A NEW PREEMPTION AVOIDANCE AND LOAD BALANCING POLICY FOR TRAFFIC ENGINEERING IN MPLS NETWORKS

Ji-Feng Chiu, Yu-Ben Miao, *Chi-Wen Lo, *Zuo-Po Huang, *Wen-Shyang Hwang and Ce-Kuen Shieh
Department of Electrical Engineering, National Cheng Kung University, Taiwan R.O.C.
*Department of Electrical Engineering, National Kaohsiung University of Applied Sciences, Taiwan R.O.C.

ABSTRACT

The objective of traffic engineering is to optimize resource efficiency and network performance. Its study issue is to make the use of the available bandwidth in IP backbone networks effectively. MPLS (Multi-Protocol Label Switching) approach proposed by the IETF (Internet Engineering Task Force) is a new technology that facilitates significantly the process of traffic engineering. In MPLS networks, the higher-priority LSP (Label Switching Path) will preempt the resource of lower-priority LSP when the bandwidth resource is strained. The LSP preemption introduces a setup and holding priority. When preemption occurs, the lower- priority LSP will be destroyed, and its bandwidth resource is released. The higher-priority LSP obtains the freed bandwidth resource to establish its path, while the preempted lower-priority LSP has to be rerouted by selecting another LSP. However, the LSP cannot ensure that bandwidth resources won't be preempted again. If this situation occurred frequently, routers would have superfluous overhead and encounters an awful quality of service.

In this paper, a new policy for preemption avoidance and load balancing is proposed. It complements with traditional Constraint-based Routed (CR) scheme and aims to network resource utilization and the number of LSP preemption. The difference is considered between the traditional method and our policy that depends on the preemption probability of the LSP. The preemption probability combines two criteria: the priority of LSP to be delivered, and the remaining bandwidth of link along the LSP. Each node of LSPs calculates the preemption probability, the minimal preemption probability LSP is selected to service the flow. The simulation results show that our policy with comparable network performance is better than CR.

KEY WORDS

MPLS, Traffic Engineering, Preemption Avoidance and Load Balancing

1. INTRODUCTION

With the exponential growth of the Internet over the last few years, technology is continuously developed to conform to the demand in bandwidth growth. In addition, the Internet will follow the dramatic growth due to the increasing demand for more bandwidth to home. In order to meet the growing demand for bandwidth, Internet Service Providers (ISPs) will need higher performance switching and routing products. Currently, there are some automatic traffic engineering schemes. Specifically, routing protocols such as OSPF enable routers to dynamically change the route to given destination on a packet-by-packet basis to achieve network load balancing. However, these routing protocols react in a very simple manner to congestion. All traffic between two endpoints follows the same route, which may be changed when congestion occurs. As today's ISPs look for new and efficient ways to keep pace with the demand for emerging technologies, increase revenue and simplify operations, MPLS is becoming the backbone of choice for new multi-service networks [1][2].

MPLS integrates the label-swapping paradigm of layer-2 technologies, such as ATM (Asynchronous Transfer Mode) or frame relay. It offers an aggregated data path for all services, while allowing combinations of control plane scheme within the same backbone to provide multiple logical service networks. With MPLS, it is possible to set up routes on the basis of the individual flows. Two different flows between the same end-points may follow different routers. Further, when congestion occurs, LSPs can be rerouted automatically. That is, instead of simply changing the route on a packet-by-packet basis, MPLS changes the routes on a flow-by-flow basis, taking advantage of the known traffic demands of each flow. The effective use of traffic engineering can substantially increase the usable network capacity.

The most important application of MPLS is in traffic engineering [3] [4] [5] [6]. In MPLS networks, the construction block of traffic engineering is LSP, which can be managed by network administrators to direct the traffic. Traffic engineering usually targets the ability to efficiently map traffic onto an existing network topology in such a way as to optimize the utilization of network resources. Constraint-based Routing (CR) is a mechanism used to meet traffic-engineering requirements for MPLS networks. Its basic concept is to extend LDP for support of constraint-based routed LSPs by defining mechanisms [7] [8].

CR can be set up as an end-to-end operation that the idea is for the ingress router to initiate CR and for all affected nodes to be able to reserve resources using LDP. CR-LDP conveys the resources required by a path on each hop of the route. If existing LSPs cannot find a router with sufficient resources, they may be rerouted to reallocated resources on the new path. In order to control the path of LSPs effectively, each LSP can be assigned one or more attributes. These attributes are summarized as follows: bandwidth, path attribute, setup priority, holding priority, affinity, adaptability, and resilience [4]. Setup priority is the priority of LSP currently being established. Holding priority is the priority of the LSP has been established and is currently active in the LSR. Using different combinations of these priorities, user can effectively preempt an already established LSP to give access to the priority user traffic if a sufficient resource cannot be found. Signaling a higher holding priority expresses that path, once it has been established, should have a lower chance of being preempted. Signaling a higher setup priority expresses the expectation that, in the case that resources are unavailable, the path is more likely to preempt other paths. Then, the lower-priority LSP will be destroyed, freeing its bandwidth resources and the higher-priority LSP can obtain bandwidth resources to establish. While lower-priority LSP frees bandwidth, it will be rerouted by selection another LSP. But the LSP cannot ensure that bandwidth resources won't be preempted again. If the situation occurs often, routers would have superfluous overhead and encounters an awful quality of service. In this paper, a new policy for preemption avoidance-load balancing is proposed. It complements with traditional constraint-based routed (CR) scheme and aims to networks resources utilization and LSPs number of preemption. The difference between traditional method and our policy lies in the way that the preemption probability of the LSP is considered. The preemption probability combines two criteria: priority of LSP to be delivered, remaining bandwidth of link along the LSP. In finding a appropriate LSP for a certain flow, every nodes of each LSP calculate preemption probability and the minimal preemption probability LSP is selected to service that flow.

The rest of this paper is organized as follows: in section II, we introduce related work of MPLS and traffic engineering. Section III describes the policy proposed in the paper. Section IV provides simulation results. Finally, a conclusion and future work are presented.

2. RELATED WORKS

So far several researchers have proposed to extend MPLS capabilities, such as load balancing, restoration and QoS (Quality of Service) routing. A variety of QoS routing techniques have been presented recently [9] [10] [11] [12] [13]. Those algorithms are designed to use resources efficiently while providing the desired QoS level. Paper [11] describes a scheme based on an adaptive MPLS-TE approach that utilizes multiple existing parallel LSPs to achieve QoS constraints for different incoming classes of traffic in an IP network. Paper [12] proposed a QoS routing scheme that gives a priority to multimedia traffic prone to block and differentiates network links into four classes based on link state information.

The main objection is to focus on load balancing for decreasing the possibility of congestion and maintaining high resource utilization. Paper [14] is a label switched path setup algorithm used with the flooding and forwarding style defined in OSPF-OMP (Open Shortest Path First-Optimized Multipath) [15]. MPLS-OMP (Multi-Protocol Label Switching-Optimized Multipath) is intended to be used with a link state protocol used as an interior gateway protocol, with loading information flooded via the link state protocol as described in OSPF-OMP or ISIS-OMP (Intermediate System Intermediate System-Optimized Multipath) [16].

In CR-LDP related to each other, [17] proposed whereby a source node can learn about the successes or failures of its path selections by receiving feedback from the paths it is attempting. This information is most valuable in failure scenarious but is benificial during other path setup functions as well. This fed-back information can be incorporated into subsequent route computations, which greatly improves the accuracy of the overall routing solution by significantly reducing the database discrepancies. In [18], authors proposed crankback routing mechanism whereby the ingress LSR or intermediate LSR knows the location of blocked link or node and the LSR can designate an alternate path and then reissue the setup request. Paper [19] used reversed messages of CR-LDP signaling protocol. The reserved signaling messages include the location identifier of blocked node or link and the information of each link that the signaling messages are reserved.

In [20], authors proposed to avoid network congestion by adaptively balancing the load among multiple paths based on measurement and analysis of path congestion. MATE (MPLS Adaptive Traffic Engineering) adopts a minimal approach in that intermediate nodes are not required to perform traffic engineering or measurements except normal packet forwarding. Paper [21] proposed a maximum sharing algorithm for providing recovery against a single random link failure and a greedy heuristic that provides recovery against two random link failures that consider the problem of pre-computing end-to-end backup paths, while maximizing the sharing of reserved resilient capacity. In [22], a new preemption policy is proposed and complemented with an adaptive scheme that aims to minimize rerouting. The preemption policy is both simple and robust, combining the three main optimization criteria: number of LSPs to be preempted, priority of LSPs to be preempted, and amount of bandwidth to be preempted.

3. PREEMPTION AVOIDANCE AND LOAD BALANCING POLICY

We assume that our policy operates in a MPLS network supporting traffic engineering and these LSPs are established using CR-LDP that is from ingress router to egress router. In these LSPs setup procedure, our policy is used for each link of each LSP to calculate *Preemption Probability*. The flow of preempting probability ($P_{(flow)}$) is defined equation (1), which means the probability of this LSP be preempted by other higher-priority LSPs. It combines priority level and requisition bandwidth both. In this case, we assume that the arrival rate and requisition bandwidth for each level LSP equally All LSP with priority greater than this LSP and requires bandwidth more than the available bandwidth of the link can be expressed as

$$P_{(flow)} = \left(\sum_{i=0}^{i<flow} P_i \Big/ N_p \right) \times \left(\sum_{j=b}^{j<Total} B_j \Big/ B_{Total} \right) \qquad (1)$$

Where N_p is level of all priority, P_i is the priority of the flow i_{th}, B_{total} is the link bandwidth and b is remaining bandwidth of the link.

After each links of each LSP calculated, the LSP selects the maximum preemption probability to stand for it. Finally, our policy selects the LSP to deliver packets with the minimum preemption probability in all LSPs, called preemption avoidance, are shown in Fig.1.

1. Using CR-LDP find those LSPs that are from ingress router to egress router
2. If LSPs exist and remaining bandwidth ≥ requisition bandwidth

   For each links of each LSPs compute its preemption probability

$$\left(\sum_{i=0}^{i<flow} P_i \Big/ N_p\right) \times \left(\sum_{j=b}^{j<Total} B_j \Big/ B_{Total}\right)$$

   Select maximum preemption probability for the LSP in each links of the LSP
   Select minimum preemption probability for the flow in each LSPs

   elseif LSPs exist and requisition bandwidth > remaining bandwidth
   It preempt other LSPs to service the flow
   elseif LSPs not exist or it cannot preempt other LSPs
   Rejecting request

Figure 1. *Our policy for preemption avoidance and load balancing*

4. SIMULATION RESULTS

In this section, we show the results from the simulation in the previous section. We used the network simulator NS-2 with new modules supporting our policy to CR described earlier [24] [25]. In order to fully understand the effect of the our policy, we concentrate on two network topologies: the topology 1 is a single ingress-egress LSR connected by multiple LSPs, and the topology 2 is multiple ingress-egress LSRs where some links are shared among the LSPs from different LSRs. Fig.2 shows the network topology 1 where hosts 0-7 send data to hosts 8-15 respectively, between these host are LSR nodes. The link bandwidth between host and router is set to 45Mbps (T3), and its propagation delay is 10ms. The link bandwidth between routers is set to 155Mbps (OC-3), and its propagation delay is 1ms. Figure 3 shows the topology 2 in which hosts 24-31 send data to hosts 0-7 and hosts 8-15 send data to hosts 16-23 respectively. The other nodes are LSRs in Figure 3. The link bandwidth between host and router is set to 45Mbps (T3), and its propagation delay is 10ms. The link bandwidth between routers is set to 620Mbps (OC-12) with 1ms propagation delay.

In our simulations, two scenarios are proposed. In the scenario 1, senders send data at fixed requisition bandwidth (40Mbps), and generated the flow priority (0-7) randomly; flows are active time in sequence. In the scenario 2, senders send data in fixed flow priority and generated requisition bandwidth randomly; flows are active time in every domain as in scenario 1.

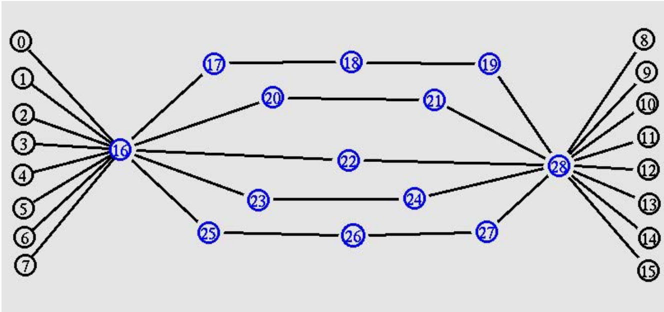

Figure 2. *Simulation topology1*

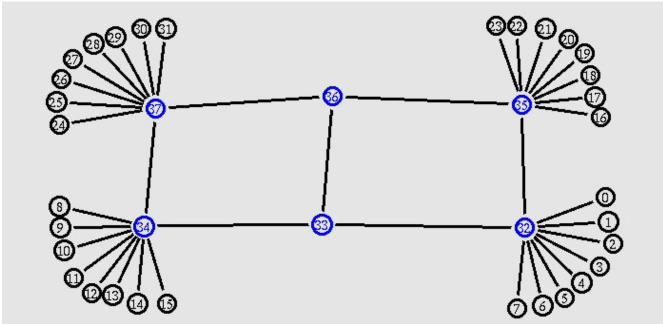

Figure 3. *Simulation topology2*

A. Preemption Avoidance

Table1 and Table2 show all flow-preempted numbers in network topology1 and topology2 respectively. We see from these tables that some lower-priority LSPs have occurred preempting. At the same scenario, our policy has avoided preemption in each flow.

TABLE 1. *Flow-preempted numbers in the topology 1*

	Traditional CR-LDP		Our policy	
	Scenario 1	Scenario 2	Scenario 1	Scenario 2
P0	0	0	0	0
P1	0	0	0	0
P2	0	0	0	0
P3	1	0	0	0
P4	1	1	0	0
P5	2	1	0	0
P6	2	2	0	0
P7	2	2	0	0
Total	8	6	0	0

TABLE 2. *Flow-preempted numbers in the topology 2*

	Traditional CR-LDP		Our policy	
	Scenario 1	Scenario 2	Scenario 1	Scenario 2
P0	0	0	0	0
P1	0	0	0	0
P2	0	0	0	0
P3	0	0	0	0
P4	0	0	0	0
P5	1	1	0	0
P6	2	1	0	0
P7	2	2	0	0
Total	5	4	0	0

B. Load Balancing

We observe the bandwidth utilization of each node to understand load balancing. Figure 4-11 shows the bandwidth utilization of each node used traditional CR-LDP and our policy in the each scenario for both network topologies. Figure 4-7 shows that the scenario 1 is different under different policies for both network topologies. Comparing with scenario 1, the traditional CR-LDP has high-utilization for some nodes but other nodes have lower-utilization or not used. These nodes of high-utilization are shortest path (node 22, nodes 20-21 and nodes 23-24). Figure 8-11 shows that scenario2 in both network topologies is different under different policies. We can see that have the same effect with scenario1 under different traffic profiles. However, our policy can achieve load balancing and distribute traffic to each node in the networks, no matter which scenarios and which topologies is considered.

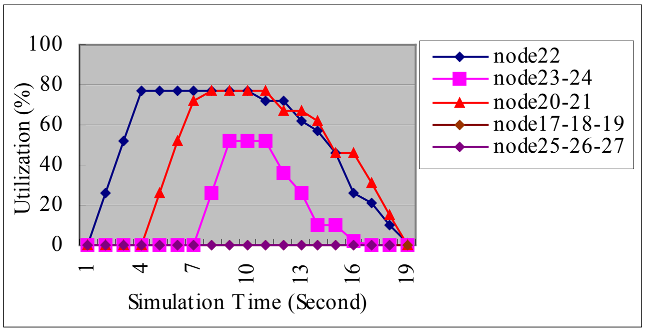

Figure 4. *Link utilization of node used traditional policy in the scenario1 in the topology 1*

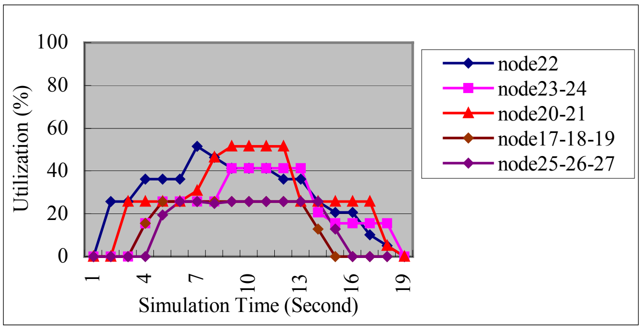

Figure 5. *Link utilization of node used our policy in the scenario1 in the topology 1*

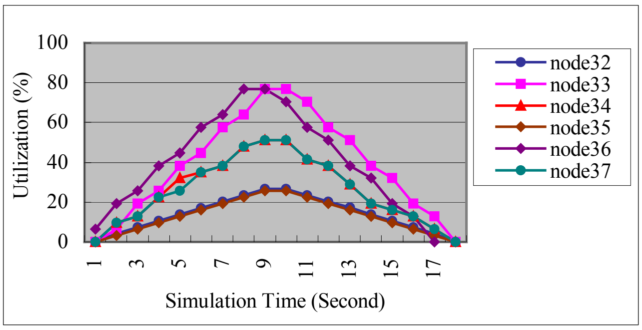

Figure 6. *Link utilization of node used traditional policy in the scenario1 in the topology 2*

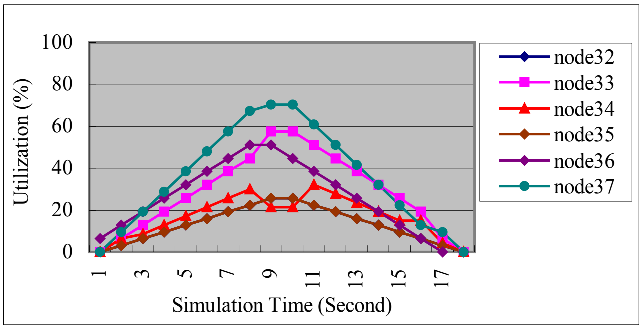

Figure 7. *Link utilization of node used our policy in the scenario1 in the topology 2*

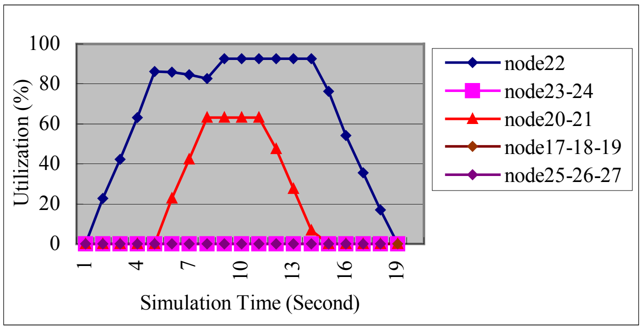

Figure 8. *Link utilization of node used traditional policy in the scenario2 in the topology 1*

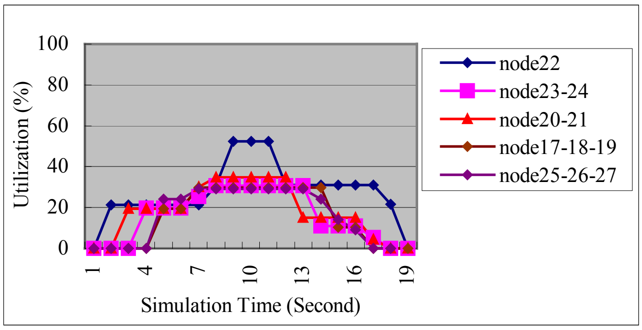

Figure 9. *Link utilization of node used our policy in the scenario2 in the topology 1*

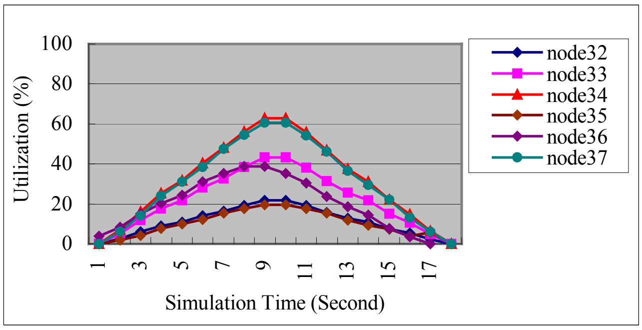

Figure 10. *Link utilization of node used traditional policy in the scenario2 in the topology 2*

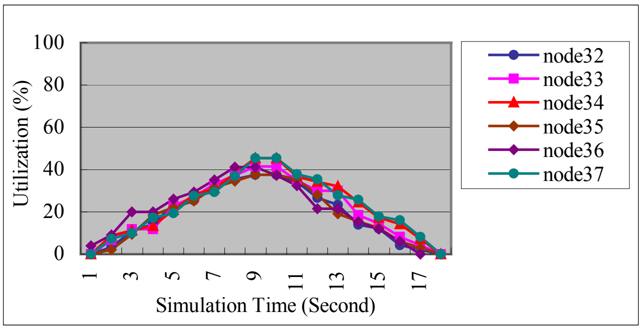

Figure 11. *Link utilization of node used our policy in the scenario2 in the topology 2*

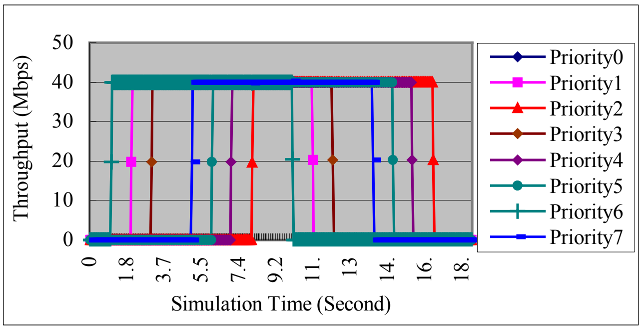

Figure 12. *Throughput of hosts used traditional policy in the scenario1 in the topology 2*

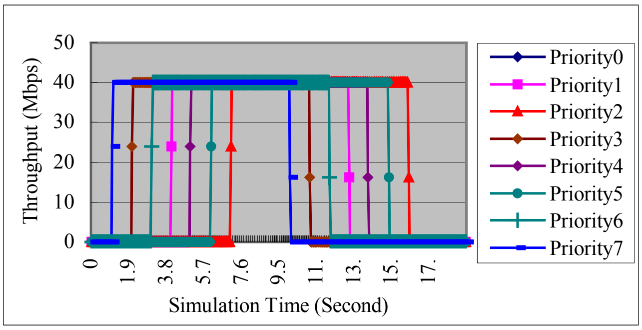

Figure 13. *Throughput of hosts used our policy in the scenario1 in the topology 2*

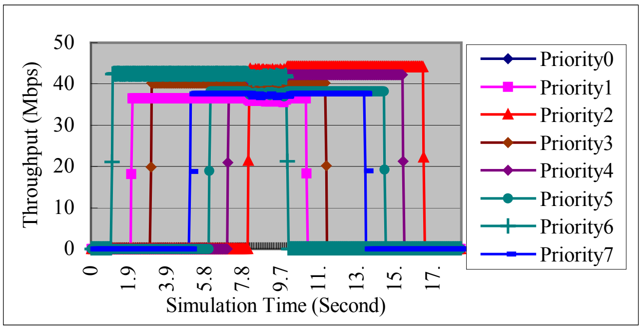

Figure 14. *Throughput of hosts used traditional policy in the scenario2 in the topology 2*

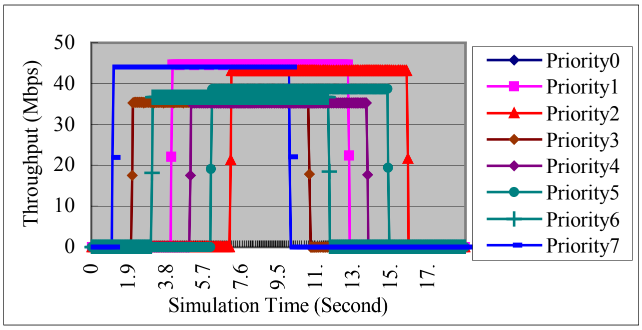

Figure 15. *Throughput of hosts used our policy in the scenario2 in the topology 2*

C. Performance Evaluation

In this sub-section, we will evaluate our policy without to influence throughput for traditional CR-LDP. Figure 12-14 show the throughput of each priority-level flow under the scenario1 and scenario2 in the network topology2. As shown, contrary to the traditional CR-LDP (Fig.12), each flow gets good throughput while our policy is applied. So we can say that our policy do not influence throughput for traditional CR-LDP.

5. CONCLUSIONS AND FUTURE WORK

In this paper, a new policy for preemption avoidance and load balancing is proposed. It complements with traditional IP routing scheme and aims to networks resources utilization and LSP quality of delivering. The difference between traditional method and our policy lies in the way preempted probability of the LSP is considered. The preempted probability combines two criteria: priority of LSP to be delivered, remaining bandwidth of link along the LSP. In finding LSP for a flow, every node of each LSP calculates preempted probability. Finally, selected LSP has the minimizing preemption probability to serve the flow. The simulation results show that our policy can optimize resource efficiency and network performance and achieves load balancing.

In the future, we will plan to discuss more real distribution for priority-level and requisition bandwidth. MPLS-based traffic engineering for DiffServ is also an important issue we are considering.

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