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Performance Evaluation of Dynamic Network Design for Provisioning of Broadband Connection Services

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Abstract—**We verify that our proposed path provisioning algorithm, which makes use of 'make before break' rerouting, reduces blocking while preventing service disruption. It is also shown that hitless rerouting can be realized without significantly increasing blocking probability.**

Index Terms—**dynamic network control, make before break, prevention of service disruption, rerouting**

I. INTRODUCTION

Due to the rapid penetration of broadband access, Internet traffic has been exploding throughout the world. Demands for IP/Ethernet-based (layer 2 and 3) virtual private network services are also rapidly increasing. In order to cope with this large increase in traffic demand, new optical transport systems employing wavelength routing via ROADMs (Reconfigurable Optical Add/Drop Multiplexers) have been widely deployed [1], [2]. Network control technologies based on ASON/GMPLS [3], [4] have also been advancing steadily. Such development is spurring carriers into providing new layer one services that offer dynamic and adaptive bandwidth for the creation of the cooperative utility backbone and that support wholesale carriers [5], [6]. Ultra-high definition video (raw bit rate of 72 Gbps) and 4-k cinema (6 Gbps) distribution, Grid-computing, and e-science will become the key services. Dynamic and adaptive bandwidth provisioning capability is a key for handling such broadband requests economically. However, the connection requests are likely to be more schedule-based (unlike telephone calls), and guaranteed bandwidths (in other words, guaranteed quality) need to be provided [5], [6]. To enable such new large-capacity services and to meet the diverse service requirements expected, novel dynamic network control technologies need to be developed.

We have recently proposed novel dynamic network control algorithms that reduce the blocking probability, prevent service disruption, and improve fairness among users [7]. The reduction in blocking probability is achieved by rerouting, and service disruption is prevented by introducing the Make Before Break Routing (MBBR) technique [4]. The proposed MBBR algorithm searches for an alternative route for each existing path connection to be rerouted so that the original route and the alternative route do not share any capacity on all common links. As a result, hitless rerouting can be easily realized under this mechanism since only the end nodes switch the paths. However, the effect of MBBR on the blocking probability has not been clarified. It is expected that the blocking probability may be degraded if we do not allow capacity sharing with the original connections.

This paper demonstrates that the impact of the route restrictions imposed by MBBR is marginal. To verify this, we developed a modified version of the proposed algorithm that searches for all alternative route candidates including routes sharing some capacity with the original routes. In this case, any node switches the paths and, therefore, where realization of hitless rerouting is difficult. Numerical experiments show that these algorithms achieve almost the same blocking probability. The results reveal that hitless rerouting can be realized without a significant degradation in blocking probability.

II. PRELIMINARIES

In this paper, we assume that the maximum number of paths/circuits, N, accommodated in a fiber is the same in all fibers in the network. Path routing is done by PCEs (Path Computation Elements) [8] that have information on the current network condition. Path connection requests are assumed to follow a Poisson process with average arrival rate of ν. Holding time of each path follows a negative exponential distribution. The average holding time, h, of each path depends on the application and can range from a few hours to several weeks or more. It is assumed that the PCE setups new paths at fixed time period, Δt.

The network operation scenario consists of two stages; initial setup stage and dynamic control stage. At the former stage, we follow the accommodation scheme described in [9]; for the given path demand, the shortest route is assigned to each path. If multiple shortest routes exist, one of them is selected randomly. At the latter stage, we release resources for the disconnected paths first. We then setup those new paths whose requests arrived in the last Δt period. In this step, we apply the accommodation methods discussed in the next section. If the accommodation of some new paths fails, they are blocked.

Throughout the paper, algorithm performance is evaluated by blocking probability, p_B, as defined by the following equation

$$p_B = \frac{B}{A+B}$$

where B is the number of blocked connection requests and A is that of successfully accommodated connection requests.

Remark: Establishing long-distance paths is more difficult than establishing short-distance paths since the former can be more affected by the other paths. This results in non-uniform blocking probability and violates fairness, however, fairness can be achieved by a simple but effective weighting technique which is adopted in this paper (see [7] for detail).

III. REROUTING ALGORITHMS

A. *Proposed MBBR Algorithms [7]*

Suppose that a path connection request fails since there are insufficient resources for all possible routes. First, we search for the shortest route candidates using Dijkstra's algorithm, and then choose one randomly for simplicity. Next, we try to create spare capacity on the route to accommodate the request by rerouting some existing connections. We proposed two procedures to select and relocate paths: *MBBR Based on Local Search for Rerouting Paths (L-MBBR(A))* and *MBBR Based on Global Search for Rerouting Paths (G-MBBR(A))*. These methods are summarized as follows.

Suppose that a new path p_{new} can not be established because some links on its route are full (not enough capacity to accommodate the new path). In L-MBBR, we check each full link on p_{new}'s route from source to destination and select paths that go through the link and have the largest number of common full links with p_{new}. In G-MBBR, we check all full links on the route simultaneously and select the minimum path set. Next, we derive a set of alternative routes for the rerouting path set by applying Dijkstra's algorithm to the topology where full links are removed. Note that we assumed that the original route and the alternative route can not share any capacity in their common links. Switching operations can be done only at the end nodes of the paths and this enables us to implement hitless rerouting by applying delay compensation at the destination node.

L-MBBR is suitable for on-demand type services, and G-MBBR is effective for services that have longer provisioning times.

B. *A Modified Version of Proposed MBBR Algorithm*

This version allows the alternative routes to share capacity with their original paths while the proposed MBBR(A) forbids any capacity sharing. The difference from the original L/G-MBBR(A) lies in the topology searched to identify reroutes discussed in Sec. III *A*. In this algorithm, we do not remove links that are on the original route and not on p_{new}. This relaxation makes the set of alternative route candidates larger and is expected to improve blocking probability. However, switching operation becomes complicated and hitless rerouting is almost impossible since all intermediate nodes must have sufficient buffers for delay compensation. In the following, we call this method L/G-MBBR(B).

IV. NUMERICAL EXPERIMENTS

This section presents quantitative evaluations conducted to verify our algorithms. The topologies examined were a 4x4 polygrid network (Fig. 1-a) and Japan's national network (Fig. 1-b).

We assumed the following general conditions.

(a) randomly distributed traffic demands

(b) traffic loads are given by $T = T_{amp} \cdot T_{static}$ where T_{static} stands for the average traffic volume used at the initial setup stage and T_{amp} is a scaling factor that ranges from 0.7 to 1.2

(c) each path has fixed capacity (ex. VC-3/4 in SDH)

(d) each fiber can accommodate 16 paths (N = 16)

(e) h is 4 hours and Δt is 2 hours

(f) ν is given by $\nu = T / h$

(g) acceptable hop increment by rerouting is set at 4

We introduce the other basic method, which randomly selects paths to be relocated in Sec. III *A* (R-MBBR). The results are shown in Figs. 2-a and 2-b for the two network topologies. They verify that rerouting improves the blocking probability substantially. Among the MBBR algorithms, G-MBBR(B) gives the best result whereas L-MBBR(A) achieves much better blocking probability than R-MBBR even though it has small computational load.

The results also reveal that the penalty caused by restricting route candidates is marginal while hitless rerouting can be only realized for MBBR(A) in practice. In conclusion, it is demonstrated that MBBR(A) enables us to realize hitless rerouting and a significant blocking probability reduction simultaneously where delay compensation is necessary only at the destination.

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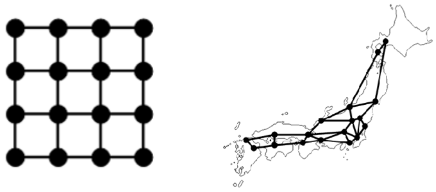
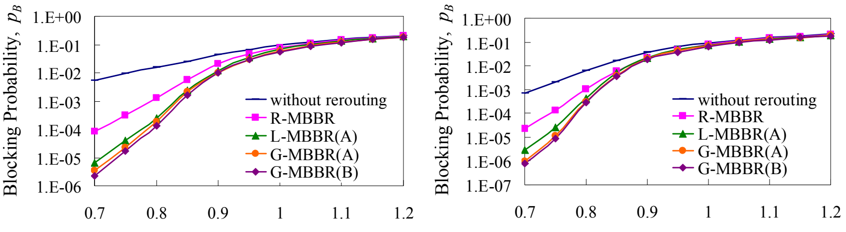


(a) 4x4 polygrid network (b) Japan's national network

Fig. 1. Network Topologies Examined



(a) 4x4 polygrid network (b) Japan's national network

Fig. 2. Impact of proposed method