



Path Selection Analysis in MPLS Network Based on QoS

Hesam HOSEINZADEH

Department of Electrical Engineering, PhD in Electrical Engineering and Faculty Member, Qaemshahr Branch, Islamic Azad University, Qaemshahr, Iran

Received: 24.04.2015; Accepted: 09.07.2015

Abstract. Multi-Protocol Label Switching (MPLS) has been proposed as a new approach for integrating layer 3 routing with the layer 2 switching. It integrates the label swapping paradigm of layer 2 (e.g. ATM and Frame Relay) with the routing of layer 3 (e.g. IP and IPX). In the MPLS networks, constraint-based routing computes routes that are subject to constraints such as bandwidth and administrative policy. Because constraint based routing considers more than network topology in computing routes, it may find a longer but lightly loaded path better than the heavily loaded shortest path. In this paper we propose a new constraint based routing algorithm for MPLS networks. The proposed algorithm which is a modification of Wang-Crowcroft algorithm, uses both bandwidth and delay constraints. It means that the reservable bandwidth of all of the links along computed path must be equal to or greater than the bandwidth constraint value and the delay of the path must be less than or equal to the delay constraint value. In the proposed algorithm, the best path is selected based on proposed algorithm. Simulation results show that in comparison with the other methods, the proposed algorithm has a better performance.

Keywords: MPLS networks, Quality of Services (QoS), Constraint Based Routing, Routing Protocols, Traffic Engineering

1. Introduction

In recent years, IP networks have been subjected to different types of Internet applications with different Quality of Service (QoS) requirements. Traffic engineering enables routed traffic to be altered from chosen standard routes to improve network resources or avoid network congestion. However, the best effort characteristic of IP makes it unable to support Traffic Engineering (TE). A technique, recently introduced, to support TE is Multiprotocol Label Switching (MPLS). MPLS allows the setup of label-switched paths (LSPs) between IP routers to avoid the IP forwarding in the intermediate routers. MPLS (Multi Protocol Label Switching) is a flexible technology that enables new services in IP networks and makes routing more effective. In IP both the route calculation and the forwarding is based on the destination address. MPLS separates the forwarding from the route calculation by using labels to forward the packets. To distribute these labels over the domain and hence set up an LSP, MPLS uses a label distribution protocol. LSPs can be setup according to the IP routing tables or the hops to be traversed can be explicitly specified. Two protocols are being standardized for constraint based routing in MPLS. One of them, CR-LDP is a modification of LDP to support constraint based routing. Other is RSVP-TE, a set of extensions to RSVP to support traffic engineering and MPLS label setup. Constraint-based routing (CR) takes into account parameters, such as link characteristics (bandwidth, delay, etc.), hop count and QoS. The LSPs that are established could be CR-LSPs, where the constraints could be explicit hops or QoS requirements. Explicit hops dictate which path is to be taken. QoS requirements dictate which links and queuing or scheduling mechanisms are to be employed for the flow. Constraints can be divided into two categories: administrative constraint and performance constraint. Administrative constraint refers to the constraint based on particular policies beyond performance issues. Performance constraint defines constraint on performance attributes of a link such as bandwidth and delay. The metrics of these attributes are associated with each link in the network. QoS-based routing and MPLS can work together, too.

QoS-based routing can select the path, and MPLS will do the packet forwarding along the path. MPLS can also provide more precise routing information for QoS-based routing, which may help QoS-based

* Corresponding author. Hesam HOSEINZADEH

routing to select better paths. In many cases, bandwidth is the most important metric, perhaps the only metric used. Even if there are QoS requirements concerning other metrics, they can usually be mapped to bandwidth requirements. Subsequently, many QoS routing schemes consider only bandwidth and hop count. Hop count is additive, but bandwidth is concave, so these routing problems fall into the category of polynomial time composite problems.

While a feasible path can be selected using any QoS based routing algorithms, additional optimality constraints need to be imposed to achieve efficient resource utilization. The most common way for a routing algorithm to achieve resource efficiency is to limit resource consumption and to keep the network load balanced. For traffic with bandwidth guarantees, resource consumption can be reduced by restricting the hop count of the path being selected, while the network load can be balanced by selecting the least residual bandwidth. Understanding the performance tradeoffs between these routing algorithms essential to the successful deployment of QoS in future networks. With attention to this summarized review, each one of QoS routing algorithms solves a specific routing problem using different constraints, special suppositions and circumstances. The nearest QoS routing algorithm to our proposed algorithm is the Wang-Crowcroft algorithm. In by using the Dijkstra's shortest path algorithm, a QoS routing algorithm that finds a path that satisfies two constraints bandwidth and delay, has been proposed. The remainder of the paper is organized as follow. In section 2, we explain the proposed algorithm in details. In section 3, by using the MPLS Network Simulator (MNS), we evaluate the performance of proposed algorithm with those of Wang-Crowcroft and CR-LDP algorithms. Finally, section 4 concludes the paper.

2. Proposed Algorithm

Based on the previous studies, it can be shown that any two or more combinations of two additive metrics are NP-complete. As shown in the only feasible combinations are bandwidth with one of four (delay, delay jitter, cost, and packet loss probability). As the bandwidth and propagation delay are two important constraints, in the proposed algorithm we use only bandwidth and delay constraints. We can make sure that these two metrics are not inter-dependent and our routing problem won't be NP-complete. As the MPLS networks use the explicit routes where the path must be computed in the source router so, the routing strategy of our proposed algorithm is the source routing. Furthermore, it is a unicast routing algorithm. The approach used in design of the proposed algorithm, first solves the QoS routing problem, then performs optimization and finally considers the future requests. In order to solve the problem; it must find a feasible path that satisfies both bandwidth and delay constraints. It means that the reservable bandwidth of all of the links along computed path must be equal to or greater than the bandwidth constraint value and the delay of the path must be less than or equal to the delay constraint value. After we make sure that the computed path satisfies the requirements, if there is more than one feasible path, we must choose the best one. The best path is the shortest one which has the least delay value. In order to optimize network resource utilization, the path with minimum of hop count is preferred. The other optimization aspect is related to computation time complexity. The order of a routing algorithm is tightly dependent on the number of nodes / links in the network topology graph. Therefore if the dimension of this graph could be reduced, the path computation time complexity will be better. To achieve this goal, we prune the topology graph as well as we are able to. In order to minimize the probability of congestion occurrence for the future requests, the load-balancing rule is used. To conserve large capacity of the links (large amount of bandwidth) for future requests, which their required bandwidth value is large, the proposed algorithm in the load-balancing step is preferred. The high level description of our proposed QoS routing algorithm is summarized as bellow:

Step 1: eliminates all links that do not meet the bandwidth requirement by setting their delay to ∞ .

Step 2: find the minimum delay path using Dijkstra's algorithm

Step 3: if various paths are found; the path with minimum hop count is selected.

Path Selection Analysis in MPLS Network Based on QoS

Step 4: if more than one path is found in step 3; select the path with residual bandwidth to reach network load balance.

In step 1, bandwidth constraints should be used. It means that one should delete all links which have less bandwidth than the required bandwidth. Step 2 proposed algorithm should use delay constraint. It means that a path should be selected with required delay constraint, and has the shortest delay. In step 3 if several paths are found, it should be selected the path which can provide optimal utilization of our resources. In the step 4 it should be used the load-balancing rule. To do so, the residual bandwidth links with range of each path are selected and compared. Then select the path with the minimum range. To reach the range of each path the minimum residual bandwidth is subtracted from the maximum residual bandwidth.

3. Performance Evaluation

In this section, by using MPLS Network Simulator (MNS), the performance of our proposed QoS routing algorithm is compared with those of Wang-Crowcroft and CR-LDP algorithms. The evaluation parameters are the throughput, the call blocking rate, the path's delay and the end-to-end delay. The traffic parameters of AF, EF and BE services are shown in **Table 1**.

Table 1. Traffic parameters used in the simulation.

Service Model	Bandwidth	Traffic Type	Mean burst time	Mean Idle time	Shape
AF1	800 kb/s	Pareto	500 ms	500 ms	1.5
AF2	1000 kb/s	Constant Bit Rate	-	-	-
EF	800 kb/s	Constant Bit Rate	-	-	-
BE	100 kb/s	Pareto	200 ms	800 ms	1.5

The call requests are reached at each 0.5 s, periodically. The network topology used in the simulation is shown in **Fig.1**. In this figure the numbers a, b shown in each link, represent the number of requests of the desired service class which can be transmitted by this link and the link's propagation delay (in ms), respectively. In **Fig.2** for all traffic classes AF1, AF2, EF and BE, the throughput is plotted versus simulation time. It can easily be seen that the proposed algorithm has better performance than those of Wang-Crowcroft and CR-LDP algorithms.

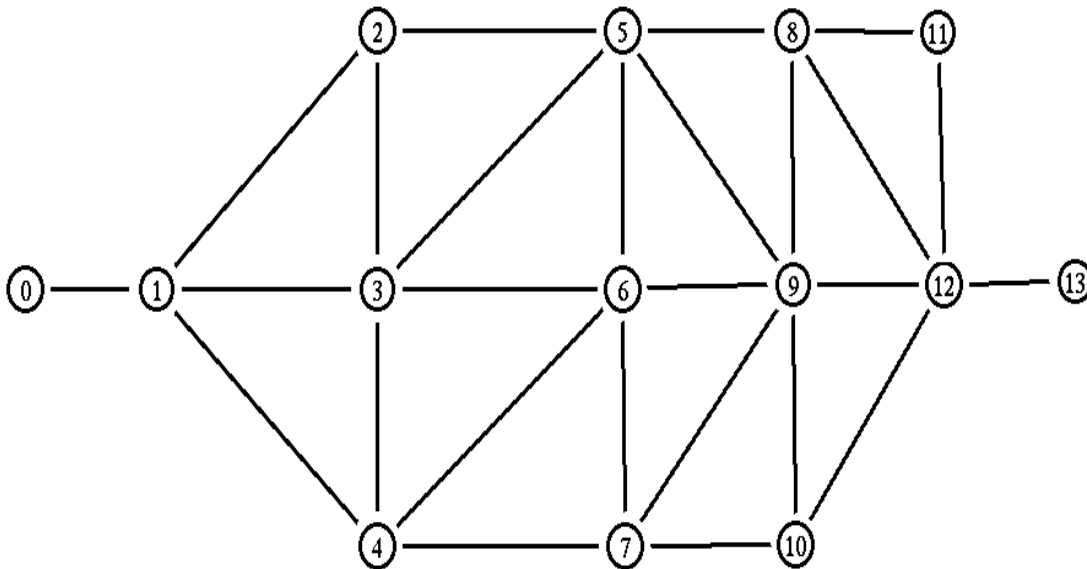


Figure 1. Network topology used for simulation

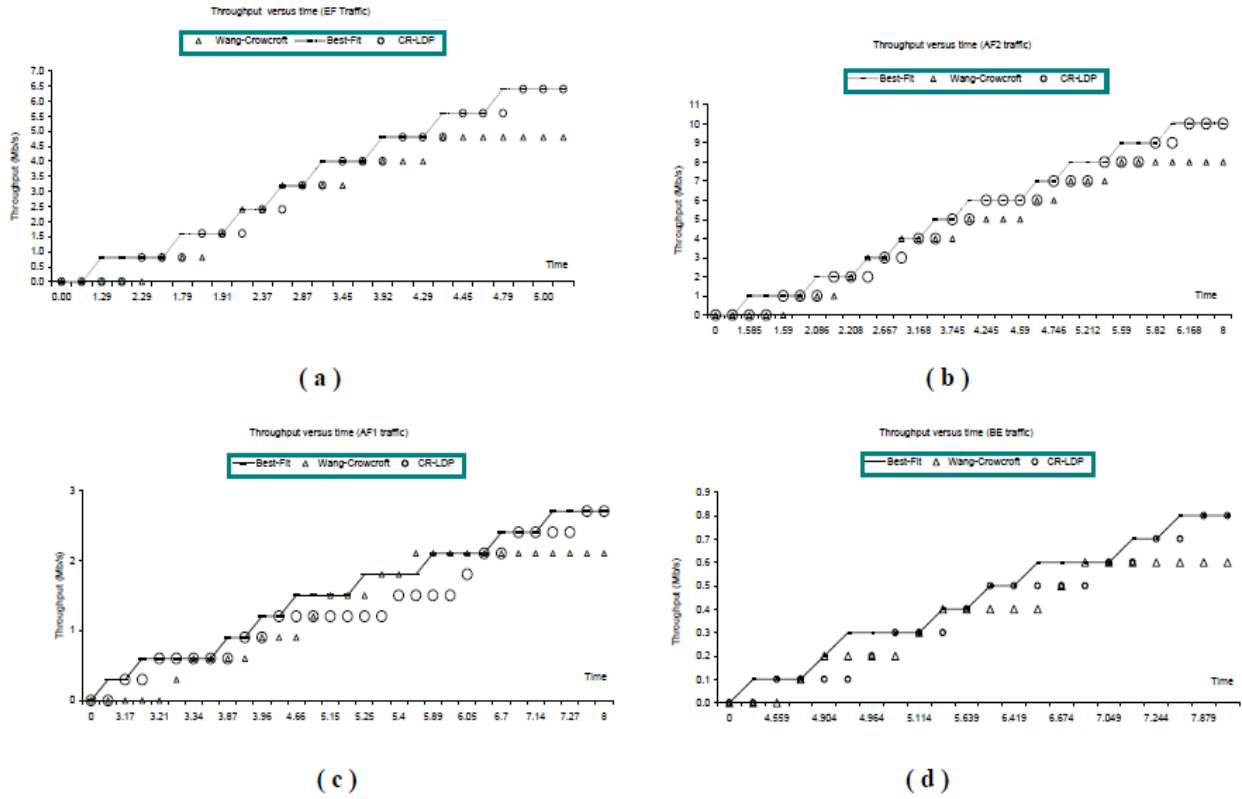


Figure 2. Throughput versus simulation time a (EF traffic b) (AF2 traffic c) (AF1 traffic d) (BE traffic)

In **Fig.3**, for all traffic classes AF1, AF2, EF and BE, the throughput is plotted versus the traffic load. This figure show the average throughput of each class of service based on the request arrival and regardless of the time. So, it doesn't indicate the momentary difference of throughput but it shows the total throughput of each service class regard to received request. Based on results shown in this figure, for all traffic types, the proposed algorithm has better throughput

Path Selection Analysis in MPLS Network Based on QoS

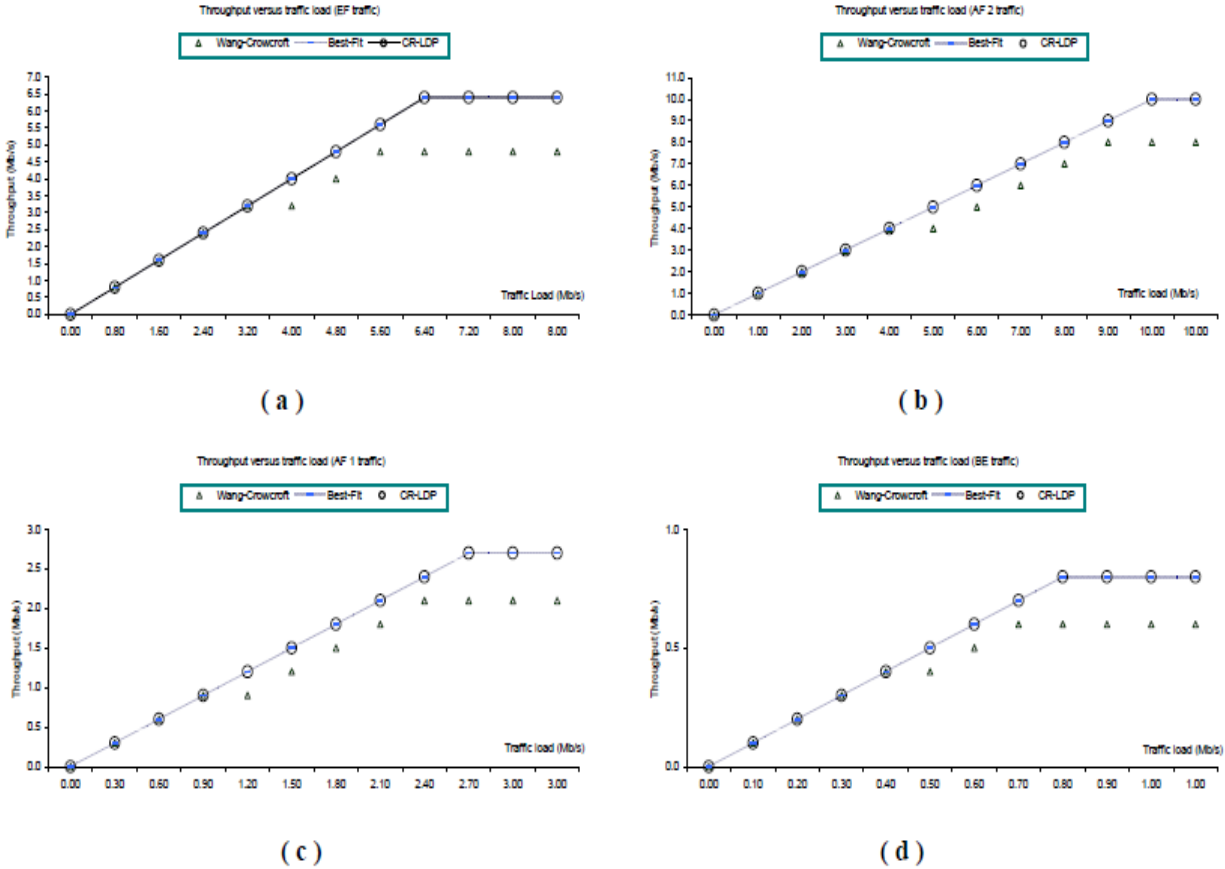


Figure 3. Throughput versus traffic load a (EF traffic) b (AF2 traffic) c (AF1 traffic) d (BE traffic)

In the next simulation trial, we evaluate the call-blocking rate of the proposed algorithm. The call-blocking rate is defined as bellow:

$$call - blocking \ rate = \frac{\text{number of rejected calls}}{\text{total number of recieved calls}}$$

In **Fig.4**, the call-blocking rate of all algorithms is plotted versus traffic load. It is shown that for all types of traffic, our proposed algorithm has a better performance than the Wang-Crowcroft algorithm. Furthermore it is observed that CR-LDP algorithm has the same performance like the proposed algorithm, but note that it cannot satisfies the delay constraints while our proposed algorithm can does it. This will be shown in the next Figures. As mentioned before, the proposed algorithm considers only two constraints including bandwidth and delay. Based on results shown in the Figures 2-4, in comparison with the Wang-Crowcroft and CR-LDP algorithms, the proposed algorithm has a better throughput and call blocking rate. In the next trials, we evaluate the delay performance of our proposed algorithm. For this purpose, we consider a new MPLS network topology. We simulated this topology in MNS simulator. The numbers a, b shown, represent the link capacity (in Mb/s) and the link's propagation delay (in ms), respectively. To compare the delay performance of the proposed algorithm with that of CR-LDP algorithm, we performed new simulation trials. In this case we considered four different scenarios. In each scenario, 8 consequences call request arrive at each time unit. **Table 2** shows the requested bandwidth of this scenario. In **Fig.5**, for both the proposed algorithm and CR-LDP algorithm, the delay of selected path is plotted versus traffic load. This figure shows that in comparison with the CR-LDP algorithm, the proposed algorithm can select a better path with minimal delay.

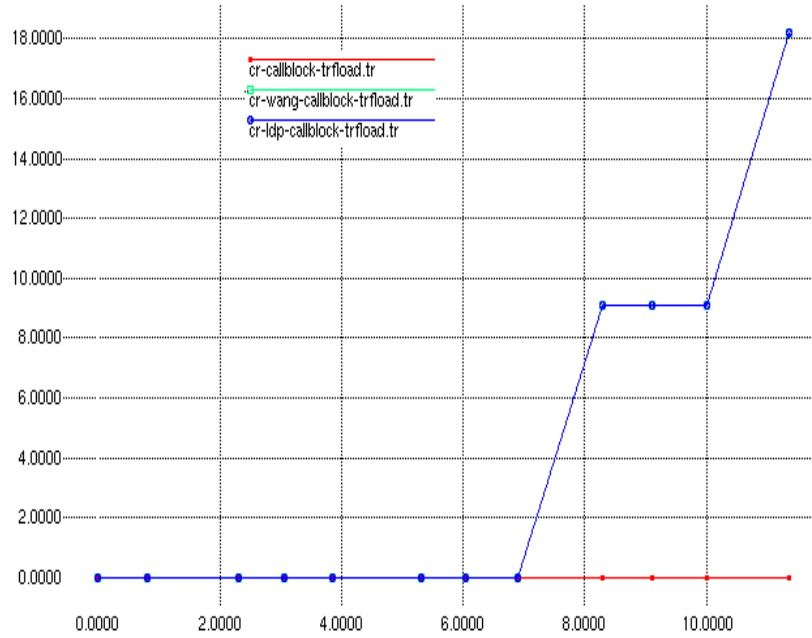


Figure 4. Call blocking rate (%) versus Traffic load (Mb/s).

Table 2. Requested bandwidth of four different scenarios

Call No.	Requested bandwidth (scenario 1)	Requested bandwidth (scenario 2)	Requested bandwidth (scenario 3)	Requested bandwidth (scenario 4)
1	50 Kb/s	50 Kb/s	400 Kb/s	500 Kb/s
2	50 Kb/s	500 Kb/s	400 Kb/s	500 Kb/s
3	150 Kb/s	400 Kb/s	500 Kb/s	400 Kb/s
4	150 Kb/s	150 Kb/s	500 Kb/s	150 Kb/s
5	400 Kb/s	400 Kb/s	150 Kb/s	400 Kb/s
6	400 Kb/s	500 Kb/s	150 Kb/s	400 Kb/s
7	500 Kb/s	50 Kb/s	50 Kb/s	50 Kb/s
8	500 Kb/s	150 Kb/s	50 Kb/s	50 Kb/s

Path Selection Analysis in MPLS Network Based on QoS

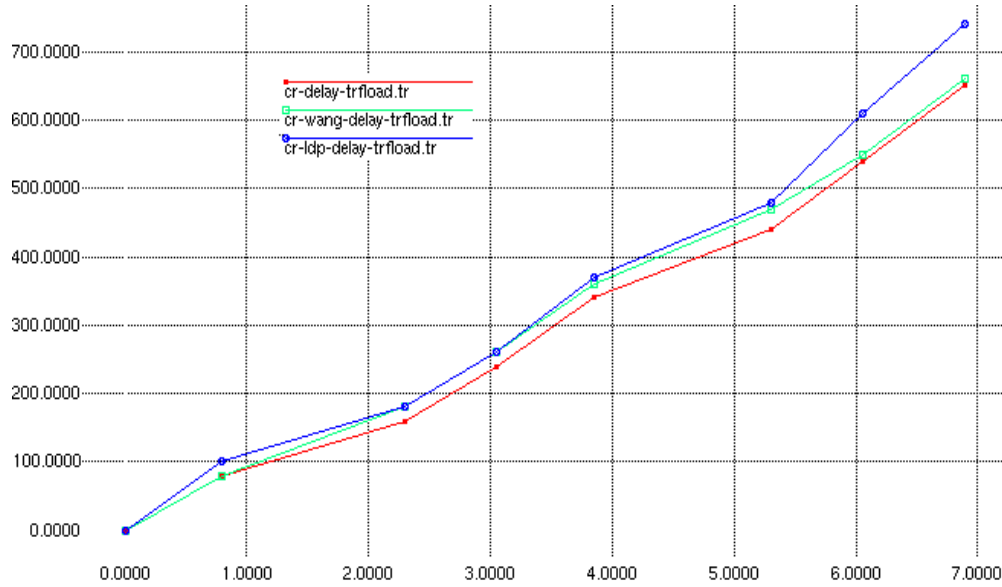


Figure 5. The path's delay(s) versus traffic load (Mb/s)

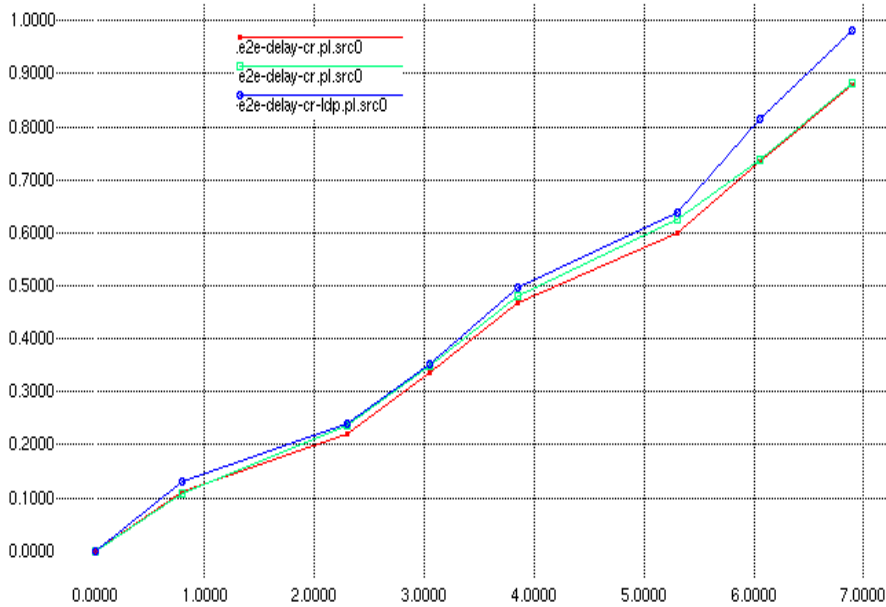


Figure 6. End-to-End delay (sec) versus traffic load (Mb/s)

In **Fig.6**, for all traffic classes, the end-to-end delay of the proposed algorithm is compared with those of Wang-Crowcroft and CR-LDP algorithms. In this figure it can be seen that for all types of traffic, our proposed algorithm has the better performance than the Wang-Crowcroft and CR-LDP algorithms. In **Fig.7**, the call blocking rate is plotted versus number of incoming requests. It can be seen that by increasing the number of requests, for all different call request processing orders, the blocking rate is increased. The results shown in figure confirm that in comparison with the other methods, the decrement band width order has the better performance.

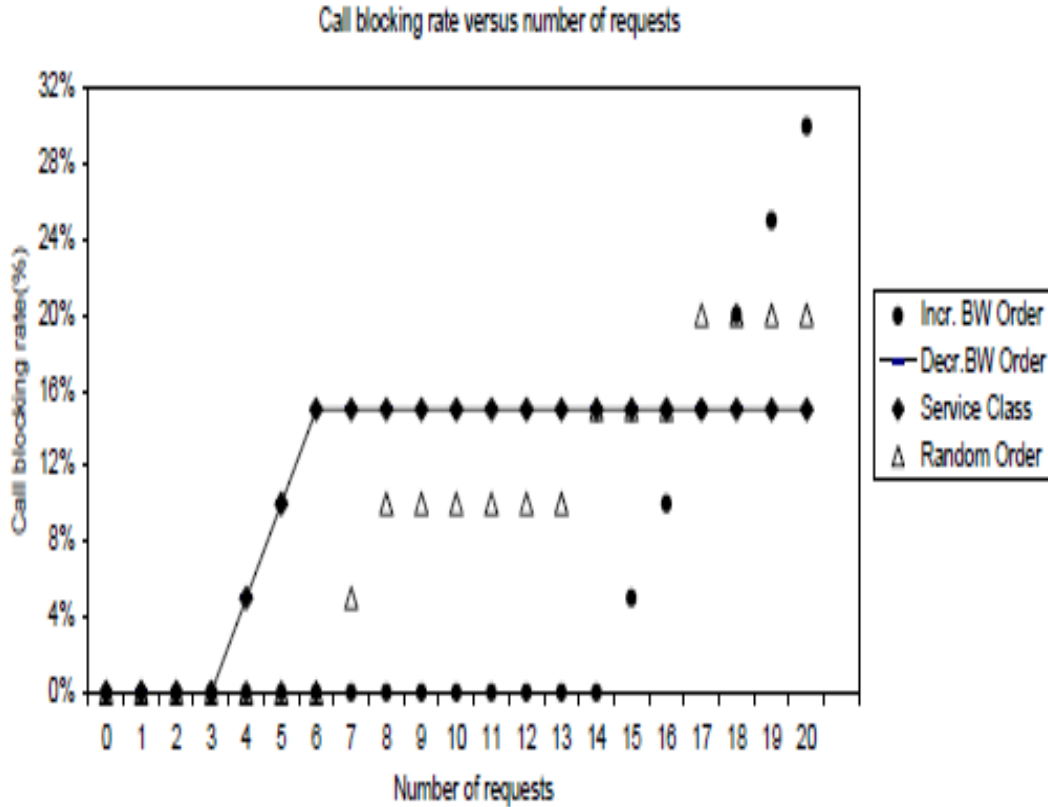


Figure 7. The study of call request processing order: call blocking rate versus number of requests

4. Conclusion

In MPLS networks, using constraint-based routing, traffic engineering can be done more effectively. Traditional routing algorithms utilized just a unique metric like as hop count or cost. So all of the traffic was sent by shortest path. As a result this path got congested and traffic engineering had to be done. When a suitable QoS routing protocol is available and each node can be added to network, the challenge is a task in QoS routing to find a path according to multiple constraints. In a specific routing problem, special suppositions and circumstances are available to solve each QoS routing algorithm or different constraints. In this paper we have introduced a constraint-based routing algorithm for MPLS networks. The proposed algorithm can help us in path selection. It selects a path which can provide the mentioned constraints for us and can also be the shortest path. The constraints which we have mentioned are: delay bandwidth which is the most important constraints in a network. With these constraints, algorithm can select the path and show us the shortest path. If we want to have the optimal utilization of network resources, among the same paths, we should use the path with minimum hop count to have the best. Algorithm makes possibility that if we have various paths in advance. The most supporting path will be chosen which supports the network band balance. Therefore, algorithm mentioning the residual bandwidth is to choose the optimal path. Using MNS simulator, the performance of our proposed QoS routing algorithm was tested and compared with Wang-crowcroft, CR-LDP algorithms. The results of algorithms lead us to a proper conclusion, because the proposed algorithm has great performance than the other algorithms.

References

- [1] Wang Z, Crowcroft J. Quality-of-service routing for supporting multimedia applications. *IEEE J Select Areas Communi* 1996; 14:1228-1234.
- [2] MPLS Network Simulator (MNS), <http://flower.ce.cnu.ac.kr/~fog1/mns/>
- [3] Jamoussi B, Anderson L, Callon R, Dantu R, Wu L, et al. Constraint - Based LSP Setup using LDP. IETF RFC 3212, January 2002.
- [4] Zhenyu L, Ke X, Jianping W. A novel QoS routing scheme for MPLS traffic engineering. *International Conference Communication Technology, (ICCT 2003)*, 2003.
- [5] P. Liu. Internet Protocols for Multimedia Communications. *IEEE Multimedia*, 4(3), July-September 1997.
- [6] B. Jamoussi, Ed., et. al. "Constraint-Based LSP Setup using LDP", IETF RFC 3212, January 2002.
- [7] Daniel O. Awduche et al., RSVP-TE: Extensions to RSVP for LSP Tunnels, Work in progress, August 2001.
- [8] Bin Wang et al., "A New Bandwidth Guaranteed Routing Algorithm for MPLS Traffic Engineering", IEEE, 2002.
- [9] Ilmari Juva "Analysis of Quality of Service Routing Approaches and Algorithms", 26.3 .2003
- [10] Manabu Konno "A Survey on QoS technology: QoS Routing and MPLS", April 2005 Authorized licensed