Study of Rerouting Strategy for Dynamic Alternative Routing in Symmetric Multiple-Service Networks

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ABSTRACT

This paper presents a study of rerouting strategy with dynamic alternative routing (DAR) in symmetric multiple-service networks. The main idea is to randomly rerouting the ongoing connections on their alternative routes back to their direct routes upon a sign of link congestion, e.g. when a new call arrival cannot have sufficient link capacity on its direct route for an admission. By doing so, the network performance is expected to be improved because the alternative route typically requires more network resources per connection than the direct route. The reported numerical results suggest that the total mean revenue rate of network as obtainable from the rerouting extension of DAR is relatively indifferent from the conventional DAR for the scenarios of single capacity-guaranteed service. However, in the investigated network with three capacity-guaranteed services, up to 12% of revenue improvement has been shown plausible, especially when the network trunk reservation is small.

Keywords: Rerouting, Dynamic Alternative Routing, Multiple-Service Networks.

1. INTRODUCTION

The basic idea of dynamic routing is to increase the network throughput by routing calls to their alternative route when the direct route is blocked. However, routing calls on alternative routes uses more network resources. Therefore, if alternative routes are not controlled, then they could lead to the decrease of network throughput and even network instability [1-3]. Trunk reservation and call repacking (also called rerouting) are two possible solutions to this problem. Previous studies on rerouting can be found in [4-6].

In recent years, various approaches to dynamic routing have been developed. Dynamic alternative routing (DAR) is one promising method originally proposed for a fully connected telephone core network with only one service [7]. The nature of DAR is to fill an alternative route between each node pair with as many connections as possible before a blocking occurs on that alternative route, and hence a packing feature. In response to the blocking, a new alternative route is randomly chosen (for future uses) from the whole set of alternative routes between the node pair, and hence a learning mechanism, which allows a spreading feature. Furthermore, DAR enjoys the advantages of implementation simplicity since DAR is decentralized and requires only local information to make routing decisions. In [8], this conventional DAR has been extended so that it can be applied to the scenarios of multiple services each with a monotone increasing and concave equivalent capacity to capture the cell-scale or packet-scale statistical multiplexing effect. Due to the benefits of DAR [8], the aim of this paper is to investigate how DAR performance can be further improved by the additional capability of rerouting strategy.

In order to address rerouting extension of DAR, this paper simplifies the problem by exploiting the network symmetry. The symmetric features are here comprised of (1) a fully connected network structure, (2) an identical traffic load for every origin-destination node pair and (3) an identical capacity for every link.

2. EXTENSION OF DYNAMIC ALTERNATIVE ROUTING

2.1 Routing Operation

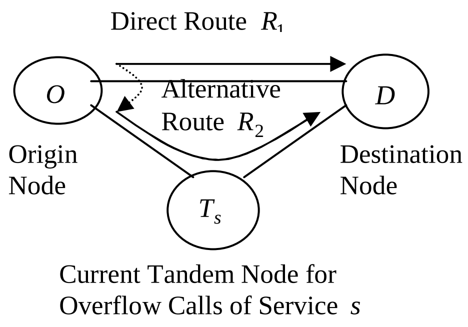

Fig. 1 Diagram of DAR operation when service- s calls arrival at a node pair.

Fig. 1 depicts a diagram showing the routing operation of DAR with multiple services as naturally extended from the conventional DAR [8]. Within a fully connected network, each pair of origin node O and destination node D has a current tandem node T_s assigned to each service s. A new call of service s arriving at the node pair is routed on the direct route R_1 (via the direct link between the node pair) whenever possible. If the new call is blocked from its direct route, then a two-link alternative route R_2 will be tried via the current tandem node associated with the call's service type. If the call is also blocked from any of the links on the alternative route, then the call is lost and a new tandem node is randomly selected for this service from the set of all nodes excluding the call's origin and destination. The current tandem node remains unchanged if the call is admitted. Note that call routing of a given service does not depend on the current tandem nodes of other services and no alternative routes with more than two links are allowed.

2.2 Connection Admission Control Operation

To define Connection Admission Control (CAC) operation, suppose that each link, with the capacity C, is used by S (capacity-guaranteed) services and R routes. For $s = 1,..., S$ and $r = 1,..., R$ let $n_{s,r}$ denote the number of ongoing connections of service s on route r and define $G_s(n_{s,r})$ as the amount of link capacity required by the $n_{s,r}$ connections. Regarding the non-linear equivalent capacity, in order to produce numerical results throughout this paper, the equivalent capacity function of the form $G_s(n) = \alpha n + \beta\sqrt{n}$ is adopted. This form of function, derived from the stationary approximation (or the Gaussian traffic model) in [9], allows us to vary the non-linearity in equivalent capacity by changing two parameters α and β. That is, function $G(n)$ should be less (more) non-linear with higher value of $\alpha(\beta)$. Based on the dynamic service separation with dynamic route separation [10] and the trunk reservation policy [11], CAC operation is defined as follows.

CAC Policy Definition: Calls of service s on route r are blocked from accessing a given link on the route if and only if

$$C - \sum_{s=1}^{S} \sum_{r=1}^{R} G_s(n_{s,r}) < TR_{s,r}, \qquad (1)$$

where $TR_{s,r}$ is the trunk reservation parameter assigned by that link for service-s calls using route r.

The trunk reservation parameter can be assigned in various ways. For instance, to allow calls a full-capacity access on each link on their direct route r, $TR_{s,r}$ can be set to $G_s(n_{s,r}+1) - G_s(n_{s,r})$. Further, to put some restriction to the link access of calls on their alternative route, $TR_{s,r}$ can be set to a constant greater than $G_s(1)$. Note that $TR_{s,r}$ can depend on the number of ongoing connections $n_{s,r}$ if $G_s(.)$ is nonlinear (although we write here $TR_{s,r}$ rather than $TR_{s,r}(n_{s,r})$ for notational convenience).

2.3 Rerouting Strategy

The purpose of rerouting is to redistribute network load to free up more capacity for calls on their direct route. For example in Fig. 1, after the completion of ongoing connections on link OD has freed up enough link capacity, a connection on the alternative route OT_sD can be rerouted back to link OD. Consequently, rerouting is expected to increase the remaining capacity on all alternatively routed links (links OT_s and T_sD) and the network throughput can be improved.

Rerouting can be implemented in many ways, depending on the triggering mechanisms for rerouting [6]. In this paper, a simple rule has been adopted as follows. A new call is routed on its direct route R_1 whenever possible. If the new call is blocked from its direct route R_1, then enough alternatively routed connections on the direct route R_1 will be chosen *randomly* and rerouted back to their direct routes to free up space for the new call. However, if not enough link capacity can be freed up from the rerouting, then the new call will resort to being alternatively routed via its current tandem node by the DAR operation. The rerouting operation can be summarized in Fig. 2

3. NUMERICAL RESULTS

Numerical results in this section are aimed at evaluating the performance of rerouting extension of DAR herein proposed and the conventional DAR [8] in two CAC scenarios based on either the nonlinear equivalent capacity or the standard peak-rate assignment. It is interesting to compare the network performance from both CAC scenarios because, while the equivalent-capacity CAC may be capable of accepting more connections for capacity-guaranteed services, the peak-rate CAC should be able to accept more connections for the best-effort services.

The system performance is here measured in terms of lower and upper bounds of the obtainable mean revenue rate (the long-run average rate at which the revenues are obtained with the unit in, say, Baht per second) [8]. The mean revenue rate from capacity-guaranteed service s can be calculated from the revenue rate of service s being multiplied by the average number of ongoing connections of service s. The mean revenue rate from best-effort services can be calculated from the revenue rate of best effort service being multiplied by the average capacity that is not utilized by any capacity-guaranteed services. Finally, summing the mean revenue rates from all the services results in the total mean revenue rate. The same settings of revenue rates as in [8] are here adopted.

Our performance study is based on a discrete event computer simulation of a five node fully connected symmetric network. Mean of the exponentially distributed holding times of (capacity-guaranteed) service-s calls = 1 (time unit) for each s.

3.1 Scenarios of Single Capacity-Guaranteed Service

This subsection considers two scenarios each with a different capacity-guaranteed service. The settings and results can be found in Fig. 3 for a peaky source scenario and in Fig. 4 for a smooth source scenario. Peakedness of a cell or packet stream is defined as the ratio of peak rate over average rate. Here, the peakedness is then equal to $(\alpha + \beta)/\alpha$. Note that the values of (α, β)= (3,0), (2,7.0711) and (1,14.1421) have been chosen in this and the next subsections such that the equivalent capacity function of every service passes through both points (0 connection, 0 Mbits/s) and (50 connections, 150 Mbps) while the level of nonlinearity is varied. In Fig. 3 and 4 trunk reservation is set to $G_1(n+1) - G_1(n)$ for direct route and 30 Mbits/s for alternative route. Capacity of each link is 150 Mbits/s.

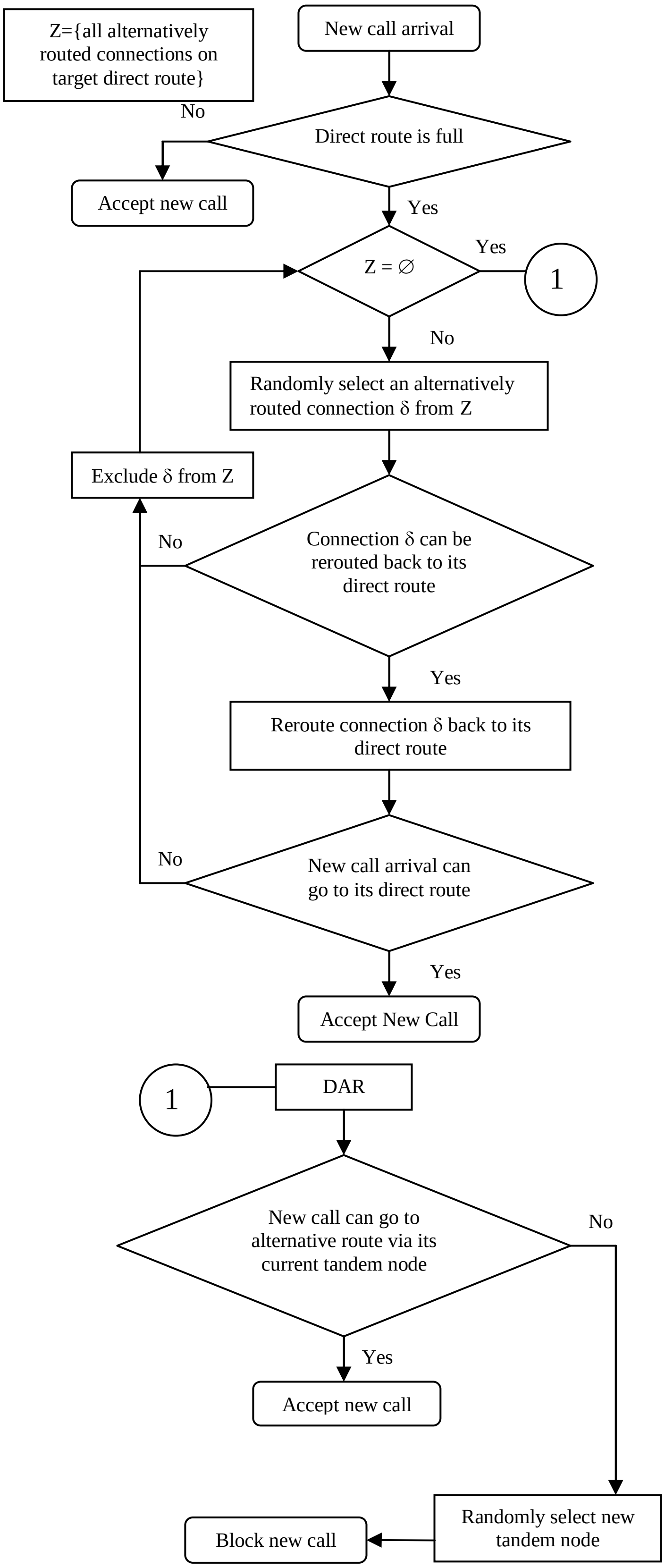

Fig. 2 Diagram for arrival triggering and random rerouting call selection method

Figs. 3 and 4 shows that the total mean revenue rate from the rerouting extension of DAR and the conventional DAR are relatively indifferent. In particular, up to 2.9% and 1.3% of revenue improvement can be expected from the peaky source scenario of Fig. 3 and the smooth source scenario of Fig. 4, respectively.

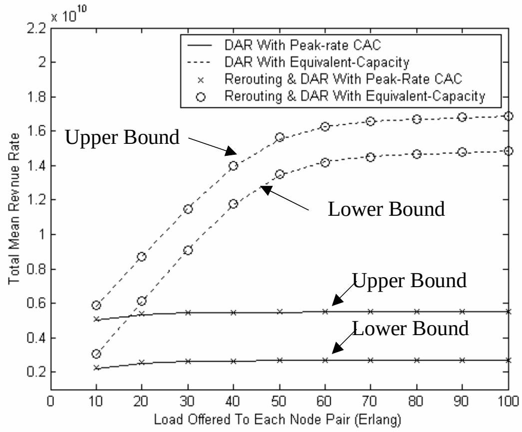

Fig.3 Peaky source scenario $(G_1(n) = n + 14.1421\sqrt{n})$

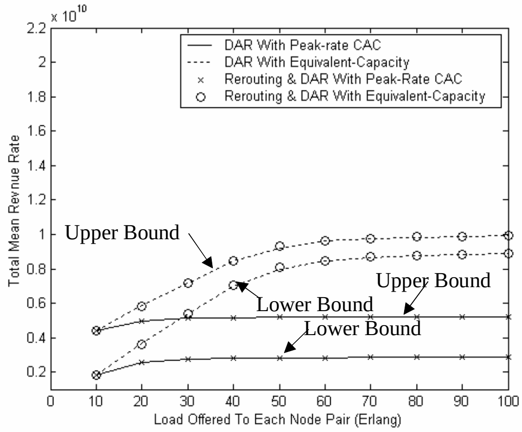

Fig. 4 Smooth source scenario $(G_1(n) = 2n + 7.0711\sqrt{n})$

3.2 Scenarios of Three Capacity-Guaranteed Services

This subsection considers two more scenarios each with three capacity-guaranteed services. The settings and results of both scenarios are depicted in Figs. 5 and 6 with the offered load of 10 Erlangs for each service. In Fig. 5, trunk reservation is set to $G_s(n+1) - G_s(n)$. In Fig. 6, the capacity of each link is 150 Mbits/s.

In Fig. 5, the effect of link capacity is studied. It shows that the rerouting extension of DAR can increase the total mean revenue rate of DAR by up to 12%.

In Fig. 6, the effect of trunk reservation is examined. All directly routed calls are allowed the full-capacity access on every link and alternatively routed calls are equally varied from 20 up to 60 Mbits/s. From Fig. 6, it shows that the rerouting extension of DAR can increase revenue of DAR by up to 9% especially when the network has insufficient trunk reservation.

Note also that the revenue is improved more for the scenarios of three capacity-guaranteed services than for those of single capacity-guaranteed services. This is due to the nonlinearity in equivalent capacity. In particular, the more services, the less statistical multiplexing gain within the alternatively routed calls of each service on each route. Hence, if rerouting can reduce such unnecessarily inefficient capacity usage on the alternative routes, then higher revenue improvement can be expected.

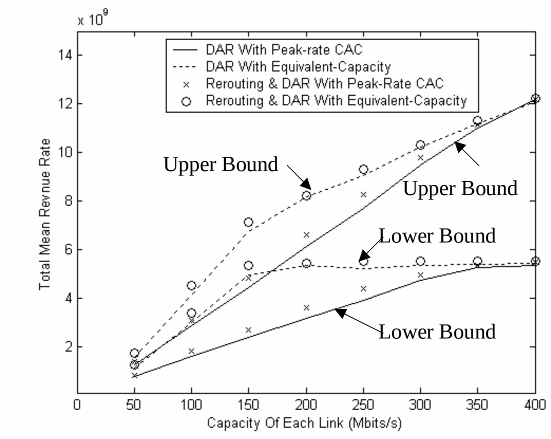

Fig. 5 Scenario of three capacity-guaranteed services $(G_1(n) = n + 14.1421\sqrt{n},\ G_2(n) = 2n + 7.0711\sqrt{n},$ $G_3(n) = 3n)$

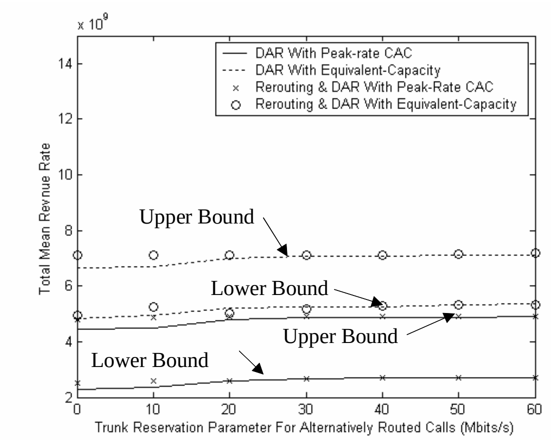

Fig. 6 Scenario of three capacity-guaranteed services $(G_1(n) = n + 14.1421\sqrt{n},\ G_2(n) = 2n + 7.0711\sqrt{n},$ $G_3(n) = 3n)$

4. CONCLUSIONS

In this paper, routing problems have been addressed in symmetric networks. An emphasis is placed on how to increase revenue from dynamic alternative routing with nonlinear equivalent capacity in multiple-service networks by a rerouting strategy. This paper uses the arrival triggering and random rerouting call selection method. Numerical results show that the performance obtainable from the rerouting extension of DAR herein proposed and the conventional DAR [8] are relatively indifferent for single capacity-guaranteed service. However, up to 12% of revenue improvement has been here deemed possible when the network has to accommodate three capacity-guaranteed services especially when the trunk has not been sufficiently reserved for alternatively routed calls.

In this paper, the call arrival rates are time-invariant so DAR alone is efficient enough to manage call blocking problems. In the future, it is worth investigating the scenarios of non-stationary call arrival process and how rerouting implementations may improve DAR performance in those practical scenarios with asymmetric network structure.

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