Extending QoS Policy-based mechanisms to B3G Mobile Access Networks

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ABSTRACT

In order to provide end-to-end QoS in B3G systems, based on the UMTS architecture, the DiffServ framework can be used in the data plane of the IP core network of the mobile access network. Among the different schemes proposed for the control plane of DiffServ, the Internet2 bandwidth broker approach has been chosen for its centralized management nature, which is needed to coordinate QoS between the different entities of the heterogeneous access network: the core network, the radio, external bearer services and the user. It will be shown that policy-based service negotiation is an important component of the bandwidth broker and of the control plane, in order to provide a flexible end-to-end QoS management in B3G systems. Furthermore, the following issues regarding the proposed policy-based architecture are identified: the need for a policy decision point at the radio bearer service entity, the interaction of service negotiation and mobility management protocols, and the impact of WLAN coupling.

Index Terms: beyond 3G, end-to-end QoS, DiffServ, heterogeneous access network, policy-based service negotiation.

I. INTRODUCTION

The objective of the EVEREST project is to devise and assess a set of specific strategies and algorithms for access and core networks, leading to an optimised utilisation of scarcely available radio resources for the support of mixed services with end-to-end QoS mechanisms within heterogeneous networks beyond 3G.

The mobile access network following the B3G paradigm is based on the architecture of UMTS. The UMTS access network is composed of three sub-networks: the UTRAN, the circuit switched domain and the packet switched domain. In the packet switched domain, the Core Network (CN) connects the UTRAN with the Internet backbone through the GGSN and the GGSN. In the release 5 of UMTS the CN is an IP based network. SGSNs are connected to RNCs through the Iu-PS interface where ATM is used at layer 2 and IP can be used at layer 3. In the IP CN of UMTS, one can consider that no specific QoS provisioning mechanism below the GTP protocol is needed if the IP CN itself and the Internet backbone are not considered bottlenecks of the system. However in a heterogeneous access network where the IP CN has to support several types of radio access technology and has to deliver different network services to users, a QoS mechanism will be needed in order to fulfil these requirements and to use efficiently the CN resources (over-provisioning would not be cost-effective). In the CN QoS mechanisms at the transmission medium (ATM or another technology) could be used. The IP QoS mechanism envisaged here is based on the DiffServ framework [1].

Previous papers [2] [3] have focused on the use of DiffServ in the UMTS CN and on its data plane functions with issues related to the mapping of DiffServ code-points to UMTS QoS traffic classes. In this paper the focus will be on the control plane functions of the CN Bearer Service (BS) and its interactions with the adjacent BSs: the radio BS and the external BS (also called IP BS), in order to guarantee end-to-end QoS to the user. Regarding the control plane of DiffServ functionalities in the CN, the Internet2 Qbone Bandwidth Broker [4](BB) approach has been adopted. It is thought that the central nature of management of the BB is needed in order to coordinate QoS between the different entities: the user, the external BS (i.e. the neighbour domain's QoS manager) and the radio resource manager. Furthermore, the integration within the B3G concept of different radio access network technologies mandates this QoS management solution to be flexible enough to cope with such heterogeneity. Policy-based QoS schemes with dynamic service level negotiation are envisaged in order to fulfil these needs and the extension of this approach to cope with common radio resource management strategies is discussed.

The rest of the paper is organized as follows. First the current UMTS QoS approach, and then the architecture of the Internet2 BB are presented, moreover different signalling protocols are reviewed in order to identify the functionalities required for QoS negotiation between the different BSs and the user. Then QoS management is analysed from the perspective of an heterogeneous access network, and the focus is on the interactions of the other QoS entities with the Common Radio Resource Manager (CRRM). Finally open issues of the proposed architecture are analysed: an extension of the architecture based on release 6 of UMTS and the implications of the WLAN coupling method on the proposed architecture.

II.CURRENT UMTS QoS APPROACH

The main concepts arisen from the 3GPP UMTS QoS general framework [21] are illustrated in Figure 1. A
policy-based framework is introduced in Release 5 to manage QoS for multimedia services supported within the IMS Domain and the framework is extended to other services in Release 6. This policy framework is intended to enable the coordination between events in the application/service layer and resource management in the IP bearer layer and it can be used to provide a policy-based admission control in charge of authorising specific QoS resources for the set of IP flows within a user session. In this way, the service provider (e.g. the mobile operator) could decide which level of QoS is offered taking into consideration the characteristics of the service being requested but also any other consideration related to business models and management (premium users, etc.).

Figure 1. QoS framework in UMTS R5.

This 3GPP UMTS policy framework is aligned with the policy framework defined within IETF. According to this IETF framework, the UMTS Framework introduces the Policy Decision Function (PDF) entity, that is equivalent to the PDF in the IETF model, and the PEP, located in this case in the GGSN (Figure 1). The interface between the PDF and GGSN, named Go interface, supports the transfer of information and policy decisions between the policy decision point and the IP BS Manager in the GGSN. The PDF generates a maximum authorized QoS class and a maximum bandwidth for the set of IP flows and this information is mapped by the translation/mapping function in the GGSN to give the authorized resources for UMTS bearer admission control. An additional entity named Application Function (AF) is used to offer services that require the control of IP bearer resources (e.g. SIP Proxy). The AF maps QoS-related application level parameters (e.g. SDP) into policy set-up information, and sends this information to the PDF in order to obtain the authorisation of the QoS settings for the requested service.

As also illustrated in Figure 1, end-to-end QoS support in UMTS mandates the existence of an IP BS Manager function in charge of managing IP bearer services using standard IP mechanisms. According to [21], interaction between UMTS bearer services and IP bearer services shall only occur at the translation function in the GGSN or in the UE. While the existence of the IP BS Manager in the GGSN is mandatory, in the UE is left to be optional. IP QoS parameters available at the IP BS Manager are enforced at the Gateway SGN and a translation of these parameters into the Packet Data Protocol (PDP) context is done. Then, it is the UMTS Bearer Service (BS) manager which will apply such a QoS requirement in the different segments within UMTS.

In the specification of QoS in 3GPP, issues regarding the CN BS are not specified. In the next section we propose as CN BS, the bandwidth broker, which would act as a central entity and as an intermediate BS between the RAB and the IP BS.

II. UMTS MANAGEMENT AND THE BANDWIDTH BROKER ENTITY

A. Architecture of the Internet2 bandwidth broker

The concept of bandwidth broker (BB) appeared in [5] and its functionalities have been further specified by the Internet2 Qbone BB work group [4]. The BB concept is a centralized solution to the QoS management problem of a DiffServ domain (nevertheless more distributed approaches with a hierarchy of BBs have also been proposed [6][7]). The BB controls the network resources in its domain, by giving different priorities to aggregated flows following the DiffServ principal; and also interacts with QoS managers in neighbour domains for QoS negotiation and reservation. The following main BB functionalities have been specified by the Internet2 Qbone WG[8]:

- **inter-domain communication interface** with adjacent cooperating BBs. A protocol named SIBBS (Simple Inter-domain BB Signalling Protocol) has been specified by the WG.
- **intra-domain communication interface**. A communication method is needed for the BB to configure and allocate resources to the edge routers of the DiffServ domain. Only the edge routers keep QoS related states, the core routers are stateless. The BB has to communicate with the edge routers in order specify how edge routers should classify, condition and mark the entering flows into appropriate aggregated flows classes. For this communication, the following options are available:

1. **telnet**: a command line interface that can be used to configure remote routers.
2. **SNMP (Simple Network Management Protocol)**: an application layer protocol that allows the exchange of management info between agents residing on a managed device and a network management system. The SNMP SET message could be used for the configuration of edge routers.
3. **COPS (Common Open Policy Service)** [9]: discussed in next subsection.

- **knowledge of the domain and its resources**: this function can be achieved by the use of SNMP which allows to monitor a set of routers. Another solution is to use a QoS routing in the domain so that the BB can have a knowledge of the resources (for example the
available bandwidth at each link with the QOSPF routing[10]) through an interface with the routing protocol. Furthermore information about exterior routing is also needed for decision regarding the communication with adjacent BBs (this information can be retrieved from an interface with an exterior routing protocol (BGP)).

- **admission control:** a mechanism is required that can evaluate if requested resources (by a user or an adjacent domain QoS manager) is available in the domain, or more precisely in a set of routers under the control of the BB. Admission control can be done based on the arrival time of each request, i.e. new flows are accepted sequentially until the capacity of the domain is reached; or another method is to practice a policy-based admission control [11]. In a policy-based admission control, the admission is not based on the only availability of the network resources but also on the identity of the user or application, and how, when and where the flow enters the network.

![Figure 2. Architecture of the BB.](image)

**B. Policy-based service negotiation protocol**

In the Internet2 architecture of the BB (Figure 2), it can be noticed that the concept of policy management plays an important role. Even if policy management is not a requirement in the intra-domain communication of the BB with the edge routers thanks COPS (SNMP could be used instead) or in the admission control (non policy-based admission control could be used), policy management has the following advantages:

- **Flexibility for admission control.** In a policy-based admission control, a variable set of parameters which has been dynamically set by the operator can be taken into account. Thus, there is a possibility of building new services without changing the protocol (based on COPS) itself.
- **Automation of the admission process.** A set of conditions and actions specific to the operator, can be defined.

- **For the intra-domain communication of the BB with the edge routers, COPS provides a layer of abstraction between the manufacturer's router specific command and some generic protocol configuration primitives (in our case DiffServ primitives).**

Furthermore it can also be noticed that the inter-domain communication between adjacent BBs is not policy-based in the Internet2 architecture. Except the inter-domain signalling SIBBS proposed by the Internet2 WG, other proposals have been done: RSVP, BGRP[12], a modified version of BGRP[13], DSNP[14] (a dynamic service negotiation protocol for heterogeneous mobile access network), COPS-DRA[15] and COPS-SLS[16]. In this list, which is not exhaustive, except COPS-DRA and COPS-SLS, these protocols focus on the scalability issues and how aggregation can be achieved for request messages.

What differentiates the policy-based negotiation protocols (COPS-DRA and COPS-SLS), is the flexibility of the signalling and the independence of the signalling from the IP QoS mechanism used in each domain. Moreover the aggregation techniques used in the other signalling protocols can be applied to COPS-SLS, however aggregation and scalability issues are out of the scope of the project. As policy-based negotiation protocol uses the flexibility of the COPS protocol, it allows a negotiation specific to the policy of each domain. Each domain might have a specific set of negotiation parameters (or a set of SLSs) and specific policy for admission control. The set of SLS negotiation parameters has to be specified following the IETF draft [17]; nonetheless each domain has the possibility to select its own set of parameters, and implement its own policy for negotiation and admission.

**IV. QoS MANAGEMENT IN HETEROGENEOUS RANs**

From the EVEREST project point of view, heterogeneous networks will be built around the UMTS architecture solution where other technologies different than UTRAN will be used to provide the network access services. In this way, GERAN is being considered in 3GPP as a natural integration of the GSM-evolved RAN with a UMTS CN through the already defined UMTS Iu-PS interface. WLAN access networks are also addressed under different degrees of coupling to an UMTS network (further discussed in next section). The availability of different access networks mandates the existence of a flexible QoS management able to cope with the establishment of end-to-end connections over different network domains with negotiated service level requirements. Besides, as it is envisaged that RAN sharing could be a common practice among mobile and network access operators, the need of an open and global QoS provision become practically mandatory.

Within such complex scenario, within EVEREST, it is proposed to identify each different radio access network as a single QoS domain where specific QoS mechanisms and policies are deployed. In this sense, and extending the BB concept already described for IP DiffServ domains, each domain will have a kind of **wireless QoS broker**. This
entity will be in charge of QoS provisioning within RANs. Furthermore, a dynamic negotiation of SLAs is envisaged as the solution to negotiate QoS among involved domains[20]. Thus, each RAN has its own policy management and these policies are kept consistent by means of a signalling mechanism (i.e. COPS-SLS). A mobile or network operator domain, even though externally can be seen as a single QoS domain, internally it could consist of several QoS domains (at least a CN domain and a RAN domain) coordinated by means of policy-based negotiation (these dependencies are further discussed in next section).

Furthermore, within each RAN, the concept of policy based QoS management and the feasibility of policies to configure QoS functions (such as admission control and packet scheduler) are envisaged to be extended up to radio network controllers (this means that apart from IP level resources, also some RRM strategies are tuned based on policy rules [22]). So, the proposed wireless QoS broker will be in charge of applying policies to control and configure QoS resources made “visible” at radio network controllers or its equivalents.

Another interesting concept that could be addressed from the proposed QoS Management perspective is the introduction of common RRM (CRRM) strategies deployed over different radio access networks with shared coverage. Focusing on CRRM issues, two main approaches are envisaged under 3GPP to support CRRM in UTRAN and GERAN: integrated CRRM and loose CRRM [TR 25.881, TR 25.891]. Loose architectures are based in a CRRM server linked by open interfaces to the RNC (UMTS) and BSC (GERAN). CRRM Server establishes CRRM policies and each RAT executes RRM algorithms according to the CRRM server policies (e.g. when a determined load is overcome). Within this approach, CRRM policies could be seen as a part of the QoS management policies in the sense that operations such as admission or handovers among RANs can be supported by the wireless QoS Broker according to CRRM rules. On the other hand, integrated CRRM, also referred to as tight CRRM, incorporates CRRM functions into the existent UTRAN/GERAN nodes and no specific CRRM server is needed. In this case, in the same way than having a single RRM, CRRM functions can be still made visible to the wireless QoS Broker to manage QoS accordingly.

V. End-to-End QoS approach within EVEREST

The main research topics in EVEREST will be addressed within a proposed end-to-end QoS management framework aligned as much as possible with the QoS architecture envisaged in 3GPP Release 5 and 6 and other relevant IETF proposals. In this sense, it is assumed within the project that any end-to-end QoS architecture for converged 3G mobile – wired IP networks should be compliant with 3GPP UMTS QoS general framework.

![Figure 3. EVEREST proposal for QoS architecture in a heterogeneous radio access network.](image-url)

According to previous addressed concepts, Figure 3 shows a proposed architecture for QoS handling in a Heterogeneous Radio Access Network with CRRM capabilities. As shown in the figure, different RANs are envisaged to offer access to the same Core Network and CRRM functions are used to manage radio resources optimally. The policy-based framework introduced in UMTS R5 is extended further from the GGSN up to the radio access part. The proposed architecture is more aligned with the vision of UMTS Release 6. Issues to be addressed within the project are the following.

A. Mobility Management in CN

The trend of UMTS beyond R5 is to use native IP transport down to the RNC. This would allow to use fully the IP functionalities in the CN (multicast, IP native routing, etc.) and this would also mean to separate the SGSN's functions from its routing functions. In this framework of R6, an IP mobility management (mobile IP[18] or a micromobility protocol[19]) has to be used in the CN. The interactions of the mobility management with the policy-based service negotiation envisaged previously, has to be considered as a roaming user might have to renegotiate its service before an IP handover process. Renegotiation might be needed as the roaming user might have to renegotiate its service before another customer with higher priority)

- the external BS, because not enough resource is available in an adjacent domain, due for example to a policy reason (the resource has been reallocated to another customer with higher priority)
- the radio resource manager, which reports that the signal quality of the user's connection is decreasing
- the user, who wants to use high QoS demanding application
- the BB, which is in charge of the CN's resources.
Thus, the handover process has to be reconsidered, and has to include the service negotiation process. The handover process is not purely dependent on the mobility of the user and the signal quality of the available attachment points, but on the overall QoS available through an attachment point and therefore on the result of the service negotiation. The service negotiation has a central role in the handover process and the way the service negotiation process can be coupled efficiently, has to be investigated:

- how does the service negotiation influence the access selection and access discovery phases of the handover process?
- which additional attributes, representing “wireless hints”, should be included in the SLS template, necessary for service negotiation between the user and the access network?

B. Negotiation models among PDPs within the access network.

In the precedent subsection, the interactions of the user with the access network and their implications on mobility management have been highlighted. However inside the access network, the communication between the identified entities: the bandwidth broker (cf. section 3) and the wireless QoS broker (cf. section 4), hasn’t been investigated. The complexity of these two entities has to be hidden to the user, which has to negotiate its service with the mobile access network. For this, one possibility is to have an entity, called “master PDP”, which on one side negotiates with the user and on the other side communicates with the BB/PDP and the wireless QoS broker/PDP and solves negotiation problems between these two PDPs. The other possibility is to have peer-to-peer communication between the two PDPs, and then the user would negotiate directly its service with one of the PDPs. Furthermore the communication between these two PDPs and a possible master PDP will be based on COPS, however the content of the message exchange remains to be defined.

C. Impact of the WLAN coupling

A WLAN network is composed of WLAN access points (APs) and access routers to which several APs are connected. QoS mechanisms used in this type of network are: DiffServ at the IP level, as stated previously, and at the link layer 802.11e, 802.11p standards can be used. Different coupling methods can be considered, tight coupling: WLAN is seen as another 3G radio access network and is connected to the SGSN through an entity equivalent to the RNC in UTRAN; very tight coupling: existence of an interface between the RNCs of the different RANs and the WLAN AP is connected to an RNC through an equivalent UTRAN Iub interface; loose coupling: utilizes standard IETF-based protocols for AAA and mobility and the WLAN network is inter-connected to the CN through the GGSN.

The case of loose coupling has an impact on the proposed architecture, as in this case the separate WLAN network has also a BB/PDP and a wireless QoS broker/PDP entity. In order to provide a domain-wide policy, a master policy manager (also called master PDP)[20] has to coordinate the policies between both physical access networks. Moreover a more complex scenario can be imagined in the loose coupling case, where the loose-coupled WLAN network is shared by two operators. In this scenario, the master policy managers of each domain have to communicate together in order to solve cases of conflicting policies.

VI. CONCLUSIONS

The control plane of DiffServ framework in UMTS CN has been analysed. The functionalities of the BB have been reviewed and a particular interest has been given to policy management which plays a central role in the service negotiation between the user and the mobile access network. The different entities, with which the BB/PDP has to interact, in order to provide end-to-end QoS, have been identified. And an entity, called wireless QoS broker, has been introduced, which has the capabilities of configuring RRM functions of the different RANs and can exchange information with the BB. Finally the implications of the service negotiation on the mobility management in release 6 of UMTS and the implications of the WLAN coupling have been considered.

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REFERENCES

[21]. 3GPP TS 23.207, “End-to-end Quality of Service (QoS) concept and architecture (Release 6)”.