International Journal of Information, Control and Computer Sciences
ISSN: 2517-9942
Vol:4, No:4, 2010

SIP-Based QoS Management Architecture for IP Multimedia Subsystems over IP Access Networks

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***Abstract*—**True integration of multimedia services over wired or wireless networks increase the productivity and effectiveness in today's networks. IP Multimedia Subsystems are Next Generation Network architecture to provide the multimedia services over fixed or mobile networks. This paper proposes an extended SIP-based QoS Management architecture for IMS services over underlying IP access networks. To guarantee the end-to-end QoS for IMS services in interconnection backbone, SIP based proxy Modules are introduced to support the QoS provisioning and to reduce the handoff disruption time over IP access networks. In our approach these SIP Modules implement the combination of Diffserv and MPLS QoS mechanisms to assure the guaranteed QoS for real-time multimedia services. To guarantee QoS over access networks, SIP Modules make QoS resource reservations in advance to provide best QoS to IMS users over heterogeneous networks. To obtain more reliable multimedia services, our approach allows the use of SCTP protocol over SIP instead of UDP due to its multi-streaming feature. This architecture enables QoS provisioning for IMS roaming users to differentiate IMS network from other common IP networks for transmission of real-time multimedia services. To validate our approach simulation models are developed on short scale basis. The results show that our approach yields comparable performance for efficient delivery of IMS services over heterogeneous IP access networks.

***Keywords*—**SIP-Based QoS Management Architecture, IP Multimedia Subsystems,IP Access Networks

I. Introduction

NEXT Generation Networks, a communication technology capable to provide the QoS-Based enrich multimedia applications over heterogeneous networks. IMS is the NGN architecture connected to different access networks to enable the streaming of multimedia contents between various users over the wireless or wire-line networks. IMS was originally introduced by 3GPP (a standard body setup to develop and maintain the technical specifications for the 3G) and adopted by 3GPP2 and TISPAN later.

The promising feature of IMS is its access independence. They are targeted to provide real-time multimedia services with low bit and high error-rate nature over IP communication networks.

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To support such services, transmission network is conscious about QoS. QoS provisioning assures the reliable delivery of multimedia services with sufficient network resources. IMS Users are able to access and drop variety of IP-based services in a single session and this integration requires more resource reservations and efficient delivery of contents. The IMS policy based QoS mechanism provides the interaction between IMS network and the underlying IP access networks [6]. But when UE roams among IMSs, QoS parameters have to be renegotiated thus introducing significant delay in resource reservation and increase the hand off disruption time in real time multimedia services. So the QoS provisioning and handoff management should be seriously addressed for roaming users in IMS over heterogeneous networks to distinguish IMS from other common IP networks for transmission of real-time multimedia services. The hand off management enables user connectivity with network when point of attachment is changed.

Mobile and fixed operators are deploying NGN based on IMS networks. IMS network should maximize their connectedness with underlying access network by introducing the roaming arrangements and QoS provisioning mechanisms to appreciate the full value of multimedia services. TCP-migrate, Mobile IP and SIP are handoff management protocols proposed for the IP-based Mobile networks [6]. SIP is signaling protocol in IMS and can manage Mobility in IMS networks but at the same time other protocols required significant modifications to work with IMS networking infrastructure.

To solve the aforementioned problems in IMS networking infrastructure, numerous solution are proposed which are discussed in section III. This paper proposes an extended SIP-Based QoS management architecture based on SIP proxy modules. The main objective of introducing this architecture is to distinguish IMS networks from other available IP networks to manage the QoS more efficiently and to reduce the hand off disruption time over IMS and underlying access networks. We introduce the SIP-based proxy QoS modules to handle IMS traffic over heterogeneous networks. These QoS modules implement the combination of Diffserv and MPLS mechanisms to support QoS. SIP is a session negotiation protocol provides service continuity in IMS network. But SIP performance is restricted by the performance of TCP and UDP which introduce considerable transmission delay in real-time multimedia services. These modules use SCTP protocol instead of UDP because of its multi-streaming and multi-homing feature.

In section II we will present the overview of IMS, its architecture and Policy based QoS management in IMS. Section III presents the QoS related research in IMS. Section IV describes the QoS issues in IMS communication networks and finally section V and VII explains the proposed Architecture and its Simulation analysis and results respectively.

II. Overview of IP Multimedia Subsystems

IMS is being developed by 3GPP; aims to provide converged services over Mobile or fixed networks. The idea behind the IMS evaluation is to provide the capability of using different type of services at single device with best QoS to end users. According to 3GPP IMS was not intended to standardize applications but rather to aid the access of multimedia applications over network.

A. IMS Architecture

The basic IMS architecture is the enhancement of UMTS over IP Connectivity adding some different network entities with the QoS provisioning. SIP is the building block in IMS network. The other protocols used in IMS architecture are Diameter, COPS, RTP and RTCP for transmission.

Protocols in IMS

SIP: SIP is the application layer protocol used for establishing, modifying and terminating multimedia sessions over IP networks. SIP Proxy servers receive and forward SIP requests.
SDP: Session Description Protocol is intended to describe multimedia sessions. It is text-based protocol used to indicate caller and callee respective receive capabilities and media formats.
RTP: Real-time Transport protocol is used for end-to-end delivery of real time data. It contains end-to-end delivery services, payload type information and delivery monitoring.
RTCP: RTP Control Protocols are used to monitor QoS of real time data distribution and also convey the session control information.
COPS: COPS is a simple query and response protocol used to exchange policy information between a policy server (Policy Decision Function) and its clients (Policy Enforcement Point).
Diameter: Diameter is Authentication, authorization and Accounting protocol developed by IETF. It provides AAA services for the range of access technologies.

IMS architecture can be functionally divided into three layers.

1. Transport and Endpoint Layer.
2. Session and Control Layer
3. Application or Service Layer

1. Transport and endpoint Layer.

Transport and endpoint layer controls the signaling session and provides the bearer services for the end users [4]. It also supports the media convergence if required. This layer provides the authentication and registration functionality to setup and maintain sessions between end users. Multiple transport services can be merged into a single session [4]. The bearer services used to transport IMS contents over network is provided by the common IP based mechanism and IMS uses the RTP over UDP to transport the media uses the IPv6.

2. Session and Control Layer

In IMS Core network several SIP servers or proxies are collectively called CSCF and used to process SIP signaling packets in IMS. CSCF (Call Session Control Function) occupies the central position in IMS and are used for setup and control multimedia sessions. There are three different kinds of Call Session Control Functions. They perform specific tasks but all common is that they play a role during the session establishment and registration and form the SIP routing machinery.

Call Session Control Functions:

- The P-CSCF (Proxy CSCF) is the local contact point of user in the visited IMS network. It acts as a SIP proxy server and forwards all the requests to the directed addresses. This may contain the PDF (Policy Decision Function) for the QoS specification.

- The S-CSCF (Serving CSCF) is central node of the signaling plane and has the main functionality in user registration. Each SIP message of IMS is inspected by S-CSCF to verify HSS depends upon user Profile. S-CSCF is also used for load balancing and always located in home network.

- The I-CSCF (Interrogating CSCF) is provided at the entry point to the operator’s network. It is connected with HSS through Diameter protocol to retrieve the user location for routing purposes. Its IP address in published in the DNS of domain so that the remote servers can find it as a forwarding point.

Databases

- HSS (Home Subscriber Server) is the central database containing the subscription related information and the network entities that provide the user’s information. It includes subscriber’s profile, authentication and authorization information, user physical location, access parameters and security concepts.

- SLF (Subscription Locator Function) SLF is used as resolution mechanism to locate the HSS containing relative information when multiple HSS servers are involved in network. Both HSS and SLF use the DIAMETER protocol for communication. The Figure shows the Complete IMS Architecture.

Media Servers

Media Resource Function is used to provide media related information. Each MRF is further divided into two

- MRFP: implement all media-related functions process and mix the media streams.
- MRFC: Signaling plane node to handle the SIP communication to and from S_CSCF.

These both together provide the mechanism for bearer-related services.

Breakout Gateways

BGCF (Breakout gateway Control Function) is SIP based server includes routing functionality, used to perform necessary protocol conversion and send SIP session request to I_CSCF for session termination.

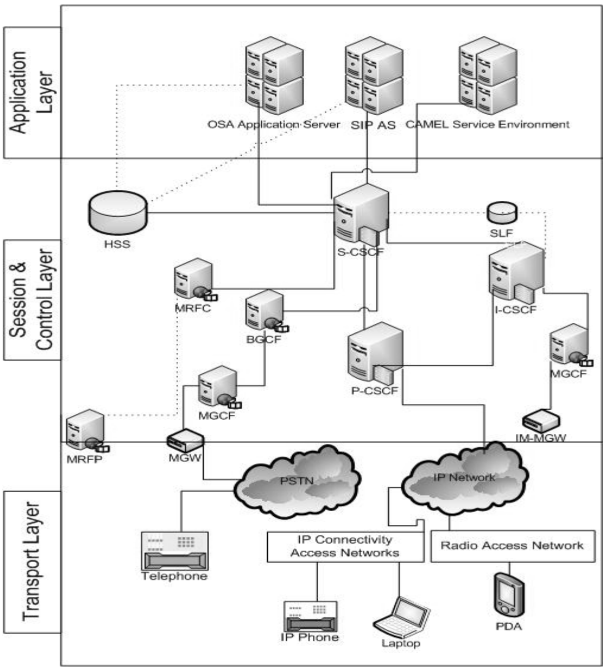


Fig. 1: IP Multimedia Subsystems Functional Architecture

3. Application Layer

Application Layer contains the different Application servers like SIP AS, CAMEL servers to provide the actual services to users [5]. The basic services of IMS are controlled by external or core AS servers. Application Server is a SIP component to host and execute services. AS process and impact the incoming SIP request from IMS and also have the capability to originate SIP request. These servers provide the services like SMS, conference call and presence services according to the server description. The registered sessions are directed towards Application servers to provide the actual services. Multiple sessions can be merged into single application [4]. Media servers (MRF) are used to manipulate the media functions such as voice stream mixing.

Application Servers

- SIP-AS native IMS application Server. It is SIP based server that hosts wide range of services such as presence, conference etc.
- IM-SSF: IM-SSF was introduced to support the legacy services developed by CSE (CAMEL Service Environment). It hosts and interface with CAMEL application servers using the CAP.

B. Quality of Service in IMS

The mechanism for authorization and control the bearer traffic for IMS is based on SDP. Primary QoS architecture model used by 3GPP and 3GPP2 is Diffserv, developed by IETF. Diffserv is more scalable than IntServ Model [7]. It allows the network traffic to be broken into number of flows for appropriate marking so that these flows can be identified and treated accordingly. Ensuring QoS in IMS, 3GPP2 uses the policy-based QoS architecture. The overall interaction between GPRS and IMS is called SLBP.

Policy-Based QoS Architecture

Session establishment in IMS involve end-to-end message exchange using SIP and SDP. IMS QoS architecture consists of two main elements PDF (Policy Decision Function) and PEP (Policy Enforcement Point) [6]. PDF can be either integrates with P-CSCF or it may be a separate physical entity in IMS Core Network. During the establishment of new SIP session SDP collects the multimedia session information and QoS parameters defined by the user Entity. These QoS parameters can be media characteristics (e.g. common codec). The Authorize QoS Resources procedure is used during an establishment of a SIP session. The P-CSCF (PDF) use the SDP contained in the SIP signaling to calculate the proper authorization. The PDF authorizes the required QoS resources by mapping the SDP parameters to the authorized IP QoS parameters for transfer to GGSN. The P-CSCF entity processes the user SIP request and GGSN maps the QoS parameters to the layer2 architecture. Transport Layer actually implements the QoS according to available resources and user requirements. Admission control information between PDF and PEP are carried out by COPS [8].

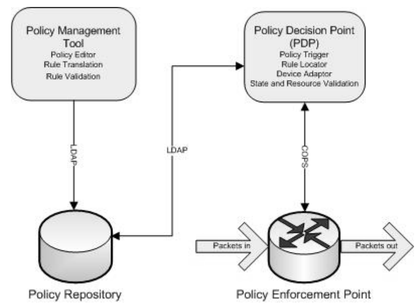


Fig. 2: IETF Policy Framework [25]

1. PDF

During the establishment of new SIP session, GGSN used the information in SDP to map the requirements into Layer2 architecture. P-CSCF processes the user request and communicates PDF through Go interface. GGSN serves as the Edge router in Diffserv network architecture. PDF implements the SBLP in IP bearer layer for media authorization and policy decision [7]. SDP with its QoS parameters activates the PDP context and in result GGSN and PEP negotiates with PDF. PDF makes policy decisions and indicate to PEP that user is allowed to access the request resources for the particular sessions.

2. PEP

PEP is the logical entity that enforces policy decisions made by PDF for performing the admission control and authorization. When the PDP context activation request is received PEP asks PDF for the authorization information. Then PDF compares the received information with stored authorization information and if the requested parameters lie in the limit then the request of PDP Context activation is approved.

3. IP Bearer Service (BS) Manager

IP BS Manager manages the IP BS using the standard IP mechanism. It resides in the GGSN and optionally in UE.

4. Translation/Mapping Function

This function provides the internetworking between the mechanisms used by IP BS and UMTS BS. It also resides in GGSN.

5. UMTS BS Manager

UMTS BS Manager handles the resource reservation requested by the UE.

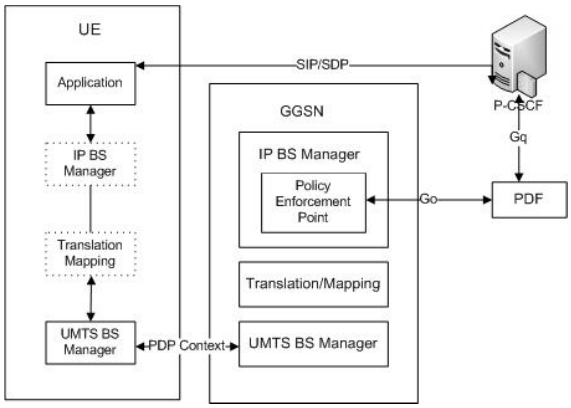


Fig. 3: Policy Architecture in IMS [*21*]

III. Related Research

IMS provide converge real time multimedia applications that demand high resources and ensured QoS. Many solutions have been proposed to ensure the QoS in Multimedia systems. In [Nov, 2008] a new SIP multicast-based mobile QoS architecture is proposed by the Shun-Ren Yang and Wen-Tsuen Chen. This model reduces the handoff disruption time between roaming users among heterogeneous networks [6]. This framework introduces a comprehensive QoS reservation model which leads to preserve the service agreements without degrading the QoS for roaming services. Recently in IMS a new robust STB technique is introduced to provide end-to-end QoS. This technique uses the concept of digital homes where home network gateways are being used to provide centralized network control and monitors the network performance [11]. And the QoS control mechanism is proposed by introducing the SIP extensions for hybrid access and UMTS core networks so that users can add their contexts during registration and the border proxies manage the QoS [13]. Alexander A. Kist and Richard J. Harris [15] consider the SIP signaling issues and provide a QoS provision for SIP signaling in advanced carrier evaluation networks. This framework uses the Virtual SIP links which are abstraction of connections between SIP nodes and dynamic allocations resource schemes. The QoS issue about domains in multimedia applications and mobility management is addressed in [16]. They proposed a solution to the critical multimedia applications by introducing the inter-domain vertical handover to ensure the accepted QoS. A centralized QoS manager is used for decision-making and mobility integration in domains [16]. The QoS and mobility integration architecture claims to improve the end-to-end QoS management in domains and also reduce the functionality in network entities. E. Lopes Filho, G. T. Hashimoto, P. F. Rosa PhD has discussed the SIP protocol over SCTP and PR-SCTP. They suggest the IMS architecture over SCTP and (Partial Reliability Extension of Stream Control transport protocol) PR-SCTP instead of UDP [19]. SCTP protocol is used for transmitting multiple streams of data at the same time and an alternate to TCP that manage reliable transport. They anticipated that PR-SCTP is the distinctive SIP protocol during the IMS session setups, authentication and authorizations and user can access better services as service degradation and congestion is well managed in SCTP than UDP.

IV. QoS Issues in IMS

The introduction of end-to-end QoS model in IMS bear many technical problems as establishing QoS may lead to comprise different wired and wireless access networks with different technologies [13]. One of the main motivations of IMS is to enable the delivery of real time multimedia services using IP related technologies, but IMS has to manage the different access related constraints imposed by heterogeneous access technologies. The domains of internet contain distinctive access networks offered by different ISPs having SLA between users to ensure requested QoS. But there is no SLA between visited domains and mobile users [16]. When the user roams from one network to other network delay and degradation is imposed which is critical in Multimedia applications. In particular, this makes the establishment of end-to-end QoS guarantees quite difficult. The QoS architecture in IMS, provided by 3GPP and 3GPP2 has the architectural limitations and they setup weak signaling protocols [13]. Also SIP is the session initiation protocol and does not support wide range of services.

V. Proposed Architecture

As discussed above IMS provide the convergence between packet-switched and circuit-switched networks. The 3GPP QoS architecture does not provides the correspondence between different access networks to exchange their policies and introduce network restrictions which cause the network degradation. So it is relatively inflexible to manage QoS in underlying access networks for real-time multimedia services. To improve the communication between core and access networks and to reduce the handoff disruption time for multimedia services, an extended SIP based QoS Architecture solution is proposed in this paper. In this architecture QoS SIP Proxy Modules are introduced to monitor the network and to ensure the end-to-end QoS. This architecture introduces the new aspect of handling IMS traffic over access networks. They issues commands if any degradation occurs during the session. These SIP proxy modules are added to Access networks among core networks.

SIP-Based Proxy QoS Modules (SPQMs)

SPQMs are network nodes that perform QoS Management tasks for IMS services over access networks. They collect the traffic traces and available resource information to manage the network QoS. SPQM receives SIP data from the IMS network and requests the resources for particular session. SPQMs collectively decide end-to-end services as well as corresponding QoS and traffic parameters. It is multiparty service negotiation mechanism. These modules implement the combinations of Diffserv and MPLS QoS mechanisms [26] to assure the guaranteed QoS for multimedia services. To achieve reliable delivery of services these modules use SCTP instead of UDP. IMS core network uses the Diffserv as QoS provisioning so deploying this mechanism in SIP modules reduce the handoff disruption time for roaming users. MPLS performs the traffic engineering in IP access networks based on resource provisioning or traffic provisioning mechanism. MPLS evenly distribute SIP traffic load over available links and also provide fast rerouting in case of link failure.

SPQM Architecture

SPQM uses the SCTP protocol over access networks because it provides the advancement in multimedia transmission. SCTP is transport layer protocol and serving in the similar role as the TCP but operates in the message-oriented fashion like UDP, preserving the message boundaries. SCTP supports multiple transmission paths so that several independent streams of chunks can be transferred at once. Main purpose of using the SCTP in SPQM is its multi-streaming feature. In TCP, control and data typically share the same connection, which can be problematic because control packets can be delayed behind data packets. If control and data were split into independent streams, control data could be dealt with in a timelier manner, resulting in better utilization of available resources.

SCTP Features

SCTP is reliable, general purpose transport layer protocol used in IP networks. It solves some limitations of TCP while borrowing the some beneficial features of UDP. The main purposes of using SCTP in SPQM are:

- Multi-homing: A Multi-homed host has more than one network interfaces and thus provide the applications with high availability.
- Multi-streaming: SCTP provides multiple streams within an association and each stream in association is independent but related to association.
- Initiation Protection: This feature protects the initiation request from DOS attack by introducing the four way handshake mechanism.
- Graceful shutdown: SCTP provides cleaner termination sequence as compared to TCP. When a peer close its socket both endpoints are required to close and no further data movement is allowed to transfer data.

SPQMs Architecture is composed of two Functions.

- SIP-based QoS Monitoring Function
- SIP-based QoS Control Function

SIP-based QoS Monitoring Function

Monitoring function analyzes the SIP traffic of IMS over core and access network using the update link state information. It also maintains identifiers for routing purposes in MPLS aware diffserv network. It helps to monitor congestion in network, by monitoring the available bandwidth, transmission delay and error rate. Monitoring is useful not only in QoS control but also helpful as troubleshooting purposes. QMF monitors the network for pre-defined scenarios. It is reactive agent and issues commands if any unwanted condition occurs in network.

SIP-based QoS Control Function

SIP QCF controls the QoS over network via monitoring function and manages the QoS using the routing mechanism described in Table1 for SIP applications. It is main function that tells how to manage the network for the multimedia applications. This function implements the modification of LDP in MPLS aware Diffserv network to introduce QoS routing. LDP is used to reserve the resources for multimedia services.

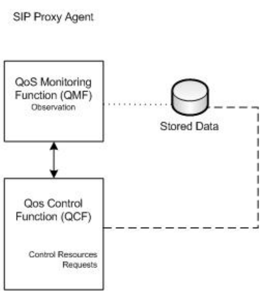


Fig. 4: Conceptual Block Diagram of QoS in SIP Proxy Module

The QoS management architecture proposed in this paper is shown in figure 5. The IMS User requires IP connectivity to access the IMS services. UE negotiates the QoS requirements during session establishment and reserves suitable resources from access networks using the SIP proxy modules and GGSN in GPRS access network.

TABLE 1 SIP-QOS-ROUTING FOR IMS

```
Algorithm: SIP-QoS-Routing for IMS

% New SIP Session for IMS Core
while ( QoS request == available) do
if  PDF (Yes)
  Process User Request   for Multimedia Services
end while
% IMS traffic over Access Networks
a)  IMS Packets arrives at the IP Access Network
   While(packets== SIP)
       Enable SIP-QoS Module
            • Remove Packets header
            • Insert SIP-QoS header
   Else Process other packets
b)  Compute the shortest path between two nodes
c)  Process SIP Packets to next SIP module
d)  Update the link state information.
       end while
  Else Process Other available data
```

The IMS access network and transport network provides the end-to-end QoS via IMS and SPQMs. Proxy modules communicate with the IMS underlying access network to access the services and provide them efficiently to the UE. In access networks SIP modules handle the SIP requests and forward the request to next available module or IMS. The routing mechanism used for these modules are based on MPLS and Diffserv [26]. To support DiffServ over MPLS packets with a variety of Differentiated Services Code Point (DSCP) values need to get the proper QoS at each LSR in the network. So this architecture uses the modification of LDP in MPLS aware Diffserv network to manage QoS.

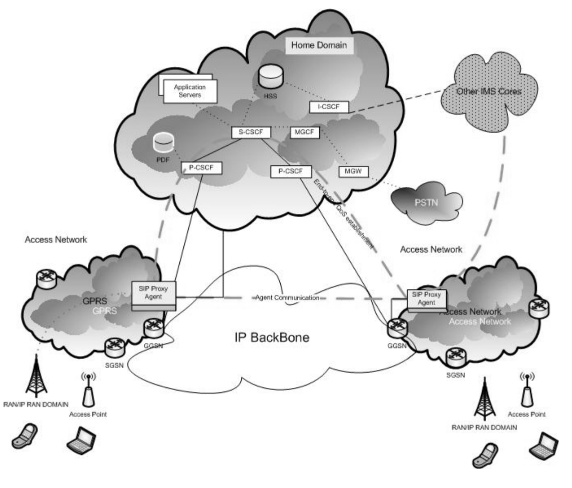


Fig. 5: Proposed Architecture for QoS Management

VI. SIMULATION RESULTS AND ANALYSIS

We present an evaluation of architecture described in section V using NS-2 simulator. Our goal is to provide desired QoS for the IMS multimedia traffic over IP access network so that the SIP-based QoS routing modules can achieve controllable and predictable QoS results and to compare our architecture with existing architectures. The results obtains from simulated model are described in Table2. We have two common multimedia applications (Data, voice) to simulate the architecture.

A. Simulation Setup

We test the architecture of SIP-based QoS modules for mix SIP and UDP traffic. The link between the routers is 155Mbps, and each 155Mbps link has a propagation delay of 5ms; each source and destination link has a propagation delay of 20ms. Both SIP and UDP server start sending traffic at same time. All flows of SIP servers consist of packets with a fixed size of 577 Bytes, and the experiment lasts 3.10 seconds of simulated time.

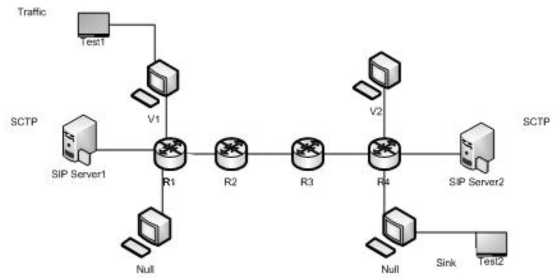


Fig. 6: Sample Simulation Topology

In this Simulation topology UDP traffic and SIP traffic is presented in the network from SIP server1 and udp1 to sink1 and SIP server2 to null. The simulation experiment with high rate of SIP traffic and UDP traffic being mixed in the same link via routers shows that the routers deals with traffic at same level. Figure 7(a) shows the results for the simulation experiment with normal traffic of SIP and UDP over link. The bandwidth utilization for SIP traffic shown in Table2 is measured from source to destination.

TABLE II SIMULATION RESULTS FOR PROPOSED QOS MANAGEMENT ARCHITECTURE

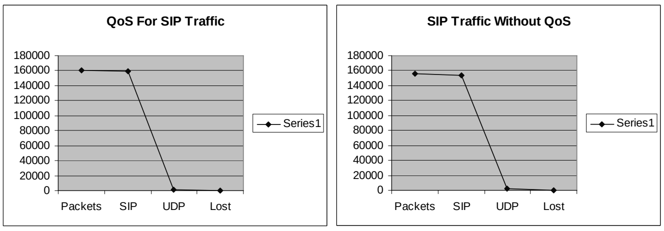
Schemes	Bandwidth Utilization	Average throughput of link	Average throughput for SIP traffic
SIP-Module-Disabled	56.97%	98.70%	97.71%
SIP-Module-Enabled	59.60%	99.90%	99.52%

Figure 7(b) shows the results for the simulation experiment with SIP-based module enabled in the network. In this case, SIP-based modules handle the IMS multimedia traffic over IP access network over MPLS-aware Diffserv routers. MPLS over Diffserv rerouting Module act as a pre-established Explicitly Routed Label Switched Path (ER-LSP). These sample results show that UDP is getting negatively affected on a significant increase in SIP traffic.

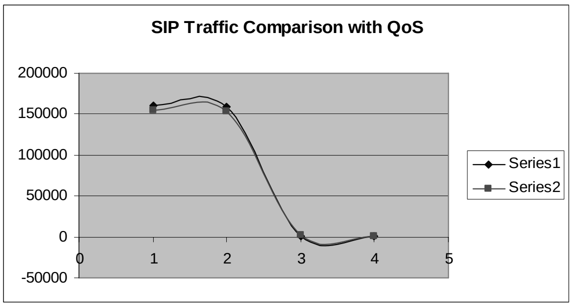
Experiments were also conducted to compare the mechanism under various experiments and the results are shown in Figure 7 (c). In this figure, the experiment without SIP-Module-Enabled and the experiment with SIP-Module-Enabled for SIP traffic are denoted, respectively.

B. Simulation Results

We investigate the average throughput and the average utilization of bandwidth for IMS applications as given in Table2. The average bandwidth is calculated from source to destination for SIP traffic. The average throughput is calculated as the total number of traffic of SIP servers received by the destinations divided by the number of nodes. First, if we look into Fig. 7(b), our SIP-QoS module significantly improves the performance of multimedia traffic over network. Furthermore, Fig. 7(b) shows the more efficient utilization of bandwidth as compared to simple network. Similarly, Fig. 7(c) shows the comparison of throughput performance of both two cases. It can be also verified in Fig. 7(c) that our proposed architecture improves throughput performance and bandwidth utilization over the IP access Networks.



(a) QoS Disabled (b) QoS-Enabled



(C) Comparison

Fig. 7: Simulation Results

VII. Conclusion and Future work

This paper proposed a SIP-Based QoS framework for IMS and its underlying access networks to distinguish the IMS services over IP access networks. To introduce the QoS provisioning this framework supports the SIP-Based QoS Modules based on the mobility management. In our approach we have used the combination of Diffserv and MPLS for QoS provisioning over access networks. To guarantee QoS, QoS SIP Modules reserve resources in advance from available resources to provide best QoS to IMS users over heterogeneous networks. To obtain a more efficient use of these SIP Modules, our approach allows the use of SCTP protocol instead of UDP due to its multi-streaming feature. We developed an analytic model for our proposed QoS management scheme. This analytic model is different from the existing approaches due to the combination of Diffserv and MPLS in IMS underlying access networks. The simulation results show that SIP-based QoS architecture provides the comparable results for transmission of IMS services.

Currently we research our architecture to improve and validate according to the newly available QoS mechanisms. The objective is to integrate the different QoS mechanisms for QoS provisioning in SIP QoS Modules. Our future work is to analyze the QoS performance of SIP-Based QoS Management architecture based on combinations of different available QoS schemes.

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