Matching QoS Routing Algorithms with Network Conditions

B.Peng, A.H.Kemp, I.Elahi

School of Electronic and Electrical Engineering
University of Leeds, LS2 9JT, UK

eenbp@leeds.ac.uk

Abstract: This paper aims to discover in detail the relationship between the routing algorithms and network conditions (traffic load and the scale of the network topology) both in single and multiple source-destination pairs. We demonstrate that network scale affects the performance heavily, and give evaluation of different locations of source-destination pairs. We also point out the importance of using length of route as a metric to evaluate algorithms. This has seldom been used in previous simulation studies.

1 Introduction

QoS routing is a routing scheme to find a path in the network for each traffic flow able to guarantee some quality parameters (e.g. bandwidth and/or delay), it has been widely accepted as an efficient way to provide the Internet with guaranteed QoS [5-10]. In the architecture of Multiprotocol Label Switching (MPLS) [7] proposed by IETF, QoS requirements can be supported between an ingress-egress node pair which is called a Label Switching Path (LSP). There are two goals for QoS routing to achieve: (1) To select routes able to meet the particular QoS requirements; (2) To provide efficient utilization of the network.

Three proposed QoS routing algorithms are Shortest-Widest Path (SWP) [4], Widest-Shortest Path (WSP) [5] and Shortest-Distance Path (SDP) [8]. An extensive simulation study of these algorithms can be found in [3]. However, most studies actually use so called *pruning* to remove the links whose available bandwidth is lower than the requested bandwidth before calculating the explicit path. In general, it improves the effectiveness of QoS routing under small to moderate load by allowing connections to consider nonminimal routes. However, when state information is imprecise, it was observed in [2] that the source may incorrectly prune a feasible link. Even with accurate link state information, *pruning* degrades performance under heavy load since nonminimal routes consume extra link capacity at the expense of other connections. Therefore, in this paper, pruning is disabled. A somewhat similar study was undertaken by [1]. That study has investigated two QoS routing algorithms, namely, WSP and SDP under wide topologies with different connectivity and with threshold update policy. It has drawn a general conclusion that the resource conservation (RC) and load distribution (LD) approaches have their limitations. We expand upon the work in three dimensions. (1) We include the SWP routing algorithm in the comparison which is not considered in [1]. (2) We use different single source and destination pairs to simulate the routing algorithms which can reflect the property of the routing algorithms in detail among complicated network conditions. We also use multiple source-destination pairs to obtain a general conclusion. (3) We use the average length of routes as one of our metrics to evaluate different routing algorithms operating on different topologies and different traffic loads. This has seldom been used in previous simulation studies.

We try to shed some light on the relationship among the routing algorithm, traffic load and topology scale and obtain more detailed conclusions as reference for the future design of routing algorithms. This study is concerned with the evaluation of WSP, SWP and SDP without pruning under different network conditions which has not previously been studied. The remainder of this paper is organized as follows, section 2 describes the three QoS routing algorithms which are evaluated in this paper. Section 3 contains the detailed simulation metrics and model to be used. Section 4 presents the results for both single and multiple source-destination pairs. Conclusions are provided in Section 5.

2 QoS Routing Algorithms

Existing QoS routing algorithms from the literature addressing the problem of choosing a feasible path which can optimize both resource efficiency and network load are described as follows:

- **Shortest-Widest Path** [4]: a path with the maximum bandwidth between an ingress-egress pair. If there is more than one such path, the one with the minimum hop-count is chosen. If there are several such SWPs, one is randomly selected.

(a) Random Topology (b) ISP Topology

Figure 1: Network topologies used in simulations

- **Widest-Shortest Path** [5]: a path with the minimum hop-count between an ingress-egress pair. If there is more than one such path, the one with the maximum bandwidth is chosen. If there are several such WSPs , one is randomly selected.
- **Shortest-Distance Path** [8]: a path with shortest distance. The distance function is defined by

$$dist(p) = \sum_{i=1}^{m-1} \frac{1}{b_{i,i+1}}$$

  where $b_{i,i+1} = b(n_i, n_{i+1})$ is the available bandwidth on link (n_i, n_{i+1}). If there are several such SDPs, the one with the least hop count is selected.

SWP gives high priority to balancing the network load, while WSP to limiting the hop-count. SDP can dynamically balance the hop-count and load by the distance function.

3 Simulation Study

3.1 Metrics

The metrics used to measure the performance of the algorithms are bandwidth blocking rate (BBR) and average length of routes (ALR).

- **bandwidth blocking rate** is defined in [3] as:

$$BBR = \frac{\sum_{i \in BG\_blk} bandwidth(i)}{\sum_{i \in BG} bandwidth(i)}$$

  where BG_blk is the set of blocked sessions and BG is the set of requested sessions, $bandwidth(i)$ is the requested bandwidth of session i.

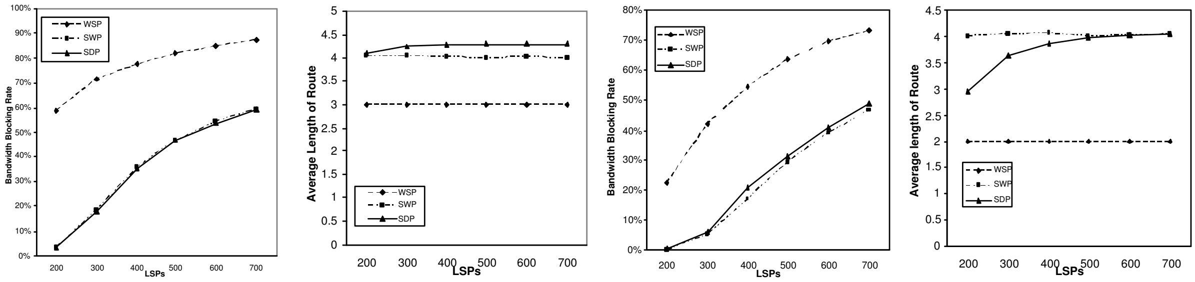
- **average length of routes** is defined as:

$$ALR = \frac{\sum_{i \in Acp} hopcount(i)}{Acp}$$

  where Acp is the set of accepted sessions, and $hopcount(i)$ is the number of hops travelled by the accepted sessions.

3.2 Simulation Model

Two topologies used in our simulation are shown in Figure 1, one is a random topology borrowed from [6], the other is an ISP topology which is widely used in simulation study. We use the random topology for single source-destination pair simulation and ISP for multiple source-destination pairs simulation. In both toplologies, all links



(a) Bandwidth Blocking Rate (b) Average Length of Route (c) Bandwidth Blocking Rate (d) Average Length of Route

Figure 2: From Source 1 to Destination 1 ((a)(b)) and From Source 3 to Destination 3 ((c)(d))

are symmetric and have the same bandwidth of $6Mb/s$. We use a fixed propagation delay of $10\mu s$ for every link. For the random topology, the fixed source and destination pairs (S,D) are indicated in the figure. For the ISP topology, the source will be randomly selected in node 1,2,3 (dark nodes) and destination in node 10,11,12 (shaded nodes) The requested LSPs arrive following a Poisson distribution with rate λ where the requested bandwidth arriving is uniformly distributed from $64kb/s$ to $1Mb/s$, with mean value $\bar{b} = 0.532Mb/s$. Call holding time is exponentially distributed with a mean $l = 12s$. We change the network load by increasing the number of requested LSP.

We assume guaranteed sessions are the only traffic type in the network. We do not consider inaccurate information due to delay, which means the topology information maintained at each node is accurate and up to date. In addition, the topology remains fixed throughout each simulation experiment, i.e. we do not model the effects of link failures. All simulations run for $100s$ and the results are the average of repeating each simulation 50 times.

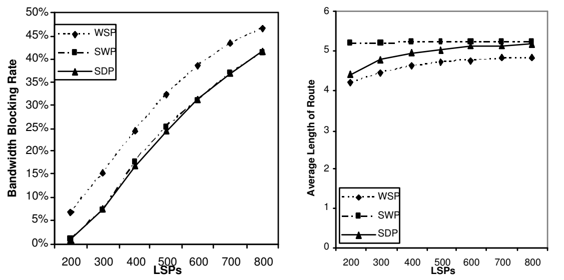
4 Results

4.1 Simulation for Single Source-Destination Pair

In this section, we study transmitting between the single source-destination pairs by using the random topology in figure 1(a). All the LSP requests are sent from one source and received by another destination. Two pairs are considered here: S1-D1 and S3-D3. As shown in figure 2, when the network load is increased by increasing the number of LSPs, WSP consistently performs worse than SWP and SDP according to the blocking rate because it only uses the shortest path between source and destination pair even if it has been heavily congested. Moreover, because S3-D3 has multiple shortest paths (4-1-2 and 4-3-2), its blocking rate is much lower than the S1-D1 (more than a 50% reduction). This suggests that WSP is better suited for the topologies whose connectivity degree is high.

As shown in figure 2(c), when transmitting between S3 and D3, the blocking rate of SWP is consistently lower than SDP. While in figure 2(a), SWP and SDP's performance are virtually the same. This suggests that the difference of topology scale and distance of source and destination pairs do affect the performance of routing algorithms. SWP is more suitable for transmitting in short distance with few hops between source and destination according to its lower blocking rate because it can make the most of the resource by using longer but idle paths.

Figure 2(b) and figure 2(d) show that the route length depends heavily on the particular QoS routing algorithm and obviously the location of the source-destination pair. WSP always chooses the shortest path for S1-D1 and S3-D3, which is 3 hops and 2 hops respectively. We are particularly interested here is SWP and SDP. For SDP, on average it chooses a longer route as the traffic load becomes high. However, SWP is less sensitive to traffic load and location of source-destination pairs. SWP always selects the widest path no matter how many hops it has. It provides a nearly constant length of route over a wide range of network load for different locations of source-destination pairs. In figure 2(b), the route length of SDP is continuously longer than SWP and slowly increases as network load becomes high. While in figure 2(d), the route length of SDP is much shorter than SWP when network load is light, and when network load increase, the route length of SDP increases rapidly and to be almost same as SWP when network load is high. This suggests that the different location of source-destination pairs will lead SWP and SDP to have opposite performance and the reason is the nature of these two algorithms. For instance, for real time applications, in our case, the S1-D1 pair will prefer SWP, while S3-D3 pair will prefer SDP, because the shorter path will meet the requirement of time sensitive applications. The BBR metric we use here and the length of route, sometimes conflict with each other. For example, as shown in figure 2(c), SWP outperforms SDP because



(a) Bandwidth Blocking Rate (b) Average Length of Route

Figure 3: Multiple source-destination pairs

of lower blocking rate. However, in figure 2(d), SDP outperforms SWP because of a lower route length. If they can not be achieved simultaneously, we need to balance which one is more important under which conditions. As we have mentioned, for time sensitive applications, the shorter route maybe preferred.

4.2 Simulation for Multiple Source-Destination Pairs

In this section, we study transmitting between the multiple source-destination pairs by using the ISP topology in figure 1(b). The reason we present this study after the study of single source-destination pair is that this is a more practical condition than a single pair. All the LSP requests are chosen randomly from three source nodes and sent to three destinations randomly, so all the traffic generated by these pairs will impact each other and we are interested in the overall performance. In figure 3(a), the results show that WSP still performs worst according to the BBR among the three routing algorithms. This confirms the finding in previous studies [1] [3] that WSP can not balance the network load well. SDP gives a similar performance with SWP under all traffic load. As shown in figure 3(b) , WSP avoids longer routes by selecting only the shortest path. The route length of SDP slowly grows with network load, and it is constantly shorter than SWP. This is the same case with the S3-D3 pair and suggests that although SWP and SDP have similar performance according to BBR, the shorter route length of SDP will benefit time sensitive applications in this condition.

5 Conclusions

In this paper, we have evaluated the impact of three QoS routing algorithms on network performance in both single and multiple source-destination pairs. We have displayed some of our observations in this paper and make the following conclusions: (1) Network scale affects the performance. Even across the same topology, different locations of sending and receiving nodes will lead the routing algorithms to have different performance. This suggests an appropriate routing algorithm should be seleted according to the network scale. It is not practical for a routing algorithm to suit all network scales. (2) Although the metrics of BBR are commonly used in previous studies, the route length is another crucial metric needed to be considered for evaluating algorithms, especially for delay sensitive applications. (3) RC and LD approaches seem not to be achievable simultaneously by these three existing algorithms, hence we need to assess which one suits which conditions. Notably this study is related to a basic architecture without considering the inaccurate information introduced by update policy. Hence future work will investigate the performance of these algorithms under different update policies.

References.

[1] Kowalik, K.; Collier, M., “Should QoS routing algorithms prefer shortest paths?”, Communications, 2003. ICC ’03. IEEE International Conference on, Vol.1, Iss., 11-15 May 2003 Pages: 213- 217 vol.1

[2] A.Shaikh, J.Rexford, K.G.Shin, “Evaluating the Impact of Stale Link State on Quality-of-Service Routing”, IEEE/ACM Trans. Networking, Volume: 9 , Issue: 2 , April 2001 Pages:162 - 176

[3] Q.Ma, P.Steenkiste “On Path Selection for Traffic with Bandwidth Guarantees”, Proceedings of IEEE International Conference on Network Protocols, Atlanta, Georgia, Oct. 1997

[4] Z.Wang, J.Crowcroft, “Quality-of-Service Routing for Supporting Multimedia Applications”, IEEE JSAC, 14(7): 1288-1234, Sept. 1996.

[5] R.Guerin, A.Orda, D.Williams, “QoS Routing Mechanisms and OSPF Extensions”, Proc. 2nd Global Internet Miniconference, Phoenix, AZ, November 1997.

[6] M.Kodialam, T.V. Lakshman, “Minimum Interference Routing with Applications to MPLS Traffic Engineering” In Proceedings of INFOCOM 2000

[7] E.Rosen, A.Viswanathan, R. Callon, “Multiprotocol Label Switching Architecture”,RFC3031, January 2001

[8] Q.Ma, P.Steenkiste, and H.Zhang. “Routing High-Bandwidth Traffic in Max-Min Fair Share Networks”, In ACM SIGCOMM96, Stanford, CA, August 1996