Exploring the Issues in Policy-Based Approaches for QoS Support in $3G^+$ Mobile Networks

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***Abstract*— In this paper, we explore the issues in policy-based approaches for Quality of Service (QoS) support in Beyond 3G ($3G^+$) mobile networks. QoS support in mobile environments per-user and per-service is a formidable task. Third Generation Project Partnership (3GPP) puts emphasis on a uniform QoS policy management (definition, control, and enforcement) and Common Open Policy Service (COPS) is specified for policy signalling. We show that the policy-based QoS approach is a promising solution to address QoS issue in 4G (a.k.a. $3G^+$) networks. That is, end-to-end QoS policy approach enables finer-grained service and user differentiation, leading to better subscription-tiering management.**

***Keywords*—QoS, COPS, Beyond 3G networks, 4G networks, mobile communications, 3GPP**

I. Introduction

AVAILABILITY of the network services anywhere, at anytime, can be one of the key factors that attract individuals and institutions to the new network infrastructures, stimulate the development of telecommunications, and propel economies [14]. This bold idea has already made its way into the telecommunication community bringing new requirements for network design, and envisioning a change of the current model of providing services to customers. This requirement set has made its way into the 3G standards such as stringent QoS [5], IP core network, IP multimedia services, and higher bandwidth. But their dramatic effect seems to be on the 4G mobile network research and subsequent proliferation [13]. QoS is taking and will take the center stage in that effort. In this paper, we explore the issues in policy-based approaches for QoS support in $3G^+$ mobile networks.

COPS protocol has been defined in the context of the Internet Engineering Task Force (IETF) RAP working group as means to support policy control in an IP quality of service (QoS) environment [6]. It is a simple query and response protocol that allows policy servers (PDPs) to communicate policy decisions to network devices (PEPs). In order to be flexible, the COPS protocol has been designed to support multiple types of policy clients. Each client type is described in a different usage document. The protocol uses TCP to provide reliable exchange of messages. COPS provides the means to establish and maintain a dialogue between the client and the server and to identify the requests.

The underlying architectural model foresees that policy servers administrate the network, communicating decisions to policy clients (e.g., network elements) where the policy decisions are enforced. The policy repository is a remote database such as a directory service or a network file system. Consequently, authorization in network resource management can be handled easily. For example, if IP QoS is deployed, the users can access different transport services, and this access can be administratively regulated.

COPS is a potential candidate for implementing policy-based QoS for $3G^+$ networks [8]. In this paper, we explore the issues raised for this implementation. That is we present a background work in policy-based QoS supports both in 3G and $3G^+$ networks, and propose and/or discuss architectures and frameworks such as COPS-DRA, Moby Dick, which may be employed and/or modified for a viable QoS framework for $3G^+$ networks.

This paper is organized as follows: Section II presents the DiffServ/IntServ models for IP QoS along with COPS. Section III-VI present specifications and requirements for QoS support in 3GPP and Beyond 3G models, respectively. Section VII concludes this work underlying the needs for successful QoS enabled networks.

II. COPS and DiffServ/IntServ

Two architectural models for IP QoS have been proposed in the IETF: the integrated services *(IntServ)* and differentiated services *(DiffServ)* architectures. A very good introduction to the topic of IP QoS can be found in [1], where the two approaches are described and compared. Due to scalability issues of the IntServ model, the DiffServ model seems preferable for the development of IP QoS in a real-life network.

The concept of policy control applies to both IntServ and DiffServ networks, but the different signalling and admission control models need to be taken into account. As for the IntServ model, it is conceptually easy to add policy control on top of the signalling and admission control framework. In fact, the standardization process in the IETF followed this path: the RAP working group developed the COPS (Common Open Policy Service) protocol with the idea to complement the resource-related admission control defined in the IntServ model with a policy-related admission control. This working group is responsible to define general-purpose objects that facilitate the manipulation of policies and provisioned objects available through COPS and COPS-PR. Where appropriate,

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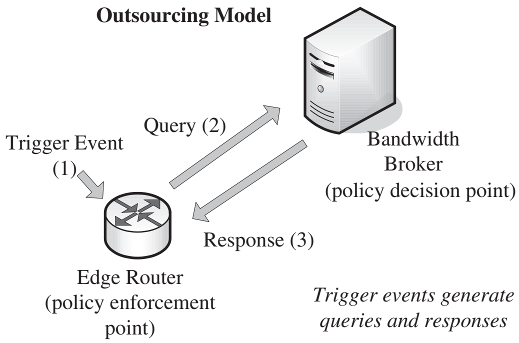

Fig. 1. Outsourcing model in COPS.

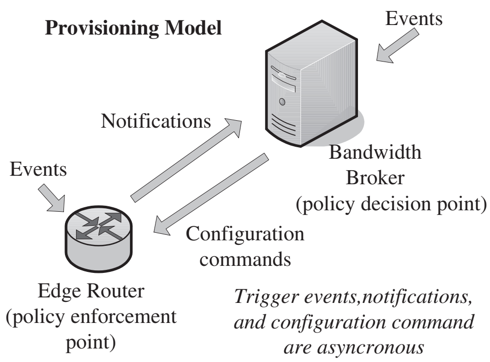

Fig. 2. Provisioning model in COPS.

these will include frameworks clarifying the applicability of COPS objects and the best practices for the definition of additional objects defined in other IETF working groups.

The requirements for the initial definition of the policy-based admission control architecture and of the COPS protocol were mainly derived considering the IntServ RSVP signalling protocol. In this scenario [2] , the network nodes, running RSVP, represent the policy enforcement points (PEPs), while a logically centralized element acts as a policy server and is called the policy decision point (PDP). The PEP makes requests to the PDP for policy-related admission control and the PDP provides the needed policy decisions. As for the DiffServ model, an extension to COPS to support the provisioning of resources within network elements has been defined, called COPS-PR [3]. Basically, it supports the static provisioning model discussed above. A kind of logically centralized management center acts as the PDP and "installs" the proper configuration (decisions) in the DiffServ network elements (routers) that represent the PEPs.

The PEP is a component of a network node, and the PDP is a remote entity that may reside at a policy server. Usually there is a PDP in a network domain and several PEPs. The PDP may make use of additional mechanisms and protocols to achieve additional functionalities (e.g., user authentication, accounting, policy information storage). To exchange information with the policy repository, for storage and retrieval of policy information, the PDP uses the Lightweight Directory Access Protocol (LDAP). The PEP notifies its PDP of all events that require a policy decision. Thus, the PDP is a logical aggregation point for monitoring network activity. Moreover, COPS allows a PEP to asynchronously send report messages associated with a specific request to the PDP. These messages enable the PEP to provide the PDP with accounting and monitoring information regarding an existing request state.

In order to be flexible, the COPS protocol has been designed to support multiple types of policy clients. Each client type is described in a different usage document. The protocol uses TCP to provide reliable exchange of messages. COPS provides the means to establish and maintain a dialogue between the client and the server and to identify the requests. Two main models are supported by the COPS protocol: outsourcing and provisioning, as seen in Fig. 1 and Fig. 2 respectively.

A very important COPS facility is that it provides the download of the QoS configurations to the network devices. The PDP only needs to know that a device uses a certain set of rules, and then pushes those rules to the device. The QoS policy configurations include the mechanisms for packet classification, the definition of the rate limits in the shapers, the definition of the service classes (in the case of a DiffServ network) and excess actions for out-of-profile traffic, and the scheduling mechanisms and drop preferences to be applied to packets according to their classification.

III. Drawbacks of Static Provisioning in DiffServ and a Proposed Resolution

The static provisioning model for a DiffServ network, which is usually considered for core packet networks of 3G and 4G systems, although interesting in an early deployment phase for its simplicity, has some annoying limitations. For example, the preconfiguration of network elements may lead to underutilization of resources; it is difficult for the provider to adapt to changes in traffic demand; the service offering of the provider is basically limited to the transfer of large and stable traffic aggregates. The evolution of the DiffServ model envisages the capacity to dynamically handle resource requests. A higher utilization of network resources and the possibility of offering more advanced services are some of the benefits of the dynamic resource allocation.

In [8], Salsano et al. describe a dynamic DiffServ resource allocation model that relies on COPS as a signalling mechanism. The COPS protocol provides the opportunity to combine policy control, QoS signalling and resource control in a unified framework. The model is applied to a realistic SIP (Session Initiation Protocol) based IP telephony scenario. The SIP protocol is the IETF standard for IP telephony, and it seems to be the most promising candidate for call setup signalling for the future IP-based telephony services. It has been chosen by 3GPP as the protocol for multimedia application in 3G mobile networks. In this context, the authors describe a very simple solution that binds the SIP signalling to the proposed COPS-based QoS model. The SIP protocol is enhanced to convey QoS related information, preserving backward compatibility with current SIP applications and decoupling SIP signalling as much as possible from QoS handling [5]. An implementation of the overall architecture is described and the proposed solution is stated to be fulfilling the requirement of QoS support in SIP-based IP telephony.

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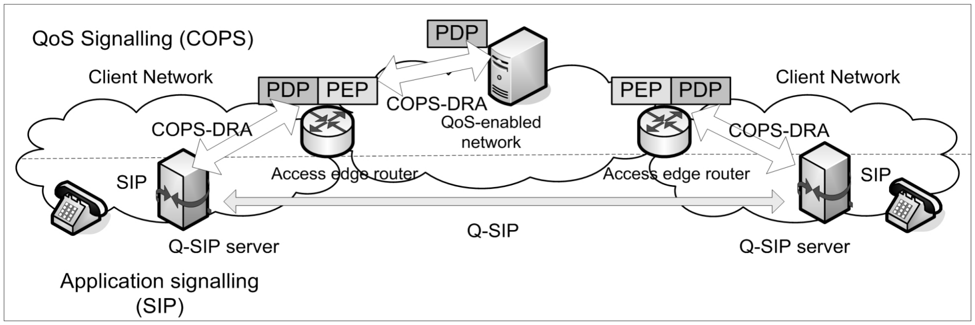

Fig. 3. QoS SIP architecture in [8].

IV. QoS IN 3GPP

The 3GPP end-to-end QoS framework leverages existing work from IETF for IP-based control signalling and bearer services, encompassing extensions and unique functions to handle wireless specific requirements. The current 3GPP release, Rel-5 (and also the upcoming release, Rel-6) provides a framework for end-to-end Quality of Service, i.e. for IP bearers with guaranteed QoS properties not only in the Universal Mobile Telecommunication System (UMTS) domain but also within the domain of external IP networks [5]. For this purpose, interworking between the UMTS QoS mechanisms and the IP QoS mechanisms (as mentioned above, defined by IETF - mainly DiffServ and IntServ) are crucial.

A. Call Admission Control (CAC)

CAC is the procedure that decides if a connection is established or rejected. CAC uses the connection traffic descriptors and requested QoS as input into its algorithm. A connection is accepted if capacity is available and the requested QoS can be met, and if other existing connections and their agreed-upon QoS will not be impacted. CAC is carried out at every node along the path from the source to the destination. In a multi-node multi-domain network, CAC operated with consistent network based policy management will prevent network congestion and overload while ensuring each accepted session to get its required resource and adapting resource allocation depending on the network load conditions.

In a UMTS network, QoS policies are provisioned and stored in a central repository, the Home Location Register (HLR). Each subscriber is linked to a QoS policy or multiple QoS policies. Each policy reflects the service subscription, and its associated QoS attributes. A subscriber's policy is locally stored at the Serving GPRS (General Packet Radio Service) Support Node (SGSN) during the time the subscriber's terminal is attached to this SGSN. SGSN operates as PEP, one of its main roles is to coordinate CAC. The Gateway GPRS Support Node (GGSN) will apply PDP function to modify the negotiated QoS based on network load conditions and additional information, and respond with the final negotiated QoS back to the SGSN.

CAC shows the importance of QoS policy. Service level guarantee across networks with disparate technologies, such as $3G^{+}$ networks, depends on consistent network-wide applications of policies. Additionally, both CAC and QoS policies are important in the security of the network to prevent rogue users from stealing unsubscribed resources.

B. COPS and QoS Considerations for the IP Multimedia Subsystem

3GPP Release 5 (3GR5) introduces the IP Multimedia (IM) Subsystem or Domain, an IPv6 overlay of the Packet Switched domain that enables an operator to offer SIP based multimedia services over an all-IP network. Advanced voice (Voice over IP associated with web services), multimedia messaging, 1-2-1 video, and video conferencing are typical services delivered by the IM domain. To complete the definition of QoS in the end-to-end service architecture, 3GPP is addressing the QoS behaviors of the remaining IP-based bearer services: MS Local bearer Service and the External Bearer Service, and how they interact with the UMTS Bearer Service defined in Release 99 [5].

3GR5 (and to-be-standardized Release 6 and 7, as well) faces the challenge of providing QoS in the IP layer between the user equipment (UE) and the multimedia application servers. The multimedia application servers can be located outside of the UMTS network and not under direct control of the Call State Control Function (CSCF), which is the main session control entity in the IM subsystem. The CSCF uses HTTP-encoded SIP for session control and authorizes QoS resources for each session. In addition, the UE and GGSN have important roles in the IP-layer QoS framework, they translate or map QoS parameters between the UMTS bearer service and the IP (application) bearer service layer (RSVP, Diffserv). GGSN is required to provide edge Diffserv function for QoS interworking with external IP networks.

3GR5 puts emphasis on a uniform QoS policy management (definition, control, and enforcement), as the IM domain is expected to carry more various types of traffic. IETF's Policy framework is recommended for policy management and COPS is specified for policy signalling.

V. BEYOND 3G

3G networks were proposed to eliminate many problems faced by 2G and 2.5G networks, like low speeds and incompatible technologies (TDMA/CDMA) in different countries. In theory, 3G would work over North American as well as European and Asian wireless air interfaces. But there are

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still concerns considering the success of 3G mobile networks. Part of the problem is that network providers in Europe and North America currently maintain separate standards bodies (3GPP for Europe and Asia, and 3GPP2 for North America). These standards bodies mirror differences in air interface technologies. In addition there are financial questions as well that cast a doubt over 3G's desirability. There is a concern that in many countries, 3G will never be deployed. This concern is grounded, in part, in the growing attraction of 4G wireless technologies.

Unified, secure, multi-service, and multiple-operator network architectures are now being developed in a context commonly referenced to as networks Beyond 3G or, alternatively, 4G networks [18]. A homogeneous network architecture for heterogeneous environments, where all types of services may be jointly provided while simultaneously fulfilling its different inherent requisites, has been a consistent objective of network providers. The 4G concept supports the provisioning of multiple types of services, ranging from simple network access to complex multimedia virtual reality, including voice communication services, which are themselves a challenge in packet-based mobile communications environments.

A 4G network promises seamless roaming/handover and best connected service, combining multiple radio access interfaces (such as HIPERLAN, WLAN, Bluetooth, GPRS) into a single network that subscribers may use. A brief review and comparison of these various wireless and mobile networking technologies can be found in the work by Arshney and Vetter [9]. With this feature, users will have access to different services, increased coverage, the convenience of a single device, one bill with reduced total access cost, and more reliable wireless access even with the failure or loss of one or more networks [14].

At the most general level, 4G architecture will include three basic areas of connectivity: Personal Area Networking (such as Bluetooth), local high-speed access points on the network including wireless LAN technologies (such as IEEE 802.11 and HIPERLAN), and cellular connectivity. Under this umbrella, 4G will support for a wide range of mobile devices that support global roaming. Each device will be able to interact with Internet-based information that will be modified on the fly for the network being used by the device at that moment. In short, the roots of 4G networks lie in the idea of pervasive computing.

A. 4G Characteristics

The defining features of 4G networks are listed below [15]:

- **High Data rate and reduction of data transmission cost per bit** - 4G systems should offer a peak speed of more than 100Mbps in stationary mode with an average of 20Mbps when travelling.
- **IP-based network**
- **High Network capacity** - Should be at least 10 times that of 3G systems. This will quicken the download time of a 10-Mbyte file to one second on 4G, from 200 seconds on 3G, enabling high-definition video to stream to phones and create a virtual reality experience on high-resolution handset screens.
- **Fast+Seamless handover across multiple networks** - 4G wireless networks should support global roaming across multiple wireless and mobile networks and achieve seamless connections.
- **Next generation multimedia support** - The underlying network for 4G must be able to support fast speed and large volume data transmission at a lower cost than today. Service integration is a requirement.

VI. QoS FOR 4G: A CHALLENGE

Supporting QoS in 4G networks will be a major challenge. QoS support can occur at the packet, transaction, circuit, and network levels. QoS will have to be tweaked at these different operating levels, making the network more flexible and possibly more tolerant to QoS issues.

Below the network layer, in comparison with current 2G and 2.5G networks, 4G will have more fault tolerance capabilities built-in to avoid unnecessary network failure, poor coverage, varying rate channel characteristics and dropped calls. 4G technology promises to enhance QoS by the use of better diagnostic techniques and alarms tools. 4G will have better support of roaming and handoffs across heterogeneous networks. Users, even in today's wireless market, demand service transparency and roaming. 4G may support interoperability between disparate network technologies by using techniques such as LAS-CDMA (large area synchronization CDMA) signalling. Other solutions such as software-defined radios could also support roaming across disparate network technologies in 4G systems.

Considering the network layer and above (which is the main concern of this study), the IP protocol, and in particular IPv6, due to their intrinsic technology heterogeneity, is being targeted as the interconnection layer across the multiple access technologies envisaged. Nevertheless, even with a common network protocol, many problems have to be solved. 4G concept claims supporting multiple types of services, from simple network access to complex multimedia virtual reality, and including traditional telecommunication services such as telephony in mobile environments. This implies the development of a network able to associate service agreements to network control constrains, able to monitor this usage per service and user, and able to provide these services while the user moves (with its terminal changing access technologies). Both convergence of access technologies and unification of multiple protocols (for signalling, QoS, security and Authentication, Authorization, Auditing and Charging (AAAC)) under real operator environments are major research topics nowadays.

One of the important points in this context is the development of a QoS architecture for 4G networks. This architecture should be able to support "any" type of user service, in a secure and auditable way. Both user interfaces and inter-operator interfaces have to be clearly defined, and multiple service providers should be able to interoperate under the guidelines of this architecture.

Gozdecki et al. has proposed an architecture in [18] for supporting end-to-end QoS for 4G networks which has been

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studied in IST[1]-Moby Dick Project. An integrated service and resource management approach is presented based on the cooperative association between QoS Brokers and AAAC systems. This QoS architecture is able to support multi-service, multi-operator environments, handling complex multimedia services, with per user and per service differentiation, and integrating mobility and AAAC aspects. The main elements in the presented architecture are the MT (mobile terminal), the AR (access router) and the QoS Brokers. The interactions between QoS Brokers (acting as PDPs), edge routers (acting as PEPs) and AAAC systems (also acting as PDP, but at a higher level) are based on COPS message exchange. This architecture is currently being evolved for large testing in field trials across Madrid and Stuttgart.

This architecture still has some shortcomings, though, mostly due to its Diffserv orientation. Each domain has to implement its own plan for mapping between network service and a DiffServ code point (DSCP), and thus, for inter domain service provision, a service/DSCP mapping between neighbouring domains is essential. Furthermore, an adequate middleware function is required in the MT, to optimally mark the packets generated by the applications and issue the proper service requests, which requires extensions in current protocol stacks. Nevertheless, the proposal facilitates the deployment of multiple service provision models, as it decouples the notion of service (associated with the user contract) from the network management tasks. It seems to provide a simple, flexible, QoS architecture able to support multimedia service provision for future 4G networks.

In order to ensure a reliable end-to-end QoS delivery in Beyond 3G networks, the challenge of elaborating a novel and consistent QoS policy scheme should be in agreement with the followings. The core network setup should be sufficient in representing a real-world Beyond 3G network. The configuration of network elements should be well defined for supporting real-time multimedia communications. The testbed should comprise the various access scenarios such as WLAN, Ethernet, and intra and interdomain handoff scenarios. This is a quite big challenge due to the complexity of the setup. Many software components such as PDP and AAAC modules, SIP server and their relevant protocols should be developed. The proper strategy should be to use the available COTS (commercial off-the-shelf) and open-source software base as extensively as possible. New enabling technologies, such as software defined radio, novel signalling schemes, fault-tolerant networks, personal mobility and security frameworks, have to be integrated in a QoS-aware manner.

VII. Conclusion

It has been shown that the ability to control and manage end-to-end QoS policy enables finer-grained service and user differentiation, leading to better subscription-tiering management.

The goal of 4G networks is to replace the current proliferation of 3G networks with an IP-based single core network for all services. This will provide uniform video, voice, and data services to the mobile hosts. In other words, the objective is to offer ubiquitous, seamless connectivity to an all-IP-based infrastructure through heterogeneous access technologies, with rich and configurable services anywhere, at anytime. This is an ambitious goal and it augments the QoS requirements set of 3G specifications with more stringent and formidable elements. For 4G networks, there are various proposals to implement a consistent, robust, policy-based and end-to-end QoS framework. For such a framework to be effective, interworking operations among various QoS mechanisms, involving OSI Layer 3 and/or above, are crucial. The policy-based approach, namely COPS protocol, provides the opportunity to combine policy control, QoS signalling and resource control in a unified framework.

[1]IST stands for Information Society Technologies and is a European Union initiative.

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