A Possible Path per Link CBR Algorithm for Interference Avoidance in MPLS Networks

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Abstract: This paper proposes an interference avoidance approach for Constraint-Based Routing (CBR) algorithm in the Multi-Protocol Label Switching (MPLS) network. The MPLS network itself has a capability of integrating among any layer-3 protocols and any layer-2 protocols of the OSI model. It is based on the label switching technology, which is fast and flexible switching technique using pre-defined Label Switching Paths (LSPs). The MPLS network is a solution for the Traffic Engineering (TE), Quality of Service (QoS), Virtual Private Network (VPN), and Constraint-Based Routing (CBR) issues. According to the MPLS CBR, routing performance requirements are capability for on-line routing, high network throughput, high network utilization, high network scalability, fast rerouting performance, low percentage of call-setup request blocking, and low calculation complexity. There are many previously proposed algorithms such as minimum hop (MH) algorithm, widest shortest path (WSP) algorithm, and minimum interference routing algorithm (MIRA). The MIRA algorithm is currently seemed to be the best solution for the MPLS routing problem in case of selecting a path with minimum interference level. It achieves lower call-setup request blocking, lower interference level, higher network utilization and higher network throughput. However, it suffers from routing calculation complexity which makes it difficult to real task implementation. In this paper, there are three objectives for routing algorithm design, which are minimizing interference levels with other source-destination node pairs, minimizing resource usage by selecting a minimum hop path first, and reducing calculation complexity. The proposed CBR algorithm is based on power factor calculation of total amount of possible path per link and the residual bandwidth in the network. A path with high power factor should be considered as minimum interference path and should be selected for path setup. With the proposed algorithm, all of the three objectives are attained and the approach of selection of a high power factor path could minimize interference level among all source-destination node pairs. The approach of selection of a shortest path from many equal power factor paths approach could minimize the usage of network resource. Then the network has higher resource reservation for future call-setup request. Moreover, the calculation of possible path per link (or interference level indicator) is run only whenever the network topology has been changed. Hence, this approach could reduce routing calculation complexity. The simulation results show that the proposed algorithm has good performance over high network utilization, low call-setup blocking percentage and low routing computation complexity.

Keywords: Constraint-Based Routing, QoS Routing, Minimum Interference Routing, Label Switching, and MPLS network

1. INTRODUCTION

The Multi-Protocol Label Switching (MPLS) network has been claimed to be the next generation of the Internet backbone network. It has been developed to support many types of layer-3 protocols to run over many layer-2 protocols of the OSI model. Nowadays, the MPLS can support various types of protocols in the areas of Constraint Based Routing (CBR) capabilities, Quality of Service (QoS) routing, Virtual Private Network (VPN) and Traffic Engineering (TE) problems [1,2,3].

In this paper, we consider the problem of setting up bandwidth guaranteed tunnels (path or route) in the MPLS network where tunnel set-up request arrive one-by-one and future demands are unknown. The only dynamic information available to the tunnel routing algorithm is the residual capacities of a link provided by its Link-state protocols such as OSPF. The general requirements (or the problems) for MPLS routing algorithm [4] are listed as following.

1. Necessity to use on-line algorithms.
2. Use knowledge of ingress-egress points of LSPs.
3. Good-rerouting performance upon link failure.
4. Routing without traffic splitting.
5. Support QoS or CBR Routing
6. Fast routing computational time.
7. Low algorithm complexity.

According to the above requirements, we propose a MPLS CBR routing algorithm, which is based on weight of possible path per link (or possible link-sharing ratio), which can be used to indicate the interference level of the link. The minimum link weight signifies the minimum interference level of the link. Moreover, our proposed algorithm can be categorized into link-constrained and path-constrained routing problems [5]. Related to link-constrained routing, the proposed algorithm selects only links those have sufficient residual bandwidth to set up MPLS tunnel or Label Switching Path (LSP). Simultaneously, in according to path-constrained routing, the purposed algorithm will select a path that has the high power factor value. Finally, we verify our proposed MPLS routing algorithm by simulation and introduce blocking probability, network utilization and computational CPU time as the evaluation performance metrics. The simulation results show that our proposed algorithm has good performance as discussed in section 4 and 5.

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2. RELATED WORKS

Many approaches of constraint-based or QoS routing algorithm over MPLS networks had been proposed to solve the MPLS routing problem [4,5,6,7,8,9,10]. There are many selectable routing constraints such as bandwidth, delay and/or cost, etc. However, the constraint selected by most previous works is bandwidth. Those works try to select a path that has sufficient residual bandwidth to support request bandwidth of an incoming traffic which arrive one at a time and there is no prior knowledge of future requests. They also try to minimize the usage of network resources by selecting a minimum hop path.

The simplest and most popular algorithm to route guaranteed demand is Minimum Hop routing (MH). In this scheme a minimum hop path which satisfies the requirement of traffic demand is chosen. While this scheme has an advantage of being simple and using the least network resource, it has the drawback of always using up some links, while other paths maybe under-used. This is more likely to increase the chance of not being able to service new demands which may require traversing those bottleneck links.

Widest Shortest Path (WSP) algorithm [6] is an improvement over MH routing, where the shortest path with the largest available bandwidth is chosen. This will enable load balancing between the equal hop count paths for different traffic request. However, it still chooses to use up all available capacity on particular shortest paths before longer paths with more capacity are under-utilized.

Minimum Interference Routing Algorithm (MIRA) [4], uses the knowledge of ingress-egress label switching router that are potential traffic source-destination pairs. It makes the routing decision for a demand based on the "interference" level that it would have on the future demand from other source-destination. This interference level is used as the link weight to calculate the shortest path for a new demand. The novel of this algorithm results the less chosen the critical links to other source-destination pairs. However, it has two major drawbacks. The first is complexity to calculate the maximum flow between any source-destination pairs and the link weight of all links. The second, it considers only balance traffic flow of source-destination pairs, while the pair with much higher maximum traffic than other pairs is not considered [7].

In the next section, we will present a new MPLS routing algorithm as an improvement of MH, WSP and MIRA.

3. A PROPOSED ALGORITHM

As describes in the introduction section, our proposed algorithm is one of link-constrained and path-constrained routing. It uses an idea of how much traffic demand of all source-destination node pairs possibly used on each links in the network. The details of key issues, weight calculation, path selection and routing algorithm are described as followings**.**

3.1 Main objectives

Our routing algorithm is developed based on three main objectives which related to MPLS routing requirements.

1. To minimize interference levels among other source-destination node pairs.
2. To reduce algorithm complexity
3. To minimize resource usage by selecting a minimum hop path as a first route.

3.2 Interference level indication

Firstly, to minimize the interference level to other source-destination node pair, we define weight per link based on possible traffic demand paths traverse through the link.

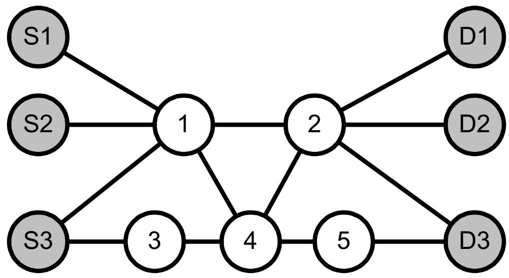

Fig. 1 Sample topology of a network

An example of a simple network topology is shown in Figure 1. Let us define the assumtion that there are three source-destination pairs, those are S1-D1, S2-D2, and S3-D3 where S1, S2 and S3 are sourse nodes, and D1, D2 and D3 are destination nodes, respectively. Then, the possible path for each pairs are shown in the Table 1. In the table, all node pairs have 9 total possible paths which affect number of possible traffic (routes or tunnels) per each links as shown in Table 2. Let us define IL_i as the interference level of the link i, PPL_i is the number of possible paths per link i, and TP is the total number of possible paths per link. Then, from Table 2, the interference level of link i can be calculated by equation (1).

$$IL_i = \frac{PPL_i}{TP} \qquad (1)$$

Table 1 Possible Paths of each source-destination pairs

Node Pairs	Number of Possible Paths	Possible Paths
S1-D1	2	1-2 1-4-2
S2-D2	2	1-2 1-4-2
S3-D3	5	1-2 1-4-2 1-4-5 3-4-2 3-4-5

Table 2 Number of possible paths per link

Link	Possible Paths per Link (PPL_i)	IL_i
1-2	3	0.20
1-4	4	0.27
3-4	2	0.13
4-2	4	0.27
4-5	2	0.13
Total	15	1.00

We define that the higher IL_i value indicates the higher interference level of the link i. Therefore, the proposed algorithm must avoid to choose the link that has high IL_i value. This approach satisfies our first objective. Furthermore, the interference level of link would be updated whenever the network topology has changed. This will satisfy our second objective because the most of network topologies are rarely changed. This then can reduce the complexity of the algorithm.

3.3 Power factor of a link

As mention in the related works section, we take into account the residual bandwidth of link. Let RB_i is residual bandwidth (available bandwidth) of the link i. Then we can define the power factor (PF_i) of each links using equation (2). The link with highest PF value is the most preferred link that has high residual bandwidth and low interference level. The PF value of link i is updated after the change in residual bandwidth of link i.

$$PF_i = \frac{RB_i}{IL_i} \qquad (2)$$

3.4 Path selection

With our first objective, a minimum interference-level path with high residual bandwidth would be preferred. This can be obtained by summation of power factor of all links along the path. Let us define DPW_p as the Dynamic Path Weight of path p and calculated by equation (3) as below.

$$DPW_p = \sum_{i=1}^{n} PF_i \qquad (3)$$

Where n is the number of links along path p.

Selection of a path with maximum DPW value will satisfy the first main objective. Moreover, inverse of DPW value can be considered as the distance constraint of sourse-destination node pair, which can be used as the distance input of Dijkstra routing algorithm.

From the example network in Fig. 1, up on the investigation time, if the residual bandwidth of all links is equal 100 units. Then from equation (2) and (3), the DPW values can be evaluated as shown in Table 3. The DPW of path 1-2, 1-4-2, 1-4-5, 3-4-2 and 3-4-5 are 500, 741, 1140, 1140 and 1539, respectively. Therefore, with interference avoidance, the best path selected for S1-D1, S2-D2 and S3-D3 node pairs are 1-4-2, 1-4-2 and 3-4-5, respectively.

When there are more than two paths which have the same maximum DPW, the algorithm will select the path that has minimum hop at first, this will satisfy our third objective. Also, if there are more than two paths which have equal maximum DPW and equal minimum-hop, the algorithm will select the path that has the highest residual bandwidth (widest) as result.

Table 3 The DPW value of sample network in Fig. 1

Possible Paths	DPW Calculation	DPW
1-2	100/0.20	500
1-4-2	100/0.27+100/0.27	741
1-4-5	100/0.27+100/0.13	1140
3-4-2	100/0.13+100/0.27	1140
3-4-5	100/0.13+100/0.13	1539

3.5 Detail description of proposed algorithm

We can describe the detail of our proposed algorithm procedures as shown in Figure 2 and Figure 3. We simply call the proposed algorithm as the Possible Path per Link (PPL) algorithm. In Fig. 2, there is a detail of the calculation of interference level of each links. It needs to be run only during the starting phase of the algorithm or whenever the network topology has been changed. Also, from Fig. 3, the detail of our MPLS on-line routing algorithm is shown.

```
Procedure Interference_Level_Calculation
{
1. List combination of all possible paths
2. Route all paths in Step 1 over the network with request bandwidth of 1 unit.
3. Link weight of link j is total bandwidth usage on the link divided by summation of total bandwidth usage of all links.
}
Note that the Interference_Level_Calculation procedure is only run whenever the network topology has been changed.
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Fig. 2 the Interference_Level_Calculation procedure

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Procedure MPLS_Online_Routing
{
1. Reduce network graph by eliminate all links that have residual bandwidth less than requested bandwidth.
2. Use Dijkstra algorithm to find the path that has maximum path-weight by using PFi value.
3. Select the minimum hop path if there are more than two paths that have equal maximum path-weight.
4. Choose the path that has maximum residual bandwidth if there are more than two paths that have equal minimum hop.
5. Establish the selected path found in Step 4. and update all PFi along the path.
6. If no path is selected, the algorithm fails.
}
```

Fig. 3 The MPLS_Online_Routing procedure

4. SIMULATION RESULTS

Extensive MATLAB simulations were carried out to study the performance of our proposed routing algorithm. We simulated the developing simulation by using 1.5-GHz-speed Pentium-4 processor personal computer.

We use the network topology [4] shown in Figure 4 in our performance studies. It consists of 15 nodes and four source-destination pairs which are S1-D1, S2-D2, S3-D3 and S4-D4. All links are bidirectional. There are two different kinds of links in the network. The thin links have a capacity of 1,200 units and the thick links have a capacity of 4,800 units. The arrival traffic requests are varied from 1 to 3 units generated by the uniformly distribution. We use the call blocking ratio as shown in equation (4) to be the performance metrics of each algorithm. Here, the successful traffic request is the traffic that has a selected path successfully under the constraints of the respective algoritms.

$$\text{Call Blocking Ratio} = \frac{\text{Successful Traffic (Call) Request}}{\text{Total Requested Traffic (Call)}} \qquad (4)$$

And,

Blocking Percentage = (Call Blocking Ratio) x 100 (%)

Here, the name of previously related algorithms and the proposed algorithm are abbreviated as MH, WSP, MIRA, and PPL, respectively.

Figure 5, 6, 7, 8 and 9 show results of call blocking ratio corresponding to requested traffic. These results show that the proposed PPL algorithm gain the best performance compared among other algorithms, that is PPL achieved lower call blocking ratio than others.

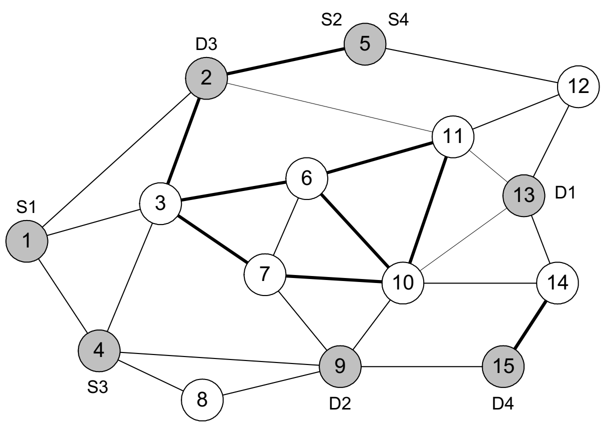

Fig. 4 Model of network topology for simulation

5. CONCLUSIONS

The MPLS network itself has a capability of integrating among any layer-3 protocols and any layer-2 protocols of the OSI model. It is based on the well-known label switching technology, which is fast and flexible switching technique using pre-defined Label Switching Paths (LSPs).

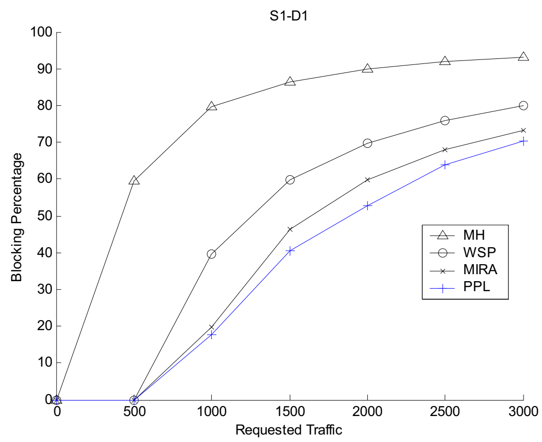

Fig. 5 Call blocking (%) of S1-D1 pairs

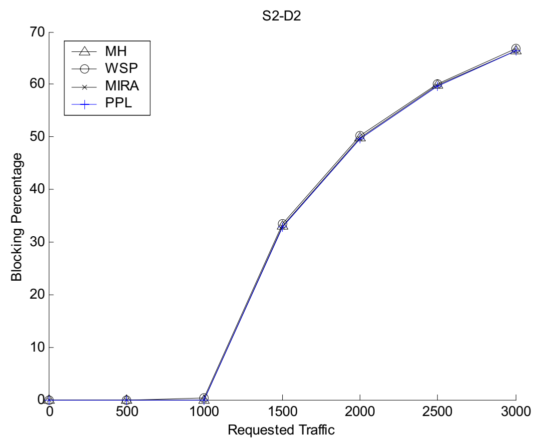

Fig. 6 Call blocking (%) of S2-D2 pairs

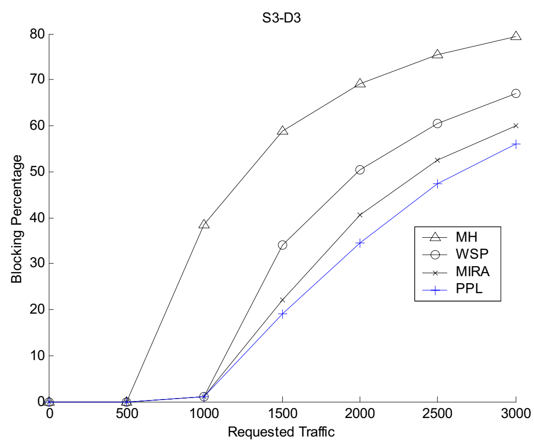

Fig. 7 Call blocking (%) of S3-D3 pairs

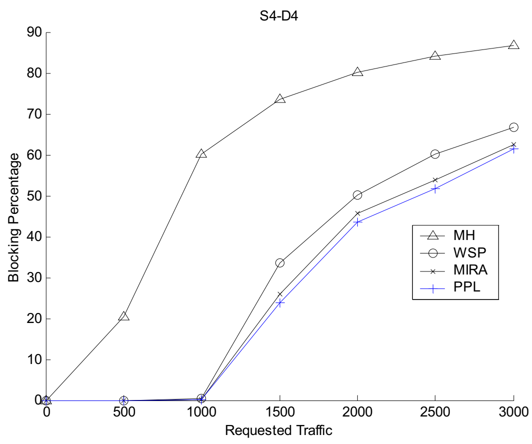

Fig. 8 Call blocking (%) of S4-D4 pairs

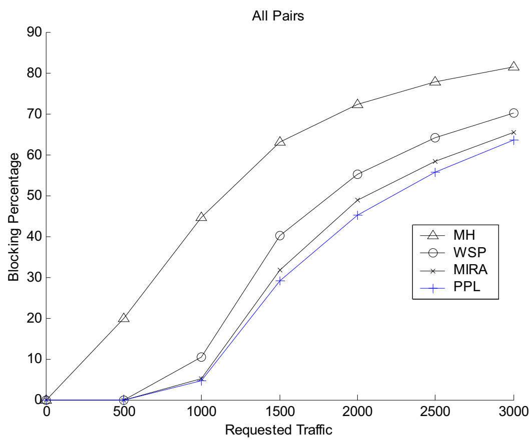

Fig. 9 Average call blocking (%) of all pairs

According to the MPLS Constraint-Based Routing (CBR), performance requirements are capability for on-line routing, high network throughput, high network utilization, high network scalability, fast rerouting performance, low percentage of call-setup request blocking, and low calculation complexity. There are many previously proposed algorithms such as minimum hop (MH) algorithm, widest shortest path (WSP) algorithm, and minimum interference routing algorithm (MIRA). The MIRA algorithm is currently seemed to be the best solution for the MPLS routing problem in case of selecting a path with minimum interference level. It achieves lower call-setup request blocking, lower interference level, higher network utilization and higher network throughput. However, it suffers from routing calculation complexity which makes it difficult to real task implementation.

Hence, this paper proposes an interference avoidance approach for CBR algorithm in the Multi-Protocol Label Switching (MPLS) network, which could minimize interference levels with other source-destination node pairs. It based on power factor calculation of possible path per link and residual bandwidth in the network. A path with minimum interference level should be considered as minimum interference path and should be selected for path setup. The approach of selection of a shortest path from many equal power factor paths approach could minimize resource usage of the network. Then the network has higher resource reservation for future call-setup request. Moreover, the calculation of possible path per link (or interference level indicator) is run only whenever the network topology has been changed. Hence, this approach could reduce routing calculation complexity. From simulation results, the proposed algorithm has well performance over high network utilization, low call-setup blocking percentage and low complexity than the MIRA algorithm.

Further research works are directed among simulation test upon various network topologies, integration of other new QoS constrains, mathematical analysis, and evaluation of computational complexity of the proposed algorithm.

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