J. Indian Inst. Sci., Nov.–Dec. 2006, **86**, 785–789

Short Communication

Dynamic QOS routing in a mesh network

G. VARAPRASAD[1],* AND R. S. D. WAHIDABANU[2]
[1]Department of Computer Science and Engineering, B. M. S. College of Engineering, Bangalore 560 019, India.
[2]Department of Electronics and Communication Engineering, Government College of Engineering, Salem 636 011, India.
email: varaprasad2001@yahoo.com, Ph: 91-80-2662 2130, Fax: +91-80-2661 4357

Received on May 8, 2004; Revised on May 19, 2006.

Abstract

This paper proposes an algorithm which helps in reducing the network traffic at intermediate nodes in a mesh network. This model analyses the network performance by using queuing theory and provides QoS for end-users. The performance metrics are mean waiting time, throughput and delay. Each node is assumed to be *M*/*M*/*m* model in the network. The major focus of this work is to provide better QoS for end-users by effective utilization of bandwidth and balancing load over the network.

Keywords: Parallelism, arrival rate, service rate, QoS.

1. Introduction

In recent years, communication networks have become robust and play a vital role in providing QoS for end-users under different networks. Network performance is measured by delay and reliability. Many traditional routing algorithms [1–3], proposed for optimal/suboptimal routes, suffer from several drawbacks. First, the computation is massive to find optimal/suboptimal routes. Secondly, the speed of computation to bind new route is less when component fails [2]. Thirdly, the failures of node are affected by others [3].

Currently, two main functions are performed by dynamic routing. The first function uses a number of routes from source to destination to route the packet. The second function uses a variety of protocols for communication. The well-known Bellman–Fordman's successive appreciation algorithm [4], which uses the shortest path problem, takes $0(n^2)$ and Dijkstra algorithm [5-6] needs $0(n^3)$. In the best path routing, path length between the nodes is measured in terms of distance, bandwidth, average traffic, communication cost, mean queue length, measured delay, etc. By changing the weighting function, the best path is measured according to any one of the criteria or a combination of criteria mentioned above. The shortest path has been applied in packet routing for communication system [7], path planning in robotic system [8], and vehicle routing in transport system [9].

*Author for correspondence.

This model proposes dynamic QoS routing for mesh type of networks. In this model, the distribution of packets is considered to be exponential at each node in the network. Queuing theory is used to analyse the number of packets in the queue for transmission over the network. A guaranteed bound-delay mechanism is used to achieve QoS for end-users. The rest of the paper is organized as follows. Section 2 presents the description of network topology. System analysis and design is presented in Section 3. Simulation results are presented in Section 4. Section 5 concludes the work.

2. Network model

2.1. *Network graph*

A graph $G \equiv (I, J)$ is a finite non-empty set of nodes and a collection of links. I is a set of nodes $\{L, M, N, O, P, Q\}$ and J is set of links $\{(L, M), (L, N), (M, O), (M, Q), (N, O), (N, P), \text{and } (P, Q)\}$.

$$Z_{IJ} = \begin{cases} 1 & \text{if } (I,J) \in A \\ 0 & \text{otherwise.} \end{cases}$$

2.2. *Mesh network*

In mesh network (Fig. 1), nodes are fully connected, that is, every node on the network is logically one hop away to the other and provides guaranteed communication. It can be easily distinguished from other networks, as each node in the network has redundant links [10]. Cohen *et al*. [11] have demonstrated that it has higher throughput and supports burst traffic than conventional star [12] and bus [13]. It has multiple paths for communication. Data travels across several links to reach the destination, which is mainly due to limited buffer.

3. System analysis and design

The *M/M/m* queuing model (Fig. 2) is identical to *M/M/*1 model except that m servers are used to forward the packets from one node to the other. The packets at the head of the queue are forwarded to any server depending on availability. If there are m servers, all m servers are busy, then the mean rate is μ and the mean system output rate is equal to $m\mu$.

3.1. *Queuing analysis*

Queuing analysis is used to measure the performance of the network. Figure 3 illustrates how to reduce network congestion at the bottleneck routers and improve the throughput.

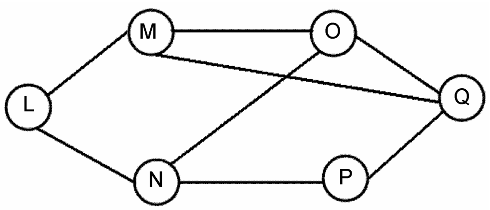

FIG. 1. Mesh network.

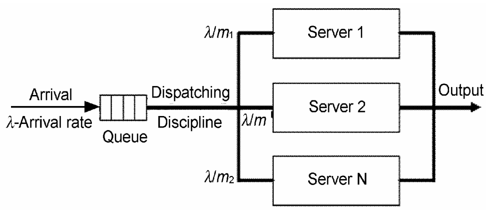

FIG. 2. Structure of *M/M/m* queuing model.

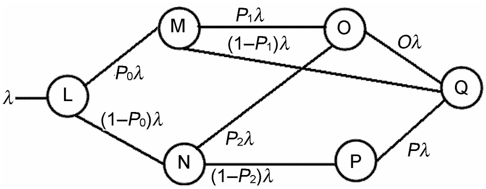

FIG. 3. Network congestion.

Here, L, M, N, O, P and Q are backbone routers in the network. Source node 'L' and destination node 'Q' have four paths, namely, Path 1: $L \rightarrow M \rightarrow O \rightarrow Q$, Path 2: $L \rightarrow M \rightarrow Q$, Path 3: $L \rightarrow N \rightarrow P \rightarrow Q$, Path 4: $L \rightarrow N \rightarrow O \rightarrow Q$.

The packets arrive at node L with mean arrival rate λ. They are served and buffered in the queue of either node M with probability P_0 or node N with probability $(1\text{-}P_0)\lambda$. Similarly, the traffic distribution at nodes M and N are differing from incoming distribution. The Poisson stream with mean arrival rate of packet $P_0\lambda$ at node M has two paths O and Q. If the packet moves towards O then the probability is $P_1\lambda$, else $(1 - P_1)\lambda$. The traffic arrival rate of packets $(1 - P_0)\lambda$ at node N has two paths, O and P, to move to next node. If it goes towards node O then the probability is $P_2\lambda$, else node P probability is $(1 - P_2)\lambda$.

$$\text{Path 1} = T_{wl} + T_{wm} + T_{wo} + T_{wq}$$
$$\text{Path 1} = \frac{\lambda}{2\mu(2\mu-\lambda)} + \frac{P_0\lambda}{2\mu(2\mu-P_0\lambda)} + \frac{(P_0P_1+P_2-P_0P_2)\lambda}{2\mu(2\mu-(P_0P_1+P_2-P_0P_2)\lambda)} + \frac{\lambda}{2\mu(2\mu-\lambda)}. \tag{1}$$

In general, the traffic distribution of streams O and P is different from the incoming distribution stream.

$$\text{Path 2} = T_{wa} + T_{wm} + T_{wq}$$
$$\text{Path 2} = \frac{\lambda}{2\mu(2\mu-\lambda)} + \frac{P_0\lambda}{2\mu(2\mu-P_0\lambda)} + \frac{\lambda}{2\mu(2\mu-\lambda)}. \tag{2}$$

The two Poisson streams, $P_1\lambda$ and $P_2\lambda$, arrive at node O; the next hop is Q whose stream and means arrival of packets is probability $O\lambda$.

$$\text{Path 3} = T_{wl} + T_{wu} + T_{wp} + T_{wq}$$
$$\text{Path 3} = \frac{\lambda}{2\mu(2\mu-\lambda)} + \frac{(1-P_0)\lambda}{2\mu(2\mu-(1-P_0\lambda)} + \frac{(1-P_0-P_2+P_0P_2)\lambda}{2\mu(2\mu-(1-P_0-P_2+P_0P_2)\lambda)} + \frac{\lambda}{2\mu(2\mu-\lambda)}. \tag{3}$$

The Poisson streams with mean arrival rate of packets $(1 - P_2)\lambda$ at node P. Here packets are forwarded from path Q only. The packets are served and buffered in the queue of node Q with probability $P\lambda$. The arrival rates of packets $E\lambda$ and $D\lambda$ and $(1 - P_2)\lambda$ at node Q, which include resulting stream have mean rates of $O\lambda$ and $P\lambda$ and $(1 - P_2)\lambda$.

$$\text{Path 4} = T_{wl} + T_{wu} + T_{wo} + T_{wq}$$
$$\text{Path 4} = \frac{\lambda}{2\mu(2\mu-\lambda)} + \frac{(1-P_0)\lambda}{2\mu(2\mu-(1-P_0\lambda)} + \frac{(P_0P_1+P_2-P_0P_2)\lambda}{2\mu(2\mu-(P_0P_1+P_2-P_0P_2)\lambda)} + \frac{\lambda}{2\mu(2\mu-\lambda)}. \tag{4}$$

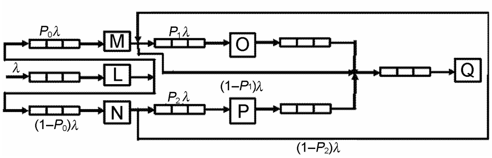

FIG. 4. Tandem mesh network.

Table I
Mean delay for paths

Probability	Path 1	Path 2	Path 3	Path 4
0.1	0.0010	0.0009	0.0019	0.0013
0.2	0.0010	0.0009	0.0018	0.0013
0.3	0.0011	0.0009	0.0017	0.0012
0.4	0.0011	0.0010	0.0016	0.0012
0.5	0.0011	0.0010	0.0015	0.0011
0.6	0.0012	0.0011	0.0015	0.0011
0.7	0.0012	0.0011	0.0014	0.0010
0.8	0.0013	0.0011	0.0013	0.0010
0.9	0.0013	0.0012	0.0013	0.0010

Figure 4 illustrates the tandem mesh network. It contains four paths in the above said model. Depending upon the conditions, the scheduler will route the packets from one path to the other. If the network is in a tandem network, then it is a stable one, since it has many alternative paths when network is congested. The minimum delay problem based on edge path representation (1) or (2), or (3) or (4) is a linear programming problem.

4. Simulation results

Here the performance of four paths mentioned earlier has been calculated. The scheduler allows the network operator to choose the guaranteed performance bound-delay path and will choose the best path to get QoS. It reduces the network congestion (Table I). When probability is 0.1, path 2 is well suited for QoS. In case probability is 10, path 4 is found to be suitable.

The main focus of the work is on QoS and reduced network congestion at the intermediate nodes. The network delay is measured by the mean waiting time. In the summation, at each time, it varies mean delay of each path. The scheduler chooses best path to forward the packets. Results are plotted against probability (Fig. 5).

The proposed model is simulated using *M*/*M*/*m* model (Fig. 6). It shows better results than *M*/*M*/1 model.

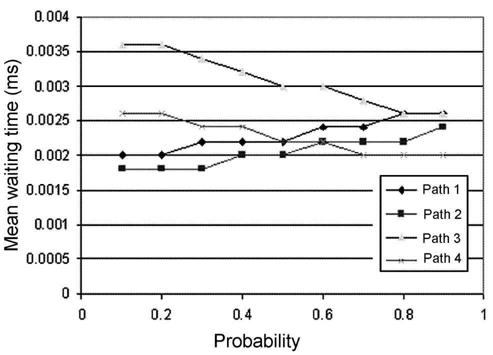

FIG. 5. Mean waiting time vs probability using *M*/*M*/1 model.

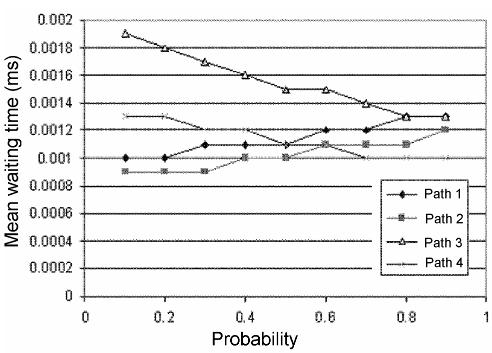

FIG. 6. Mean waiting time vs probability using *M*/*M*/*m* model.

5. Conclusions

The proposed model is presented for guaranteed bound-delay mechanism for end-users. The switching nodes are modeled as parallel servers by considering *M/M/m* model. The *M/M/m* model mimics the behavior of 3G packet switch effectively. This is a mathematical model, given solution is also a mathematical analysis and does not consider the packet loss/ dropping probability in the network.

References

1. A. G. Greenberg, and J. Goodman, Sharp approximate models of adaptive routing in mesh networks, *Teletraffic analysis and computer performance evaluation* (O. J. Boxma, J. W. Cohen, and H. C. Tijms, eds), pp. 255–270, Elsevier (1988).
2. A. G. Greenberg, and B. Hajek, Deflection routing in hypercube networks, *IEEE Trans. Commun.*, **40**, 1070–1081 (1992).
3. G. Varaprasad, and R. S. D. Wahidabanu, Shortest path between source and destination in a mesh network, *Proc. Int. Conf. on Emerging Technology*, Bhubaneswar, India, 2004, pp. 67–70.
4. E. A Varvarigos, and D. P. Bertsekas, Performance of hypercube routing schemes with or without buffering, *IEEE/ACM Trans. Networking*, **2**, 299–311 (1994).
5. G. Varaprasad, R. S. D. Wahidabanu, and S. Gowrishankar, Flexible routing in a mesh network, *Proc. Society for Information Science*, Chennai, India, 2004, pp. 120–128.
6. S. Jum, and K G. Shin, Shortest path planning in distributed workspace using domain relation, *IEEE Trans. Networking,* **7**, 342–350 (1991).
7. G. Varaprasad, and R. S. D. Wahidabanu, Adaptive routing in a wide area network, *Proc. National Conf. on Networking*, Coimbatore, India, 2003, pp. 140–148.
8. G. Varaprasad, and R. S. D. Wahidabanu, Versatile routing in a mesh network, *Proc. National Conf. on Image and Signal Processing*, Pundi, India, 2004, pp. 224–230.
9. G. Varaprasad, and R. S. D. Wahidabanu, Routing in communication network using neural network, *Proc. National Conf. on Image Processing and Signal Processing,* Kovalpettai, India, 2003, pp. 58–63.
10. G. Apostolopoulos, R. Guérin, S. Kamat, A. Orda, and S. Tripathi, Intradomain QoS routing in IP networks: A feasibility and cost/benefit analysis, *IEEE Networks,* **13**, 42–52 (1999).
11. Reuven Cohen, Yoram Ofek, and Adrian Segall, A new label-based source routing in multi-ring networks, *IEEE Trans. Networks*, **3**, 320–328 (1995).
12. C. Y. Roger Chen, Georges A. Makhoul, and Dikran S. Meilisetian, A queuing analysis of the performance of DQDB, *IEEE/ACM Trans. Networking*, **3**, 872–881 (1995).
13. A. Girard, and R. Zidane, Revenue optimization of B-ISDN networks, *IEEE Trans. Commun.*, **43**, 1992–1997 (1995).

Nomenclature

λ = Arrival rate of packets
μ = Service rate of packets
w = Number of packets awaiting transmission
T_w = Mean waiting time of packet
T_r = Mean time packet spends at each node