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Performance analysis of alternate routing with trunk reservation in multirate switched networks☆

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Abstract

The traditional approach to implementing call routing in PSTN networks uses trunk reservation to achieve high throughput by avoiding possible routing oscillations in dynamic alternate routing. The purpose of trunk reservation in PSTN networks that support only a single class of traffic, e.g. voice is to limit the use of alternate paths for call routing when the network is heavily loaded.

In this paper, we model the system of dynamic alternate routing with trunk reservation for multirate switched networks where the Markov chain is not time reversible, and analyze it by using an iteration method. Then as the calculation to find the optimal reservation size is intractable, we slightly modify the conventional Kaufman's recursive method that has been applied for the reversible Markov chain system. The complexity of the modified approximation is the same as that of the Kaufman's method. For a network of which link capacity is 50 channels, the approximation shows quite similar results to the analysis. For a network of which link capacity is 750 channels, which state size is not workable, we compare our approximation with simulation results. If we count some computation errors caused by the reduced load effect in the approximation, we can conclude that our approximation is quite accurate. As alternate routing with trunk reservation is expected to run on the top of multirate switched networks, our proposed approach can be used to obtain the near optimal trunk reservation size in real time, which results in maximal throughput. © 2002 Elsevier Science B.V. All rights reserved.

Keywords: Alternate routing; Trunk reservation; Irreversible Markov chain; Multirate services

1. Introduction

Dynamic routing of calls in circuit switched networks that support a single class of traffic, i.e., voice can improve throughput and robustness. Throughput is improved by establishing calls on alternate routes when the primary route is blocked. Robustness measured in terms of the network's ability to respond to unexpected network conditions, is improved by transferring calls to backup routes. Alternate routing with trunk reservation is the well-known dynamic routing scheme used to alleviate network congestion, and there is a large literature investigating the performance of variants of this scheme [1–9].

However, diverse traffic patterns and statistical multiplexing of traffic in B-ISDN networks complicate the design of routing schemes. Users in B-ISDN networks require various levels of QoS, and they can be satisfied with appropriate bandwidth and buffer assignment [11–13]. In this paper, we assume that a user's QoS can be mapped into bandwidth requirement only. If the network finds that a call's requested bandwidth size is smaller than the available bandwidth size, it accepts the call request. Otherwise it blocks the call.

A lot of investigations have been done for single service loss networks where a call occupies exactly one circuit (or channel) in each link along its route [6]. Given the great gains in performance achieved by dynamic routing in single rate loss networks, it seems quite natural to apply similar routing techniques for B-ISDN networks. However, system modeling and analysis of dynamic routing in B-ISDN networks are not so simple as those in single rate networks. Especially modeling dynamic routing with trunk reservation requires much more work. This is basically due to inherent complexity in the modeled Markov system.

In Refs. [9,10], single rate traffic for a couple of variants of dynamic routing was considered and relevant routing procedures were studied. These results are not simply applicable to multirate switched networks. In this paper we consider dynamic routing with trunk reservation in B-ISDN networks and develop the studies of Refs. [9,10]. In an attempt to analyze the given time irreversible system, we

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first formulate the system in an iterative form. As exact performance evaluation with the iterative method requires lots of computation, we try to obtain approximate performance by our modified Kaufman's recursive method.

The reduction in computation time by this approximation is important for the trunk reservation routing algorithm to run on real networks because fast finding of the trunk reservation size is made possible, which allows the network to efficiently face network problems caused by abrupt network changes. Our proposed approximation gives accurate results to the problems of interest with acceptable complexity when compared with the exact analysis in a small size network. For a large size network where the analytical results from the iterative method are no longer available, we use simulation to evaluate the exactness of our approximation.

This paper is organized as follows. We investigate the network model of the dynamic routing algorithm with trunk reservation in Section 2 for multirate switched networks. Section 3 deals with an approximate method to obtain its performance. The analysis and simulation results are compared with our approximation ones in Section 4 followed by the conclusion in Section 5.

2. Network model

When a call setup is requested, the network runs the routing algorithm and selects an appropriate path from the set of candidate paths. The selected path can be the shortest path or an alternate path. This routing decision is mainly depending on the network loading status. In this section, we state a network model for multirate supporting networks, and review the product form solution for shortest routing (i.e. no alternate path use) first. Then we formulate the trunk reservation based alternate routing system into *global balance equations* and represent call blocking probabilities. Note that if a modeled system can have *detailed balance equations* instead of global balance equations, it becomes a time reversible system [14].

The considered network is assumed to form a mesh with N nodes. Without loss of generality, we assume that the shortest (or direct) path consists of one hop only while alternate routes consist of M disjoint two-link paths ($M \le N-2$). This kind of network configuration can be achieved by running some trunk engineering scheme. The network supports K classes of traffic. Class i call arrivals form a Poisson process with rate λ_i, and call holding times are exponentially distributed with mean $1/\mu_i$. The offered class i traffic intensity is $\rho_i = \lambda_i/\mu_i$. For convenience, we assume that each link has equal capacity and a call requests a discrete value of bandwidth which unit is channel. We define the following notations for our modeling.

$C \triangleq$ the total number of channels that a link can support,
$\mathbf{A} \triangleq (c_1,c_2,\ldots,c_K)$; the bandwidth requirement vector where c_i is the number of channels required by a class-i call,
$\mathbf{x} \triangleq (x_1,x_2,\ldots,x_K)^{\mathrm{T}}$; the state vector of a link where x_i represents the number of class-i calls on that link,
$P(\mathbf{x}) \triangleq$ the equilibrium state probability that the link is in state $\mathbf{x}$.

We can write the set of all possible states that a link can have as

$$\Omega(C;K) := \{\mathbf{x} : \mathbf{A}\mathbf{x} \le C\} = \left\{\mathbf{x} : \sum_{i=1}^{K} c_i x_i \le C\right\}, \tag{1}$$

and the probability of the link being unreachable states as

$$P(\mathbf{x}) = 0 \qquad \text{for } \mathbf{x} \notin \Omega(C;K). \tag{2}$$

In the shortest path routing scheme, a call tries the one hop direct path only. As alternate routed calls are not admitted into the network, the total offered load of class-i calls on a link is ρ_i only. The unique equilibrium probabilities associated with the shortest path routing model are well known to have a product form solution [5–7]. Then $P(\mathbf{x})$ is given by

$$P(\mathbf{x}) = G^{-1}(C;K)\hat{P}(\mathbf{x}), \tag{3}$$

where

$$\hat{P}(\mathbf{x}) = \prod_{i=1}^{K} \frac{\rho_i^{x_i}}{x_i!}, \tag{4}$$

and

$$G(C;K) = \sum_{\mathbf{x}\in\Omega(C;K)} \prod_{i=1}^{K} \frac{\rho_i^{x_i}}{x_i!}. \tag{5}$$

The quantity $G(C;K)$ is termed the normalization constant, and the class-i call blocking probabilities B_i which are the same as the blocking probability at a link, are given by

$$B_i = 1 - \frac{G(C-c_i;K)}{G(C;K)}, \qquad i = 1,\ldots,K. \tag{6}$$

2.1. Alternate routing scheme with trunk reservation

The purpose of trunk reservation for alternate routing is to limit excessive alternate routing during periods of general overload, and yet not to exclude alternate routing altogether. As the alternate route consumes twice as much of the bandwidth resource, the allowance of too many alternate calls into the network deteriorates overall throughput. Therefore it is reasonable to block alternate path calls when a minimum number of idle trunks, say R_i channels for class-i calls, are not available. This means that if a link is being occupied over $C - R_i$, it blocks alternate routed calls. Here R_i represents the size of reserved channels for class-i directed routed calls. Basically the direct shortest path is always tried first and, if busy, alternate paths will be tried. If there are several possible alternate paths, one of them will be chosen according to the order of preference.