Abstract – In the latest specifications of the Universal Mobile Telecommunication System (UMTS) networks, the 3GPP defines the IMS technology. That is why the multimedia sessions in the IMS are processed by a set of network elements originally designed to support IP multimedia services in the UMTS. The QoS mapping between IMS services and IP transport is fundamental for maintaining a suitable quality. The differentiation of these two technologies can lead to unpredictable and unwanted behavior for services. The possibility of employing DiffServ and IntServ mechanisms into the IMS environment in order to achieve full QoS support for real-time applications is the object of interest.

1 Introduction

Increasing requirements for personalization, consumer’s mobility and agile services call for a new communication environment. Consumers are looking for easier and better ways of reaching out to each other over whatever terminal or access technologies which are available at the moment. Users want to share their latest experiences anywhere and anytime, therefore the network infrastructure must provide sufficient network resources for high-value services. A natural way to make this new approach possible is the evolution towards an all-IP environment which appears to be a strong trend. The IP Multimedia Subsystem (IMS) represents such an architecture providing multi-access to required services and large-scale interoperability. The IMS technology originated from the Third Generation Partnership Project (3GPP) Release 5 specifications as a part of the core network evolution from circuit-switching to packet-switching architecture [1]. The idea was to integrate traditional telecommunication services with the Internet Protocol. Therefore, this architecture uses two of the most successful representatives in communications, namely fixed/mobile networks and the Internet. The IMS refers to a functional architecture based on Session Initiation Protocol (SIP) specification, which allows voice, text and multimedia services to pass through all connected networks. The architecture is also based on other important protocols, especially Diameter, Real-time Transport Protocol (RTP) or Megaco/H.248, and a wide range of interfaces. It is designed to be access-independent so that IMS services can be provided over any network. IMS is a technological framework that allows the evolution of standardized person-to-person communication services from multi-access to interactive multimedia experiences in real time anywhere and at any time. IMS can provide a range of interesting services including video telephony, push-to-talk over cellular, presence, instant messaging and combination of these services in one session.

In spite of cellular networks providing mobility and a wide range of services, the main reason for creating IMS is to offer more than the mere Quality of Service (QoS) support. The term QoS is widely used in the telecommunication world today. All IMS solutions should guarantee the QoS that customers need and demand. Deployment of new services depends on the QoS level that the IMS technology is capable to provide. Since the IMS involves a large amount of protocols, it is important to define ways in which different end system can reach the end-to-end QoS for a connection. One of the questions is how to use lower layer QoS mechanism to achieve upper layer QoS within the network. There is a need to ensure the interoperability among different layers, domains and networks. The network capacity is currently adequate for the majority of applications. In spite of that, it often happens that the user’s perceived qualities of network traffic characteristics are not satisfactory. To provide end-to-end QoS, it is necessary to manage the QoS within each domain along the path. In the IP domain, there are some well-known mechanisms for QoS provisioning, such as Differentiated Services (DiffServ) and Integrated Services (IntServ). The utilization of these mechanisms in the IMS is still an open issue. The end-to-end QoS in the IMS architecture introduces several challenges which have to be faced.

In order to solve QoS challenges in the IMS, the emulations and simulations have to be accomplished. OPNET Modeler is the software simulation tool that enables the investigation and research of the network behavior. A partial goal of this paper is to find out if the capabilities of this network simulator are sufficient to analyze and design IMS networks and monitor service quality.

2 State of Research

The research follows the objectives mentioned in previous chapter. Multimedia applications require sophisticated management of system components affecting the Quality of Service [3]. To achieve demanded QoS characteristics, all the components across the entire network must work correctly. It means that the QoS depends on the weakest element of the network. On the network level, two traffic mechanisms are in use: resource reservation model based on IntServ and traffic prioritization model based on DiffServ. One of the potential configurations to support real-time traffics is represented by IntServ and DiffServ capabilities. The impact of IntServ and DiffServ architectures and their respective benefits ensure the QoS on the network level.
The QoS architecture, to be used in the 3GPP system, is described in the 3GPP TS 23.107 specification [4]. The end-to-end QoS concept and architecture is proposed in the 3GPP TS 23.207 specification [5].

2.1 QoS mapping

The provision of the QoS guarantees in fully integrated multimedia network is a complex issue. It involves several inter-related aspects such as QoS specifications, QoS mapping, policy control and other not less important parameters. The following intention is focused on the QoS mapping. The QoS mechanisms can be divided into two parts: a vertical mechanism and a horizontal mechanism. The vertical mechanism links the lower layer and the upper layer QoS mechanisms. While the horizontal mechanism links the lower layer QoS control between different domains and networks.

The process of translating QoS specifications between two different levels of the Internet Protocol Suite is called QoS mapping. An example of layered view of communication and QoS mapping in the Internet Protocol Suite is described in Figure 1. Each layer of the protocol stack may offer its own type of QoS. The mapping is needed to translate the QoS provided by the lower layers into parameters that are meaningful in the higher layers. The reverse direction of mapping has to be taken into consideration. It means that the parameter sets of the upper layer protocol can be used to control the lower layer. Appropriate mapping rules across all layers have to be considered for required QoS achievement.

The QoS mapping between IMS services and IP transport is fundamental for maintaining a suitable quality. The differentiation of these two technologies can lead to unpredictable and unwanted behavior for services. There are many cooperating components such as routers or servers to provide end-to-end QoS guarantees to the customers. The traditional IP networks were designed using Best Effort paradigm without any guarantee. It means that packets are forwarded without any awareness of QoS requirements of different types of services. This leads to unpredictable delay and packet losses. In order to ensure QoS, the IntServ and DiffServ mechanisms are provided. The technology of DiffServ is the most widely implemented solution.

2.2 QoS in the IMS

In the latest specifications of the Universal Mobile Telecommunication System (UMTS) networks, the 3GPP defines the IMS technology. That is why the multimedia sessions in the IMS are processed by a set of network elements originally designed to support IP multimedia services in the UMTS. The end-to-end QoS architecture is provided in Figure 2 [5]. The framework for QoS within UMTS is applicable to GPRS (General Packet Radio Service) packet switched access services and includes the aspects of interworking to the IMS. The basis of provision of the required QoS is the selection of bearers with appropriate characteristics. The bearer service includes all aspects to enable the provision of the QoS. Each bearer service performs an offer to individual services using the lower layer services. The circuit-switched access services are not covered.

The traffic passes different bearer services of the network from a Terminal Equipment (TE) to another one. This TE is connected to the UMTS network by the use of a Mobile termination (MT). The TE/MT Local Bearer Service, the UMTS Bearer Service and the External Bearer Service are used for End-to-end Service realization.

3 Ensuring QoS for IMS services

The QoS cannot be controlled without the interaction between the Signalling layer and Transport layer. Therefore, a mechanism to authorize and control the usage of the bearer traffic intended for IMS media traffic was created. This mechanism is based on the Session Description Protocol (SDP) parameters negotiated at the IMS session. The QoS applies in a SIP-based communication scenario. During a SIP session setup, the User Equipment (UE) negotiates its capabilities and expresses its QoS requirements at the application level. The UE is able to negotiate media type, direction of traffic, packet size, bandwidth etc. Then the suitable resources from the access network are reserved. With an appropriate protocol (RTP) are the media packets sent to the access and transport network by using TCP (Transmission Control Protocol) or UDP (User Datagram Protocol).
Protocol) over IP protocol. The QoS in the core network is offered and guaranteed by the providers afterwards. The QoS control and policy management are two conclusive functions. The concept of QoS control is included in the Policy and Charging Control (PCC) architecture [2]. The policy control means the capability to authorize and control the barrier traffic usage for IMS media. The Policy and Charging Rules Function (PCRF) encompasses flow based charging control functionalities and makes policy decisions. These decisions are enforced by the Policy and Charging Enforcement Function (PCEF) which can be located at the Gateway GPRS Support Node (GGSN) [4].

The most common model, when a mobile terminal is used, is to have the GGSN. The GPRS is a packet-switched domain of the UMTS network with IP connectivity to attached terminal through a Packet Data Protocol (PDP) context. The PDP context offers a packet data connection over which the terminal and the network are able to exchange IP packets. The primary PDP context activation is initiated by the terminal and is used to establish a logical connection with the QoS from the terminal to the GGSN. The PDP context is established right after performing a GPRS attach. The terminal’s IP address and PDP context’s QoS characteristics are stored by the network regarding this PDP context. A second PDP context activation can be established for different QoS profile.

4 QoS support in the IMS using DiffServ and IntServ

To provide IP QoS end-to-end, it is necessary to manage the QoS within each domain. There are two QoS mechanisms configured in order to ensure the QoS on the network level. The focus is on mapping of QoS requirements for flows in DiffServ and IntServ domains.

4.1 DiffServ mapping

Both edge and core DiffServ routers use to be supported in order to implement DiffServ in the IMS. The edge routers are placed in the border area of a DiffServ domain and core routers provide IP routing functions inside the core network. The DiffServ mechanism is scalable and it can be implemented with long term setup. With a special marking in the packet’s IP header based on DiffServ codepoints, it is possible for routers inside the network to process the packet flow. The packets with the same codepoints operate with forwarding behavior PHB (Per-Hop Behavior) inside the domain. The most suitable PHB groups for IMS implementation are: Expedited Forwarding (EF), Assured Forwarding (AF) and Best Effort (BE).

The Expedited Forwarding PHB [6] is aimed for low loss, low delay, low jitter and assured bandwidth which is needed for real-time services. The Assured Forwarding PHB [7] defines a method by controlling the drop preference of packets at the time of congestion. No priorities are forwarded to packets in the case of Best Effort PHB. The service performance depends directly on the network status.

The DiffServ mechanism can be applied to IMS networks by using EF, AF and BE PHB classes. Table 1 describes an example of such mapping [8]. The advantage of this mapping is the absence of extra signalling along the path as in the IntServ. In the case of Conversational class, the EF forwarding is used. The Streaming traffic is assigned with higher drop priority within AF Class 1. The same rule is applied to Interactive traffic classes, but in Class 2 and Class 3. The Best Effort is used for background transmissions.

<table>
<thead>
<tr>
<th>UMTS Class</th>
<th>DiffServ service level</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conversational</td>
<td>EF PHB</td>
<td>Voice/Video</td>
</tr>
<tr>
<td>Streaming</td>
<td>AF PHB Class 1</td>
<td>Video streaming</td>
</tr>
<tr>
<td>Interactive</td>
<td>AF PHB Class 2</td>
<td>Web browsing</td>
</tr>
<tr>
<td>Background</td>
<td>BE</td>
<td>Email</td>
</tr>
</tbody>
</table>

The DiffServ routers do not have to store any state information of the flows. These routers consist of following components: Packet Classifier, Traffic Marker, Traffic Meter and Traffic Sharper. The Packet Classifier performs the identification of incoming packets and their separation into several groups according to predefined rules. The Traffic Marker sets the value of the DSCP (Differentiated Services Code Point) field so that the packet receives appropriate PHB. The Traffic Meter measures the rate of traffic streams selected by the classifier and Traffic Sharper may drop packets if there is not sufficient buffer space. The traffic classes, traffic policies and associated Access Control List (ACL) are configured by the edge routers.

4.2 IntServ mapping

The network resources are reserved according to an application QoS request. This model specifies the characteristics of a traffic flow, reserves the resources within the network using RSVP (Resource reservation protocol) signalling and provides the traffic control in order to ensure QoS. As it was mentioned in the second chapter, the IntServ involves three types of services: Controlled Load, Guaranteed and Best Effort. The Controlled Load service class emulates the behavior of better than Best Effort service. The Guaranteed service class offers the highest level of the QoS per flow because it closely emulates a virtual circuit. The Best Effort service class does not include any kind of quality control notification. An example of UMTS classes mapping to IntServ is in Table 2.

<table>
<thead>
<tr>
<th>UMTS traffic Class</th>
<th>IntServ service level</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conversational</td>
<td>Guaranteed</td>
<td>Voice/Video</td>
</tr>
<tr>
<td>Streaming</td>
<td>Controlled load</td>
<td>Video streaming</td>
</tr>
<tr>
<td>Interactive</td>
<td>Controlled load</td>
<td>Web browsing</td>
</tr>
<tr>
<td>Background</td>
<td>BE</td>
<td>Email</td>
</tr>
</tbody>
</table>
4.3 Simulation Model

To meet the requirements of the QoS in the IMS, a simulation model of IMS subnetwork was designed and implemented. Since the IMS is the NGN technology, the network characteristics investigation through a simulation tool is required. Gained network characteristics should follow expected results and help to think of the IMS as simulation-capable architecture. The OPNET Modeler implements some important elements for IMS simulations. From the Internet Protocol Suite layer architecture point of view, the Internet Protocol is supported on the Internet layer. The most well-known transport protocols TCP and UDP are implemented in the OPNET Modeler solution. Also SIP, RTP and RTCP protocols are fully supported. The Diameter protocol is available in a contributed model.

In order to solve QoS challenges in the IMS, the contributed SIP-IMS simulation model for the OPNET Modeler simulator was developed. The SIP-IMS Model for OPNET Modeler is an enhanced model of the original SIP model provided by the standard library. It enables full implementation of the IMS session establishment mechanism. The S-CSCF (Serving Call Session Control Function), P-CSCF (Proxy Call Session Control Function) and I-CSCF (Interrogating Call Session Control Function) servers are supported.

Two basic elements are used for subnetwork application selection and configuration in OPNET Modeler tool: Application Config and Profile Config. These elements are independent simulation components, which predefine the applications and profiles that will be used by a subnetwork. The Application Config element defines several applications, namely VoIP, video conferencing, e-mail, FTP (File Transfer Protocol), web browsing, database access and others. The Profile Config element assigns profiles to particular applications. The setup of start time offset, duration or repeatability is able in Profile Config table.

In order to configure the QoS support, the QoS Attribute Config model is implemented to the simulation tool. The configuration of QoS global parameters is involved. There are many different end-to-end scenarios that may occur in the network. The following scenarios are considered to be significant. Three scenarios were configured in the OPNET Modeler simulator for testing. These scenarios give examples of different QoS mechanisms in different parts of the network which should deliver end-to-end QoS. The first scenario is based on the DiffServ mechanism, the second scenario is based on the IntServ mechanism and the third one follows the principles of Best Effort.

4.4 DiffServ implementation

The first scenario configured in the OPNET Modeler is described in Figure 3. This scenario assumes the DiffServ support. The network consisted of end users, especially SIP phones or UMTS workstations connected to the UTRAN (UMTS Terrestrial Radio Access Network). The DiffServ domains were used in the backbone IP network. The IMS subnetwork represented a central element of the logical topology.

As it was mentioned in previous chapter, the Application Config, the Profile Config and the QoS Attribute Config were used. The network components were connected with the required type of communication links (e.g. 10BaseT, 100BaseT). The edge DiffServ routers were boundary routers and provided the interconnection between DiffServ domains and another domain. The core DiffServ routers examined incoming packets and forward them according to assigned mark. According to Table 1, the conversational traffic class was assigned to the EF PHB.

4.5 IntServ implementation

For comparison, a second scenario with IntServ implementation was created. The second scenario configured in the OPNET Modeler is described in Figure 5. This scenario assumes the IntServ support. The network configuration remained similar to DiffServ except IntServ domains implement-
tation variation. The routers utilized RSVP to reserve their required resources through the network. The application configuration utilized RSVP flow specifications. The characteristics of an outbound flow were carried in the PATH message to be sent from sender to receiver, and the characteristics of inbound flow parameters were carried in the RESV message to be sent in opposite direction.

![Figure 5: Topology of IMS subnetwork with IntServ created in OPNET Modeler](image)

Finally, it is important to mention that the Best Effort implementation was used for characteristics comparison. This mechanism does not provide any guarantees and serves only like base model.

5 Simulation Results

Different solutions concerning the measurement of QoS were tested. The OPNET Modeler tool allows monitoring different types of statistics. Figure 6 describes the delay statistics. This graph summarizes the simulation results for SIP voice traffics over three different scenarios. From the graph can be seen that in the case of Best Effort mechanism, the delay indicated the highest values according to expected results. The simulation results follow ITU-T (International Telecommunication Union) specification limits for voice quality.

![Figure 6: Plot of delay versus time generated by OPNET Modeler](image)

The second plot indicates the packet delay variation over time (Figure 7). Since the focus is on the SIP voice, the red curve of the Best Effort mechanism remained the weakest solution according to expected results. The IntServ and Diff-Serv curves showed similar simulation results.

![Figure 7: Plot of delay variation versus time generated by OPNET Modeler](image)

The goal of the last examined simulation statistic is to verify SIP voice MOS (Mean Opinion Score) values (Figure 8). Only the Best Effort mechanism showed the MOS value lower than three points.

![Figure 8: Plot of MOS versus time generated by OPNET Modeler](image)

Given the increasing complexity of systems, the Mean Opinion Score (MOS) parameter is an object of discussion. This parameter is replaced by another parameter called an E-Model [9]. The E-model was described to help the evaluation of handset telephony. It presents a transmission rating model which ensures transmission planning. The E-model is based on subjective tests of delay and the effect of delay can be estimated by the use of this model. The output of the model is called Rating Factor. Factor R is a scalar quality rating factor, which varies with the conversational quality and includes all transmission parameters of considered connection. The R-factor takes values from 0 to 100, where the value of zero represents extremely poor quality. The R-factor combines all parameters relevant for the considered connection. This rating factor R is composed of:
where $R$ represents the basic signal-to-noise ratio, factor $I_s$ is a combination of all impairments which occur more or less simultaneously with the voice signal. Factor $I_d$ represents the impairments caused by delay and the equipment impairment. Factor $I_e$ represents impairments caused by low bit rate codecs. Factor $A$ is an advantage factor and there is no relation to all other parameters [9]. If the MOS parameter is needed, the factor $R$ can be transferred into the scale from 1 to 5 using formula:

$$\text{MOS} = \begin{cases} 1, & R \leq 6.5 \\ 1 + 0.35R + 7 \cdot 10^{-6} \cdot R(R-60)(100-R), & 6.5 < R < 100 \\ 4.5, & R \geq 100 \end{cases}$$

6 Conclusions

The IMS architecture opens the door to endless business and communication opportunities in the global community. The IMS has the potential to revolutionize not just the telecommunication market but the everyday lives. Convergence of the Internet, fixed, mobile and wireless networks results in an all-IP network. The all-IP network should guarantee Quality of Service that customers need, and the evaluation of a service matches the users’ degree of satisfaction. Providing end-to-end QoS guarantees in IP-related networks is a complex task which requires the assurance of dedicated bandwidth, controlled jitter and delay, and improved loss characteristics. For example the real-time multimedia services for transmitting information under the certain QoS parameters are one of the most actual issues in telecommunication world. The QoS mapping issue was investigated through simulation studies. For designing, analyzing and testing of the IMS subnetworks and IP networks, the OPNET Modeler simulation tool was used. This simulation environment managed with complicated processes related to the cooperation between different layers and used domains. To provide IP QoS end-to-end, it is necessary to manage the QoS within each domain. Efficient mechanisms to provide the demanded level of service were needed. Two QoS mechanisms were configured in order to ensure the QoS: Integrated Services and Differentiated Services. Also the Best Effort mechanism, which does not include any kind of quality control notification, was considered for comparison. The possibility of employing DiffServ and IntServ technologies into the IMS environment in order to achieve full QoS support for real-time applications was the object of interest because the IMS architecture does not deal with all problems connected to heterogeneous networks. The goal of the simulations was to verify the implementation results in realistic scenarios based on DiffServ, IntServ and Best Effort models. The impacts of different QoS mechanisms utilization were described in related characteristics. These characteristics followed expected results and helped to think of the IMS as simulation-capable architecture. The IMS represents a promising technology but several challenges connected to the end-to-end QoS have to be faced.

Acknowledgment

This paper has been supported by projects FRVS 2954/2010/F1a and FRVS 2986/2010/G1.

References


