第 26卷 第 3期　　电子科技大学学报　　Vol. 26 No. 3
1997年 6月　　Journal of UEST of China　　Jun. 1997

。学术论文与技术报告。

Traffic Model and Performance Analysis for Multi-point and Multi-class Teleconferencing Networks

Feng Gang
(Department of Information Engineering, The Chinese University of Hong Kong Hong Kong)
Liu Ying
(Shenzhen Huaqiang Holdings Limited Shenzhen 518042)

Abstract In this paper, the traffic model and the performance analysis for multi-point and multi-class teleconferencing network are studied. The knapsack model is used to analyze the blocking probability performance of the teleconferencing networks. In the teleconferencing traffic model, an array of video services ranging from lower to higher quality is assumed. The star network topology is considered in this paper. An illustrative example is provided.

Key words teleconferencing; traffic model; knapsack model

Among the many potential broadband video services for business applications, teleconferencing has been regarded as one of the most welcomed service. In teleconferencing system, good quality compressed video requires much larger bandwidth than audio and thus careful allocation of bandwidth resources to the video streams in the network is essential.

There are various ways to present the video images of the sites at different locations and there are also many teleconferencing network design approaches proposed. The single camera system[1], split screen system, voice switched system, and continuous presence system are other possible types. Virtual space teleconference[2] is designed to connect multiple conference sites to provide continuous visual presence of all sites and conveys the spatial relationship between participants. J. Ferguson and L. Mason[3] studied a video conference network design problem for multipoint conferences. The traffic engineering aspects of teleconferencing were studied in Ref. [4], assuming all conferences involve only two studios. In addition, there are many other related works focusing on the variable bit rate (VBR) video source traffic model and statistic multiplexing[8]。

The first research conclusions of Ref. [4] suggest that the most economical structure might be a simple star network where all studios are connected directly to a central switch facility. In addition, ITU H. 320/T. 120 defines a centralized multipoint control unit (MCU) for multiparty teleconferencing over ISDN. This paper focuses on the traffic model and analysis of multi-point teleconferencing with star network topology. Section 1 presents the teleconferencing traffic aspects including descriptions of network structure, class of service, quality of service, etc. In section 2, we make use of the stochastic knapsack model to study the performance of teleconferencing traffic. As a main measure of quality of service (QoS), the call blocking probability is derived in

---

Received September 2, 1996 and revised December 4, 1996

Section 3. An illustrative example is provided in Section 4.

1 Traffic Characteristics and Network Structure

1.1 Teleconferencing Service

The network under consideration connects a moderately large number of studios. The teleconferencing service is provided based on privately owned or rented studios located on user premises. The studios can be grouped according to their location in a number of geographical zones. A transit facility is needed for the concentration and concentration and switch for videos in every zone.

We suppose the area covered by the teleconferencing network to be divided into N zones with M_i studios located in zone i, $1 \leqslant i \leqslant N$.

1.2 Network Configuration

There is a transit facility (TF) called conference node in every service zone. Every conference node is connected to a central server (MCU) using one link. All conference video streams are transmitted to MCU, which then distributes composed and/or selectable streams to the various participants.

In the network, let $S_1, S_2, \cdots S_N$ be the total number of conference subscribers at node $1, 2, \cdots, N$. Let there be one video in a zone to be transmitted for the same conference. Define the conference size W as the total number of conferees in a conference and let the distribution of W be denoted as $w_i = Pr[W = i], i = 2, 3, \cdots, M$, where M is the maximum number of conferees allowed in a conferencing.

1.3 Class of Service

Among the key developments expected in the near future is the demand for a variety of communications services with wide range of video quality[7]. It is therefore possible to provide a mix of services such as extended quality (EQTV), high definition (HDTV) and super HDTV as well as existing a NTSC, to meet various need. In this paper, we will study the teleconferencing traffic model with mult-class service, each requires a different bandwidth.

Let b_k be the equivalent capacity unit required by class k service and K is the number of service classes in the teleconferencing under consideration. In addition, let $q_k, k = 1, 2, \cdots, K$ be the probability that a new conference call request is class k.

1.4 Quality of Service

We assume that a teleconferencing network would be dimensioned with the objective to offer a "good" grade of service (QoS) to the subscribers. In this paper, the probability of the conference call being blocked is chosen as a measure of the QoS. This probability should be small, say less than 10^{-2}.

2 Traffic Model and Traffic Decomposition

For a star work, we call transmission from TFs to the MCU as "inbound" transmission and from MCU to TFs as "outbound" transmission. The bandwidth requirements on a involved link of common media teleconferencing of class k are the same b_k for both inbound and outbound transmission. Obviously, we need only to consider the inbound transmission in the following analysis. It is similar for the outbound transmission.

2. 1　Traffic Decomposition Principle

Like those in Refs. [10, 12], we assume that the number of conference subscribers is large enough, and we can model the class k conference call as a Poisson process with arrival rate λ_k ($k = 1, 2, \cdots, K$). Let $1 / \_ _{k}$ be the mean holding time for the class k conference.

A properly designed teleconferencing service should have a low blocking probability(for example $< 10^{-2}$). Under this condition, the link occupancies can be approximated to be independent[11]. As different numbers of channels are required on different links for a conference, we can decompose a conference call into a number of channel requests on different links.

Let $a_p(s)$ be the probability that a s-conferee conference has a conferee attached to node p. Under the assumption that all conferees have equal community interest on all the others, the probability $a_p(s)$ is

$$a_p(s) = 1 - \left[1 - \frac{S_p}{\sum_{i=1}^{N} S_i} \right]^{s} \tag{1}$$

where N is the number of nodes of the conferee network, $p \in [1, N]$. By traffic decomposition, the arrival rate of class k traffic on link l_p from node p to the MCU, denoted as $\lambda_p(k)$, is given by

$$\lambda_p(k) = \sum_{Y=2}^{N} \lambda_k * a_p(Y) * w_Y \tag{2}$$

where K is the number of classes of teleconferencing service.

2. 2　Stochastic Knapsack Model

By decomposing the teleconferencing traffic onto every link, we can model the bandwidth of a link as the capacity of a " Stochastic Knapsack" , as shown in Fig. 1. A class-k conference using this link will occupy b_k space of this Knapsack. Futhermore, let $b = (b_1, b_2, \cdots, b_K)$ be the size vector and let $n = (n_1, n_2, \cdots, n_K)$ be the state vector for the Knapsack, where n_k is the number of ongoing class-k conferences occupying the link under consideration.

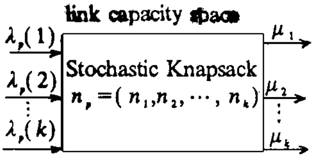

Fig. 1　The stochastic knapsack model of the link capacity space

Since the total number of occupied equivalent bandwidth units on link l_p can not be larger than the link capacity L_p, the set K_p of all admissible states on link l_p is

$$K_p = \left\{ n \,\middle|\, \sum_{k=1}^{K} b_k * n_k \leqslant L_p \right\} \tag{3}$$

where $n = (n_1, n_2, \cdots, n_k)$.

Based upon the principle of stochastic knapsack[8], the equilibrium distribution for the link occupancy state, denoted as $c(n)$, is given by a product form solution

$$c[n] = \begin{cases} \dfrac{1}{G} \dfrac{d_1^{n_1}}{n_1!} \dfrac{d_2^{n_2}}{n_2!} \cdots \dfrac{d_K^{n_K}}{n_K!} & n \in K_p \\ 0 & \text{otherwise} \end{cases} \tag{4}$$

where the dependency of n_i on p is dropped for simplicity, and

$$d_k = \lambda_p(k) / \_ _{k} \tag{5}$$

$$G = \sum_{n \in K_p} \prod_{k=1}^{K} \frac{d_k^{n_k}}{n_k!} \tag{6}$$

Define

$$H(c) = \left\{ n \in K_p \,\middle|\, \sum_{i=1}^{K} b_i n_i = c \right\} \tag{7}$$

With that, the link channel occupancy, denoted as N_p, has distribution

$$P(N_p = c) = \sum_{n \in H(c)} c(n) = \frac{\displaystyle\sum_{\sum_{k=1}^{K} b_k * n_k = c} \prod_{i=1}^{K} d_i^{n_i} / n_i!}{\displaystyle\sum_{c=0}^{L_p} \sum_{\sum_{j=1}^{K} b_j * n_j = c} \prod_{i=1}^{K} d_i^{n_i} / n_i!} \tag{8}$$

Then, the probability $B_p(k)$ that link l_p cannot accommodate a class-k video is given by

$$B_p(k) = 1 - \sum_{c=0}^{L_p - b_k - 1} P(N_p = c) \tag{9}$$

3 Call Blocking Probability

Let $\tilde{K}_1, \tilde{K}_2, \cdots, \tilde{K}_N$) be random variables representing the number of sites located at node 1, 2, $\cdots$, N. For a s-site conference, let $\tilde{K}(s) \equiv (\tilde{K}_1, \tilde{K}_2, \cdots, \tilde{K}_N$ with $\tilde{K}_1 + \tilde{K}_2 + \cdots + \tilde{K}_N = s$. Let $k = (k_1, k_2, \cdots, k_N)$ where the k_i's are non-negative integers. Under the assumption that all conferees have equal communtiy interest on all the others, we have

$$P[\tilde{K}(s) = k] = \begin{cases} \dbinom{s}{k_1, k_2, \cdots, k_N} \displaystyle\prod_{i=1}^{N} [a_i(s)]^{k_i} & \text{for all } k \text{ with} \displaystyle\sum_{j=1}^{N} k_j = s \\ 0 & \text{otherwise} \end{cases} \tag{10}$$

A teleconferencing call will be blocked if any involved link does not have the requested bandwidth. Given that a conference call requests class-k service and has s conferees, the blocking probability $B(k,s)$ can be found as

$$B(k,s) = 1 - \sum_{k \in A} \left[\prod_{p=1}^{N} (1 - B_p(k) * e(k_p)) * P(\tilde{K}(s) = k) \right] \tag{11}$$

where $B_p(k)$ is given by Eq. (9) and the state space A is defined as

$$A = \left\{ k \,\middle|\, \sum_{i=1}^{N} k_i = s \right\} \tag{12}$$

and

$$e(k_p) = \begin{cases} 1 & \text{for } k_p > 0 \\ 0 & \text{else} \end{cases} \tag{13}$$

Finally, removing the conditioning on s, we can obtain the blocking probability for class k teleconferencing call

$$B_k = \sum_{s=2}^{N} B(k,s) * w_s \tag{14}$$

Removing the conditioning k, the call blocking probability is obtained as

$$B = \sum_{k=1}^{K} (\lambda_k * B_k) \Big\backslash \sum_{k=1}^{K} \lambda_k \tag{15}$$

4 Illustrative Example

To demonstrate the validation of the proposed traffic model, we give an example to the performances obtanied from the analysis. Consider a star-shaped network with 5 zones ($N=5$), with subscribers S_i ($i=1,2,\cdots,5$) = 1 000, 1 000, 2 000, 1 500, 3 000 respectively. Two classes of video are provided, each with 2 and 1 equivalent bandwidth units respectively. The one-direction capacities of these five links are $L_1=25$, $L_2=25$, $L_3=40$, $L_4=35$ and $L_5=50$ respectively. Two types of teleconferencing size distributions are assumed. One is of uniform distribution with $E(w)=3.5$ and the other is of truncated geometric distribution with $E(w)=3.0$.

Table 1 and 3 shows the class 1 call blocking probabilites when the conference size is uniform distribution (with mean 3.5) and truncated geometric distribution (with mean 3) respectively. Table 2 and 4 shows the results for class 2 call. Where $d_1=\lambda_1/\_{1}$ and $d_2=\lambda_2/\_{2}$ is the class 1 and 2 offered load respectively. Without the loss of generality, in this example, $\_{1}=\_{2}$ is assumed.

Table 1　Call blocking probability for class 1 (Uniform distribution with mean = 3.5)

		d_2 (Erlang)					
		5.0	7.0	9.0	11.0	13.0	15.0
d_1	5.0	2.91e−4	2.04e−3	7.90e−2	1.86e−2	3.47e−2	5.58e−2
	7.0	4.97e−4	3.63e−3	1.14e−2	2.64e−2	4.39e−2	6.35e−2
	9.0	1.44e−3	6.19e−3	1.72e−2	3.52e−2	5.35e−2	7.66e−2
	11.0	2.76e−3	1.06e−2	2.41e−2	4.31e−2	6.44e−2	9.03e−2
	13.0	5.64e−3	1.64e−2	3.25e−2	5.56e−2	7.80e−2	1.03e−1
	15.0	9.13e−3	2.43e−3	7.90e−3	6.63e−2	9.09e−2	1.14e−1

Table 2　Call blocking probability for class 2 (Uniform distribution with mean = 3.5)

		d_2 (Erlang)					
		5.0	7.0	9.0	11.0	13.0	15.0
d_1	5.0	6.27e−4	4.36e−3	1.79e−2	4.05e−2	7.43e−3	1.13e−1
	7.0	1.48e−3	8.28e−3	2.62e−2	5.79e−2	9.22e−2	1.32e−1
	9.0	3.43e−3	1.56e−2	4.00e−2	7.26e−2	1.13e−1	1.51e−1
	11.0	7.45e−3	2.40e−2	5.30e−2	9.29e−2	1.34e−1	1.74e−1
	13.0	1.36e−2	3.65e−2	7.05e−2	1.16e−1	1.57e−1	1.99e−1
	15.0	2.13e−2	5.24e−2	9.06e−2	1.32e−1	1.79e−1	2.22e−1

Table 3 Call blocking probability for class 1 (Truncated geometric distribution with mean= 3)

		d_2 (Erlang)					
		5.0	7.0	9.0	11.0	13.0	15.0
d_1	5.0	3.30 e-5	2.41 e-4	1.59 e-3	5.13 e-3	1.14 e-2	2.07 e-2
	7.0	6.20 e-5	5.93 e-4	2.99 e-3	7.85 e-3	1.54 e-2	2.64 e-2
	9.0	2.02 e-4	1.13 e-3	4.17 e-3	1.12 e-2	2.01 e-2	3.40 e-2
	11.0	4.21 e-4	2.19 e-3	6.68 e-3	1.48 e-2	2.668 e-2	4.04 e-2
	13.0	7.81 e-4	3.29 e-3	9.52 e-3	1.89 e-2	3.23 e-2	4.87 e-2
	15.0	1.53 e-3	5.26 e-3	1.45 e-2	2.55 e-2	4.02 e-2	5.73 e-2

Table 4 Call blocking probability for class 2 (Truncated geometric distribution with mean= 3)

		d_2 (Erlang)					
		5.0	7.0	9.0	11.0	13.0	15.0
d_1	5.0	6.81 e-5	6.53 e-4	3.93 e-3	1.14 e-2	2.58 e-2	4.52 e-2
	7.0	2.14 e-4	1.63 e-3	6.56 e-3	1.68 e-2	3.49 e-2	5.67 e-2
	9.0	4.99 e-4	3.16 e-3	1.02 e-2	2.39 e-2	4.49 e-2	7.09 e-2
	11.0	1.05 e-3	5.66 e-3	1.56 e-2	3.28 e-2	5.73 e-2	8.52 e-2
	13.0	2.05 e-3	8.15 e-3	2.26 e-2	4.23 e-2	7.01 e-2	1.01 e-1
	15.0	4.02 e-3	1.33 e-2	3.27 e-2	5.56 e-2	8.56 e-2	1.21 e-1

It is interesting to note that for both teleconferencing size distribution, the call blocking probability of class 2 is approximately 2 times as that of class 1.

5 Conclusion

Network planning should be based on the knowledge of the traffic model and analysis. In the design of video conferencing network, it is important to relate network capacities to the traffic and the QoS quantitatively. The object of this paper is to present a traffic model and engineering tool for multipoint and multiclass teleconferencing. Using traffic decomposition and stochastic knapsack principle, we derive the call probability of the star-shaped communication networks. An illustrative example of 5 nodes network and 2 class services is given.

Reference

1 Sabri S, Prasada B. Video conferencing systems. Proc of IEEE, 1985, 73(4): 671~688

2 Haruo Noma, Yasuichi Kitamura. Multi-point virtual space teleconferencing system. IEICE Trans Commun, 1995, E78-B(7): 797~805

3 Ferguson M J, Mason L. Network design for a large class of teleconferencing systems. IEEE Trans Commun, 1984, COM-32(7): 789~796

4 Liao K Q, Roberts J W. Videoconference traffic and network design. IEEE Trans Commun, 1987,

COM-35(3): 275~282

5　Leung Y W. Routing and switching in teleconferencing networks. PhD Dissertation, The Chinese Univ of Hong Kong, 1992

6　Gharavi H, Partovi M H. Video coding and distribution over ATM for multipoint teleconferencing. Proceedings of IEEE GLOBECOM' 93, 1993: 1~7

7　Ross K W. Multiservice loss models for broadband telecommunication networks. New York: Springer-Verlag, 1996

8　Reibman A R, Berger A W. Traffic descriptors for VBR video teleconferencing over ATM networks. IEEE/ACM Trans on Networking, 1995, 3(6): 329~338

9　Elwalid A, Heyman D. Fundamental bounds and approximations for ATM multiplexers with applications to video teleconferencing. IEEE Journal on Selected Areas in Commun, 1995, 13(6): 1 004~1 016

10　Yum T S, Chen M S, Leung Y W. Video bandwidth allocation for multimedia teleconferences. IEEE Trans on Commun, 1995: 457~465

11　Whitt W. Blocking when service is required from several facilities simultaneously. AT&T Technical Journal, 1985, 64(8): 1 807~1 856

12　Leung Y W, Yum T S. Connection optimization for two types of videoconferences. IEE Proc Commun, 1996, 143(3): 133~140

多点多业务等级电视会议网模型与性能分析

冯　钢*　　　　刘　英
(香港中文大学信息工程系　香港)　(深圳华强集团有限公司　深圳　518042)

【摘要】　研究多点多级电视会议网络的业务模型及性能分析。采用knapsack模型分析网络的呼叫阻塞概率。在此模型中,假设网络能提供多级视频信号质量。业务模型用于研究网络结构及线路规模要求。主要考虑了星型网。给出了一个分析实例。

关　键　词　电视会议;　业务模型;　knapsack模型
中图分类号　TN918.8

编辑　叶　红

1996年 9月 2日收稿, 1996年 12月 4日修改定稿

* 男　32岁　博士生