Dynamic Multicast Routing Based on Mean Number of New Calls Accepted Before Blocking for Single Rate Loss Networks *

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Abstract. In this paper, we investigate the dynamic multicast routing problem and briefly discuss the well-known dynamic multicast routing algorithm called Least Load Multicast Routing (LLMR). We propose a new multicast routing algorithm called Maximum Mean Number of New Calls Accepted Before Blocking (MCB) multicast routing, which can more accurately reflect the current and future loading of a network. Simulation results show that this algorithm, compared with LLMR, not only has a smaller network revenue loss, but also results in smaller call blocking probabilities for all classes of traffic.

1 Introduction

Multicasting refers to the ability of a set of more than two nodes or end-users in a communication network to communicate simultaneously with each other. Applications that require multicast capability (either point-to-multipoint (PTM) as in distributional video or multipoint-to-multipoint (MTM) as in video conferencing, online collaboration and others) will be an integral part of future broadband services. Given the popularity of multicast

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end-user services and applications, we study the problem of multicast call routing in single rate loss networks. A single rate loss network is one where each connection request requires that a unit capacity be allocated to it on each link that it is routed. If a route cannot be assigned to a connection request it is assumed that the call is lost and it does not retry. Examples of single rate loss networks include telephone networks and homogeneous VP-based ATM networks [3].

Recent research efforts are focused on dynamic multicast routing, which does not decide routes to use beforehand, but takes into account the state of the network at the instant a connection request arrives to assign a route. The scenario is a circuit-switched network or a virtual-circuit based packet switched network where all connection requests have the same bandwidth requirement. The arrival process of a connection request is assumed to be a random process. Each connection requests to set up a multicast connection among a set of randomly chosen nodes. Each connection request, if accepted, departs from the network after a random amount of time. Some previous research works in the area of dynamic multicast routing schemes in single rate loss networks are reported in [4] and [1] as Least Load Multicast Routing (LLMR). An analytical model is provided in [2] for symmetrical networks. The idea of LLMR is to find a connected tree for the multicast call by spanning tree searching with a link cost function which represents the link loading or the number of free circuits. By considering the loading of links involved, LLMR chooses the links with the least loading to establish the connection.

In this paper, we focus on the link cost function of the spanning tree searching so as to improve the network performance. The paper is organized as follows. We begin by presenting in Section 2 the new link cost function: mean number of new calls accepted before blocking, which can result in better network performance compared with LLMR. We will discuss why it can more accurately reflect the loading of a link and describe the steps to determine its value. The network model and the multicast routing algorithm will be presented in Section 3 along with a simple example. Section 4 shows the numerical results of our proposed algorithm and compares its performance with LLMR. Finally, we conclude in Section 5 by summarizing the paper and outlining avenues for future research.

2 Mean Number of New Calls Accepted Before Blocking (MCB)

In this section, we introduce a new link cost function that can better represent the current and future loading of links so that better network performance can be achieved. Consider a fully connected single rate loss network. When a multicast call arrives, a set of direct links will be considered and, if available, a connected tree is established among them for the call. We assume all multicast call connection requests are Poisson arrivals and the holding times
of accepted calls are exponentially distributed. With the link independence assumption, the queueing model of a link can be modeled as a general M/M/N/N queue as shown in Figure 1, where $1/\mu$ is the mean holding time of calls and $N$ is the total number of circuits of the link. In addition, given that there are $k$ occupied circuits in the link, we define $\lambda_k$ and $M_k$ as the state dependent arrival rate at state $k$ and the mean number of new calls that can be accepted starting from state $k$ before reaching state $k + 1$, respectively. By examining the possible state transitions from state $k$, it is not difficult to see that $M_k$ satisfies the first-order difference equation

$$M_k = \frac{\lambda_k}{\lambda_k + k\mu} + \frac{k\mu}{\lambda_k + k\mu}[M_{k-1} + M_k]$$

(1)

with the initial condition $M_0 = 1$. Equation (1) can be simplified as

$$M_k = \frac{k\mu}{\lambda_k}M_{k-1} + 1$$

(2)

and thus $M_k$ can be easily obtained by the above recursive equation. Let $\hat{M}_i$ be the mean number of new calls that can be accepted starting from state $i$ before blocking, i.e. the mean number of new calls accepted starting from state $i$ before reaching state $N$. It is easy to observe that $\hat{M}_i$ equals to the sum of $M_k$, $k = i, i + 1, \ldots, N - 1$, i.e.

$$\hat{M}_i = \sum_{k=i}^{N-1} M_k.$$  

(3)

![Figure 1: General M/M/N/N queueing model](image)

Note that the computation of $\lambda_k$ is very difficult and thus $\lambda_k$’s would be computed based on real-time measurements. For a multicast call connection, there are many ways to establish its connected tree. To minimize the future call blocking, an intuitive way is to choose a connected tree such that all links that participate should give the maximum mean number of new calls accepted before blocking. In LLMR, the number of free circuits is used
to represent the current available resources of a network and, based on this information the routing decision is made. However, the LLMR approach does not take into account the future call arrivals of the network and thus sometimes cannot make a good decision. The mean number of new calls accepted before blocking can more accurately reflect the current and future loading of a link. Its value reflects more accurately the actual available network resources that one can make use of before blocking. For example, consider two links: both have a capacity of 50 circuits. The mean call holding time is 1 unit. The call arrivals of the first and second links follow a Poisson process with rate 45 calls per unit time (90% loading) and 40 calls per unit time (80% loading) respectively. The first link has 5 free circuits while the second link has 2 free circuits only. Using equations (1), (2) and (3), we find that the first link on average can accept 60.4 new calls before blocking while the second link can accept 75.5 new calls before blocking. This example shows that the number of free circuits alone cannot accurately reflect the current available resources of links.

### 3 The Network Model and The Proposed Routing Algorithm

As mentioned in the Introduction, multicast connection requests can be classified as being Multipoint-to-Multipoint (MTM) or Point-to-Multipoint (PTM). In PTM connections, a single node transmits and the other nodes listen. However, in MTM connections, all nodes that participate in the connection are allowed to transmit information to all others. For the case where a network transports only MTM connections the underlying graph can be assumed to be undirected. However, in the presence of PTM connections, the underlying graph has to be assumed to be directed due to the asymmetric nature of the traffic. In view of the above observation, in this paper, for notational simplicity we assume that all connection requests are MTM.

Before proceeding further, we would like to introduce necessary definitions and notations. We consider a single rate loss network to be an undirected graph \( G = (V, E) \) where \( V \) and \( E \) are the set of nodes and links respectively. Denote by \( \hat{M}(e), e \in E \), the mean number of new calls accepted before blocking for link \( e \).

Consider a connection request \( c \) with destination set \( S(c) \) (each node \( s \in S(c) \) is referred to as a destination of \( c \)). Let \( d(c) \) be the number of nodes involved in a connection request \( c \), i.e., destination size. Let \( s_r \in S(c) \) be the destination node initiating the connection request; henceforth referred to as the root node. Note that if it is a PTM connection request, \( s_r \) is the source node. If it is a MTM connection request, \( s_r \) may be chosen randomly. A connection \( c \) requires a connected, acyclic graph (tree) \( T(c) = (V(c), E(c)) \), where \( S(c) \subseteq V(c) \) and a unit bandwidth is reserved on each link \( e \in E(c) \). The flowchart of
the multicast routing algorithm employing the new link cost function is shown in Figure 2.

Two points need to be clarified. (i) We employ the link independent assumption, which assumes the link occupancy distributions are independent. (ii) We know that the mean number of new calls accepted before blocking in the blocking state is 0. Thus, in the MCB algorithm, if a link has no free circuits for establishing a connected tree, its link cost is zero.

4 Numerical Results

In this section, we give numerical results to illustrate the performance of the MCB algorithms when compared with Least Load Multicast Routing (LLMR) proposed in [4] and [1]. We consider a fully connected network with 8 nodes. The capacity of each link is randomly generated between 40 and 60 bandwidth units or circuits. There are three classes of call connection requests in the network and their destination sizes are 2, 3, and 4. The loadings of the three classes are equal and the call arrivals of each class follow a Poisson Process. All call holding times are exponentially distributed with unit mean. All processing time, including call setup and release time, are negligible. When a call connection request is rejected, it will not retry and is cleared immediately from the network. For each set of simulation point, the length of each run is 10^6 units of mean interarrival time of connection request and the initial 10% is discarded to avoid the effect of transient state. The vertical lines about each point represent the 95% confidence intervals. We define the network loading as the ratio of the total offered load to the total network capacity and set 80% as the engineered load (i.e., 0% overload). We use a performance measure called normalized revenue loss, which was proposed in [1]. We set the corresponding revenue of a call connection request with destination set of size \( d \) to \( d - 1 \) (i.e., the number of direct links used) and thus the expression of the normalized revenue loss is

\[
\frac{\sum_{d=2}^{4} (d - 1)\lambda_d B_d}{\sum_{d=2}^{4} (d - 1)\lambda_d},
\]

where \( \lambda_d \) is the call arrival rate of class \( d \) and \( B_d \) is the call blocking probability of class \( d \).

Figure 3 shows the mean call blocking probabilities for LLMR and MCB under the same range of overload conditions. We find that MCB always outperforms LLMR in terms of achieving lower call blocking probabilities for all three classes. It is because LLMR just captures the current information (the current loading of links) but MCB makes use of all information (the current state of the network and the state dependent arrival rates of links) to forecast the future congestion. From the figure, it shows that, by using MCB, the biggest improvement is in class 2 since class 2 does not have any choice in selecting its direct path while class 3 and class 4 can forecast the congestion and hence reserve more
bandwidth or circuits for class 2 to avoid blocking. We also find that the improvement of class 4 is better than that of class 3 because the possible number of connected trees in class 4 is more than that in class 3 and thus MCB can make a better decision.

The relative improvement of the normalized revenue loss of MCB over LLMR is shown in Figure 4. We find that the relative improvement can be up to 50% and, as we expect, it decreases when the overload increases because, when the overload is too high, there is insufficient resources to accept incoming calls and hence no algorithm can improve the situation.

5 Conclusions

In this paper, we have investigated the dynamic multicast routing in single rate loss networks. We proposed a new dynamic multicast routing algorithm called Maximum Mean Number of New Calls Accepted Before Blocking (MCB) multicast routing. The goal is to search for a connected tree with maximum mean number of new calls accepted before blocking. The computation of the mean number of new calls accepted before blocking of a link is based on the general M/M/N/N queueing model with real-time measurements of state dependent arrival rates. Through the simulation results, we find that MCB always outperforms LLMR in all cases.

Substantial work is already in progress to develop an approximation so that the complexity of real-time measurement can be reduced without degrading the performance of MCB. We are also trying to investigate the performance of MCB when alternative nodes are employed.

References


\( T_1 = (V_1, E_1) \)
where \( V_1 = \{S_r\}, E_1 = \phi \)
\( i = 1 \)

\[ V_i = S(c)? \]

\[ E_{i+1} = E_i + e^* \]
\[ V_{i+1} = V_i + s^*_2 \]
\( i = i + 1 \)

Choose a link \( e^* = (s^*_1, s^*_2) \)
where \( s^*_1 \in V_i, s^*_2 \in S(c) - V_i \)
s.t. \( \dot{M}(e^*) > \dot{M}(e) \forall e = (s_1, s_2) \)
where \( s_1 \in V_i, s_2 \in S(c) - V_i \)

\[ \dot{M}(e^*) > 0? \]

The connection request is denied

Accept the call request and a tree \( T_d = (V_d, E_d) \) is used to route the call.

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Figure 2: Flowchart for the routing algorithms
Figure 3: Mean call blocking probabilities of MCB and LLMR

Figure 4: Relative improvement of revenue loss of MCB over LLMR