve these QoS functions in a cost-effective manner.

V. CONCLUSION

As broadband mobile platforms and services proliferate, wireless carrier networks are required to transport a wide variety of applications with diverse traffic characteristics. Customer success for network operators will be determined by their ability to deliver these applications with good quality of user experience. Operators must deploy innovative service models to maximize their ROI and operating margins. To address these challenging objectives, mobile networks with comprehensive QoS capabilities must be deployed. IP-based LTE networks that provide increased bandwidths and improved latency are becoming a popular choice of mobile network infrastructure. Comprehensive QoS, leveraging the IP QoS concepts and standards such as DiffServ, can be achieved in LTE networks. Implementation of LTE QoS in the network elements requires a state-of-the-art silicon and software platform, such as the LSI Axxia communication processor, which holistically supports the functionalities of the LTE QoS framework. Axxia is a multicore processor solution which implements a wide range of packet processing and traffic management functions such as scheduling, shaping, policing, and queue management and packet classifications. It provides high performance by implementing function-specific hardware accelerators and offers flexibility through user-programmable options to achieve comprehensive QoS in LTE networks.

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