Performance Analysis of an Adaptive Link Status Update Scheme Based on Link-Usage Statistics for QoS Routing

Mijeong Yang, Taeil Kim, Haewon Jung, Myoung-Hee Jung, Seung-Hyuk Choi, Min Young Chung, and Jaehyung Park

ABSTRACT—In the global Internet, a constraint-based routing algorithm performs the function of selecting a routing path while satisfying some given constraints rather than selecting the shortest path based on physical topology. It is necessary for constraint-based routing to disseminate and update link state information. The triggering policy of link state updates significantly affects the volume of update traffic and the quality of services (QoS). In this letter, we propose an adaptive triggering policy based on link-usage statistics in order to reduce the volume of link state update traffic without deterioration of QoS. Also, we evaluate the performance of the proposed policy via simulations.

Keywords—QoS routing, link state update, link-usage statistics, blocking probability, update rate.

I. Introduction

In the current Internet, whenever a new connection request occurs, routers associated with the request perform shortest-path routing algorithms to determine a path with the minimum cost based on physical topology information. On the contrary, constraint-based routing algorithms select a minimum cost path for satisfying some given requirements, such as the number of hops, bandwidth, delay, and so on [1], based on both physical topology information and link state information such as remaining bandwidth [2].

Since link state information dynamically changes, performance of a constraint-based routing algorithm depends on the triggering policies of generating link state update messages. A constraint-based routing algorithm selects an efficient constraint-satisfied path from precise information by updating link state information whenever it changes. However, such an updating scheme causes the volume of update traffic to increase. On the other hand, using a delayed updating scheme to reduce update traffic volume, routing algorithms may inefficiently perform their functions due to inaccurate link state information. Therefore, the triggering policy greatly affects the performance of constraint-based routing algorithms [3], [4].

In this letter, we investigate the previously proposed triggering policies to reduce the volume of update traffic. Moreover, we propose an adaptive triggering policy based on link-usage statistics which not only decreases the traffic volume but also maintains routing performance. We also compare the performance of our proposed policy with that of other policies by simulations.

II. Related Works

To effectively determine a route for a connection request, routing algorithms can use accurate link state and network topology information. The updating scheme informing neighbor routers of state-changed information is closely related with the triggering policy which determines the instant of disseminating state-changed information. In order to reduce the

volume of update/dissemination traffic, various triggering policies have been proposed. They can be classified into three categories: basic, deterministic, and semi-adaptive policies.

1. Basic Triggering Policy

In the basic triggering policy, the updating of link state information is conducted whenever link state information changes. Since the state-changed information is disseminated immediately after the changing of link state information, routing algorithms can accurately reflect current link state information, instead of increasing link state information updates.

2. Deterministic Triggering Policies

In deterministic policy schemes, there are three triggering policies, namely, periodical, threshold-based, and class-based. The periodical triggering policy disseminates state-changed information at every fixed period T. However, this policy has the disadvantage that the fixed period T is independent of link states in network and data traffic characteristics. In case of time period T being smaller than the time difference between two consecutive changes of link status, traffic overhead increases due to the volume of state-changed information. In other cases, the routing performance decreases due to imprecise link state information. This is why the state-changed information is not disseminated and updated. In this policy, the value of period T is the most delicate factor reflecting network states and traffic characteristics.

In the threshold-based triggering policy, state-changed information is disseminated whenever the changed value of the link state is larger than the fixed threshold th. That is, dissemination of the changed information is triggered as follows;

$$\frac{|bw_c - bw_o|}{bw_c} \geq th, \tag{1}$$

where bw_c and bw_o denote the values of the current link state and the previous link state, respectively. In this policy, the value of threshold th is the most important factor as in the periodical triggering policy.

The class-based triggering policy disseminates state-changed information whenever a link state changes into a different class from the current class. To support such a function, the link state is classified into several classes. For example, in a case in which a link is partitioned by B capacity on the link with C capacity, there are n classes: $(0, B), (B, 2B), \cdots, ((n-1)B, C)$ for $n \geq 1$. When the previous and current link states are in classes α and β ($0 \leq \alpha$ and $\beta \leq n-1$), the state-changed information is disseminated if $\alpha \neq \beta$. The class-based triggering policy still has a limitation in reflecting the precise state information

because the changed information is not updated when the state changes within a class.

3. Semi-adaptive Triggering Policies

To overcome the limitation of the deterministic triggering policies, semi-adaptive threshold-based triggering policies (Ariza's scheme) were proposed [4], [5]. Instead of using a fixed threshold value, adaptive threshold-based triggering policies use a threshold value which varies with the number of update message generated during a fixed duration. The threshold value used in k-th duration, th_k, is determined as

$$th_k = \begin{cases} th_{k-1} + \Delta th, & \text{if } \widetilde{R}_k \leq R_o, \\ th_{k-1} - \Delta th, & \text{if } \widetilde{R}_k > R_o, \end{cases} \tag{2}$$

where R_o is the target update rate and $\widetilde{R}_k$ is the update rate within a fixed duration.

An alternative semi-adaptive triggering policy called a stability-based link state updating policy (Zhao's scheme) uses statistical information on links to update the link state [6]. Let μ_u be the average link capacity used and σ_u be its standard deviation. The link state is determined by

$$F(\mu_u, \sigma_u^2) = \frac{\sigma_u^2}{(C - \mu_u)} \frac{1}{C}. \tag{3}$$

Link state update information is disseminated whenever the value of $F(\mu_u, \sigma_u^2)$ is greater than the specified threshold value. This policy has a delicate problem, in that the threshold value should be carefully chosen considering the network load to maximize network performance.

III. Proposed Adaptive Threshold-Based Triggering Policy

Since deterministic and semi-adaptive triggering policies determine the time of dissemination of link state update information based on predetermined values, their routing performance strongly depends on the threshold values used. It is very difficult to find the optimal threshold value under dynamic traffic environments. Thus, in this letter, we propose an adaptive threshold-based triggering policy employing link-usage statistics to approximately reflect network conditions.

In the proposed policy, the threshold value adaptively varies according to link-usage statistics. The proposed triggering policy disseminates link state information whenever the absolute value of the difference between the available bandwidth A_{bw} immediately after the link state changes and the average value of available bandwidth μ_a is equal to or greater

than the value of f_{th}, that is, $|A_{bw} - \mu_a| \geq f_{th}$. We can determine f_{th} as the function of the n-th moment of the available bandwidth. In this letter, f_{th} is defined as

$$f_{th} = \sigma_a, \qquad (4)$$

where σ_a denotes the standard deviation of available bandwidth. Since μ_a and σ_a are newly calculated after every notification of link state information, the value of f_{th} is adaptively varied according to network conditions.

Consequently, in the proposed scheme, only when the variation of available bandwidth is equal to or larger than the long-term statistical variation, link state update messages are transmitted.

IV. Performance Evaluations

To compare the performance of the proposed triggering policy with that of other policies, we consider two networks as shown in Fig. 1. The MCI network consists of 18 nodes and 30 links and that of NSFNET consists of 14 nodes and 21 links. Each link is assumed to be bidirectional with a bit rate of 45 Mbps. Also, we assume a bandwidth requirement as a constraint in a newly requested path. That is, a connection request is routed as a source node s, a destination node d, and a required bandwidth BW, that is, (s, d, BW). Connection requests are generated as a Poisson process with the average rate λ. The duration of the connection successfully routed is determined as the exponential distribution with the average value τ. The source and destination node pair of a connection request is randomly selected, excluding the possibility for two nodes s and d to be the same. The requested bandwidth is uniformly distributed from the minimum (1 Mbps) to the maximum (5 Mbps).

To evaluate the performance of our proposed policy, the blocking probability of connection requests P_{block} is defined as

$$P_{block} = \frac{N_{block}}{N_{total}}, \qquad (5)$$

where N_{total} and N_{block} denote the total number of the connection requests and the number of blocked connection requests, respectively. Each connection request can be blocked in one of two blocking types: type 1 and type 2. Type 1 can occur when there is no available path satisfying the requested bandwidth BW from s to d. Type 2 can occur when there is no currently available bandwidth of links on the selected path based on link state information. Thus, N_{block} is the total number of blocked connections of types 1 and 2.

In general, performance of the existing triggering policies strongly depends on the values of the control parameters used. For each triggering policy, we determine specified values as
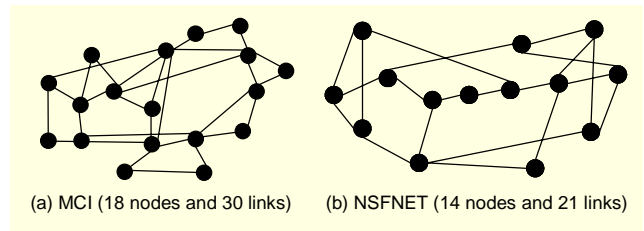

(a) MCI (18 nodes and 30 links)   (b) NSFNET (14 nodes and 21 links)

Fig. 1. Considered MCI and NSFNET networks.

Table 1. Semi-optimal values of control parameters used in three existing triggering schemes.

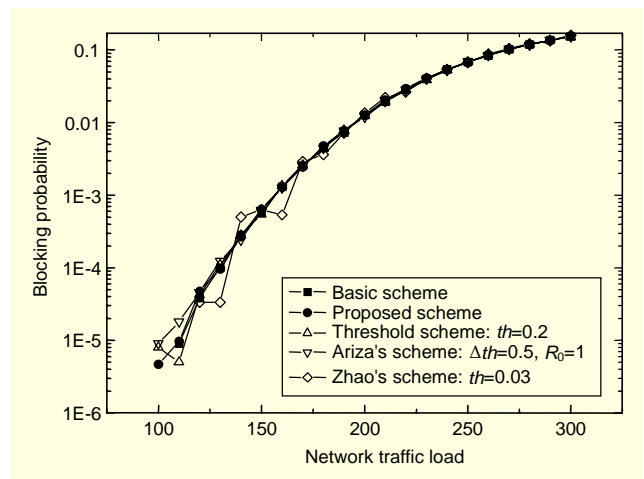|	Threshold	Ariza's scheme	Zhao's scheme
Semi-optimal values	$th = 0.2$	$R_0 = 1$, $\Delta th = 0.5$	$th = 0.03$

Fig. 2. The blocking probability of the considered MCI network varying network traffic load.

semi-optimal values of parameters if the blocking probability is close to that of the basic triggering scheme. Therefore, in our simulations, most block rates are caused by type 1. For the MCI network and τ equal to one second, the semi-optimal values of control parameters for the threshold and the two semi-adaptive triggering policies are given in Table 1. These semi-optimal values are used to evaluate the performance of the existing triggering policies.

Figure 2 shows the blocking probabilities of five triggering policies under varying network traffic loads ($=\lambda\tau$: Erlang) in which τ is equal to one second. Since semi-optimal values are used for the threshold and for the two semi-adaptive triggering policies, their blocking probabilities are close to that of the basic policy.

Under the same condition, the number of link state information updates per second are shown in Fig. 3. The differences in link state information update rates between our
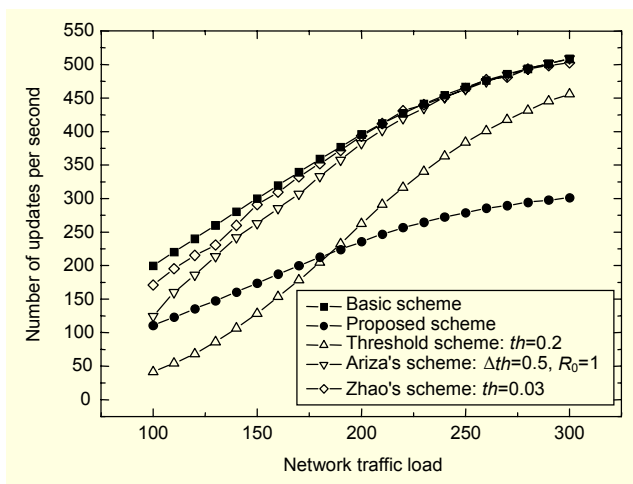
Fig. 3. The number of link state information updates per second varying network traffic load for the considered MCI network.
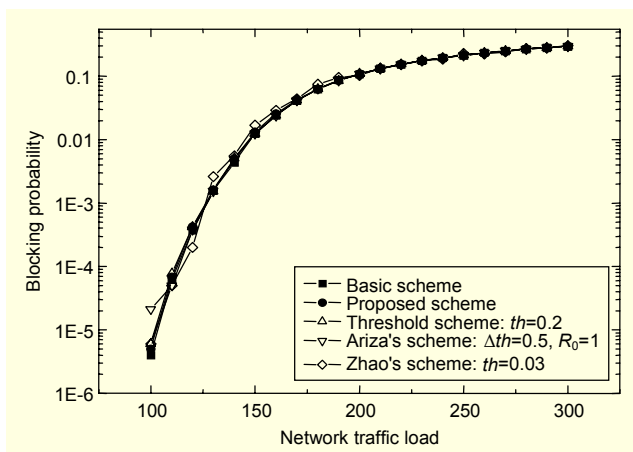

Fig. 4. The blocking probability of the considered NSFNET varying network traffic.
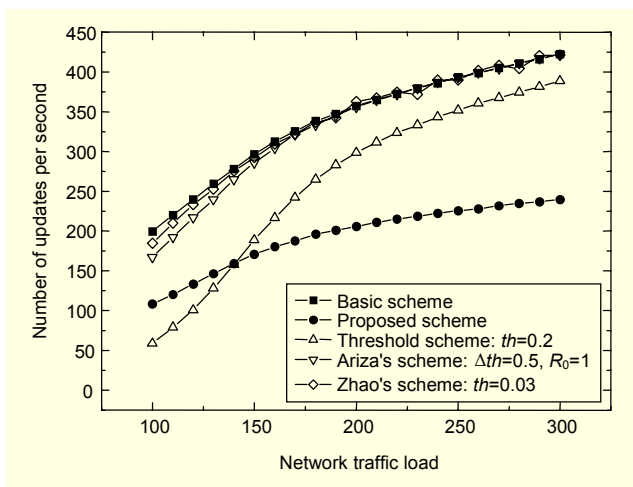

Fig. 5. The number of link state information updates per second varying network traffic load for NSFNET.

proposed policy and the existing policies increase as the network traffic load increases. When the network traffic load is lower than 170, the threshold scheme generates the lowest rate of update traffic. When it is not, our proposed scheme generates the lowest rate of update traffic.

For NSFNET and the semi-optimal values given in Table 1, blocking probabilities and link state information update rates of five triggering policies under varying network traffic loads are shown in Figs. 4 and 5, respectively. Blocking probabilities of our proposed scheme are similar to those of the basic policy, the threshold policy, Zhao's scheme, and Ariza's scheme. The general trend of update rates is similar to that for the MCI network.

V. Conclusion

In this letter, we investigated the four existing triggering policies. For improvement of network performance, we proposed an adaptive threshold-based triggering policy using link-usage statistics and compared its performance with the four existing policies. The proposed triggering policy disseminates the state-changed information when the requested bandwidth is larger than the average available bandwidth. While maintaining a similar blocking probability as the basic triggering policy, our proposed policy can significantly reduce the volume of update traffic compared with others for high traffic loads.

References

[1] G. Apostolopoulos, R. Guerin, S. Kamat, and S. Tripathi, "Quality of Service Based Routing: A Performance Perspective," *Proc. of ACM SIGCOMM*, 1998, pp. 17-28.

[2] D. Hong, C.S. Hong, and G.H. Lee, "M_CSPF: A Scalable CSPF Routing Scheme with Multiple QoS Constraints for MPLS Traffic Engineering," *ETRI J.*, vol. 27, no. 6, Dec. 2005, pp.733-746.

[3] G. Apostolopoulos, R. Guerin, S. Kamat, and S. Tripathi, "Improving QoS Routing Performance under Inaccurate Link State Information," *Proc. of ITC*, 1999, pp. 1351-1362.

[4] A. Ariza, E. Casilari, and F. Sandoval, "Strategies for Updating Link States in QoS Routers," *Electronics Letters*, vol. 36, Sept. 2000, pp. 1749-1750.

[5] A. Ariza, E. Casilari, and F. Sandoval, "QoS Routing with Adaptive Updating of Link States," *Electronics Letters*, vol. 37, Mar. 2001, pp. 604-606.

[6] M. Zhao, H. Zhu, V.O.K. Li, and Z. Ma, "A Stability-Based Link State Updating Mechanism for QoS Routing," *Proc. of ICC*, 2005, pp. 33-37.