비계층 통신망에서의 포화 경로 선정 알고리즘의 성능분석

박영철
천안대학교 정보통신학부

요 약

포화 경로 선정 알고리즘은 주로 전술적 응용 및 패킷 라디오 망에 유용한 경로 선정 알고리즘으로 알려져 있는데, 이유는 통화로 개설 시간이 짧고 경로 선정 테이블을 갖고 있지 않기 때문이다. 통신망 효율 면에서는 통제 메시지의 오버 해드로 인해 약점이 있기도 하다. 본 논문에서는 4개의 링크로 구성된 격자형 전술 회선 교환망에 두개의 우선 순위 음성 트래픽을 갖는 망을 고려하였다. 최소 1차 미분 길이를 갖는 경로를 이용하여 통화로 개설 시간 및 알고리즘 처리 부하를 증가 시키지 않으면서 회선망의 차단 확률을 향상 시켰다.

Performance Analysis of Saturation Routing Algorithm in Non-Hierarchical Networks

Young Chul Park

ABSTRACT

Saturation routing algorithm is known to be an effective routing mechanism for tactical application and packet radio networks, since it minimizes the call set-up time and does not have to maintain routing tables. But, it is known that it has significant drawbacks with respect to the network efficiency, the overhead on the control messages [1]. We consider a tactical circuit-switched grid network with a maximum of four links and two priority classes of voice traffic. Using the minimum first-derivative length (MFDL) path, we improve the blocking probability performance of a circuit-switched network without increasing the call set-up time and processor loading of the algorithm.

Ⅰ. Introduction

In this paper, we study the saturation routing algorithm for non-hierarchical circuit-switched networks. The tactical network and packet radio network are highly mobile and are constantly in a state of change. Neither the subscribers nor the communications assets remain fixed for a long period of time. The networks are frequently subject to stress situations such as dynamic traffic, damage, and jamming. In addition, tactical circuit-switched networks must accommodate numerous levels of precedence with a preemption capability for high-priority subscribers.

The highest priority class of subscribers must be guaranteed no blockage given the existence of a physical path between them. For such a tactical network, the survivability and the robustness of the saturation routing algorithm (also called flooding or flood search algorithm) is highly desirable. Flood search algorithm for circuit-switched networks offers many advantages. This technique has a great advantage of not having to maintain any routing tables at the intermediate nodes. Flooding algorithm is also known to be an effective method for routing and forwarding packets in packet switching networks. The ARPANET, the oldest of the packet switching networks, exchanges its routing information using a form of flooding [2]-[3]. Several new architectures to promote high speed packet switching have been proposed [4]-[5]. The premise of these networks is that a great deal of the routing computation is done ahead of time so that when the actual data packets start traversing the network, intermediate nodes do not have to consult with routing tables that would have slowed down their operation.

For circuit-switched networks. it results in undesirable effects, particularly with respect to the network efficiency. An avalanche effect may occur, reducing the overall network efficiency [6]. In addition, in an equally loaded network the effect of high usage overflow routing is lost and increases the probability of blocking on the shortest routes [7]. It is shown that the flooding algorithm gives the most reliable performance in all aspects under possible network outage conditions in the battlefield environment [2]. These algorithms do not deal with optimization of performance such as the minimization of average end-to-end blocking probability (EEBP) in circuit- switched networks. As a result, this algorithm has relatively poor blocking performance , since it does not concern with the probability of blocking.

In this paper, with the same or less level of call set-up time and processor loading of the flood search algorithm, we propose a modified flooding algorithm, thereby improving the blocking performance in the networks. Using the optimization technique to solve the problem of flooding algorithm has never been attempted before. Finding the optimal solution that minimizes the average EEBP, P_B, with constraints on the link blocking probability is complicated and time consuming. Therefore, in the proposed approach, instead of calculating P_B, we compare the gradient of the objective function at each node, and choose the shortest path so that the link length is minimum, that is, determine the minimum first-derivative length (MFDL) path between the source node S and the destination node D. The link length here is defined to be the marginal increase of the objective function with respect to the marginal increase of the amount of traffic flow of the link.

II. Modeling and Analysis

Let the nodes of an n-node network be represented by the integers 1,2,⋯,n and let a link from node i to node j be represented by (i, j). Each link has a fixed number of channels, each of which is able to carry one call at a time. A link is said to be busy if all of its channels are busy for transmission of calls. In general, there may be several paths between a (S, D) pair or commodity. Now we denote

D_{ij}: Expected number of data units per second transmitted on $link(i,j)$ times the expected blocking per call.

F_{ij} : Total flow on $link(i,j)$(in calls/s).

X_p : Flow of path p(in calls/s).

w : A source-destination (S,D) node pair, i, e, $w=(S,D)$

W: A set of all (S,D) node pairs, w's.

P_w : A set of all directed paths connecting source and destination nodes of (S,D) pair w.

r_w : Arrival rate of traffic entering the network at node i and destined for node j (in calls/s).

For each (S,D) pair w, the input traffic arrival process is assumed stationary with rate r_w. Assuming that D_{ij} is a function of the link flow F_{ij} only and a monotonically increasing cost function, an optimal routing problem can be written as

$$\min imize \sum_{(i,j)} D_{ij}(F_{ij}) \tag{1a}$$

$$= \min imize \sum_{(i,j)} D_{ij} \cdot \sum_{all\ paths\ p\ comaining(i,j)} x_p \tag{1b}$$

$$\sum_{p \varepsilon P_w} x_p = r_w, \text{ for all } w \varepsilon W \tag{1c}$$

$$x_p \geq 0, \text{ for all } p \in P_w,\ w \in W \qquad (1d)$$

where F_{ij} on link (i,j) is the sum of all path flows traversing the link. Thus, the problem is formulated in terms of unknown path flows $s=\{x_p | p \in W\}$. Optimal solutions of the routing problem may be characterized as done by Bertsekas and Gallager [8]. We assume that each D_{ij} is a differentiable function of F_{ij}. Now, taking the partial derivative on D with respect to x_p, we have

$$\frac{\partial D(x)}{\partial x_p} = \sum_{all\, links\, (i,j)\, on\, path\, p} D'_{ij} \qquad (2)$$

where the first-derivatives D'_{ij} are evaluated at the total flows corresponding to x. From (2) it is seen that $\partial D/\partial x_p$ is the length of path p when the length of each link (i,j) is taken to be the first-derivative D'_{ij} evaluated at x. Consequently, $\partial D/\partial x_p$ will be called the first-derivative length (FDL) of path p. The minimum first- derivative length (MFDL) path here is defined to be the sum of the minimum of FDL's along the path. With this MFDL path, we will find the shortest path between S and D do that the link length based on the blocking probability is minimum.

Considering a call routing procedure of the modified flood search algorithm, there are two major functions as in the original flood search algorithm. One is a subscriber location function which searches the network for the called subscriber and the other is a route search function which searches the network for an available route to connect the calling to the called switches. In the original flooding algorithm, the route search need not have to be concerned with the probability of blocking through the switch matrices [1]; but in the modified flooding algorithm the FDL or the gradient of the objective function represented by blocking probabilities need to know the probability of blocking.

The network model used in this study is a circuit-switched grid network with a maximum of four links. All the links which have the same transmission bandwidth are capable of transmission in both directions. The common channel signaling (CCS) method is used between nodes, and the EUROCOM recommended message format is assumed [8]. The trunk group contains 30 speech channels with a 32 kbit/s common channel. A call is considered as a basic unit of circuit-switched traffic, and each call originating from S is destined to D. The call arrival process is assumed to be

Poisson with rate λ_i on the ith link and the call holding time is exponentially distributed with mean $1/\mu$.

The call connection and disconnection times are assumed to be statistically independent. Blocked calls are also assumed to be cleared and do not return. The link blocking probability on the ith link is given by the Erlang B formula,

$$B(a_i,N)=\frac{a_i^N/N!}{\sum_{j=0}^{N} a_i^j/j!} \qquad (3)$$

where a_i is the offered load to link i (in Erlang) or the Erlang rate on link i, defined as $a_i=\lambda_i/\mu$, and N is the number of channels. Since there may exist more than one path between each (S,D) node pair or commodity, and a path may consist of more than one link, it is necessary to define a path blocking probability and an average EEBP for the traffic of one (S,D) node pair [7]. we assume that there are two classes of voice traffic, high-priority voice v_1 and low-priority voice v_2. High-priority voice v_1 can preempt low-priority voice v_2. Letting a_{π} be the offered load for circuit-switched voice of priority p, p=1,2, then the high and low-priority voice blocking probabilities are then given under the condition of trunk reservation, respectively, by $B_{1i}=b(a_{1i},N)$ and $B_{2i}=B(a_{1i}+a_{2i},N)$. Now, we can express the objective functions, $f_1(a_1)$ for v_1 and $f_2(a_2)$ for v_2, respectively, by excluding the term γ/μ in (7), that is,

$$P_{B_1}\equiv f_1(a_1)=\sum_{i=1}^{l} a_{1i}B_{1i} \quad \text{for } v_1 \qquad (4)$$

$$P_{B_2}\equiv f_2(a_2)=\sum_{i=1}^{l} (a_{1i}+a_{2i})B_{2i} \quad \text{for } v_2 \qquad (5)$$

where $a_1=[a_{11},a_{12},\cdots,a_{1l}]$, and $a_2=[a_{21},a_{22},\cdots, a_{2l}]$. Now, we can derive the gradient of the objective function with respect to the link flow as,

$$\nabla f_1(a_1)=\frac{\partial f_1(a_1)}{\partial a_{11}}e_1+\frac{\partial f_1(a_1)}{\partial a_{12}}e_2\cdots + \frac{\partial f_1(a_1)}{\partial a_{1l}}e_l \qquad (6)$$

$$\nabla f_2(a_2)=\frac{\partial f_2(a_2)}{\partial a_{21}}e_1+\frac{\partial f_2(a_2)}{\partial a_{22}}e_2\cdots + \frac{\partial f_2(a_2)}{\partial a_{2l}}e_l \qquad (7)$$

where e_i is a 1 x l vector whose elements are all zero except for its ith element being equal to one. Thus, at link i, the first-derivative length (FDL) for v_1 is given by $\partial f_1(a_1)/\partial a_{1i}=a_{1i}{}^{*}\partial B_{1i}/\partial a_{1i}+B_{1i}$ which is a function of N and a_{1i}

only. Similarly, the FDL for v_2 is given by $\partial f_2(a_2)/\partial a_{2i} = (a_{1i} + a_{2i}) * \partial B_{2i}/\partial a_{2i} + B_{2i}$ which is a function of N, a_{1i}, and a_{2i} only. Each node calculates these FDL's and finds the MFDL path from S to D.

The call routing procedure of the flooding algorithm is divided into three phases : forward search, backward routing, and supervision. The major difference between the modified flooding algorithm and the flooding algorithm is in the forward search phase. Here, we deal with the forward search scheme. When a subscriber wishes to call another user not affiliated with the same node, a forward search for that user begins by sending sequentially "request for routing" (RFR) messages to all adjacent nodes, starting with the trunk group which contains the most available circuits. If directory searches at these adjacent nodes do not find the called party listed, the RFR is further relayed to their adjacent nodes, and so on , until the reqest arrives at the node with which the called user is affiliated. In Fig. 1, node m receives the first search message from node a, after which the second search message from node b (and the third search message from node c, if any) will arrive at node m within △ time. Then, node m calculates FDL's and finds the shortest path MFDL from the source node S to mode m, that is,

$$MFDL_{s,m} = \min \lbrack FDL_{a,m} + MFDL_{s,a}, FDL_{b,m} + MFDL_{s,b}, FDL_{c,m} + MFDL_{s,c} \rbrack$$

where min stands for minimum. the search message with the above $MFDL_{s,m}$ information will then be retransmitted sequentially to other nodes, this search message propagation scheme is similar to the flood search algorithm. So far, the proposed algorithm with the decision rule provides the shortest path between S and D on the bases of blocking probability.

Ⅲ. Numerical Results

As mentioned, the performance measure used is average EEBP, i.e, P_B. The network topologies are depicted in Fig, 2; topology 1 (TOP1) has nine nodes, twelve links and three commodities, topology 2 (TOP2) has seven nodes, nine links and three commodities, topology 3 (TOP3) has nine nodes, fourteen links and three commodities, and topology 4 (TOP4) has ten nodes, twelve links and three commodities. The total external offered traffic of example topologies is shown in Table I. In Fig. 3, end-to-end blocking performance versus the total external traffic for high-priority voice traffic, A1(in

Erlangs), for topology TOP1 is plotted using a logarithmic scale. Three groups of curves correspond to the end-to-end blocking probability of (a) flood search, (b) modified flood search for low-priority voice, v_2, and (c) modified flood search for high-priority voice, v_1. It is seen that our modified flooding algorithm yields better blocking performance (curves b and c) than the flood search algorithm (curve a) under the same conditions. Also, the blocking performance for high-priority voice traffic with the modified flooding algorithm is superior to the others. We consider two different traffic load conditions which corresponds to the Case 1 in Table I, and in this case, N is fixed. It is clearly shown that if we use small values of total offered traffic for each commodity, the blocking performance (solid line) is better than the other using large values (dashed line). this is because the FDL path is affected by two factors; the number of channels, N, and the total offered load of priority p (p=1,2), a_p. The blocking performance for TOP2 and TOP3 in Case 2 is shown in Fig. 3. And it is seen that the blocking performance of TOP2. Considering the case 3, in Fig. 5, $\log(P_B)$ versus the channel number for TOP1, TOP3 and TOP4 are plotted; (a) modified flood search for high-priority voice, v_1, (b) modified flood search for low-priority voice, v_2, and (c) flood search. Increasing the number of channels with the total offered traffic fixed, the blocking performance becomes better, and the modified flood search for high-priority voice (curve a) shows the best performance. Also, it is seen that the blocking performance of TOP3 with the same offered load is superior to others. This is because TOP3 has more links than others. From the numerical results for a circuit-switched network with tow priority classes of voice traffic presented above, we can conclude that the proposed algorithm yields a strictly better blocking performance than the flooding algorithm. Specifically, the modified flooding for high-priority voice traffic shows excellent performance.

As for the processing and call set-up time, the total switch processing time per attempt of the modified flooding algorithm takes only 471 μs which is about one tenth that of the flood search algorithm, and the call set-up time for a 15 link-call of the modified flooding algorithm takes 582 ms which is less than of the flood search algorithm [9]. Thus, one can conclude that, using the modified flooding algorithm with MFDL path, one can improve the blocking performance of a circuit-switched network without increasing the call set-up time and processor loading of the algorithm.

Ⅳ. Conclusions

In this paper, we have proposed a modified flooding algorithm with MFDL path for a tactical circuit-switched grid network with a maximum of four links and two priority classes of voice traffic. We have considered the minimization of average EEBP, and studied the blocking performance of the modified flooding algorithm and the flood search algorithm. Also we have suggested the decision rule for the search message propagation scheme and analyzed the signaling traffic load of the algorithm.

With the same or less cost of switch processor loading and call set-up time as compared to the food search algorithm, the modified flooding algorithm provides the shortest path on the bases of blocking probability, Therefore, one can improve the blocking performance of a circuit-switched network. And our system provides the excellent blocking performance for high-priority voice traffic, which is very important for high-priority subscribers in tactical network. Clearly, one can see that in military applications of the technique, our scheme can improve the network efficiency over the conventional flood search algorithm.

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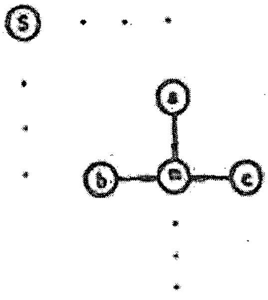


Fig.1 Reception of the forward search-messages at intermediate node m(S=source node, (a,b,c)= neighbor nodes of m).

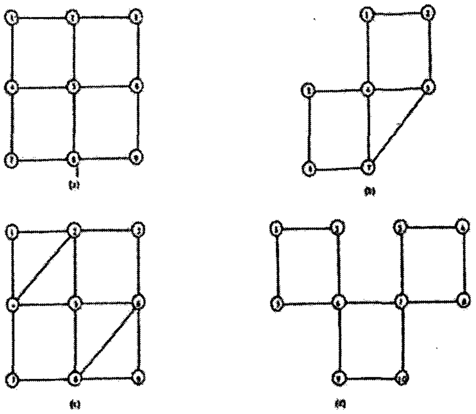


Fig. 2. Network topologies
(a) TOP1 (b) TOP2 (c) TOP3 (d) TOP4

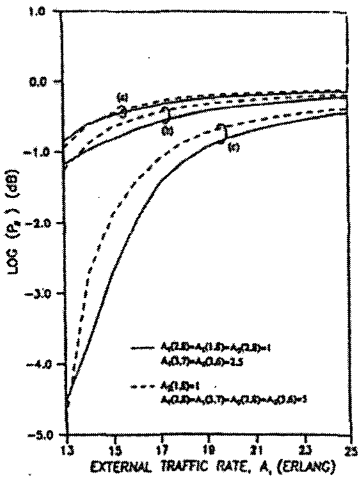


Fig. 3. Log(PB) versus external traffic rate, A1 (in Erlang), for TOP1
(a) conventional flood search
(b) modified flood search for low-priority voice, v2
(c) modified flood search for high-priority voice, v1.

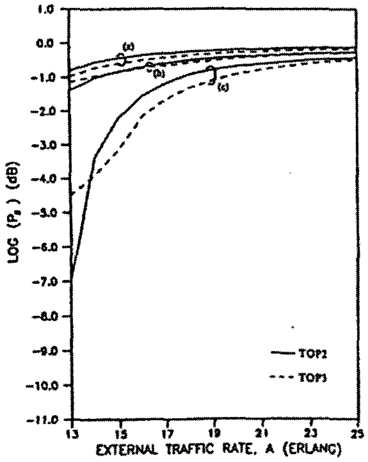
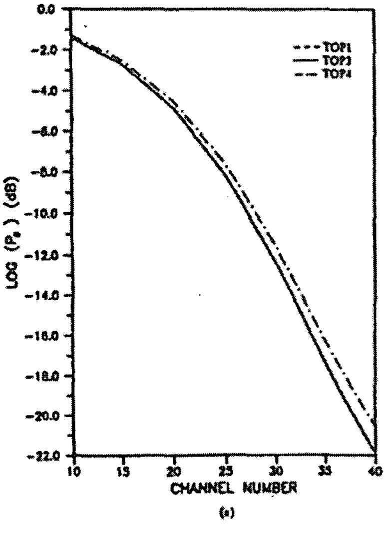


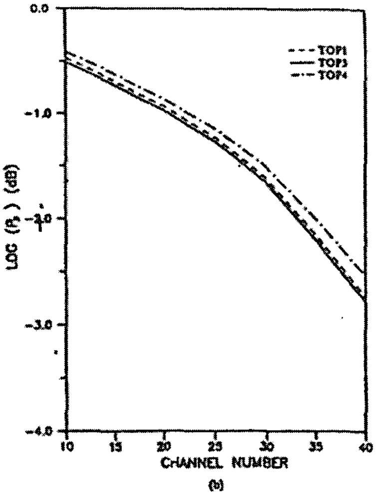
Fig. 4. Log(PB) versus external traffic rate, A1 (in Erlang), for TOP2 and TOP3

(a) conventional flood search

(b) modified flood search for low-priority voice, v2

(c) modified flood search for high-priority voice, v1.





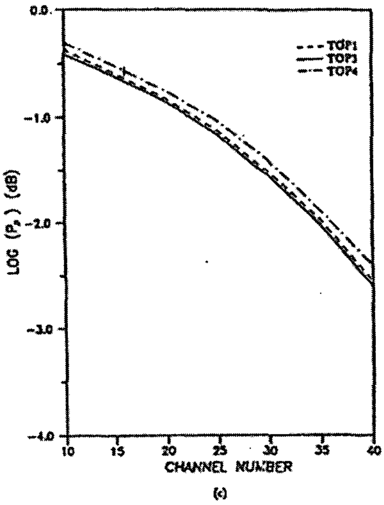


Fig. 5. Log(PB) versus the channel number for TOP1, TOP3 and TOP4.

(a) modified flood search for high-priority voice, v1

(b) modified flood search for low-priority voice, v2

(c) conventional flood search

Case	Topology	No. of Commodities (v_1/v_2)	No. of Channels	Total Offered Traffic (Erlangs)		
				Commodity 1	Commodity 2	Commodity 3
Case 1	Top 1	3/3	30	$A_1(1,9)$=VA1 $A_2(1,8)=1$	$A_1(2,8)=1$ $A_2(2,8)=1$	$A_1(3,7)=2.5$ $A_2(3,6)=2.5$
				$A_1(1,9)$=VA1 $A_2(1,8)=1$	$A_1(2,8)=5$ $A_2(2,8)=5$	$A_1(3,7)=5$ $A_2(3,6)=5$
Case 2	Top 2	3/3	30	$A_1(1,10)$=VA1 $A_2(1,9)=1$	$A_1(2,8)=1$ $A_2(2,8)=1$	$A_1(4,9)=2.5$ $A_2(4,10)=2.5$
	Top 3	3/3	30	$A_1(1,9)$=VA1 $A_2(1,8)=1$	$A_1(2,8)=1$ $A_2(2,8)=1$	$A_1(3,7)=2.5$ $A_2(3,6)=2.5$
Case 3	Top 1	3/3	VA2	$A_1(1,9)=12$ $A_2(1,8)=12$	$A_1(2,8)=1$ $A_2(2,8)=1$	$A_1(3,7)=2.5$ $A_2(3,6)=2.5$
	Top 3	3/3	VA2	$A_1(1,9)=12$ $A_2(1,8)=12$	$A_1(2,8)=1$ $A_2(2,8)=1$	$A_1(3,7)=2.5$ $A_2(3,6)=2.5$
	Top 4	3/3	VA2	$A_1(1,9)=12$ $A_2(1,8)=12$	$A_1(2,8)=1$ $A_2(2,8)=1$	$A_1(3,7)=2.5$ $A_2(3,6)=2.5$
Note		v_1=high-priority voice, v_2=low-priority voice A_p=(S,D)=total offered voice traffic of priority p ($p=1,2$) from source (S) to destination (D) node VA1=13-25, VA2=10-40				

Table 1. Experiment cases and offered traffics of example topologies.

박영철

1975년 서강대학교 전자공학과 (공학사)

1981년 서강대학원 전자 공학과(통신공학 석사)

1991년 한국과학기술원 전기 및 전자공학과공학 박사), 데이터 통신전공

1997~1998년 Univ. of California, Santa Barbara, Post-Doc, 위성 통신 연구

1976~2000년 국방과학 연구소 책임 연구원

1982년~1983년 미국 AMMRC연구소 교환연구원

2001~현재 천안대학교 정보기술 대학원장

관심분야 : 데이터 통신, 컴퓨터 네트워크, 위성통신, 무선 Internet, DVR 등.