Meeting QoS Requirements in NGN Networks using an Ajustable Bandwidth Control and Management Method

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ABSTRACT: *Next generation Networks (NGN) are required to support the seamless delivery of voice, video and data with high quality. One of the most important key features of NGN is Quality of Service (QoS), which has been a focal point of NGN research, development and standardization. In this work, we propose and demonstrate an efficient NGN QoS-Aware resource and admission control and management methodology which guarantees the QoS requirements. The advantages of the proposed method, in terms of QoS gains, are demonstrated through modeling of the main QoS parameters. Simulation results are derived to evaluate the performance of the proposed method in terms of supporting the QoS and improving the transport network scalability.*

Keywords: NGN QoS, Admission Control, Transport Resource, Control And Management, IP/MPLS

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1. Introduction

Over the past decade, several International Standardization and Development Organizations and industries have dedicated their efforts to improving and standardizing NGNs and have achieved significant breakthroughs, such as PacketCable, 3GPP, ETSI, MSF, and ITU-T, as outlined in [1], [2], [3], [6], and [8]. One of the most important key features of NGN is QoS, which has been a focal point in NGN research. Also, more research and development are still required to address some of the deficiencies in the control and transport management levels of modern NGN networks in order to harmonize the QoS needs with the network capacity. Some of the recent efforts which focused on addressing some of these limitations include developments of a limited number of resource and admission control and management methods, such as that proposed in [4]. Although this method was shown to be efficient in using network resources and adapting to various network situations. It was also characterized as complex and tends to overload the core network, since it requires sending multiple probes and control interactions over the core level. A utilization-based admission control for realtime applications method was also outlined in [5]. This method defines a utilization level that can be compared against the resource availability during admission control in order to determine whether the workload can be guaranteed to meet its QoS requirements. A bandwidth management in NGN packet networks also proposed in [7]. This solution focused mainly on issues related to bandwidth management for voice and multimedia over packet networks within the context of MSF QoS solution. Several other related control methods were published in the literature, such as in [8] and [10].

In this work, we build on previous contributions, as in [1], [2], [3], [4], [5], [6], [7], and [8] and propose a novel and exhaustive methodology for guaranteeing NGNs QoS. The proposed methodology largely extends the NGN architecture functionalities and defines new QoS-Aware resource and admission control and management architecture and proposes a set of additional rules, which deliver high-level quality session-based services.

The organization of this paper follows a standard methodology of development in three sections. The first section is this introduction. The details of the QoS-Aware resource and admission control and management method architecture and application are outlined in section 2. Section 3 presents the experimental results and their analysis. Brief summary and concluding remarks are presented in last section.

2. QoS-Aware Resource and Admission Control and Management Method

In the same context of the proposed QoS guarantee target method, in this section, we discuss the resource and admission control and management. As illustrated Figure 1 and Figure 2, the proposed NGN transport resource and admission control and management method integrates new entities for resource provisioning and QoS guaranteeing. It splits the call management and gate control functionalities into Call Server (CS) and Resource and Admission Control Manager (RACM) in order to apply call admission control (CAC), reach reliable and accurate resource management and improve the transport network scalability and resilience. It also decomposes the RACM into distinct Service Policy Decision Manager (SPDM) and Transport Resource Control Manager (TRCM) entities in order to enable the coverage and management of multiple large domains. Furthermore, it combines specific QoS-Aware rules with the RACM role and bases on the concepts of resource reservation and allocation during admission, resource adjusting and managing, appropriate processing applying, and traffic engineering (TE). At the transport level, the proposed method architecture is based on employing IP/MPLS technologies. In this architecture, the RACM entity that represents the main component in this issue, determines the resource availability, the network topology and performs the CAC procedures [9]. It communicates with edge routers via IF-3 interface, to perform the flow control procedures, select flow paths and collect information concerning the established sessions. It connects with core routers via IF-4 interface, in order to reserve resources for traffic aggregations, collect information on the QoS resource reservation and actual routing status, apply QoS guarantee rules, discover the IP/MPLS core network topology and manage TE-tunnels. The multiple RACMs interact via IF-5 interface and exchange information regarding the resource reservations and QoS control along established sessions' paths.

2.1 Resource and Admission Control and Management Architectures

As depicted in Fig.1 and Fig. 2, the flexibility of the proposed method offers the RACM the possibility to be deployed in distributed or hierarchical structures in order to provide high performance, scalability and resilience to large network domains.

2.1.1 Peer to Peer Architecture

In this architecture, the SPDMs and the peering TRCMs are implemented respectively in the borders and the core domains. The SPDM communicates with the first TRCM of the peering TRCMs of its domain. It identifies the TRCMs of the adjacent sub-domains that the session crosses. The first TRCM instance interacts with its neighboring TRCMs to determine the requested edge to edge QoS resource [7].

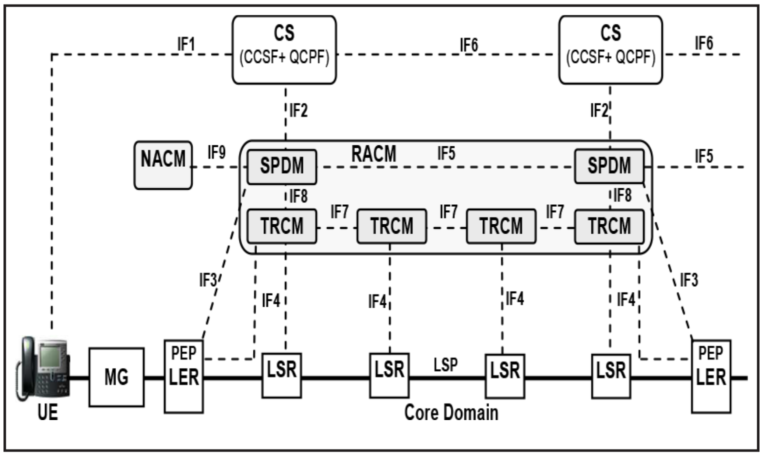

Figure 1. Peer to peer NGN-RACM architecture

2) Hierarchical Architecture

In this architecture, a SPDM instance may interact with multiple TRCM instances and a TRCM instance may interact with multiple SPDM instances to satisfy the QoS resource requirements in the involved domain. The TRCMs receive reservation requests from SPDMs and apply resource reservation and allocation control to sub domains based on resource availability states. They interact with the SPDMs in order to share the domain resources and reserve BW aggregations. The SPDM ensures the CAC based on the resource occupation state received from the TRCMs.

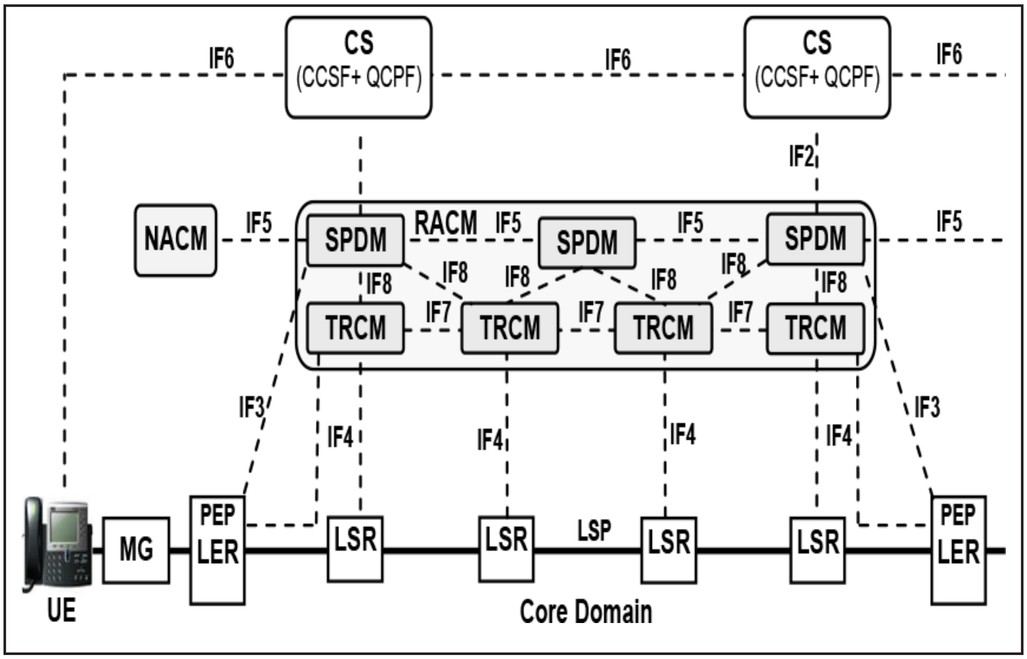

Figure 2. Hierarchical NGN-RACM architecture

Based on the proposed architecture, next we present and discuss experimental results which illustrate the gains achieved in terms of QoS guarantees.

3. Experimental Results and Discussion

In this section, we shall discuss the development of simulation scenarios consisting of modeling and evaluating the main QoS parameters over an NGN transport network based-IP/MPLS-TE and controlled by a resource and admission control and management layer.

3.1 Simulation Model and Parameters

For our practical purposes, we simulated an IP/MPLS-TE based NGN architecture, as illustrated in Fig. 3. For this purpose, we used the GNS3 [13] simulator with some new advanced configuration methods. We generated additional results which involved the implementation of the IP network simulator (*ns*) [14] and MPLS network simulator (*mns*).

As illustrated in Fig. 3, the implemented network architecture is based on an IP/MPLS transport network which consists of six LSR routers in the core level and four QoSaware LER routers [12] used in the connectivity level. This IP/MPLS transport network is “surrounded” by six IP native routers used for concentrating access traffic, and managed by a control level consisting of two CSs and two RACMs. For the MPLS core routers interconnection, we choose a speed bandwidth with value of 10 Mbps, and for the rest of network entities interconnection, the bandwidth is fixed at 1 Mbps. For the queues’ types, Drop Tail (FIFO) is selected for IP classic services, and Class-Based Queuing (CBQ) is used for real time applications.

3.1.1 Parameters Description

As listed in Table I, for the various simulations scenarios, we generated Real Time traffic (RT) as telephony traffic [11], Guaranteed Bandwidth Traffic (GBT) by resource reservation as connection-oriented data traffic and Simple Best Effort Traffic (SBT) as conventional internet traffic over an NGN transport network based IP/MPLS with traffic engineering (TE):

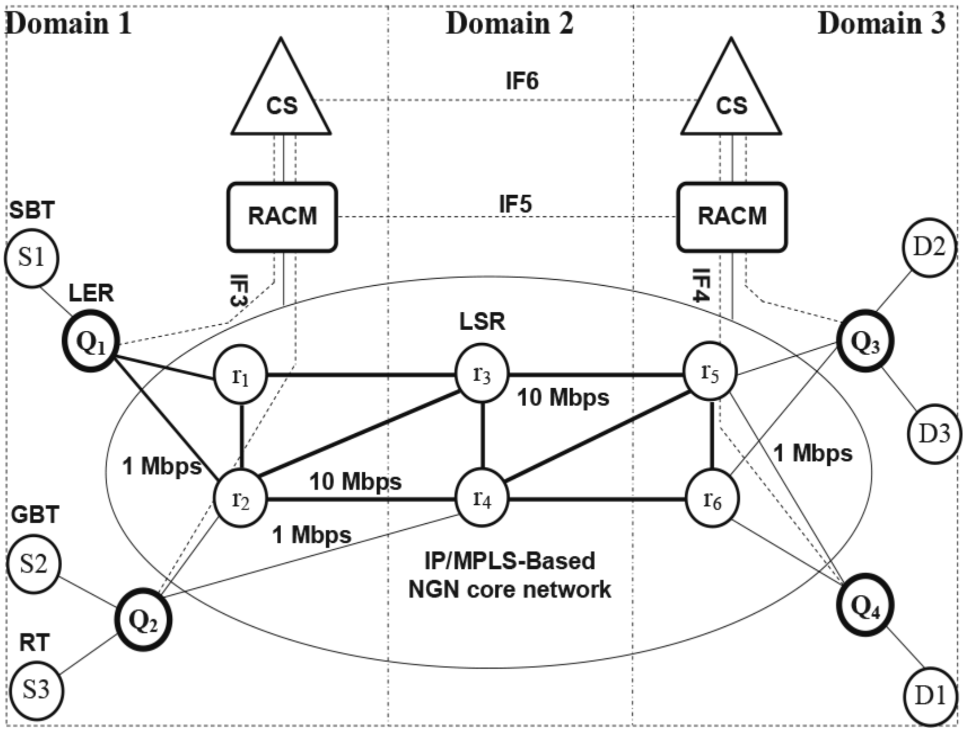

Figure 3. NGN transport network topology based P/MPLS

Services **Features**	**Simple Best Effort traffic (SBT)**	**Guaranteed Bandwidth Traffic (GBT)**	**Real time traffic (RT)**
Packet length	1500 bytes	1024 bytes	160 bytes
Source node	S1	S2	S3
Dest° node	D1	D2	D3
Throughput	300 Kbps	500 Kbps	700 Kbps
Latency	500 ms	< 200 ms	< 150 ms
Jitter	500 ms	< 100 ms	< 40 ms

Table 1. Services' Features

The considered traffic are generated from their corresponding sources to their destinations over an IP/MPLS based NGN Transport network controlled by the proposed method. In each scenario, we will compare the observed performance with the results obtained when using a conventional IP-based NGN transport network.

3.2 Transport Network Performance Analysis

At this stage, we will evaluate and compare the observed performance of an IP-based NGN transport network with the results obtained when using an IP/MPLS-based NGN transport network under the control of the RACMs for carrying multiservice traffic.

3.2.1 Throughput and Loss Ratio Evaluation

In this sub-section, we mainly interested in the evaluation and investigation of the observed performance in terms of *throughput* and *loss ratio* of different traffic types.

a) IP-based NGN Transport Network

In this scenario, we assume that all routers are IP native. The network uses OSPF routing protocol for calculating the traffic paths. The shortest path for carrying SBT packets is composed of the sequence of nodes Q1→r1→r3→r5→Q4, and the next path calculated for carrying the GBT and RT packets consists of the sequence of nodes Q2→r4→r5→Q3. We observe that the bandwidth (BW) required for GBT and RT exceeds the capacity reserved for the corresponding path. The IP native resource control mechanism equitably shares the available BW between these two traffic types. Fig. 4 shows that each of GBT and RT has 500 Kbps, in the bottle-neck link; Q2→r4. This justifies that the BW needs of the RT cannot be satisfied with the allocated BW, which leads to a throughput decrease and packet loss rate increase.

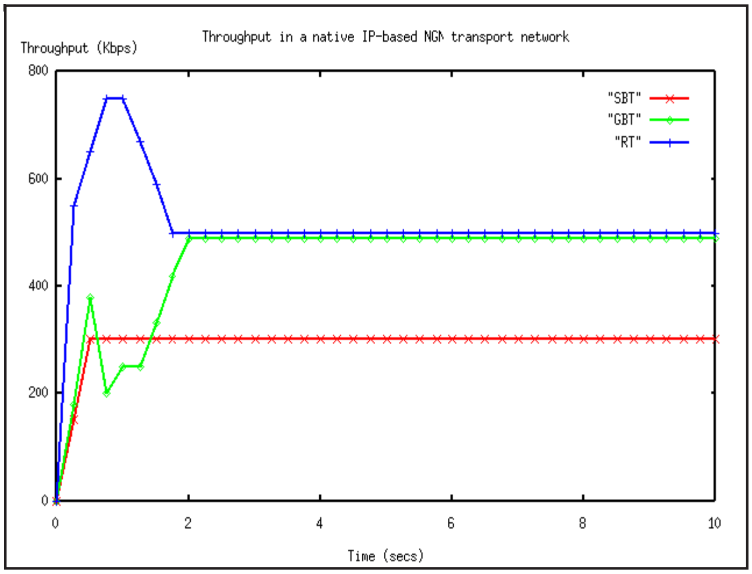

Figure 4. Throughput in a native IP-based NGN network

Unlike the case of RT, the QoS guarantees for SBT and GBT are met, as illustrated in Fig. 5. The illustrated packets loss variation shows that the QoS degradation affects RT, but did not influence SBT and GBT. SBT obtains its BW requirement and no packet is rejected or lost for this type of traffic since it is carried over a dedicated path. The BW needs of GBT are also met through the IP native resource control mechanism. The small variations of packet loss values relating to GBT are negligible and do not affect the required QoS.

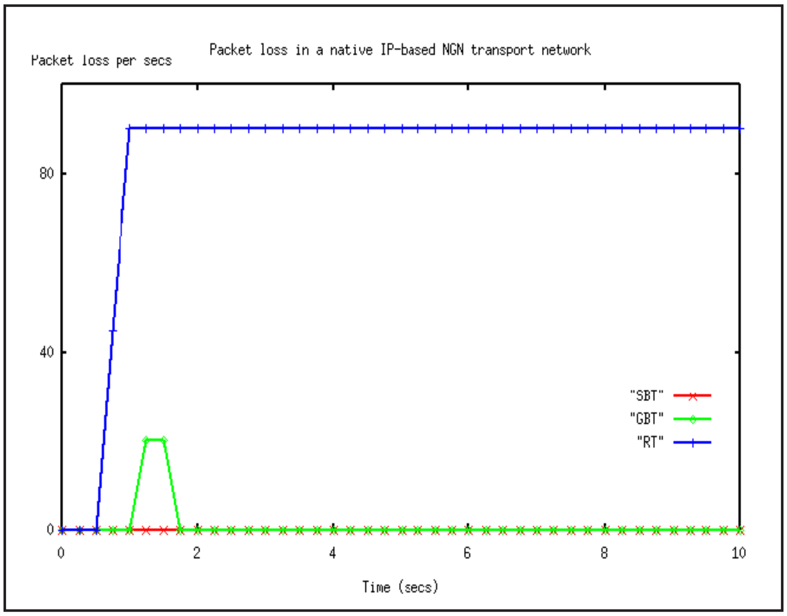

Figure 5. Packet loss in a native IP-based NGN network

Table 1 illustrates the statistics corresponding to the simulated traffic over an IP-native network. These statistics indicate an increased packet loss rate and transit delay for RT, since it did not obtain the required BW. This conflicts with the expected behavior of this type of traffic. These results suggest that without the use of the RACMs component for controlling resources and traffic in NGN transport level, we cannot preserve a strict QoS guarantee for priority traffic.

Traffic Type:	**SBT**	**GBT**	**RT**
Total transit delay:	546.072	348.292	808.420
Mean Delay:	0.122	0.098	0.146
Sent packets:	4499	3937	9999
Received packets:	4481	3754	7643
Lost packets:	18	183	2356
Lost ratio:	0.004	0.0465	0.2356

Table 1. IP-based Ngn Network Statistics

b) IP/MPLS-based NGN transport network under the control of the proposed QoS-aware method In this scenario, we consider the same topology of the NGN backbone network as the one illustrated in Figure 3. We also consider that the network do not use any traffic engineering for calculating the traffic paths.

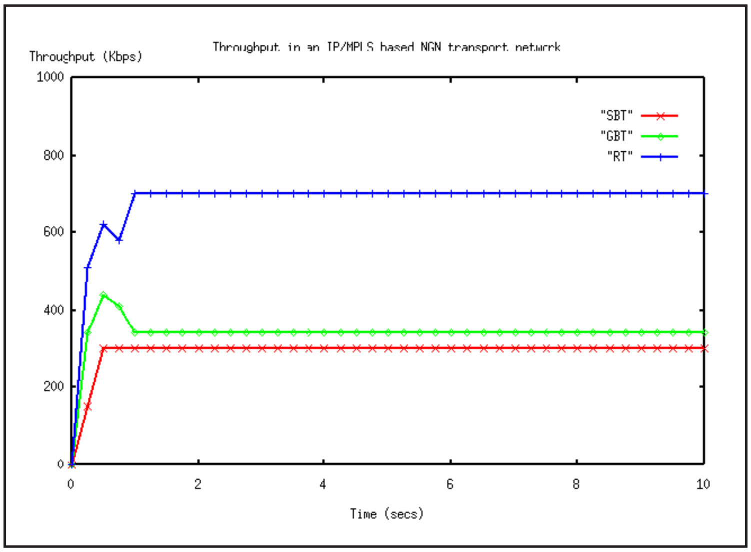

Figure 6. Throughput in an IP/MPLS-based NGN network under the control of the RACMs

According to Figure 6 and Figure 7, we deduce that the offered throughput and packet loss ratio in an IP/MPLS-based NGN transport network under the control of the RACMs is more interesting. In view of these figures, we note how the bandwidth is allocated and packets are classified according to the traffic priority type and its corresponding QoS requirements. The major part of the available capacity is reserved for RT, which requires the important throughput, whereas the remaining resources are allocated to GBT. Figure 7 shows how the packet loss rate has been significantly reduced, especially for RT. This justifies an improvement in terms of QoS guarantee for RT, since it has allocated new quantum of resource thanks to the proposed resource and admission control and management layer associated with MPLS resource priority-based management mechanisms. Again, SBT has no packet loss or rejection since it achieves the required BW.

Table 2 represents statistics relative to different traffic flows over an IP/MPLS-based NGN transport network under the control of the proposed resource and admission control and management layer. We note that, with the implementation of the RACMs entities in the control level associated with the utilization of MPLS protocol in the transport level, the mean transit delay and loss

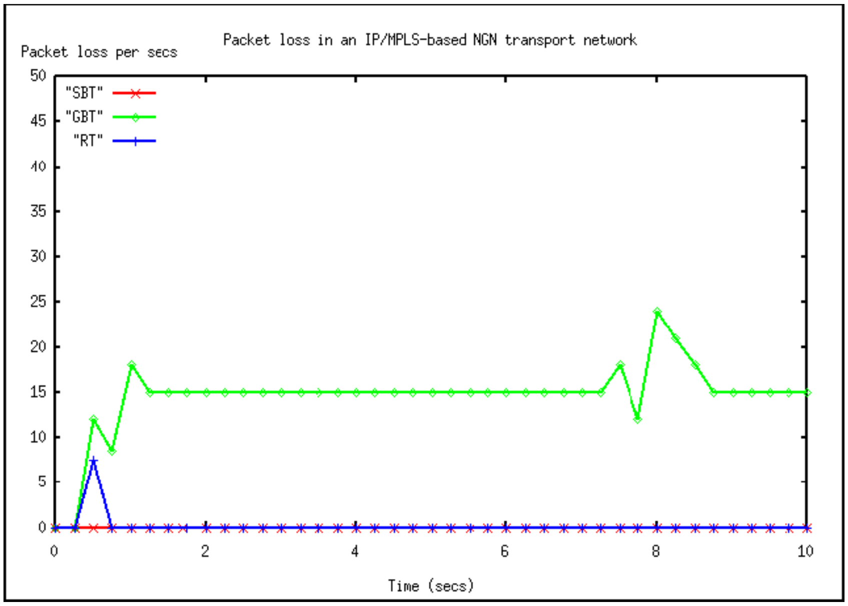

Figure 7. Packet loss in an IP/MPLS-based NGN network under the control of the RACMs

rate are considerably reduced. This offers better transport network resource control and management. It also improves the resource sharing and usage and the QoS guarantee for traffic sensitive to delay, jitter and packet loss. Accordingly, this illustrates the effectiveness of the proposed resource and admission control and management method in terms of NGN transport capacity utilization and QoS provision. Also, these results support the choice of MPLS protocol in the NGN transport level in terms of QoS guarantee.

Traffic Type:	**SBT**	**GBT**	**RT**
Total transit delay:	510.834	133.344	654.825
Mean Delay:	0.114	0.096	0.075
Sent packets:	4499	3937	9999
Received packets:	4484	2689	9847
Lost packets:	15	1248	152
Lost ratio:	0.0033	0.317	0.0152

Table 2. IP/MPLS Network Statistics

2) End-to-End Delay and Jitter Evaluation

In this sub-section, we mainly interested in the evaluation and investigation of the observed performance in terms of *latency* and *jitter* delays of different traffic types. As illustrated in Figure 8 and Figure 9, we especially observe that RT over IP-based NGN transport networks undergoes an important delay in waiting queues since these networks do not use resource and admission control management mechanisms for BW control and sharing. However, over an IP/MPLS-based NGN transport network under the control of the RACMs, the packet delay value is significantly reduced. The choice of MPLS in the transport level results in improved mechanisms, which clearly contribute to achieving the desired QoS guarantee. Figure 9 shows that, when using MPLS in the transport level and RACMs entities in the control level, NGN networks provide more reduced overall end-to-end delay.

Figure 8 also suggests that jitter is important for IP-based NGN transport network. This is not the case for IP/MPLSbased NGN

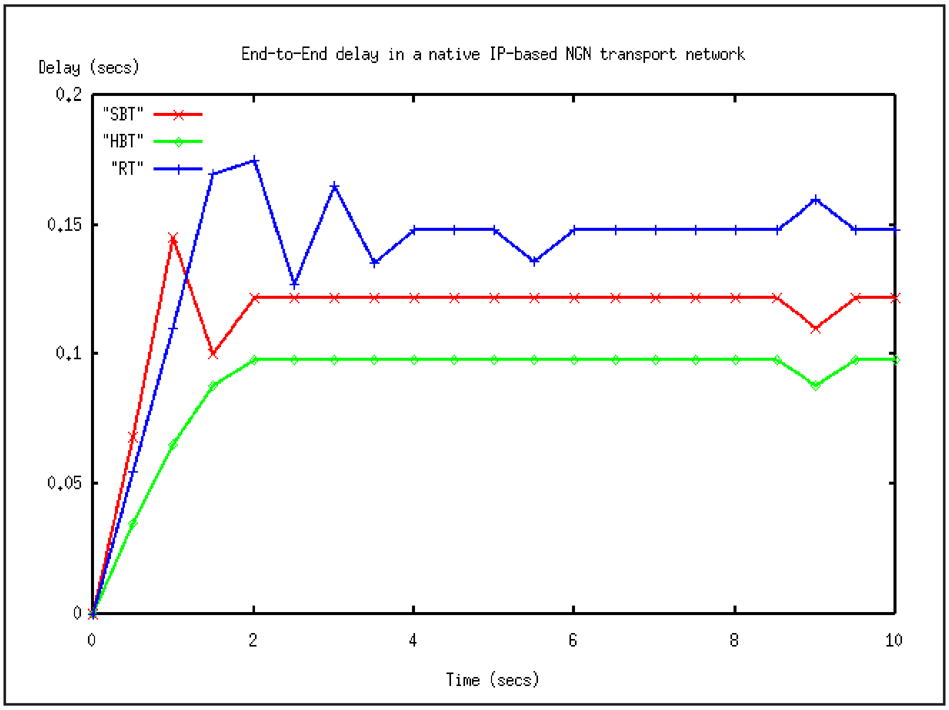

Figure 8. End-to-End delay and jitter over a native IP-based NGN transport network

transport network controlled by the RACMs entities, where jitter does not influence the required QoS guarantee. This figure also shows that, for the RT, latency and jitter are negligible compared to GBT carried over an IP/MPLS-based NGN transport network under the control of RACMs-based control level. Fig. 8 also shows that the latency and jitter graphs observed for an IP-based NGN transport network are nearly identical.

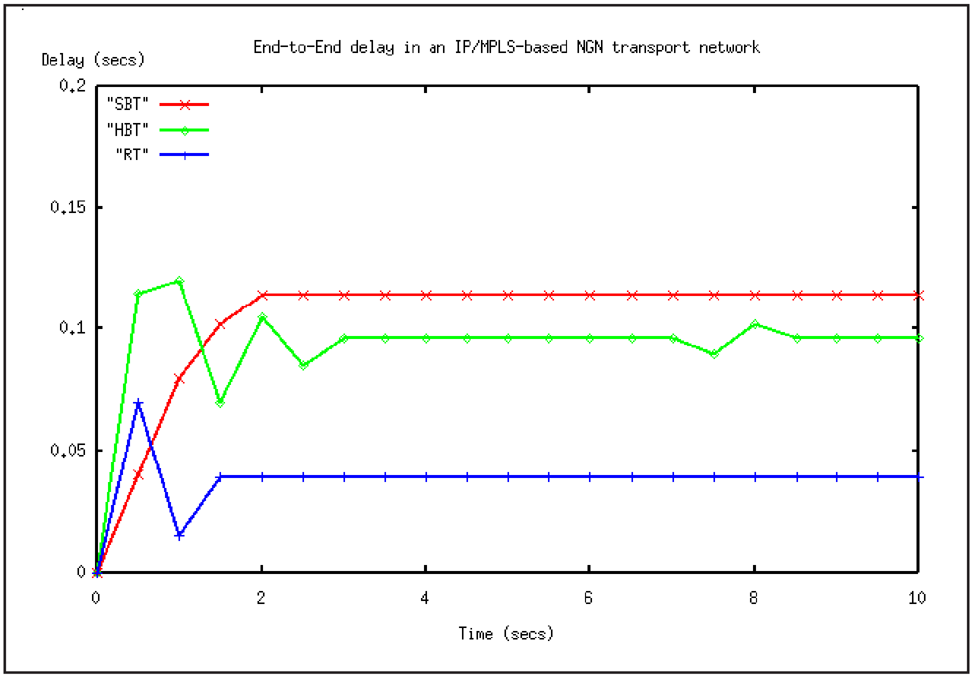

Figure 9. End-to-End delay and jitter over an IP/MPLS-based NGN transport network under the control of the RACMs

In view of Fig. 8 and Fig. 9, we observe that an IP/MPLS based NGN transport network under the control of the RACMs provides "better" QoS support for real time traffic.

Hence, this network architecture has the capacity to satisfy the expected real-time traffic needs, such as the required throughput and lower jitter and packet loss. It has "simpler" core functionalities since computationally expensive processing is pushed to the edge level. This results in better QoS guarantees and efficient network management, and justifies the choice of MPLS in the NGN transport level. Next, we discuss a simulation scenario illustrating the advantages of incorporating the traffic engineering in an IP/MPLS-based NGN transport level controlled by the proposed method.

C. TE Associated With The Proposed Qos-aware Method

In this section, we assess the effects of the TE on a set of QoS parameters for carrying multiservice traffic over an IP/MPLS-based NGN transport network controlled by the proposed resource and admission control and management layer. The simulation scenario is described in the following paragraphs.

1) Simulation Scenario

In our simulation, we consider the same topology of the NGN backbone network as the one illustrated in Figure 3. We also consider that the network uses MPLS-TE for calculating the traffic paths. For the LSPs establishment, we use the constraint routing protocol (CR-LDP) with ascending priority order. That is, the RT is the first connection to generate packets, and then the GBT and SBT connections start generating packets in this respective order. Note that, in this case, different sessions start generating traffic after the establishment of the LSPs without any service pre-emption application.

The details and results of the simulation scenario are described in the following paragraphs.

2) Throughput and Loss Ratio Evaluation

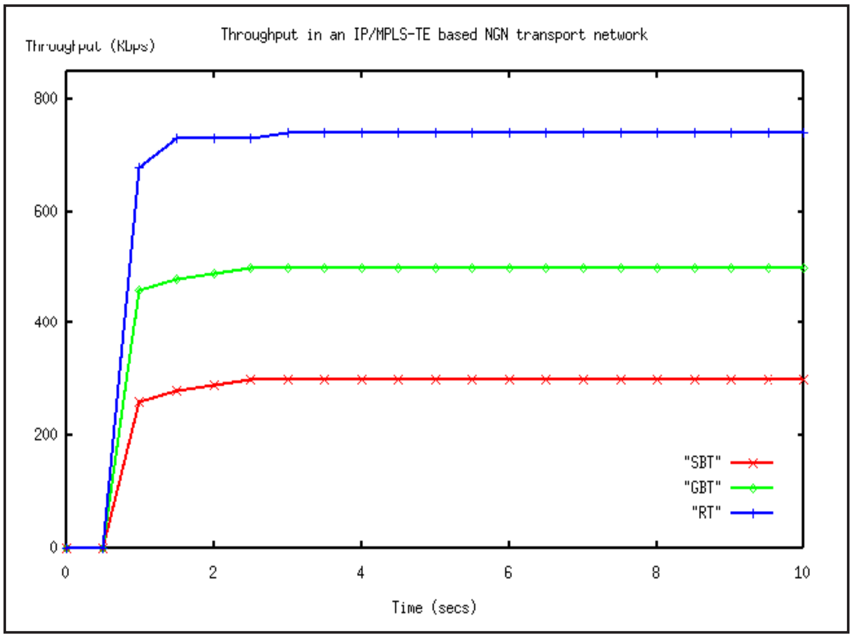

Figure 10. Throughput in an IP/MPLS-TE based NGN transport network under the control of the RACMs

In this scenario, firstly we observe that, the TE reserves for each traffic flow, a dedicated path which is explicitly established in accordance with the required QoS constraints.

Thus, there is no path shared by more than one traffic type at the same time, which explains the reliable transmission quality. The QoS guarantee for RT is illustrated by Fig. 10 and Fig. 11. The latter shows that all three traffic experience significant reduction in packet loss with preferential treatment granted to traffic having higher priority in establishment order.

Also the packets loss variation affecting the SBT is negligible and may not significantly influence the guaranteed QoS. These results may show that the proposed method can be considered as a technique for consolidating the NGN transport capacity and increasing its utilization by achieving specific treatment according to the carried traffic priority level and resource availability.

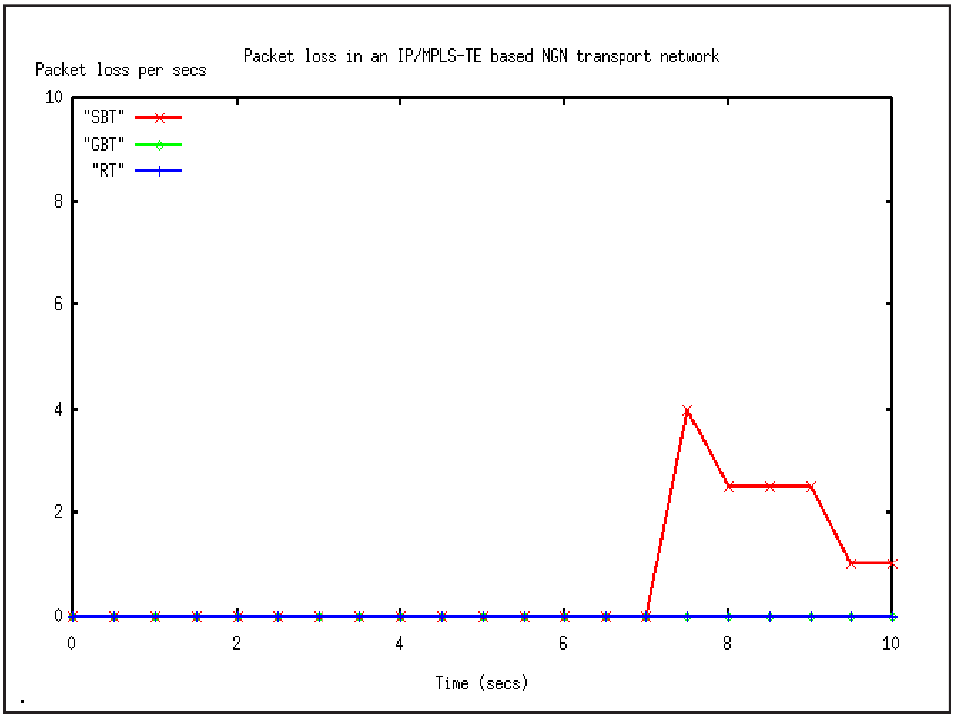

Figure 11. Packet loss in an IP/MPLS-TE based NGN transport network under the control of the RACMs

3) Delay and Jitter Evaluation

In this scenario, we observe that the TE assigns a dedicated path for each traffic flow. Since the lower priority LSP follows the longest path, it may undergo important end-to-end delay, as illustrated Table 3, that shows the traffic statistics in this scenario.

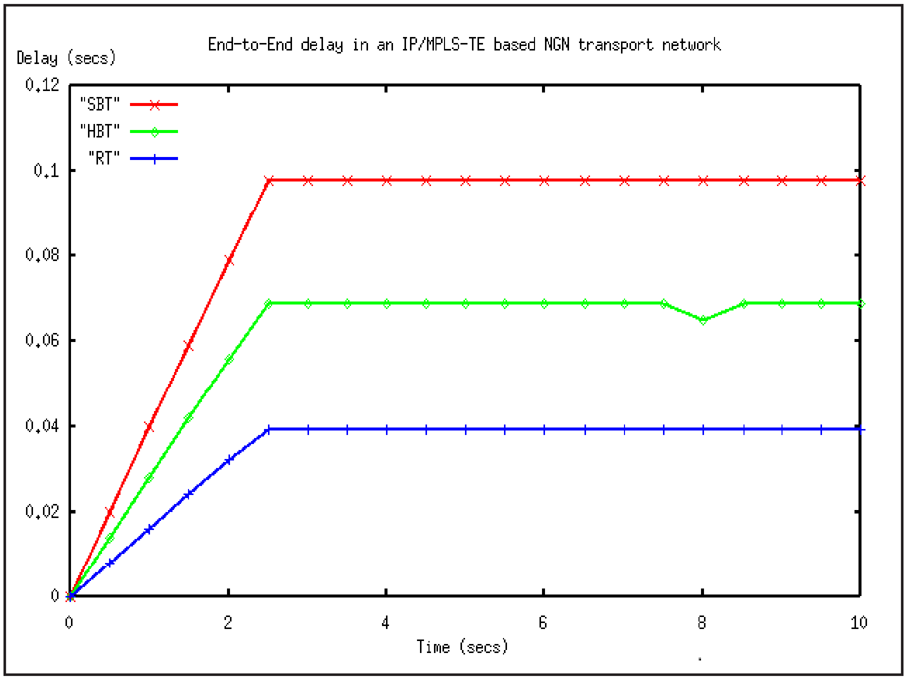

Figure 12. End-to-End delay and jitter in an IP/MPLS-TE based NGN transport network under the control of the RACMs

Traffic type:	**SBT**	**GBT**	**RT**
Total transit delay:	423.987	270.266	397.96
Mean Delay:	0.097	0.0687	0.0398
Sent packets:	4499	3937	9999
Received packets:	4486	3934	9999
Lost packets:	13	3	0
Lost ratio:	0.0028	0.00076	0

Table 3. Traffic Statistics

Figure 12 shows significant reduction of the End-to-End delay and jitter values, for three different traffic types. We also observe that this delay increases slowly until it reaches a stationary level that does not negatively affect the QoS guarantee. The increased GBT traffic End-to-End delay, as illustrated in Fig. 12, can be explained by the “long path” used for carrying this traffic. For the reason that the high priority RT follows the shortest path, it obtains a clearly reduced endto- end delay, as illustrated in Table 3. This significant reduction in overall end-to-end delay can be attributed to the use of the traffic engineering in an IP/ MPLS-based NGN transport network under the control of the RACMs. In view of Fig. 11 and Table 3, we can see how the packet loss is negligible, as compared to the values observed in section 3.2.1. This relatively small packet loss cannot negatively affect the QoS guarantee even for SBT traffic. Also we can clearly register a significant improvement in terms of QoS guarantee and resource availability and provision which supports the advantages of the proposed method in terms of network performance.

4. Conclusion

In this work, we proposed a QoS-aware resource and admission control and management method which guarantees the QoS for the transport of real-time multi-service traffic in NGN networks. It merges resource-based admission control advantages with transport resource control and management benefits. This QoS control method is based on service differentiation using priority disciplines. It is applied at the transport level under the control of the RACM as a basis component for the proposed large scale QoS guarantee architecture. More importantly the proposed method ensures that required QoS guarantees are always achieved for the incoming as well as the already established sessions. It also allocates resources in an accurate manner and improves the control and transport network scalability and resilience.

In order to evaluate the performance of the proposed method, we derived theoretical models and generated and discussed simulation results from these models. The performance of the proposed network is assessed and evaluated in terms of a set of QoS parameters such as throughput, latency, jitter, loss and waiting delay over an IP/MPLS-based NGN transport network. The generated numerical results illustrate the advantages of the proposed method in terms of performance gains and QoS benefits and provision. These gains are particularly evident through the simulation results illustrating the relationship between the network capacity and QoS requirement and guarantee.

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