The IP Multimedia Subsystem (IMS). Quality of service and performance simulation

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***Abstract*— The IP Multimedia Subsystem (IMS) is the evolution of the 3G mobile telecommunications systems towards All-IP environments supporting all the services working today through switched circuits plus new value added multimedia services (VoIP, video call, video streaming, presence, instant messaging, online gaming, etc.). Based on Internet standards and being access-agnostic, IMS is seen as a key element for achieving network convergence. This paper focuses on Quality of Service (QoS) provision, which is one of the main issues still open in the IMS. We introduce a new simulation tool that can be used to measure IMS performance for different applications and network scenarios, to evaluate the impact of QoS mechanisms and to fine tune network parameters in order to meet the quality requirements of each service.**

***Index Terms*— IMS, QoS, simulation, convergence.**

I. Introduction

THE current trend towards an All-IP convergent environment responds to the recent changes in communication scenarios where ubiquity has become one, if not the most, important factor. Given the availability of many heterogeneous access networks covering different usage scenarios, interoperability among them is an issue to solve in order to achieve the desired network convergence where the user can enjoy a broad range of services anytime, anywhere, without degrading the quality of experience. Defining a core network that deals with all the different access networks available, guarantying interoperability and hiding the details of each access technology, while providing all the requirements needed by today's and tomorrow's services (like multimedia support, security, QoS, etc.) seems the best way to enable network and service convergence.

The IP Multimedia Subsystem [1] is the answer of 3GPP to achieve convergence. Although specified as part of the All-IP core for the 3GPP UMTS (Universal Mobile Telecommunications System), its access-agnostic nature makes it well suited to guarantee interoperability even for non IP networks, thanks to the definition of media and signalling gateways. Since it is based on Internet standards, like SIP (Session Initiation Protocol) and RTP (Real Time Protocol), the implementation of IMS solutions is favored by the mature know-how in Internet technologies. Moreover, as the IMS itself is standardized too and widely supported in the industry (specially by mobile operators), the risk of adopting proprietary convergence solutions is avoided. However, there are still some practical challenges to solve in order to consider the IMS a convergence enabler.

The rest of this paper is organized as follows. Section 2 reviews the evolution towards All-IP convergent environments of the main mobile telecommunication systems, describing the IMS architecture and introducing current challenges. Section 3 focuses on challenges regarding QoS on the IMS. Section 4 presents a SIP-IMS simulation model to allow performance evaluation of different IMS scenarios. Finally, Section 5 summarizes the contributions of the paper.

II. The IP Multimedia Subsystem

A. Motivation

From an operator's point of view, moving towards a common network infrastructure supporting all kind of services is a very attractive idea. An integrated network not only takes advantage of network resources but also reduces costs, especially when using the widely supported IP protocol with more and more applications and devices available each day. In particular, the main 3G mobile telecommunication systems, UMTS and CDMA2000, are evolving this way and IMS, initially specified in the former and adopted in the latter, is the proof.

B. 3G mobile networks evolution towards All-IP

As stated before, the current trend towards All-IP environments can be noticed in the evolution of 3G mobile networks. An example is UMTS evolution, which is shown in Fig. 1. The first step is given in Release 4, specifying an architecture for the circuit switched domain that enables the transport of voice over packets. In case of choosing IP, the possibility of using a common backbone for both circuit and packet domains is open, thus driving towards an All-IP core network.

The introduction of the IMS subsystem in Release 5 allows users to access a new range of services through the packet switched domain: IP multimedia services, thus encouraging the use of IP for all type of services. This could easily be considered as the application of the All-IP concept to the world of services, eventually making the circuit switched domain unnecessary. Finally, following the works in Release 5, the logical step of supporting different IP access networks is also specified in Release 6, thus allowing the access to all the services through virtually any access network such as UTRAN (UMTS Radio Access Network) or WLAN (Wireless Local Area Network).

C. IMS architecture

Fig. 2 shows the packet switched domain as specified in UMTS Release 5, where the IP multimedia subsystem elements are introduced.

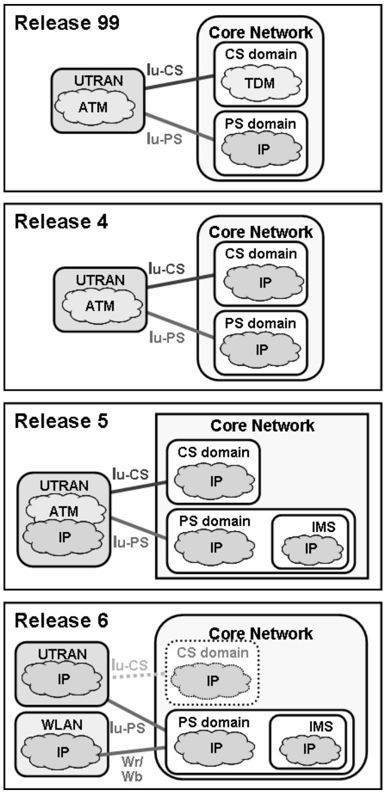

Fig. 1. UMTS evolution towards All-IP

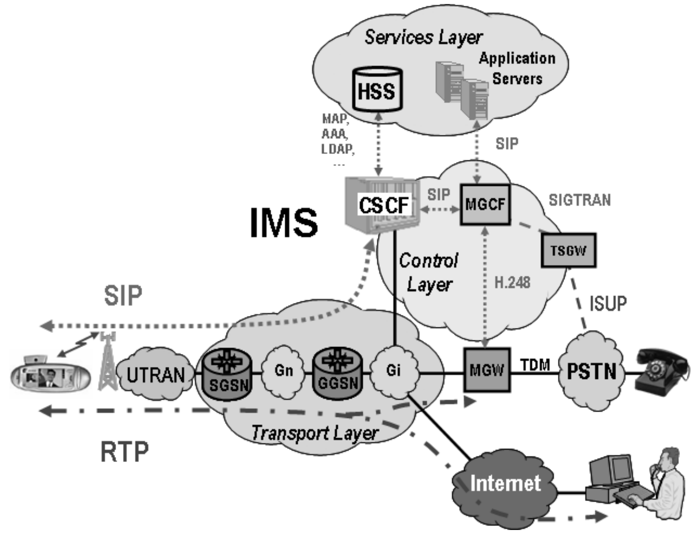

Fig. 2. IMS core architecture

The most important element is the CSCF (Call State Control Function), which is basically the combination of a SIP registrar and a SIP proxy server. Actually, there are three types of CSCF (Proxy CSCF or P-CSCF, Interrogating CSCF or I-CSCF and Serving CSCF or S-CSCF) with well defined roles in the session establishment. P-CSCF is specialized in the direct dialog with the user terminal, while I-CSCF provides localization and authentication functions by querying the HSS[1] (Home Subscriber Server), which also stores users' profiles. Finally, S-CSCF is the key element to access to available services, since it registers the users, provides billing information to mediation systems and performs service triggering, providing access to separate application servers if necessary.

The IMS also defines a set of elements to achieve interworking with conventional telephone networks. The MGCF (Media Gateway Control Function) uses MEGACO/H.248 commands to control the media gateways (MGW) that convert VoIP streams into voice streams over switched circuits of 64 kbit/s and vice versa. As signalling has to be converted too, the MGCF controls the Transport Signalling Gateway (TSGW) to do this task. This way, thanks to its All-IP nature and support for conventional networks, we can think of the IMS as an appropriate enabler technology for network and services convergence. In fact, although initially proposed for 3GPP UMTS, 3GPP2 has based its CDMA2000 Multimedia Domain (MMD) [2] on IMS, thus greatly extending its support and availability. IMS has also been adopted by ETSI TISPAN [3] (Telecoms and Internet converged Services and Protocols for Advanced Networks) to standardize converged networks using IMS as its core architecture and allow IMS access through fixed networks.

[1]The HSS is the successor of the HLR (Home Location Registry) of 2G mobile networks and acts as the user database.

D. IMS Challenges

Commercially available IMS services are still in their infancy and providers are working on the implementation of IMS in both network's and user's side. As usually, implementations may face interoperability issues since the IMS specification is flexible to allow differentiation, as stated in [4]. In particular, QoS solutions are not enforced by the specification, although QoS requirements are well defined. We are focusing on this issue in next section, as well as on a related one which is the lack of performance evaluation and simulation tools supporting the IMS.

Other non technical challenges include defining the business model. As IMS enables the provision of commercial services by the operator and third parties, another challenge is defining billing schemes for charging services, as the value chain and impact on final services' price have to be determined. Operators are likely to create an "IMS broker", interconnecting operators and third-party service providers via SLAs (Service Level Agreements), so agreements would only take part between the IMS broker and each operator and service provider, simplifying the commercial scenario.

However, the success of IMS or any other convergence enabler technology depends on the provision of value-added services that take advantage of all the core services it provides (presence information, session transfer, QoS, etc.). Currently, all the IMS services planned are ports of existent services like the voice service, walkie-talkie ("Push To Talk"), presence and instant messaging, etc. thus not showing the advantages of the convergence yet. Maybe new highly interactive multiuser multimedia applications like online gaming and collaborative work will unleash the power of IMS.

III. Provision of Quality of Service

The migration towards All-IP environments has made QoS a very important issue because traditional IP's best effort strategy is only appropriate for the first Internet services like email, telnet or web, which are in general very tolerant in terms of network parameters like available bandwidth, delay or jitter. However, as new convergent networks have to offer real-time services like telephony, video call or new highly interactive multiuser multimedia applications to come such as collaborative work or online gaming applications, the best effort strategy is no longer valid to take the advantage of network resources while guarantying user's quality of experience.

According to [4], the IMS shall offer negotiable QoS for IP multimedia sessions, as well as support roaming and negotiation between operators for QoS and for service capabilities. Roaming shall be supported enabling users to access IP multimedia services provisioned by, at least, the home environment and serving network. Of course, since the IMS pretends to be access-agnostic, it recommends operators to be able to offer services to their subscribers regardless of how they obtain the IP connection (i.e. GPRS, fixed lines, WLAN).

The IMS specification allows operators to differentiate their services in the market places as well as customise them to meet specific user needs, so it provides a flexible specification that does not enforce the implementation of particular QoS technologies. The selection of these technologies is still an open issue within the 3GPP. Some of the most recent technical documents on this aspect are [5] and [6], which identify the candidate technologies for providing end to end QoS in the IMS. These technologies, as shown in Fig. 3, currently include access control protocols like COPS (Common Open Policy Server) and DIAMETER, QoS signalling protocols like RSVP (Resource Reservation Protocol) and the recent NSIS [7](Next Step in Signalling), IntServ and DiffServ mechanisms, MPLS (Multiprotocol Label Switching) traffic engineering, solutions based on DiffServ over MPLS and so on. This wide range of available QoS solutions provides the required flexibility allowing choosing the one which best fits a certain IMS domain. However, this technological heterogeneity does not help in convergent environments with multiple access and transport operators as well as service providers where the need for interoperability among all the parties is clear.

Choosing the right QoS solution is hence one of the practical challenges. The trend is using DiffServ over MPLS, joining the simplicity of DiffServ to the forward control of MPLS, thus avoiding the scalability issues of IntServ and the per-hop behaviour of DiffServ. However, the versatility of the recently specified NSIS protocol could change this trend and turn into an alternative.

Achieving interdomain QoS is the second practical challenge as there are potentially two heterogeneities among domains. A technological one, that prevents domains from interoperating because of implementing different QoS protocols, and an administrative one, that prevents domains from interoperating because of different SLAs in each domain. Assuming the convergence network is actually a set of interworking and heterogeneous networks, its core requires the development of QoS intermediaries to convert QoS protocols and SLAs among domains. In the IP Multimedia Subsystem this would mean the specification of a "QoS gateway", similar to the already specified for media and transport signalling, that would guarantee interoperability among domains at both technological and administrative levels.

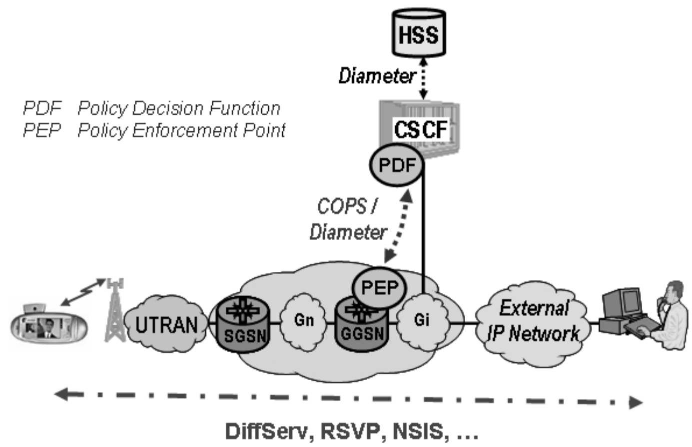

Fig. 3. Protocols involved in QoS provision

IV. IMS simulation

A. Motivation

Simulation is a useful tool in order to investigate QoS and performance issues before the actual deployment of IMS. We have reviewed the two most known network simulators, Network Simulator (NS2) and OPNET Modeler, and found that none of them include adequate support for the IMS.

NS2 include modules for many Internet protocols like TCP, UDP and IP as well as multicast and wireless networks. Support for QoS provision technologies like IntServ or DiffServ is included in recent versions as well as in third-party modules like [8] and [9]. However, MPLS and SIP [10] are only provided by third-party modules. Regarding UMTS, there are modules only for the radio access network [11], thus enforcing the need for modelling all the core network's entities in order to perform a simulation of a complete IMS network scenario.

Modeler has native modules for Intserv, Diffserv and MPLS, as well as limited SIP support and a module for UMTS Release 99 which does not include IMS. Additionally, there are contributed modules to enhance SIP functionality but they are not enough to simulate particular IMS mechanisms, like [12], which does not implement the IMS architecture or [13], which focuses in VoIP scenarios.

B. Description of the model

As stated before, there is currently no support for IMS in the most known simulators available. Hence, we have developed a SIP-IMS simulation model for Modeler [14]. The SIP-IMS model features:

- Full implementation of the IMS session establishment mechanism, including the three types of SIP-IMS intermediaries (S-CSCF, P-CSCF, I-CSCF) and the user agent client (UAC) and server (UAS) processes.

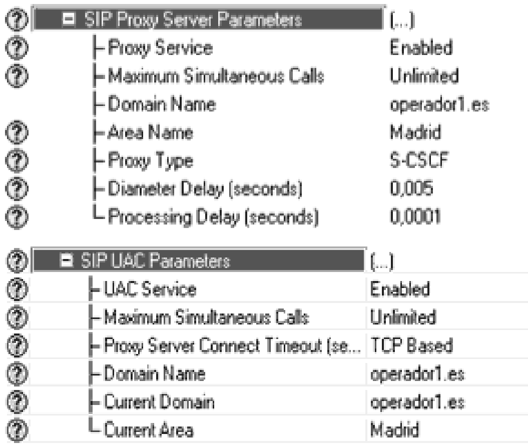

Fig. 4. SIP-IMS model parameters

- Multidomain and roaming support.
- Redundancy support for SIP intermediaries.
- Process delay control for each SIP message in the intermediaries.
- HSS queries delay control (queries to the HSS are currently modelled as a delay).

The attributes of the model are shown in Fig. 4. The upper part shows a sample SIP-IMS proxy server configured as S-CSCF, which serves users belonging to the domain operador1.es in the area of Madrid. The last two parameters model HSS queries and SIP messages processing delays. The bottom part of Fig. 4 shows the SIP UAC attributes. Domain Name is the home domain, while Current Domain and Current Area refer to the actual network that is serving the user so, in case the user is roaming, they refer to the visited network.

C. Application scenarios

The current version of the SIP-IMS model allows the simulation of different scenarios involving one or more operators. This allows us to model the establishment of IMS sessions between subscribers belonging to different operators, as well as roaming scenarios. Specific aspects about IMS signalling that can be evaluated with the tool are:

- Influence of CSCF processing delay in session establishment time.
- Traffic and signaling differentiation impact on QoS parameters.
- CSCF intermediaries setup scalability.
- Impact of roaming on QoS provision.

Fig. 5 shows two basic scenarios, both modelling the establishment of IMS sessions within a single operator's domain. The scenario on the left includes the three CSCF types with multiple P-CSCF and S-CSCF instances. The elements "Nodo 1" to "Nodo 5" represent a basic IP transport network. The scenario on the right is similar, but includes a MPLS transport network. Note that the figure only shows the IMS specific elements. The scenarios are completed with modules representing the access network (e.g. node Bs and RNCs for UTRAN, WLAN access points, etc.), the core network (SGSNs, GGSNs) and the user terminals. The icons shown on the top of Fig. 5 give access to parameter configuration windows related to applications used by the terminals, traffic load and IP/MPLS QoS mechanisms.

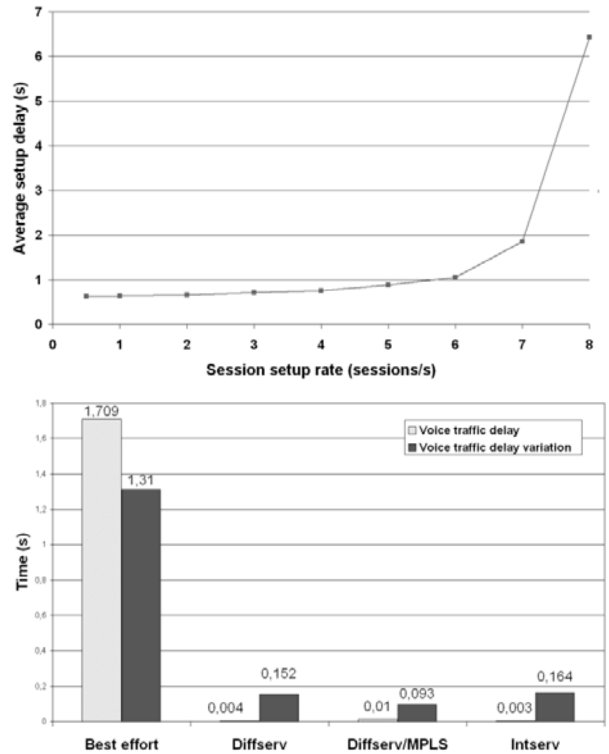

Fig. 6. Simulation results for delays in the user and control planes

These sample scenarios have been used to evaluate the session setup time considering the processing delay in CSCFs, background traffic and QoS strategies for signalling differentiation. The top graph of Fig. 6 shows the setup delay as a function of the session attempt rate for a particular configuration of the SIP-IMS model's parameters. The graph at the bottom shows the average delay and delay variation of voice packets in a session depending on the QoS mechanism in a network with high background traffic.

The simulation model provides other relevant results such as the session blocking ratio or statistics related to signalling messages delay. In addition, the user can activate the tracing feature in order to analyze signalling message sequences and other events. The model may be extended to provide other type of results as required.

V. Conclusions

As discussed in the paper, Quality of Service in IMS is still an open issue. Current specifications focus on the definition of QoS requirements as well as the identification of QoS functions and protocols for both the user and the control planes. However, the specifications give flexibility to operators so they can choose the most appropriate solution according to their particular requirements. In practice, this flexibility

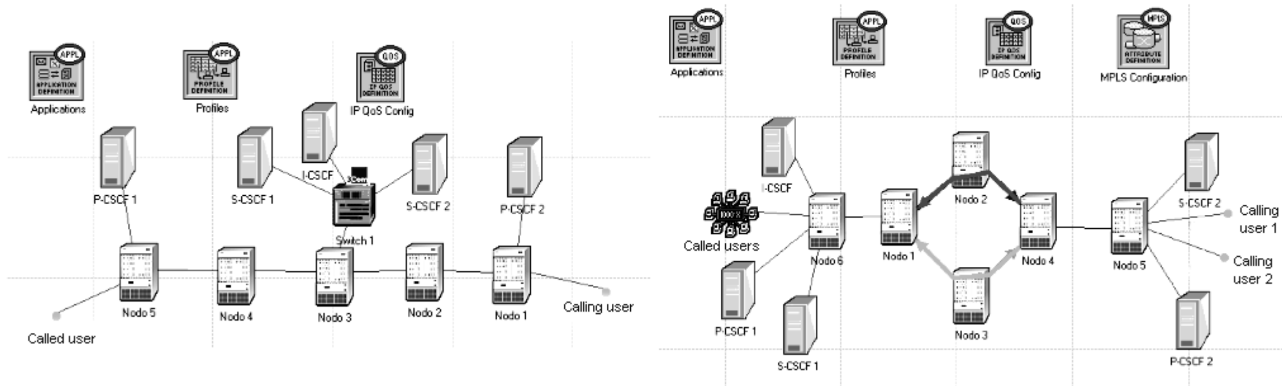

Fig. 5. Example of simulation scenarios: detail of IMS elements

translates into two issues. On the one hand, choosing the best solution for a domain, which will be potentially different in each one. On the other hand, achieving interdomain QoS, which will probably require the development of intermediaries (QoS gateways) to convert QoS protocols among domains.

Given the limitations of existing simulation tools for IMS environments, we have developed a complete and flexible simulator called SIP-IMS [14], which runs on the OPNET Modeler platform. The tool includes a detailed model of the IMS session control procedures, comprising UAS and UAC processes, S-CSCF, P-CSCF and I-CSCF intermediaries, intermediaries redundancy, multidomain and roaming support.

Our tool can be used with other Modeler library modules (traffic models, QoS mechanisms, MPLS, etc.) in order to simulate a wide range of network scenarios. Our current work includes using the simulator for evaluating the performance of IMS based multiuser multimedia applications. We are also improving the simulator with a more detailed model of the HSS and the support for session transfer.

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