An Architectural Framework for Support Quality of Service in MPLS Network

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Abstract- **This paper presents a framework for Multi-protocol Label Switching (MPLS) networks. Through this framework, configurations directives were evaluated in terms of Quality of Service (QoS) provision. Several scenarios of bandwidth reservation and routing configurations were considered and packet delay and number of dropped packets of TCP/UDP flows are compared. The simulation results were applied to establish network configuration directives to improve its performance for flow transmissions. QoS improvements achieved using the proposed directives are presented and discussed for UDP and TCP flow transmissions.**

I. Introduction

IntServ [8] and DiffServ [9] architectures can provide priority assignment to distinct data flows at high network traffic load. With low traffic IntServ, DiffServ and Best Effort services have no important differences on overall network performance.

Multi Protocol Label Switching (MPLS) [1] in IP networks allows the forwarding of data at link layer level through label switching. Such networks should have a Label Switching Router (LSR) and the labeled paths are known as Label Switched Paths (LSPs). A LSP can be established by a routing protocol like OSPF or a constraint based routing protocol. Every LSP is assigned to a Forwarding Equivalence Class (FEC), which defines which data will be forwarded to which LSP. Once the data packet is assigned to a LSP, is not necessary to do the packet header analysis at each router as was required by an usual hop-by-hop routing. This is the great advantage presented by MPLS: the FEC can represent a destination address, a VPN or a service dass.

The MPLS label distribution is done by a label distribution protocol like Label Distribution Protocol (LDP) [4], Resource Reservation Protocol – Traffic Engineering (RSVP-TE) [5] or Constraint Routing – LDP (CR-LDP) [6]. The first one only distributes the labels while the second and third ones also do traffic engineering.

II. Problem Formulation

The hop-by-hop IP routing limits the fulfillment of QoS requirements of multimedia applications mainly because of propagation delay and network congestion. The propagation delay is a direct consequence of the size of the routing tables and the time required to search on them. The congestion happens as a consequence of routing protocols choices for short path routes or low cost links. As a result, traffic tends to concentrate over a few links.

By switching intends to minimize the propagation delay speeding routing decisions. Traffic engineering is intended to minimize network congestion through rational routing.

Evaluate the network performance through bandwidth allocation and occupancy to provide QoS for TCP/UDP data streams is the main focus of this paper. To do this, it will be used the framework proposed and it will be measure the bandwidth.

The basics of traffic engineering and constraint routing concepts are presented at section III. Section IV comprises the framework and scenarios chosen. Section V presents the simulation results; a conclusion and further works are commented at section VI.

III. Traffic engineering and label distribution concepts and protocols

A. Traffic Engineering

Traffic engineering controls the network workload to prevent congestion occurrences. It assumes the main causes of congestion as the lack of network resources and the unbalanced traffic distribution. To solve resource shortage problems, is to increase the network infrastructure. The solution for unbalanced traffic distribution requires traffic measurement, characterization and modeling to control it over a network. Through Traffic Engineering an increase on network performance is expected to occur through rational resource utilization. The network performance evaluation considers bandwidth, delay, delay jitter and packet loss among others.

In general, there exist two Traffic Engineering approaches [15]:

- MPLS-TE: this approach relies on an explicitly routed paradigm, whereby a set of routes (paths) is computed offline for specific types of traffic. In addition, appropriate network resources (e.g., bandwidth) may be provisioned along the routes according to predicted traffic requirements. Traffic is dynamically routed within the established sets of routes according to network state.
- IP-TE: this approach relies on a liberal routing strategy, whereby routes are computed in a distributed manner, as discovered by the routers themselves. Although route selection is performed in a distributed fashion, the QoS-based routing decisions are constrained according to networkwide TE considerations made by the dimensioning and dynamic routing algorithms. The latter dynamically assigns costs metrics to each network interface. Route computation is usually based on shortest or widest path algorithms related to the assigned link costs. In order to allow routes to be computed per traffic type or class, a link may be allocated multiple costs, one per DSCP.

In this article, it is considered only the MPLS based approach.

B. Constraint Based Routing

The common routing processes consider the shortest path (RIP- routing information protocol) [11] or the associated weight of each link (OSPF- open shortest path first) [12] to forward incoming data flows. Both routing techniques do not consider QoS requirements of the flows. A constraint based routing applies metrics like bandwidth, delay and jitter on the forwarding decision process [10]. This decision is based on resource availability and utilization and the data flow QoS requirements. The main goals of the constraint based routing are:

a) dynamical choice of possible paths: to choose a path from a large set of possible paths, which has high probability of satisfy the data flow QoS requirements. The choice can be based on factors like path costs, internet provider, timetable, etc..

b) Resource optimization: based on efficient resource use to increasing total network throughput for example.

Examples of constraint based routing protocol for QoS performance is the Explicit Routing (ER) and Constraint Routing (CR). The Explicit Routing (ER) is defined automatically or by the network manager and can be different from the one established by a routing protocol like OSPF for example. The QoS routing allows the manager the choice of a path with non-congested links. The Constraint Routing (CR) routes are chosen based on parameters like required bandwidth for data flows.

C. Label Distribution Protocol (LDP) and Constraint Routing – Label Distribution Protocol (CR-LDP)

MPLS needs another protocol to distribute labels. The label distribution protocol is defined as a set of necessary procedures for a LSR to notify another LSR about the label meaning for the traffic forwarded between or through them. There is no unique protocol for label distribution.

The LDP creates LSPs considering network layer information provided by the routing protocol, OSPF for example, or provided by an explicit routing where the network manager previouslyassign the routes. Once a FEC is assigned to a label by the LDP, an end-to-end connection is established for data transmission. Two LSRs exchanging label information are known as LDP peers and a session is set up between them. A LSP session allows each peer to learn about the label mapping of its peer, on a bi-directional way.

The CR-LDP is a LDP extension set specially designed to make the constraint based routing easier. The main differences from the LDP are:

- a number of extensions were added to provide set up and LSPs maintenance [4];
- the path defined by the CR-LDP is not necessarily the same defined by the routing protocol.

D. Resource reservation Protocol – Traffic Engineering (RSVP-TE)

The original RSVP protocol is based on the soft-state paradigm. This implies on extra traffic caused by updating messages required for each reservation. On account of that fact, a large number of reservations makes the protocol use not interesting. The RSVP-TE was developed to prevent IP network congestions allowing routers decide about bandwidth reservation for a data flow according to their available resources. The RSVP-TE does not make any routing, which is done by a proper routing protocol. The main differences of the TE version are:

- the number of extensions added to provide set up and LSPs maintenance [13];
- the RSVP signaling exchanged between peers routers, the source LSR (entrance) and the sink LSR (exit). The soft reservation state applies to a set of flows (aggregate flows) sharing a common path and common resources. This common state decreases the necessary number of RSVP states to keep data flows at the IP network.
- the path defined by the CR-LDP is not necessarily the same defined by the routing protocol.

IV. Simulation Model and Scenarios

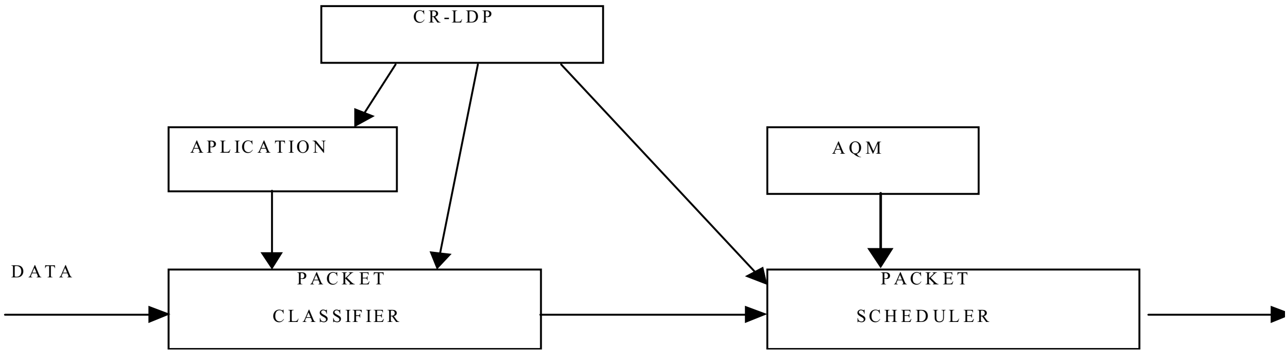

Fig. 1 – MPLS framework

Fig. 1 shows a proposed MPLS framework.

The packet classifier will be configured manually by the operator of the network. In this article, the classification is going to separate the protocols UDP and TCP. Ina Internet Service Provider (ISP) the classification will be in a similar way.

The Active Queue Management (AQM) controls the arrival rate of packets into the queue, by explicit congestion notification (ECN) marking or packet dropping to generate the congestion signal that controls the source rate. The tail-drop algorithm was not designed to be an efficient AQM, because it is a simple queue that, when filled to its maximum, overflows and drops the subsequently arriving packets.

The Random Early Detection (RED) buffer management algorithm manages the queue in a more active manner by randomly dropping packets with increasing probability as the average queue size increases.

The packet scheduler is going to provide different classes to different traffic. Class Based Queueing (CBQ) is used to divide the link in the classes and to guarantee the bandwidth to the customer.

This evaluate is going to establish a default configuration to a network that want to offer a service with QoS to their customers and decrease the congestion in the network.

TCP and UDP data flows were chosen to characterize common patterns of Internet traffic over a network with the topology presented at figure 2.

The simulation traffic considers TCP data stream as a permanent traffic source with its transmission rate controlled by a congestion control procedure (slow start algorithm). UDP stream sources generate traffic at a constant rate. The main goal of our simulation model is to evaluate the bandwidth occupancy by TCP and UDP data flows over 3 MPLS configurations:

a) MPLS without Traffic Engineering;
b) MPLS and ER (explicit routing) and RED;
c) MPLS and CR (constraint based routing) and CBQ scheduling [14].

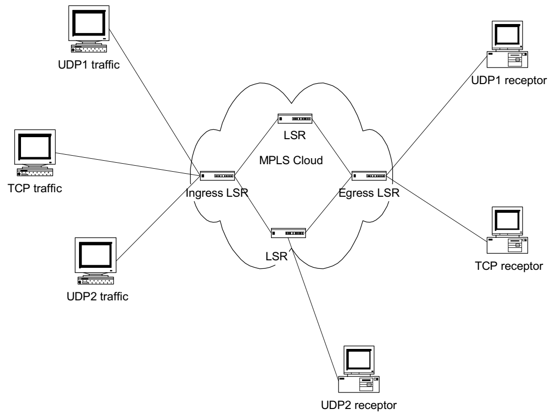

Figure 2 – Network topology of the simulation Model

Once a UDP traffic increases, link congestion occurs and the TCP traffic decreases due to its congestion control algorithm. The UDP traffic remains constant and the congestion affects mainly the TCP traffic.

Data flow processing to achieve QoS should have distinct processing for classified flows. At our MPLS simulation model, TCP traffic should have priority over UDP traffic. We simulated the MPLS network operation using two configurations: a) with ER and RED and b) with CR and CBQ. The metric selected to evaluate the network performance is the throughput. Three UDP workload scenarios were tested:

- light: UDP1 traffic equals 400kbps, UDP2 eq. 300kbps;
- medium: UDP1 eq. 800kbps and UDP2 eq. 600kbps;
- high: UDP1 eq. 1200 kbps and UDP2 eq. 900kbps

All links have 1 Mbps of maximum capacity and delay time of 10ms.

The simulation was executed over NS-2 [3], a software tool comprising all protocols here described.

V. Simulation Results

Figure 3 represents the throughput results of the MPLS network configuration without traffic engineering. The TCP throughput results are resumed at Table 1 for three workload scenarios.

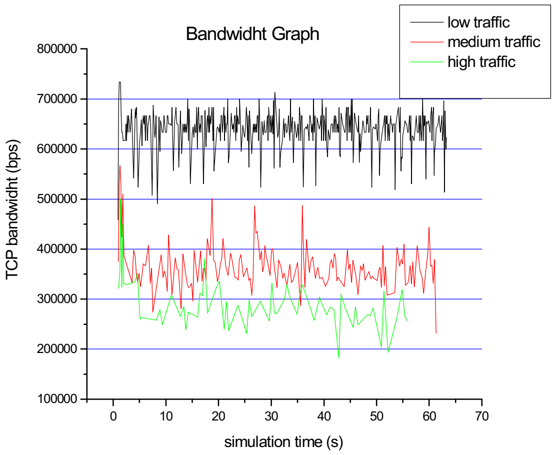

Figure 3– MPLS without Traffic Engineering

MPLS		Average	Median	Mean deviation
Bandwidth (kbps)	light	638,585	650,000	43,894
	medium	364,582	360,714	45,332
	high	302,087	282,818	85,240

Table 1 – Bandwidth occupancy results (MPLS)

The TCP bandwidth occupancy decreases as the UDP traffic increases. TCP throughput values approach the difference of maximum link capacity and bandwidth occupied by UDP traffic. The label switching seems not affect QoS values from of normal IP routing simulation results.

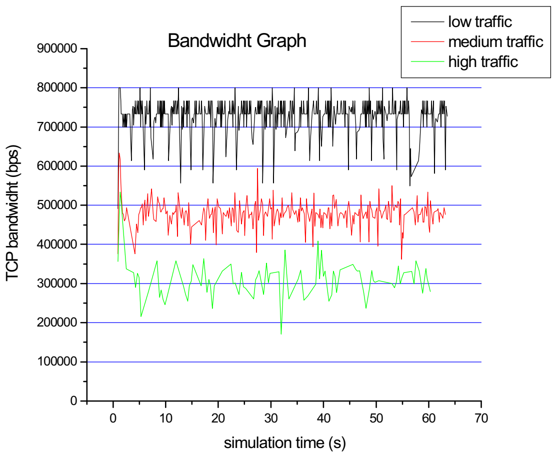

Figure 4 - MPLS and Explicit Routing

Figure 4 and Table 2 show simulation results of MPLS and ER configuration. The TCP throughput behavior is similar to the first scenario. A better performance can be noticed because the explicit routing on less congested links. And the use of the RED algorithm instead Droptail.

MPLS and ER		Average	Median	Mean deviation
Bandwidth (kbps)	light	**725,295**	**733,333**	**67,922**
	medium	470,581	481,550	70,933
	high	295,369	305,451	91,069

Table 2 – Bandwidth occupancy results (MPLS, ER)

Figure 5 and Table 3 show simulation results of MPLS and CR routing not similar to both previous configuration. Here the TCP throughput behavior depends on CR throughput routing parameter which was set to 550kbps. A CBQ packet scheduler was executed to share the link bandwidth capacity in 4 classes: 550 kbps, 350 kbps, 50 kbps and 50 kbps. TCP traffic was assigned to the first class (550kbps), UDP to the second, LDP signaling to the third and the last class was kept without traffic.

MPLS and CR&CBQ classes		Average	Median	Mean deviation
Bandwidth (kbps)	light	547,326	550,572	53,151
	medium	532,047	518,048	45,177
	high	524,3348	520,000	36,731

Table 3 – Bandwidth occupancy results (MPLS, CR and CBQ classes)

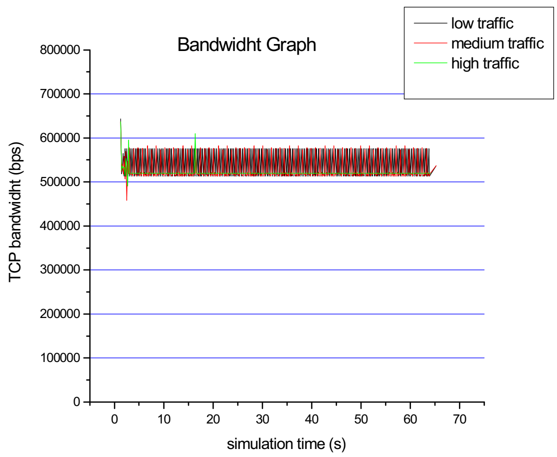

Figure 5 – MPLS, CR and CBQ classes

VI. Conclusions

There are many mechanisms that can be used to deliver required network performance. This paper proposed a framework to a MPLS network using some of them.There are two types of traffic in a network. The best-effort and the traffic that needs a minimum bandwidth that a customer specified with a SLA. If the traffic in the network is best-effort, to provide better performance can be used explicit routing with RED algorithm to reduce the congestion in the network. And if the customer needs a minimum bandwidth, must be used constraint routing with CBQ.

The results are now been used to establish network configuration methods for QoS guarantees. Further investigation results on aggregate flows about individual flow throughput performance and dynamical QoS configuration with flow preemption should be carried out soon.

VII. Acknowledgment

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