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An End to End QoS Management Framework for the 3GPP IP Multimedia Subsystem

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***Abstract*— This paper describes the IP Multimedia Subsystem, an overlay network that integrates the technologies of the Internet with the cellular and fixed telecommunications world. In theory the IMS is access independent providing services to any IP connected network, furthermore these networks can implement different QoS models. A flexible QoS provisioning mechanism is needed to dynamically control the network resources on the bearer and session level. This paper presents a Hierarchical QoS management framework and suggests enhancements to the current Policy Decision Function implementation. This scheme hides the specific QoS model and access technology from the signaling plane, providing true access independence. A practical testbed that utilises the proposed scheme is described as well as the current status of the implementation.**

I. Introduction

Telecommunications advances and different customer perceptions have created the need for a high speed, ubiquitous network capable of catering for diverse application domains. This Next Generation Network (NGN) is often seen as the convergence of fixed and mobile technologies, interworking most existing access networks with an All-IP core [1].

The increasing trend towards an All-IP based network architecture has benefits for both subscribers and service providers. Network costs are greatly reduced by the maintenance of a single core network and the convergence of fixed and mobile technologies allows for far better service integration resulting in entirely new subscriber services [2].

The realisation of an All-IP core requires careful thinking due to the complexity of the signaling, QoS, security and mobility issues handled by the previous circuit switched protocols and with IP traditionally a "best effort" technology QoS is of particular importance. There are several models for QoS provisioning over IP networks [3][4][5], but there is no standardised generic framework to ensure QoS constraints are met across different access networks.

The Third Generation Project Partnership (3GPP) standardised the IP Multimedia Subsystem (IMS) as a subsystem of UMTS to facilitate a smooth transition from the circuit switched to the packet switched domain [6]. The IMS provides a unique service delivery platform that eliminates the concept of "silo architectures" and seamlessly integrates access domains with an All-IP core, while still supporting legacy circuit switched networks.

The IMS encompasses a variety of different access networks that could each be using their own QoS models; a comprehensive QoS management framework is needed to dynamically control resources on both the session and bearer level in a tight but flexible manner. Furthermore access independence is one of the central requirements of the Next Generation of Networks [7]. While the IMS is supposedly access independent as of release 6, interworking architectures for other access networks are only due in later releases [8]. True access independence requires a generic approach, which decouples the core network components and procedures from the subtleties of the access technologies. This paper describes a QoS management framework that provides generic access to IMS services for any IP connected network, and dynamically controls the behaviour of the network with high level policies by abstracting low level network element configuration.

The remainder of this document is organised as follows. Section II reviews related literature and comments on contribution to the field. Section III introduces the IMS architecture and its salient features. Section IV describes Policy Based Networking (PBN) and how the IMS implements its QoS mechanism. Section V describes necessary enhancements to the IMS QoS management system and the current PDF implementation. Section VI illustrates how the proposed scheme can be implemented on a practical testbed and describes the current status of the implementation. Section VII concludes the paper, and discusses further areas of work.

II. Related Work

A. Access Independence

The Third Generation Project Partnership was the first organisation to introduce the IMS in its release 5 series; 3GPP is now in release 7 of its documentation and by far the principal organisation defining the IMS. The Telecoms and Internet converged Services and Protocols for Advanced Networks (TISPAN) is a standards body within ETSI and specialises in fixed and mobile convergence. They are working specifically on NGNs and consequently much of their work overlaps with 3GPP.

ETSI TR 180 001 describes the NGN architecture and how it might interconnect with 3GPP IMS [7]. This document is only release 1 and in a very early stage of development. It describes the central requirements for NGNs, most importantly true access independence.

3GPP TS 23.228 is part of the IMS release 7 documentation and specifies that the IMS is now fully access independent and all access specific issues are separated from the core IMS description [6]. In reality this is not so, any access network wanting to take full advantage of IMS services (security, QoS, etc.) must access the IMS via the GGSN in a tightly coupled fashion.

3GPP TS 23.234 specifies an architecture for accessing the IMS via WLAN, interworking 3GPP and WLAN in a loosely coupled fashion [8]. Several new entities are defined: the WLAN Access Gateway (WAG) is the gateway between the 3GPP network and the WLAN, a Packet Data Gateway (PDG) provides the entry point into the multimedia network, and an AAA server is introduced for security purposes. This architecture keeps access technology specifics entirely separate from the core network.

B. QoS Provisioning

3GPP TS 23.207 defines the architecture for end to end QoS in the IMS [9]. It specifies Policy Based Management as the QoS provisioning mechanism within the IMS and defines the Policy Decision Function (PDF). The PDF assigns QoS parameters to each IMS session and is able to assign new QoS authorisation mid-call in the case of media or codec change. the P-CSCF exchanges session information with the PDF which in turn forces QoS behaviour at the GGSN which lies in the datapath. This specification does not cater for generic access independence and all QoS enforcement is centralised at the GGSN.

Bohm and Braun discuss several limitations of the PDF implemented in the IMS [10]. These include the fact that there is no end to end resource base admission control, the PDF is limited to SIP signaling services (solved by the separation of the PDF and P-CSCF in release 6 [9]), and the scope of the PDF is limited only to the GGSN and not other network elements.

3GPP TR 23.836 is a feasibility study on the QoS requirements when interworking WLAN and UMTS [11]. This document makes recommendations on how to incorporate WLAN access networks into the IMS QoS architecture, and specifies various extension to the UE, WAG and PDG. Most notably it recommends that DiffServ should be used as QoS mechanism between the UE and PDG, and that the PDG should support Policy Execution Point functionality and interface with the PDF.

Zhuang et. al. propose a novel extension to the IMS architecture to provide QoS when interworking UMTS and WLAN [12]. To ensure resource reservation across the different access networks a new element, the WLAN PDF is introduced. However, similar to 3GPP TR 23.836 this approach decentralises the PDF and makes it less generic for other access networks.

Gouveia et. al. suggest incorporating QoS awareness into mobility management in the IMS [13]. They describe the requirements for the management of QoS and mobility in NGNs and introduce a Domain Policy Manager, which consists of a PDF, a policy repository and a resource monitoring function.

III. IMS Architecture

The IMS is essentially an overlay architecture that allows multimedia service provisioning across both wired and wireless access networks. It was initially standardised as part of UMTS Release 5 documentation, but has been extended considerably. The current stable IMS standard is Release 6, but work has already begun on Release 7 and 8. Furthermore the 3GPP2 has adopted the architecture for use on top of their Multimedia Domain [6], and TISPAN is utilising the IMS for multimedia service provisioning in their NGN architecture [7].

In the increasingly competitive ICT industry it is important for network operators to differentiate themselves through the services they offer. By moving all signaling and media transport to the packet domain the IMS not only reduces operating and capital expenditure but also provides a scalable platform for quick and efficient service development.

A. Core Components

One of the goals of the IMS is to utilise previously defined standards as far as possible [6]; these include SIP, DIAMETER, COPS, RTP and numerous others. When an IMS session is set up signaling information traverses SIP proxies between the UEs, however once the session is established the actual media does not necessarily follow the same path and will usually traverse an optimised path between end users. In multimedia sessions QoS constraints are of vital importance and it is necessary to reserve resources along the datapath; for this we need to communicate session information between the data and signaling planes.

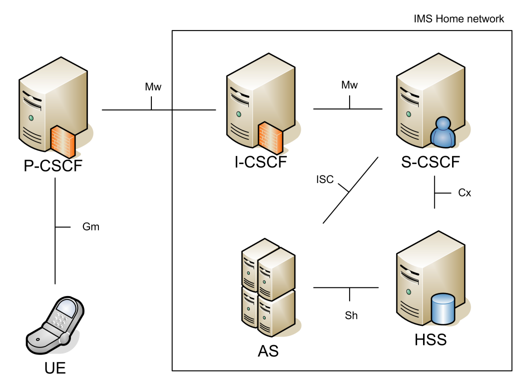

Fig. 1. IMS core components.

Figure 1 illustrates the key components for IMS session setup [14]. The User Equipment (UE) is an IMS end user equipped with a SIP user agent and identified by an Uniform Resource Identifier (e.g. sip:foo@bar.com). The Proxy Call Session Control Function (P-CSCF) is the first point of entry into the IMS network, and can be located on the users home network or a visited network. The P-CSCF validates requests, forwards messages, maintains security associations and enforces any local network polices; it can be discovered by DHCP or PDP context establishment.

The Serving CSCF (S-CSCF) is the central node in the signaling plane and performs session control services for the endpoints while maintaining session state as needed by the network operator. The S-CSCF sits on the path of all signaling messages and collects session information for billing purposes, performs routing services, enforces network policies and decides whether an Application Server is required for an incoming session. The Interrogating CSCF (I-CSCF) is the contact point within an operators network for all connections destined to a subscriber of that network operator. The main job of the I-CSCF is to assign a S-CSCF to a session, but it may also be used to hide the IMS core architecture from the outside world in which case it is known as a Topology Hiding Inter-networking Gateway.

The Home Subscriber Server (HSS) is a master user database that holds user profile information including individual filtering information, user status information and application server profiles. It also assists the I-CSCF in choosing an appropriate S-CSCF. Application Servers (AS) host and execute services within the IMS. 3GPP has standardised the signaling and administrative interfaces but not how the applications are to be programmed. This allows third party developers to use any number of programming paradigms including CAMEL, SIP AS or OSA/PARLAY and translates to easy and efficient deployment of value added services in the IMS architecture.

B. IMS Session Setup

A number of functions need to be carried out during session setup including capability negotiation and resource reservation to support QoS preconditions. A session is started when the calling UE transmits an INVITE message that is routed through the IMS core to the callee UE. It is necessary to negotiate QoS requirements and if adequate resources are available then these are reserved for the duration of the session and session may progress. It is important to note that because the media flow is decoupled from the signaling the underlying network elements in the datapath must execute the desired QoS behaviour. Figure 2 shows a typical call setup procedure.

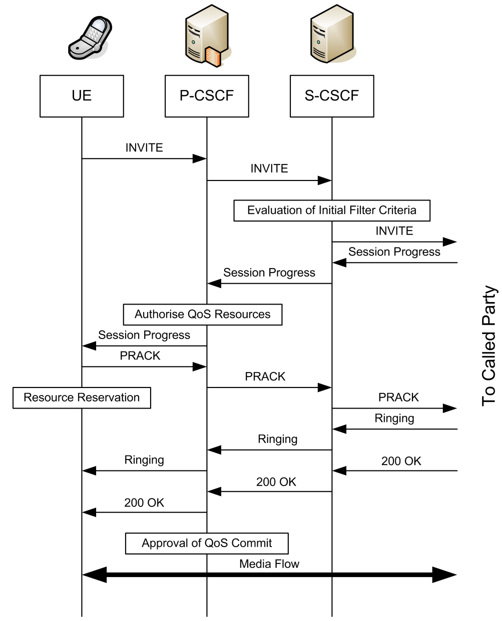

Fig. 2. IMS session setup.

IV. QoS Provisioning

The motive behind the introduction of the IMS was to provide call control for multimedia applications over All-IP networks [15]. Access independence means any IP-connected network can access IMS services, furthermore these networks can implement different QoS models. With the separation of the media and signaling planes a QoS mechanism is needed to manage resources on both the bearer and session level. Hence it is necessary to abstract low level network element configuration and dynamically control the behaviour of the network with high level policies. In this way neighbouring IMS domains can establish Service Level Agreements (SLA) with one another based on high level policies, without interfering with specific network management.

A. Policy Based Networking in the IMS

The IETF defines Policy Based Networking (PBN) as a mechanism for implementing QoS on both the session and bearer level [16]. In PBN policy rules describe the behaviour of the network without going into network configuration detail. Four new network elements are introduced [16].

The Policy Decision Point (PDP) is a logically centralised element that makes QoS decisions based on policy rules and network information. This element resides at the session level. The Policy Execution Points (PEP) are situated within the network elements and enforce the polices within the network using whatever QoS model is implemented. These elements reside at the bearer level. The Policy Repository is a relational database that holds the policy rules. The Policy Administrator is the end user that defines and modifies the policies.

The 3GPP has adopted PBN as the mechanism for providing QoS within the IMS [9]. They define the Policy Decision Function (PDF), a logical PDP that uses standard IP mechanisms to implement Service Based Local Policy enforcement in the IP bearer layer. The P-CSCF as the first point of contact in the IMS interfaces with the PDF via the Gq interface using DIAMETER. During session establishment the P-CSCF sends session information described in the Session Description Protocol (SDP) parameters to the PDF and requests an authorisation token; if the PDF authorises every component of the session an authorisation token is generated and sent to the P-CSCF[17].

Since the GGSN is in the datapath it is the logical location for the PEP. The PEP acts as a gate that allows authorised IP flows to use network resources, but drops unauthorised flows; this is known as policy based admission control [9]. The PEP communicates with the PDF via the Go interface, using the Common Open Policy Service (COPS) protocol [9]. COPS is a TCP based request/response protocol that can reliably transport policy information between the two entities. There are two models of interaction between the PDF and the PEP. In the Provisioning model the PDF decides which policy rules to install on the PEP; this would be used to start a multimedia session. In the Outsourcing model the PEP sends resource requests to the PDF; this would be used to transfer policy decisions in real time [18]. The GGSN implements DiffServ edge functionality and based on the policy decision information received from the PDF assigns appropriate Differentiated Services Codepoints (DSCP) to the packets in the media flow.

The policy rules are stored in a Policy Repository, this element may either be co-located with the PDF or a separate entity accessed via the Lightweight Directory Access Protocol (LDAP). The actual structure of these policies is not standardised but typical policy rules follow IF, WHAT, WHEN and THEN logic [19]. This kind of policy rule evaluates the identity of the user, the kind of application, the time of the request, and then takes appropriate action. Figure 3 illustrates the separation of the media and signaling planes and how the IMS implements policy based QoS provisioning.

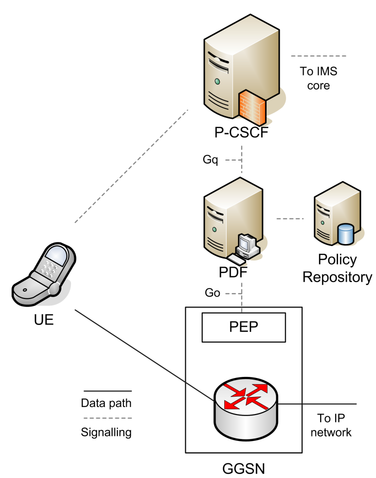

Fig. 3. Policy Based QoS Provisioning in the IMS.

B. Limitations

It should be clear from the description that in IMS QoS provisioning the PDF services only the GGSN and not other network elements. This prevents other access networks from taking full advantage of IMS services and is a barrier to the goal of true access independence [10]. While there have been attempts to incorporate QoS management into other access networks utilising the IMS [8], there is no generic QoS management framework for all access networks.

When a UE wants to establish a session with a user in another IMS domain there must be SLAs between the two domains; there is no standardised protocol for communication between neighbouring PDFs necessary to ensure fair and efficient resource reservation in both networks.

With a large proportion of IMS users being mobile it is becoming increasingly important to be able to guarantee QoS across different networks. In the current architecture there is no way of incorporating QoS information into mobility management and a handover will occur whether resources are available in the new network or not.

V. Hierarchical QoS Management Framework

A. Generic access Independence

For QoS provisioning across different access networks the scope of the PDF must be extended to act as a PDP for all network elements that participate in end to end resource control. We propose the introduction of a Packet Data Gateway (PDG) as an entry point into the multimedia network for all access networks allowing access technology specifics to be kept separate from the core network. This PDG would support policy execution point functionality and interface with the PDF via the Go interface. In this way the PDF can control resources across networks irrespective of access technology or implemented QoS model.

B. Resource Monitoring Function

For a mobility management protocol to become QoS aware the PDF must incorporate a resource monitoring function. With additional bandwidth broker functionality the PDF can keep track of the availability and status of the network resources and users. This involves extending the Policy Repository to become a Data Repository where remaining bandwidth, bandwidth allocation and requests are stored alongside the policy rules. This bandwidth related information can be used to introduce QoS awareness into the handover procedure.

C. PDF Inter-domain Communication

To guarantee resource reservation across different domains neighbouring PDFs need to be able to communicate; specifically to pass information about available resources and resource requests. The QBone Signaling Design Team has proposed an inter-domain bandwidth broker protocol called Simple Inter-domain Bandwidth Broker Signaling (SIBBS) [20]. We propose this request/response protocol be used to allow PDFs to pass resource requests to destinations that lie outside of their domains allowing resources to be reserved across networks.

D. Call Setup

In this scheme when a user establishes a session the P-CSCF passes session information to and requests authorisation tokens from the PDF via the Gq interface using DIAMETER. The session information is supplied by the SDP parameters that the P-CSCF extracts from the SIP signaling and typically specifies the kind of session and the user identity so the PDF can authorise and reserve appropriate resources in the data plane. The PDG receives decisions from the PDF via the Go interface using COPS. Once the PDF has confirmed that resources are reserved and the session is authorised the P-CSCF is notified and the call setup may continue. The specific QoS model implemented at the PDG or the access technology used is completely hidden from the PDF. Figure 4 shows the call setup procedure when implementing the Hierarchical QoS management system.

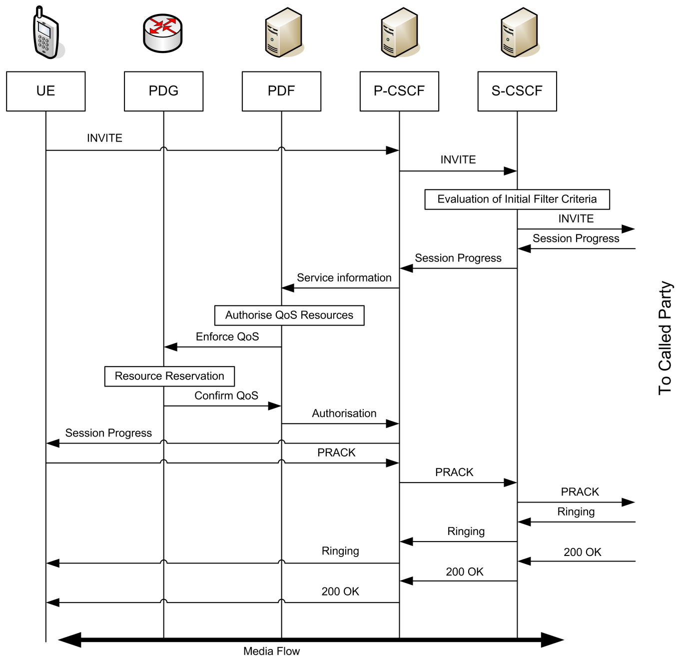

Fig. 4. IMS session setup with extended QoS mechanisms.

VI. Evaluation Framework

The IMS is an emerging technology that will have a great impact on the telecommunications world. However much research is needed to investigate and verify certain aspects of the system before it can be realised. At the time of writing there is only one known physical implementation of the IMS at a research institution, and this excludes a QoS management function [21]. Hence a practical real world implementation of the IMS is proposed to investigate and verify the functionality of the proposed Hierarchical QoS management framework.

Our current implementation consists of an IMS core and separate media plane. The various CSCFs are based on the SIP Express Router package developed by IPTEL [22], and the HSS is implemented using a MySQL database. The PDF consists of a data repository implemented as a MySQL database and interfaces to the PDG using an open source Java based COPS implementation [19]. The Gq interface that communicates session information between the data and signaling plane using DIAMETER has not yet been implemented. Figure 5 shows the complete architecture.

VII. Conclusions and Future Work

The stringent user requirements in today's connected world have introduced the need for a next generation, high speed network capable of supporting vast numbers of applications. The emerging IP Multimedia Subsystem is a service enabler that paves the way for Fixed and Mobile Convergence with an All-IP core. This paper examined the features of the IMS and specifically the QoS provisioning mechanism. A Hierarchical QoS Management Framework was proposed that incorporates access independence and policy based network administration to control and monitor resources. We described a practical

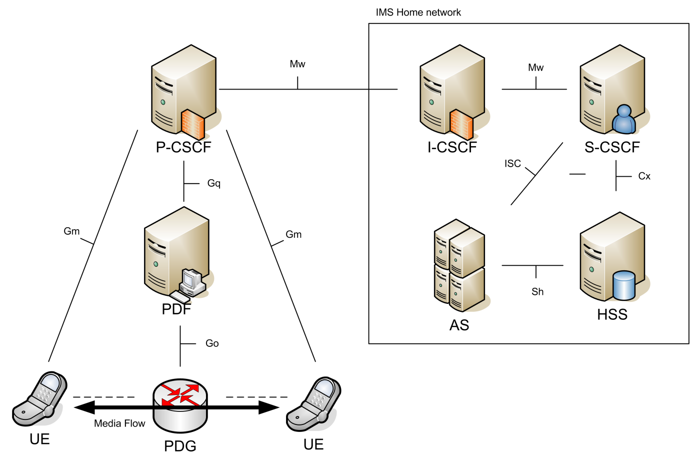

Fig. 5. IMS testbed implementation including QoS management system.

evaluation framework as well as the current status of the implementation.

Future work includes implementing the interface between the signaling and media planes and using the platform to perform proof of concept trials.

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References

[1] D. Greer, "Building Converged Networks with IMS technology," *Computer*, pp. 14–16, November 2005.
[2] J. Gibson, P. Wilderbeek, and L. Vetsergaard, "Fixed-Mobile Convergence: Unifying the Communications Experience," *The Fixed Mobile Convergence Alliance*, 2005.
[3] IETF RFC 2475, "An Architecture for Differentiated Services," 1998.
[4] IETF RFC 1633, "Integrated Services in the Internet Architecture," 1994.
[5] IETF RFC 2702, "Requirements for Traffic Engineering Over MPLS," 1999.
[6] 3GPP TS 23.228, "IP Multimedia Subsystem (stage 2)," 2006.
[7] ETSI TISPAN TR 180 001, "NGN Release 1," 2006.
[8] 3GPP TS 23.234, "3GPP System to WLAN Interworking," 2006.
[9] 3GPP TS 23.207, "End-to-End QoS Concept and Architecture," 2005.
[10] W. Bohm and P. Braun, "Policy Based Architecture for the UMTS Multimedia Domain," *Second IEEE International Symposium on Network Computing and Applications*, pp. 275–285, April 2003.
[11] 3GPP TR 23.836, "QoS and policy aspects of 3GPP - WLAN Interworking," 2005.
[12] W. Zhuang, Y. Gan, K. Loh, and K. Chua, "Policy-based QoS-management Architecture in an integrated UMTS and WLAN environment," *IEEE Communications Magazine*, pp. 118–125, November 2003.
[13] F. de Gouveia and T. Magadenz, "A Framework to Improve QoS and Mobility Management for Multimedia Applications in the IMS," *Seventh IEEE International Symposium on Multimedia*, pp. 216–222, December 2005.
[14] M. Poikselka, G. Mayer, H. Khartabil, and A. Niemi, *IMS: IP Mulitmedia Concepts and Services in the Mobile Domain*. John Wiley and Sons, 2004.
[15] R. Prasad, *Wireless IP and Building the Mobile Internet*. Artech House, 2003.
[16] IETF RFC 2753, "A Framework for Policy-Based Admission Control," 2000.
[17] 3GPP TS 29.208, "End-to-End QoS signalling flows," 2006.

[18] G. Camarillo and M. Garcia-Martin, *The 3G IP Multimedia Subsystem - Merging the internet and cellular worlds 2nd Edition*. Jonh Wiley and Sons, 2006.
[19] S. Jha and M. Hassan, "Java Implementation of Policy-Based bandwidth management," *International Journal of Network Management*, pp. 249–258, July 2003.
[20] Chimento et. al., "QBone Signalling Design Team - Final Report," 2002.
[21] "IMS Playground@Fokus." http://www.fokus.fraunhofer.de/ims/, September 2006.
[22] "SIP Express Router." http://www.iptel.org, April 2006.