Mapping Quality of Service Classes between UMTS, WiMAX and DiffServ/MPLS Networks

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ABSTRACT: *One of the major issues for Heterogeneous Wireless Access Networks (HWAN) or Next Generation IP/MPLS Wireless Network (NGWN) is integrating the different wireless access technologies (e.g. GSM, GPRS, EDGE, UMTS, WiMAX, WLAN, etc…) into a common platform. This integration should transparently provide mobile users unified and continuous services, including seamless handoff and real-time support of QoS. However, a real-time support of End-to-End QoS, in HWAN, is a challenging task that requires mapping of related messages as well as their associated attributes and parameters across all networks. In this paper, we present a novel method for mapping these messages and their attributes across UMTS, WiMAX and IP-Diffserv/MPLS networks.*

Keywords: 4G, QoS, UMTS, WiMAX, IP, DiffServ, MPLS

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1. Introduction

Over the years, different wireless networks (e.g. GSM, GPRS, EDGE, UMTS, HSPA, LTE, WiFi, WiMAX, cdma, cdma2000, etc…) have been independently designed and deployed. Even more, these networks have completely different radio interfaces, with varying access, coding and modulation techniques. Additionally, they have also adopted different concepts and protocols in their core networks. However, integrating all these networks, in what is called Heterogeneous Wireless Access Network (HWAN), also known as Next Generation Wireless Network (NGWN) and referred to as 4th Generation Network (4G); has lately become a must. Though it should enable the mobile users to always have the best and cheapest services, this integration have many major challenges. In fact, and due to different radio access characteristics with diversified available and allocated spectrums and bandwidths, different access, modulation and coding techniques, varying bit rates and fault tolerant levels, and dissimilar underlying protocols, some of these challenges are mobility management, seamless handoff, integrated security, integrated billing and real-time End-to-End QoS support [1]. Another major challenge is to connect together, either directly or indirectly through an IP-based network, all these networks.

The importance of such integration is that it will enable the mobile users to have, anywhere and at any time, the best technical service, at the lowest price. This will be achieved by having seamless connections of the mobile devices to the best radio access network that provides the best service at the lowest costs. It should also allow seamless handoff and real-time security integration as well as End-to-End QoS negotiation across all networks including the IP-Core network.

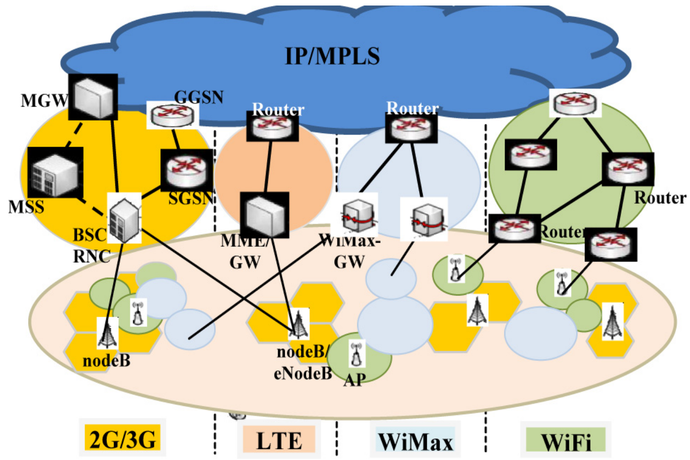

Figure 1. Heterogeneous Wireless Access Network (HWAN)

2. 4G Network Architecture

Position Heterogeneous Wireless Access Networks (HWAN), as illustrated in figure 1, alongside with the terminals, should allow multimode radio access capabilities that offer the mobile users simultaneous and seamless multiple radio connections. However, despite the fact that the terminals are capable to adapt to different radio interfaces and are able to establish multiple connections at the same time, maintaining the service continuity and the offered QoS is a complex issue that current methods do not support. Therefore, in addition to being connected to multiple radio networks, mobile devices must be able to seamlessly handoff as well as negotiate the varying security and QoS parameters between the networks. This process must be accomplished regardless the diversity of underlying protocols, mobility management and routing techniques and standards [2]. To achieve this seamless multimode radio connectivity, the different radio access technologies must first be interconnected. To establish such interconnection, two main approaches have been considered: Integrated networks or tight coupling and interworking networks or loose coupling.

In tight coupling, the different radio access interfaces are directly coupled to either the radio access network (RAN) or the core network (CN) [3]. Whereas, in loose coupling, interconnections are achieved by using edge gateways to connect the different wireless interfaces. Additionally, through IP-based networks, signaling and data are exchanged via these gateways [4, 5]. For example, the European Telecommunications Standards Institute (ETSI) has referred to these two methods –loose coupling and tight coupling– for interconnecting WLANs with cellular networks [6]. Alternatively, these two methods are also addressed in the 3GPP specifications as respectively Generic Access Network (GAN) and I-WLAN [11]. In the Tight coupling approach, the WLAN and WiMAX, as they are directly connected to the cellular core network, appear as 3G radio access networks. This interconnection can be considered as tight coupling when the connection is made at the core network level, through SGSN or GGSN or very tight coupling if the connection is made at the radio access network level though RNC [9, 10].

In all cases, all data traffic goes through the cellular core network before reaching the external Packet Data Networks (PDNs) [8]. In loose coupling, there are no direct connections between the radio access networks. As illustrated in figure2, WLAN and WiMAX are connected to the cellular core network through gateways. As the different access wireless networks are independent of each other, they provide a flexible framework. However, some of the major disadvantages of such framework are the mobility management and the support of End-to-End QoS, where the signaling messages may traverse a long path causing relatively high latency for handoff as well as for the QoS mapping [5].

3. Quality of Services

3.1 International Telecommunication Union – ITU

A model for multimedia Quality of Service categories from end-user viewpoint is defined by the ITU [7, 13]. By considering user

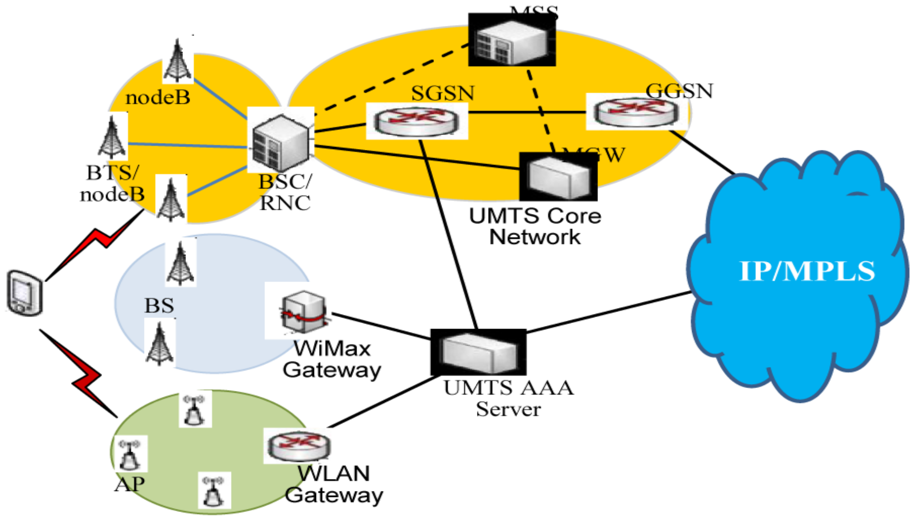

Figure 2. Loose Coupling Integration

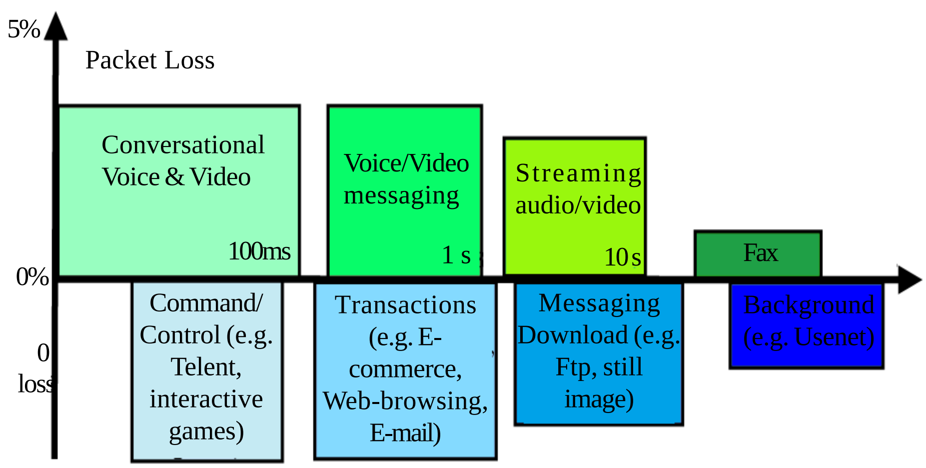

Figure 3. Mapping of user-centric QoS Requirements

expectations for a range of multimedia applications, eight distinct categories have been identified. This identification was based on tolerance to key parameters such as delay and information loss as shown in figure 3. Performance targets, such as data rates and KPIs that can be used to measure the QoS, are also defined by the ITU for audio, video and data applications. Since these performance targets, data rates and KPIs are applications' specifics, they can be applied to any type of networks, including radio access, connectivity or backbone networks, and therefore can be used, as reference, for End-to- End QoS, in 4G mobile networks.

3.2 UMTS

Four classes of services, Conversational, Streaming, Interactive and Background, have been defined in UMTS with different QOS parameters and attributes used for prioritization, scheduling and queuing. Some of the most important attributes are Maximum Bit Rate (MBR), Guaranteed Bit Rate (GBR), Traffic Handling Priority (THP) and Allocation/Retention Priority (ARP) that may be used, within the same class, for further differentiation as detailed in Table 1.

3.3 WiMAX

Similarly five QoS categories, named service flows, have been defined in WiMAX. A service flow refers to unidirectional flow of packets that is associated with a particular QoS. These five services flows as defined in [14] are listed in Table 2.

Traffic Class	ARP	THP	MBR	GBR
Conversational	Yes	No	Yes	Yes
Streaming	Yes	No	Yes	Yes
Interactive	Yes	Yes	Yes	No
Background	Yes	No	Yes	No

Table 1. UMTS Class of Services

QoS Category	Applications	QoS Specifications
UGS Unsolicited Grant Service	VoIP, T1/E1, ATM CBR	Maximum Sustained Rate Maximum Latency Tolerance Jitter Tolerance
rtPS Real-Time Polling Service	Streaming Audio or Video	Minimum Reserved Rate Maximum Sustained Rate Maximum Latency Tolerance Traffic Priority
nrtPS Non-Real-Time Polling Service	File Transfer Protocol (FTP)	Minimum Reserved Rate Maximum Sustained Rate Traffic Priority
BES Best-Effort Service	Data Transfer, Web Browsing, etc.	Maximum Sustained Rate Traffic Priority
ErtPS Extended Real Time Polling Service	Voice with Activity Detection (VoIP)	Minimum Reserved Rate Maximum Sustained Rate Maximum Latency Tolerance Jitter Tolerance Traffic Priority

Table 2. WiMAX Class of Services

3.4 DiffServ-IP/MPL

The Internet protocol (IP) is a connectionless best effort protocol; therefore it doesn’t support QoS. Consequently, Integrated Service (IntServ) and Differentiated Service (DiffServ) have been defined as the two strategies to guarantee QoS in IP networks.

IntServ is based on admission control and resource reservation/allocation approach. Through its two main classes of services –Guaranteed Services class (GS) and Controlled-Load Service class (CLS)– and by using specific signaling protocols, it is intended to manage and schedule resources on per flow [15, 23]. However, the main limitation of IntServ is its limited scalability.

To overcome the scalability problem issue by IntServ, the differentiated service (DiffServ) has been proposed [15]. In DiffServ domain, Differential Service Code Point (DSCP) and per-hope behavior (PHB) have been defined to classify different classes of service. The DiffServ Domain consists of a contiguous set of nodes that guarantee the requirements of a specific service level agreement (SLA). Depending on the value of the DSCP as inserted in its header, a packet is identified to a particular class or Behavior Aggregate (BA). Consequently, packets are forwarded within the DiffServ domain in accordance to their DSCPs. Additionally, based on the Per-Hop-Behavior (PHB) field, the forwarding is determined on per-hob basis according to the following three types:

1. **Default PHB:** In this type of PHB, as no resources are reserved, the QoS levels and network performance are not guaranteed [16];

2. **Expedited Forwarding (EF) PHB:** it is used to support real time services, such as VoIP applications, that require low-delay, low-loss and guaranteed bandwidth [17];

3. **The Assured Forwarding (AF) PHB:** with four parameters (AF1x, AF2x, AF3x, AF4x), it identifies a group of classes that are used to support services with guaranteed bandwidth. Each class has a certain amount of buffer space and bandwidth. Additionally, within each AF class, the packets are further classified by one of three drop-precedence value [18].

Recently, one of the key approaches that have been widely used to support QoS in IP-based networks is Multi-Protocol Label Switching (MPLS). With MPLS, the traditional routing methods, which are mainly based on destination address, has been changed to a switching techniques based on labels. Though label switching approaches have nothing to do with QoS categories, they can have important impacts on improving QoS performance in reducing the latency and jitter for sensitive traffic. In MPLS network, a 32-bit label, named MPLS header or shim header, is created at the ingress Label Switching Router (LSR) and used to switch packets within the MPLS domain [19]. Additionally, MPLS can offer additional benefits through its Traffic Engineering (TE) method, which controls the amount of congestion that might be experienced within the network.

Finally, combining the quality of service provided by DiffServ and MPLS would offer a better support for QoS. However, creating a DiffServ/MPLS-based network would require a mapping strategy between DiffServ and MPLS. As the packets arriving at the ingress router in DiffServ network are classified into behavior aggregates (BAs) and marked with specific DSCPs, BA groups should be similarly treated in respect to scheduling [20]. Consequently, the DiffServ BAs are mapped onto the Label Switching Paths (LSPs) within the MPLS domain.

The mapping and updating procedures depend on the 3-bits EXP field inside the MPLS shim header [21, 22]. To use EXP for PHB selection, two mechanisms have been identified: EXP-inferred-PSC LSPs (E- LSPs) and Label-only-inferred-PSC LSPs (L-LSP). While the 20-bit MPLS labels are still used to make forwarding decisions, EXP-inferred-PSC LSPs method uses the EXP to encode the PHBs and determine how the labeled packet is served. On the other hand, according to the method of Label-only-inferred-LSP, the packets, carried by the same LSP, belong to the same BA. Through this approach, the scheduling of the packet is inferred from the MPLS label, while the packet discarding (drop precedence) is bound to the EXP field.

4. Mapping Strategies

To support End-to-End QoS over loose coupling heterogeneous network, QoS gateways shall be used. These gateways should connect the different wireless systems (WLAN, WiMAX, GSM/UMTS, LTE, etc...) together. The interconnections between these gateways are, most probably, achieved through an IP-based network. This IP network might be supported by DiffServ, MPLS or both of them. Additionally, in order to support an End-to-End QoS, these gateways must provide mapping mechanisms for the different corresponding QoS classes and categories as well as their messages, attributes and parameters. The QoS between a wireless network and the underlying IP/MPLS network is accomplished by applying a process of two levels of mapping. The first level is applied between QoS related to wireless systems and DiffServ classes, whereas the second one is performed on DiffServ-MPLS level. However, in a loose coupling architecture, achieving an End-to-End QoS between 3G/UMTS and WiMAX consists of applying the above process twice, the first time between UMTS and IP/MPLS at the ingress gateway of MPLS network and the second time between the IP/MPLS and WiMAX at the egress gateway.

4.1 WiMAX/IP-DiffServ Mapping

As UGS class of WiMAX supports services with minimum delay and jitter requirements, yet requiring a higher priority than other types of traffics, it is recommended to map this class to the EF class of DiffServ. On the other hand, the rtPS class of WiMAX supports real-time applications with loss tolerant and traffic priorities, so it is recommended to map it to AF3 class of DiffServ [12].

Since nrtPS class supports non real time applications with higher delay tolerance, AF1 or AF2 of DiffServ are the classes that better match it. As extended rtPS class (ertPS) is a combination of UGS and rtPS class, it is recommended to map it to a higher AF class such as AF4. Finally, the best-effort (BE) class could be mapped into the Default (DF) class of DiffServ or lower AF class with high drop precedence. The mapping between WiMAX classes of service and DiffServ classes is summarized in Table 3.

4.2 UMTS/IP-DiffServ Mapping

The Conversational Class, in UMTS, mainly handles real-time applications that require low delay and jitter with guaranteed bit rate; therefore it is recommended to map it into EF or AF41 of DiffServ. The selection between EF and AF4 mainly depends on values of the delay, jitter and bit rate required by the application. Similarly, Streaming Class of UMTS can be mapped to AF3 of DiffServ. Alternatively, Interactive Class that mainly has 2 types of applications –Web Browsing and File Transfer– may be mapped into AF2 and AF1. Finally, the Background Class of UMTS is mapped to Default class (DF) of DiffServ. Table 4 summarizes the mapping between UMTS classes of service and DiffServ.

UMTS QoS Classes	DiffServ Class
Conversational Class	EF & AF4
Streaming Class	AF3
Interactive Class	AF2 & AF1
Background Class	DF

Table 4. UMTS/IP-DiffServ QoS Mapping

	Service Application Examples	UMTS Traffic Classes	UMTS Qos Parameters		DiffServ Network Classes & DS Assignation		MPLS Traffice Engineering	DiffServ Network Classes & DS Assignation		WiMAX QoS Parameters	WiMAX QoS Classes
			THP	ARP	PHB	DSCP		DSCP	PHB		
Real Time Applications	VoIP and Video conference Services	Conversational Class	-	ARP1	EF	101111	Reduce latency, jitter and improve QoS for time-sensitive traffic	101111 101110	EF	Maximum Sustained Rate, Maximum Latency Tolerance, Jitter Tolerance	UGS
			-	ARP2	EF	101110					
			-	ARP3	AF41	100010	Two ways for mapping DiffServ BA into LSPs:	100010	AF41	Maximum Reserved Rate, Maximum Sustained Rate, Maximum Latency, Tolerance Jitter, Tolerance Traffic Priority	ertPS
	Multimedia Streaming	Streaming Class	-	ARP1	AF31	011010	*EXP-LSP*: Routing is inferred from the 20-bit label.	011010 011100 011110	AF3X	Maximum Reserved Rate, Maximum Sustained Rate, Maximum Latency, Tolerance, Traffic Priority	rtPS
			-	ARP2	AF32	011100					
			-	ARP3	AF33	011110	Where,				
Non-Real Time Applications	Web Browsing & File Transfer Services	Interactive Class	THP1	ARP1	AF21	010010	Scheduling and packet shaping are inferred from EXP field of the MPLS shim header.	010010 010100 010110 001010 001100 001110	AF2 & AF1	Maximum Reserved Rate, Maximum Sustained Rate, Traffic Priority	nrtPS & BE
			THP1	ARP2	AF22	010100					
			THP1	ARP3	AF23	010110					
			THP2	ARP1	AF11	001010					
			THP2	ARP2	AF12	001100					
			THP2	ARP3	AF13	001110	*Label-LSP:* Routing and scheduling treatments are inferred from MPLS label.				
	MMS & Email Service	Background Class	-	ARP1	DF	000000	Where,	000000 001000 010000	Default	Maximum Reserved Rate, Traffic Priority	BE
				ARP2	DF	001000	Packet shaping is inferred from the EXP field				
				ARP3	DF	010000					

Table 5. Mappings of CoS to WIMAX QoS Catagories over IP-DiffServ/MPLS Backbone

5. End-To-End QoS Mapping Between UMTS and WIMAX in Loose Coupling

We propose, in loose coupling Heterogeneous Wireless Access Network (HWAN) over an IP-DiffServ/MPLS, an End-to-End QoS mapping between the CoS of UMTS and WiMAX QoS categories as illustrated in Table 5. This mapping, that is based on the types of applications –Real-Time and Non Real-Time, should be implemented as functions in ingress/egress nodes (Gateways) of the IP/DiffServ-MPLS network.

This proposal is based on two mapping processes; the first performs a mapping between the four classes of services in UMTS, with their parameters into IP-Diffserv classes with DS Assignation and the second consists of mapping the corresponding IP-DiffServ classes into WiMAX QoS categories and parameters.

Since each class or category supports multiple applications with different QoS performance values, differentiation, at the QoS level, is achieved through assigning specific QoS parameters/attributes. Therefore, we have proposed further mapping for each class. For example, the Conversational Class of UMTS may have three different ARP values supporting different PDPs; therefore, we proposed to map it into 2 classes of DiffServ (EF & AF41) with two different DCSP values.

In addition, MPLS-TE can be also used to reduce the latency, jitter and improve QoS performance for time sensitive applications. Two ways for mapping Diffserv Behavior Aggregate into MPLS LSPs, EXP-LSP and Label-LSP, can be used. In EXP-LSP, routing is inferred from the 20-bit label where scheduling and packet shaping are inferred from EXP field of the MPLS shim header. However, in Label-LSP routing and scheduling are treated based on the MPLS label where packet shaping is inferred from the EXP field.

6. Conclusion

Supporting the different applications with their required QoS, End-to-End over Heterogeneous Wireless Access Network, is a very challenging task. It requires appropriate mapping of related QoS categories, protocols, messages, attributes and parameters.

In this paper, we have presented, in a loose coupling environment over an IP-DiffServ/MPLS backbone, a novel QoS mapping mechanism between UMTS and WiMAX. The proposed mechanism recommends a mapping of the CoSs of UMTS associated with their attributes to WiMAX QoS categories with their corresponding attributes. These mappings, with and without the support of DiffServ/MPLS, must be evaluated and optimized in order to verify that requested QoS is provided and supported, as End-to-End QoS, over the whole Heterogeneous Wireless Access Network.

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