Quality of Service Considerations for two DiffServ scenarios in IP networks

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Abstract – **Differentiated Services (DiffServ) architecture model provides the most extensive and appealing solution for Quality of Service (QoS) support in current Internet Protocol (IP) networks. The main considerations in DiffServ model are scalability and traffic classification in order to handle large number of data efficiently. Multi Protocol Label Switching (MPLS) is a network protocol technology that can be useful for improving scalability and routing flexibility in IP networks. In this paper we compare DiffServ scenario with the scenario that represents integration of DiffServ and MPLS Traffic Engineering (TE). The results show that the implementation of MPLS TE mechanism to support DiffServ architecture in the backbone network can improve network performances.**

Keywords – **QoS, DiffServ, MPLS TE, IP.**

I. Introduction

Quality of service in IP networks is used to denote different concepts - from customer perception and evaluation of a certain service to a set of technical parameters that are required for the implementation of specific telecommunication services with required quality [1], [2], [3]. QoS can be quantitatively expressed by different parameters such as bandwidth, packet loss, delay, jitter, echo, availability etc.

Since QoS plays a crucial role in ensuring proper support for many types of applications with different quality requirements in IP networks, special attention should be paid to mechanisms which provide QoS in these networks. The most popular architecture for providing QoS in IP networks is DiffServ. Main drawbacks of DiffServ are the lack of QoS guarantees for individual IP traffic flows and inability to provide end-to-end QoS guarantees. Therefore, service providers often use MPLS to improve QoS in order to meet specific Service Level Agreements (SLAs) on the significant performance measures [4], [5], [6]. In addition, MPLS TE can improve scalability, network efficiency and service guarantees.

In this paper we explain and compare two QoS scenarios: DiffServ itself and DiffServ supported by MPLS TE. The paper is organized as follows. After the introduction, in Section 2 a brief overview of DiffServ and MPLS TE are given. In Section 3 simulation results are discussed and concluding remarks are given in Section 4.

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II. QoS Issues in IP Networks

In terms of IP technology, QoS is characterized by diverse parameters depending on the particular service and traffic carried over the IP network. QoS is mainly technical issue but it can cover the complete end-to-end system effects including user perception and evaluation of a service. It describes the ability of network to provide a service with an assured level and is related to service performances that can be measured and controlled at the users' access point [7]. QoS is defined by the bilateral contract or agreement i.e. SLA between two interconnected parties. SLA regulates guarantees involved in providing and utilization of a service as well as the responsibilities of all contracting parties.

Due to the rapidly increasing deployment of interactive and multimedia applications in IP networks, QoS becomes an integral part of various protocols, mechanisms and services in enabling computing and communication systems [8].

A. DiffServ concept

DiffServ operates at Layer 3 only and is not engaged with lower layers of the OSI model. It relies on the traffic classification in order to provide different QoS level on a per-hop basis. Traffic can be classified according to different criteria which include Type of Service (ToS) value in an IP header.

Before clustering of traffic into an aggregation, the packets belonging to the aggregation must be identified. With aim to protect the service guarantees of each aggregation, limitations in terms of the amount of traffic that any user can inject must be conducted. These aspects are addressed by DiffServ functions named classifying and policing. Routers within DiffServ architecture perform functions of measuring, shaping and dropping packets in a flow [9]. DiffServ architecture also defines the relationship among multiple administrative domains, which are specified in a SLA.

DiffServ concept implies the division of network into DiffServ domains (DS domains), each of which corresponds to an Internet service provider domain or a network that is centrally managed from a single point. DS domain nodes use the common pre-defined rules for the network resources utilization and methods of packet processing depending on the IP traffic class. A DS domain consists of DS ingress nodes, DS interior nodes (core nodes), and DS egress nodes. An ingress or egress node might be denoted as a DS boundary node, connecting two DS domains together.

Typically, DS boundary nodes perform traffic conditioning. They perform traffic classification based on the input values of several fields from the IP packet header, so that the individual streams fit into a finite and limited set of aggregate flows - a class of traffic. Each IP packet is marked by certain bits in the header, which defines the method of processing packets at each DS domain node (PHB, Per-Hop Behavior). Existing octet TOS in the IPv4 packet header or the Traffic Class octet in the IPv6 packet header is replaced by the Differentiated Services (DS) field. Six bits of the DS field are used as code PHBs (Differentiated Services Code Point, DSCP), while the remaining two bits remain unused and they are reserved for a future use. In this fashion it is theoretically possible to differentiate up to 64 different classes of traffic. Core routers perform packet classification based only on the value of DSCP field. Incoming packets are classified into pre-defined aggregates, metered in order to determine compliance to traffic parameters (whether the packet fits the profile or not), marked appropriately by writing/re-writing the DSCP and shaped (buffered to achieve a target flow rate) or being droped in case of congestion.

PHBs are applied on each network element and their assignment is to determine processing priority, allocated bandwidth, delay-bound, jitter-bound, packet drop probability etc. This combination of packet marking and well-defined PHBs results in a scalable QoS solution for any given packet and any application.

One of the drawbacks of DiffServ architecture refers to the lack of precise requirements specification and target values for the QoS parameters and consequently QoS guarantees for individual IP traffic flows, which derives from the very concept of providing QoS for the aggregate traffic flows.

Another drawback is related to the extent of providing QoS, which is limited to the DS domain without providing end-to-end QoS guarantees. DiffServ architecture does not provide explicit mechanisms for communication between applications and network in terms of dynamic QoS negotiation. Applications are not able to dynamically adapt IP traffic profiles according to the network resources availability. In case of such a change of state in DiffServ network that it is no longer able to handle accumulated traffic load, neither the input routers nor the applications will be informed about it. Furthermore, in terms of QoS negotiations, interaction between transmitting and receiving parties is not possible.

B. Multi Protocol Label Switching with Traffic Engineering

In order to ensure explicit QoS support, MPLS can be integrated with the DiffServ model. MPLS is one of the solutions which enable providing QoS guarantees and traffic prioritization for a variety of applications [4], [5]. MPLS is not a substitute for DiffServ but can be applied to support differentiated services architecture, primarily due to differences in the position within the OSI model, as can be seen in Figure 1. Contrary to the DiffServ, MPLS specifies modes that Layer 3 traffic can be mapped to connection-oriented Layer 2. It can be interpreted as an integration of Layer 2 and Layer 3 technologies. MPLS sits between these traditional layers, providing additional features for the transport of data across the network and often is summarized as a layer 2.5 networking protocol.

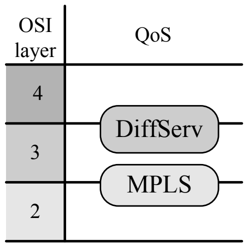

Figure 1. DiffServ and MPLS in OSI model

MPLS implies generating a special packet header - label, independent of the address that is inserted between the layers 2 and 3 headers within the OSI model. By making traditional Layer 2 features available to Layer 3, MPLS enables traffic engineering. The traffic engineered tunnels allow mapping traffic streams onto available network resources thus preventing the excessive use of subsets of network resources while other subsets are under-utilized.

MPLS TE employ label switching to improve traffic performance while network resources are efficiently utilized [10]. With MPLS, traffic engineering capabilities are integrated into Layer 3, which optimizes the routing of IP traffic, given the constraints imposed by backbone capacity and topology [11]. Labels are assigned and distributed between routers using the Label Distribution Protocol (LDP) or the Tag Distribution Protocol (TDP). After the Label Edge Router (LER) i.e. ingress router assign labels to the packet, it is forwarded across the network using label switching based solely on the label and not on the IP header information. A Label Switching Path (LSP) exists between all routers within the MPLS domain. Label Switching Router (LSR) i.e. transit router is responsible only for MPLS switching in the middle of an LSP. At the end of an LSP, egress router removes the label and the packet is again forwarded as an IP packet. MPLS TE automatically establishes and maintains LSPs across the network backbone, using Resource Reservation Protocol with Traffic Engineering (RSVP-TE) which improves scalability.

III. SIMULATION RESULTS ANALYSIS

In this section we present and analyze simulations that are performed for two QoS scenarios: DiffServ itself and DiffServ supported by MPLS TE. For the purpose of comparison these two scenarios in terms of providing the required QoS, OPNET Modeler was used, focusing on the backbone network.

The first scenario involves the application of DiffServ with a local setup of edge routers for QoS routing and prioritization of VoIP communications. The second scenario implies the application of MPLS TE with the previous setting of DiffServ approach as in the first scenario. It includes a global setting of static LSP in order to perform traffic engineering and to reduce the load from the main transmission route, defined by Open Shortest Path Protocol (OSPF) in the first scenario.

Session Initiation Protocol (SIP) signaling is not the goal of this research and SIP proxy server is not set up in the access network, as this analysis shows only the differences in the achieved QoS with focus on the backbone.

A. DiffServ scenario

The first scenario (DiffServ scenario) is designed in a manner that different PHB classes are differently transmitted through the network. Six sources of a video conferencing at the same time establish a video conferencing session and one source of VoIP communication establishes a VoIP session (in 100s of the simulation). After that each source adds session by session on the current one (in 420s of the simulation) and finally, three simultaneous sessions are established by each source (in 720s of the simulation). 2.048Mbps links are placed in the backbone network between two edge routers and 100BaseT Ethernet is set from the Ethernet switch to the edge router. 10BaseT Ethernet link is set from the source to the switch. This network is shown in Figure 2.

The total throughput after the establishment of all three sessions is approximately 6.91Mbps. Applying the OSPF routing the shortest selected path of 2.048Mbps (assuming the same rate of each link) will not be able to support the transmission of all sessions with minimal losses and therefore Class Based Weighted Fair Queuing (CBWFQ) is implemented. Dynamic queue management is performed by Weighted Random Early Detection (WRED). CBWFQ and WRED profiles for each PHB traffic class are consolidated through the traffic policy profile. Also, the extended access control list is created in the edge routers in order to identify future video and audio streams for traffic classification.

DSCP values in the header and the assigned address are used for packet identification. Each source is connected to the corresponding destination, thus the communication between two workstations can be accurately performed.

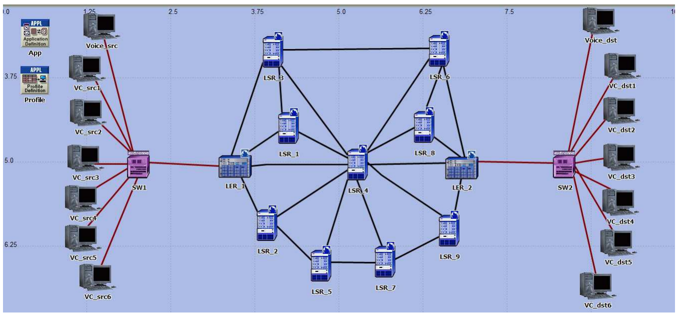

Figure 2. DiffServ scenario

B. DiffServ with MPLS TE scenario

MPLS enables the distribution of sessions to statically or dynamically determined paths. In the simulation static LSPs are used. For the purpose of classification and clustering of packets, Seven Forwarding Equivalence Classes (FECs) and seven traffic trunk profiles are defined. Based on classes and trunk profiles, flows are mapped to the defined static routes (by configuring the edge router). The layout of the network with defined paths for the second scenario is shown in Figure 3.

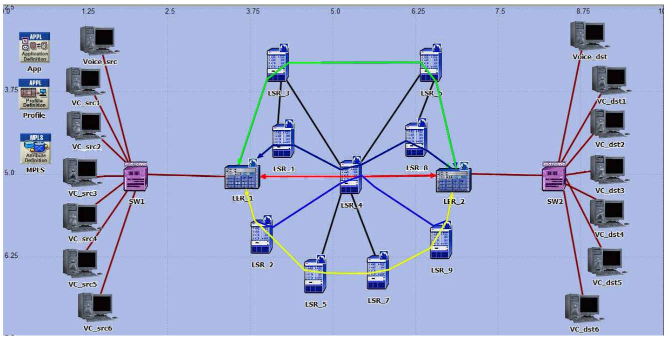

Figure 3. DiffServ / MPLS TE scenario

C. Simulation results comparisons

We performed simulations for different QoS parameters. In this paper the results for average voice end-to-end delay, average video conferencing end-to-end delay and voice traffic received are presented and discussed.

In Figure 4 it can be noticed that end-to-end delay for voice is below 68ms when DiffServ scenario is applied and below 66ms in case of DiffServ with MPLS TE (delay should be kept below 150ms). Therefore, for voice communication end-to-end delay shows acceptable level in both scenarios. In terms of delay second scenario is slightly better than the first one.

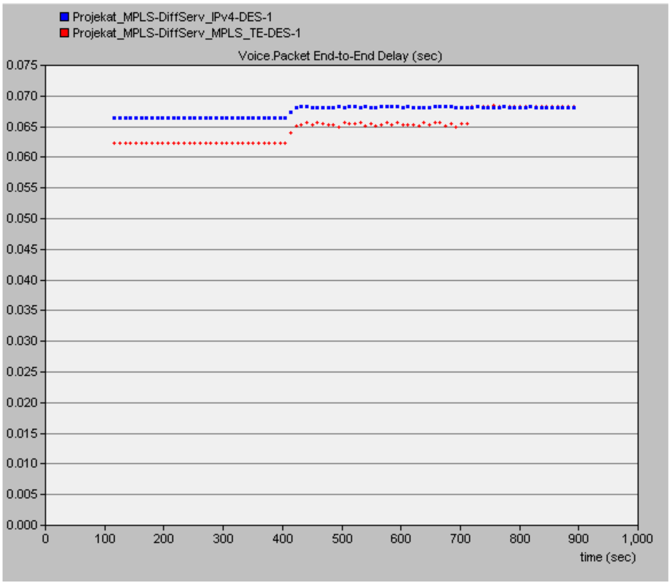

Figure 4. Average voice end- to-end delay

In Figure 5 the average end-to-end delay for video conferencing streams are shown. Applying CBWFQ algorithm has led to considerable delay due to prevention of video conference flows to take the most of the output link router LER_1 capacity. Average end-to-end delay is on the satisfactory level in the first scenario until a second session is established while excellent results in the second scenario are deteriorated with the establishment of the third session although these results are also acceptable (acceptable is up to 400ms).

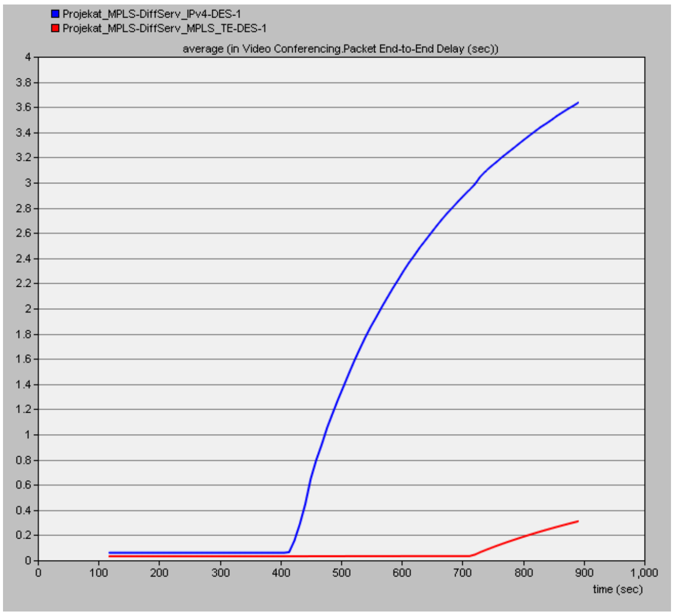

Figure 5. Average video conferencing end-to-end delay

Of all simulation results voice traffic received is the best indicator of differences between these two scenarios. In Figure 6 it is shown that the establishment of the second flow leads to a significant packets loss in the first scenario, primarily due to the overload of link LER_1 - LSR_4 - LER_2 established by OSPF protocol. On the other hand, there are no significant packet loss of voice sessions in the second scenario.

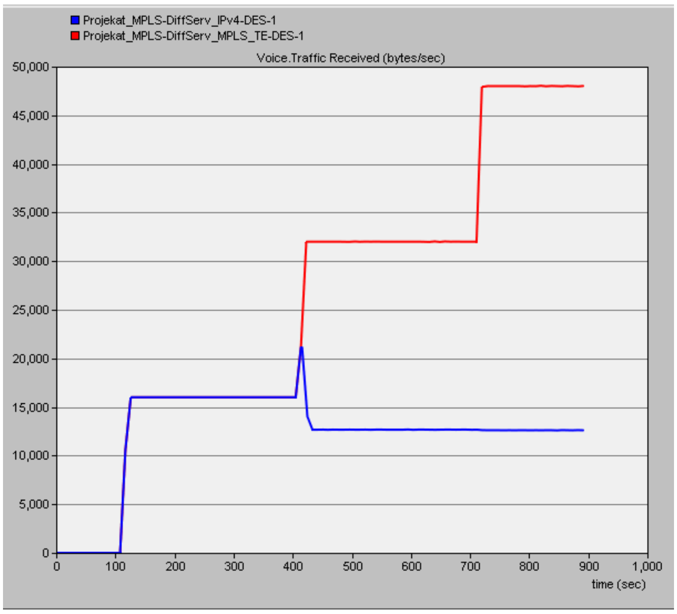

Fig 6. Voice traffic received

IV. Conclusion

DiffServ and MPLS are two separate standards dealing with QoS issues in IP networks. DiffServ itself is not capable to control the traffic which has been taken to end-to-end path with a number of congested links. On the contrary, MPLS TE has ability to control the traffic and to set up end-to-end routing path before data has been forwarded. The evolution of QoS solutions in IP networks has led to the integration of DiffServ and MPLS TE which can be suitable even for the applications with high requirements in terms of QoS, such as real-time applications.

In this paper we have focused on two scenarios: DiffServ without implementing MPLS TE and DiffServ supported by MPLS TE. Some of the simulation results for voice communication and video conferencing are presented and analyzed. The results show improvement of network performances for the scenario which includes implementation of MPLS TE mechanism to support DiffServ architecture in the backbone network.

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References

[1] J. Gozdecki, R. Stankiewicz, A. Jajszczyk, “Quality of Service Terminology in IP Networks,” IEEE Communication Magazine, vol.41, no.3, pp. 153-59, 2003.

[2] ITU-T Recommendation E.800, “Definitions of terms related to quality of services”, Geneva, 2008.

[3] ITU-T Recommendation P.10, “Vocabulary for performance and quality of service”, Geneva, 2006.

[4] M. Romdzi, A. Rahimi, H. Hashim, R. Ab Rahman, “Implementation of Quality of Service (QoS) in Multi Protocol Label Switching (MPLS) Networks”, Proceedings of the 5th International Colloquium on Signal Processing & Its Applications (CSPA), Kuala Lumpur, Malaysia, pp. 98-103, 2009.

[5] A. Jamali, N. Naja, D. EI Ouadghiri, R. Benaini, “Improving Quality of Service (QoS) in Multi-Protocol Label Switching Module”, Mediterranean Microwave Symposium (MMS), Tangiers, Morocco, pp. 1-4, 2009.

[6] Md. Tariq Aziz, Mohammad Saiful Islam, Md. Nazmul Islam khan, Prof. Adrian Popescu "Effect of packet delay variation on video/voice over DiffServ-MPLS in IPv4/IPv6 networks", International Journal of Distributed and Parallel Systems IJDPS, vol. 3, no.1, pp. 27-47, 2012.

[7] V. Radonjic, A. Kostic-Ljubisavljevic, M. Stojanovic, V. Simic, B. Dimitrijevic, “Different Aspects of Quality in NGN”, Proceedings of the 6th International Quality Conference, Kragujevac, Serbia, pp. 817-822, 2012.

[8] G. Rovithakis, A. G. Malamos, T. Varvarigou, M. A. Christodoulou, “Quality of Service Mechanisms in Multimedia Telecommunication Services”, Reliability, Survivability and Quality of Large Scale Telecommunication Systems, edited by P. Stavroulakis, John Wiley & Sons Ltd, 2003.

[9] W. Weiss, “QoS with Differentiated Services”, Bell Labs Technical Journal, vol.3, no.4, pp. 48-62, 1998.

[10] S. Alvarez, *QoS for IP/MPLS Networks*, Cisco Press, 2006.

[11] S. Naveed, S. V. Kumar, “MPLS Traffic Engineering – Fast Reroute”, International Journal of Science and Research (IJSR), vol.3, no.5, pp. 1796-1801, 2014.