Performance of a Time Slot Searching Mechanism in Multi-rate Circuit Switching System

Seung Kye Roh*, Kwang Ho Kook*, Jae Sup Lee*, Min Young Chung**, and Dan Keun Sung**

ABSTRACT

The blocking probabilities of nx64Kb/s multi-slot calls are generally much higher than that of single slot calls. In order to improve these blocking probabilities of multi-slot calls, we propose a scheme which searches the different numbers of time slots for different types of calls. We analyze the performance of our scheme in a double-buffered time-space-time switching network which accommodates multi-slot calls as well as single-slot calls. The proposed method yields the reduced blocking probabilities, the increased traffic handling capacity and the reduced CPU processing load, compared with those of the conventional methods.

Key words : multi-slot call, blocking probability, traffic handling capacity, processing load

1. Introduction

As the Integrated Services Digital Networks(ISDN) evolve from the conventional narrowband switching systems, users demand more diverse services, such as video conference, high speed data, still image, and hi-fi sound. These nx64Kb/s($n \leq 30$) services not exceeding the primary rate(2.048Mb/s) can be accommodated by assigning n 64Kb/s time slots in narrowband ISDN switching systems. In order to accommodate these multi-slot calls, we generally encounter two important problems, i.e., the time slot sequence integrity(TSSI) and the higher blocking probabilities for multi-slot calls.

The time slot sequence integrity[4, 5, 6] is generally required to accommodate multi-slot calls in multi-stage time-space-time switching networks. However, these TSSI requirements can be implemented without great difficulty by using double-buffered time-switches. We here consider a

* Electronics and Telecommunications Research Institute
** Korea Advanced Institute of Science and Technology

double-buffered time-space-time(T-S-T) switching network in this paper.

The blocking probabilities of nx64Kb/s multi-slot calls are generally much higher than that of single-slot calls. These blocking probabilities may be lowered by several methods, such as reservation schemes[2, 3] and equalization expansion method[1]. The former methods may incur inconvenience to the users and the latter one yields a little improvement in traffic handling capacity. In this paper, we propose a time slot searching mechanism which searches different numbers of time slots to find required matching time slots for different types of calls where matching time slots represent idle time slots at the same location of the incoming and outgoing time switches such that it can be used for a new call. This proposed scheme exhibits better performance in processing load, traffic handling capacity, and the blocking probabilities of multi-slot calls, compared with those of the conventional methods.

The overall organization of this paper is as follows. In section 2 we introduce a double-buffered time-space-time switching network. In section 3 we derive blocking probabilities of both single-slot and multi-slot calls and the CPU processing load in terms of the mean number of time slots searched for both single-slot and multi-slot calls, based on the proposed time slot searching method and also compare the traffic handling capacity with those of two conventional methods. In section 4, we have a conclusion.

2. A DOUBLE-BUFFERED TIME-SPACE-TIME SWITCHING NETWORK

We consider a double-buffered time-space-time switching network as shown in Figure 1. This

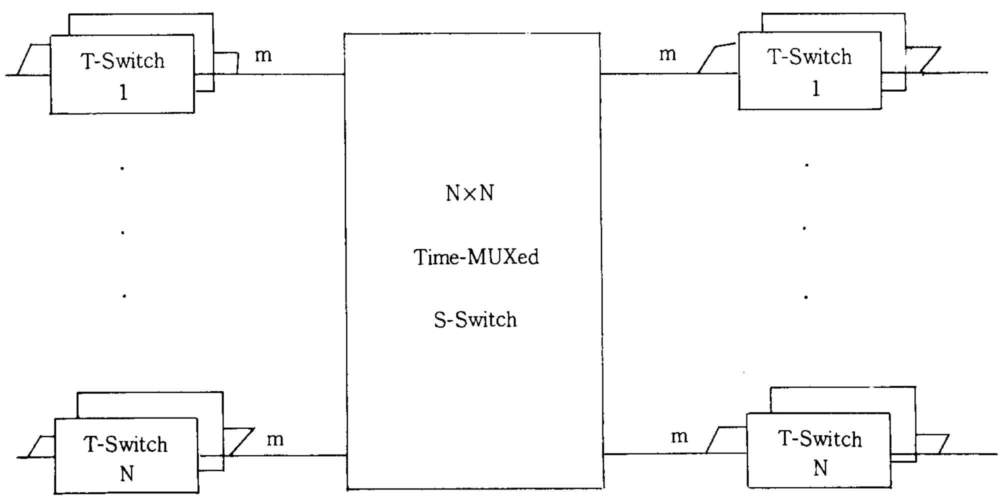

Figure 1. A typical double-buffered T-S-T switching network

switching network consists of N incoming and outgoing double-buffered time switches, a NxN space switch, and N incoming and outgoing highways with m time slots per each highway. Note that incoming and outgoing time switches are double-buffered systems that can maintain the time slot sequence integrity of multi-slot calls.

Since blockings of nx64Kb/s multi-slot calls in the above described switching network can occur either in incoming/outgoing time switches due to insufficient number of idle time slots or in the space switch due to mismatches between incoming and outgoing highways, we here consider the end-to-end blocking probabilities rather than the internal blocking probabilities only due to the space-switch mismatches.

3. PERFORMANCE ANALYSIS

The blocking probabilities of nx64Kbps multi-slot calls are generally much higher than that of single-slot calls, if we use the conventional complete sharing method in which any time slot in the switching network can be evenly assigned for multi-slot and single-slot calls.

We now propose a time-slot searching method in which type i calls are assigned the maximum number of time slots, α_i, that can be searched for matching time slots. Extending the Beshai and Manfield's result[1], we derive the end-to-end blocking probabilities and the mean number of time slots searched for single-slot and multi-slot calls.

Suppose that type i calls, $i=1,2,\cdots,s$, requiring v_i time slots arrive at each incoming time switch as a Poisson process with a mean arrival rate λ_i. We also assume that the holding time of each type of calls follows the same exponential distribution with the mean service time, $1/\mu$, for mathematical convenience. Then, the weighted offered traffic per each time switch for type i calls is $a_i=\lambda_i v_i/\mu$.

Let x and y denote the number of busy time slots in the corresponding incoming and outgoing time switches for a call setup, respectively. Then the probability that there exist k matching time slots between the corresponding incoming and outgoing time switches can be determined by the following hypergeometric distribution.

$$g_{k,x,y} = \binom{m-x}{k}\binom{x}{m-y-k}\Big/\binom{m}{y}, \quad x\le m-k,\ x+y\ge m-k, \qquad (1)$$

where m is the number of time slots at each time switch.

The internal blocking probability of type i calls requiring n time slots at state (x, y) can be obtained by

$$f_{n,x,y} = \begin{cases} 1, & m-n<x\leq m,\ m-n<y\leq m, \\ \sum_{k=0}^{n-1} g_{k,x,y} + \sum_{k=n}^{m-\max(x,y)} g_{k,x,y} \left(\sum_{z=0}^{n-1} \binom{\alpha_i}{z} \binom{m-\alpha_i}{k-z} \Big/ \binom{m}{k} \right), & x+y>m-n,\ x\leq m-n,\ y\leq m-n, \\ \sum_{k=n}^{m-\max(x,y)} g_{k,x,y} \left(\sum_{z=0}^{n-1} \binom{\alpha_i}{z} \binom{m-\alpha_i}{k-z} \Big/ \binom{m}{k} \right), & \text{otherwise,} \end{cases} \quad (2)$$

where α_i is the maximum number of time slots that can be searched to find n matching time slots of type i calls.

Let p_x and q_y be the probabilities of the incoming time switch in state x and the outgoing time switch in state y, respectively. If we assume that the offered traffic is uniformly distributed throughout the switching network, then $p_x=q_y$ for all $x=1, 2, \cdots, m$. The transition probability from state x to $(x+n)$, $F_{n,x}$, is

$$F_{n,x} = 1 - \sum_{y=0}^{m} f_{n,x,y}\, q_y, \quad x=0, \cdots, (m-n), \text{ where } q_y = p_y \quad (3)$$

and p_x can be obtained by

$$\sum_{i=1}^{S} a_i F_{v_i, x-v_i}\, p_{x-v_i} = x p_x, \qquad x=1, 2, \cdots, n, \qquad p_j = F_{\cdot, j} = 0 \text{ for } j<0, \ \sum_{x=0}^{m} p_x = 1 \quad (4)$$

Let a_i, b_i, c_i, and C denote the weighted offered traffic, the end-to-end blocking probability, the carried traffic of type i calls, and the combined carried traffic for s types of calls, respectively. Then the carried traffic of type i calls is given by

$$c_i = a_i \sum_{x=0}^{m-v_i} F_{v_i,x}\, p_x \quad (5)$$

and the end-to-end blocking probability is

$$b_i = 1 - c_i / a_i \quad (6)$$

and the combined carried traffic for s types of calls can be computed as follows

$$C = \sum_{x=1}^{m} x\, p_x = \sum_{i=1}^{S} c_i \quad (7)$$

In order to verify our analytical model, we consider a double-buffered T-S-T switching network in which time switches have 256 time slots and the space switch consists of a 20x20 matrix switch. We also assume that 2 types of calls are offered to the switching network. Type 1 calls require a single time slot and Type 2 calls require 6 time slots. Figure 2 shows the blocking probabilities of 2 types of calls when the number of searching idle time slots for type 1 calls is varied (the traffic mixture ratio of type 1 and type 2 calls is 80:20 and the offered traffic is 0.8 erlang/time slot). The simulation result is very close to analytical one. The result also shows that the blocking probability of 6-slot calls decreases as the number of searching idle time slots for single-slot calls is decreased.

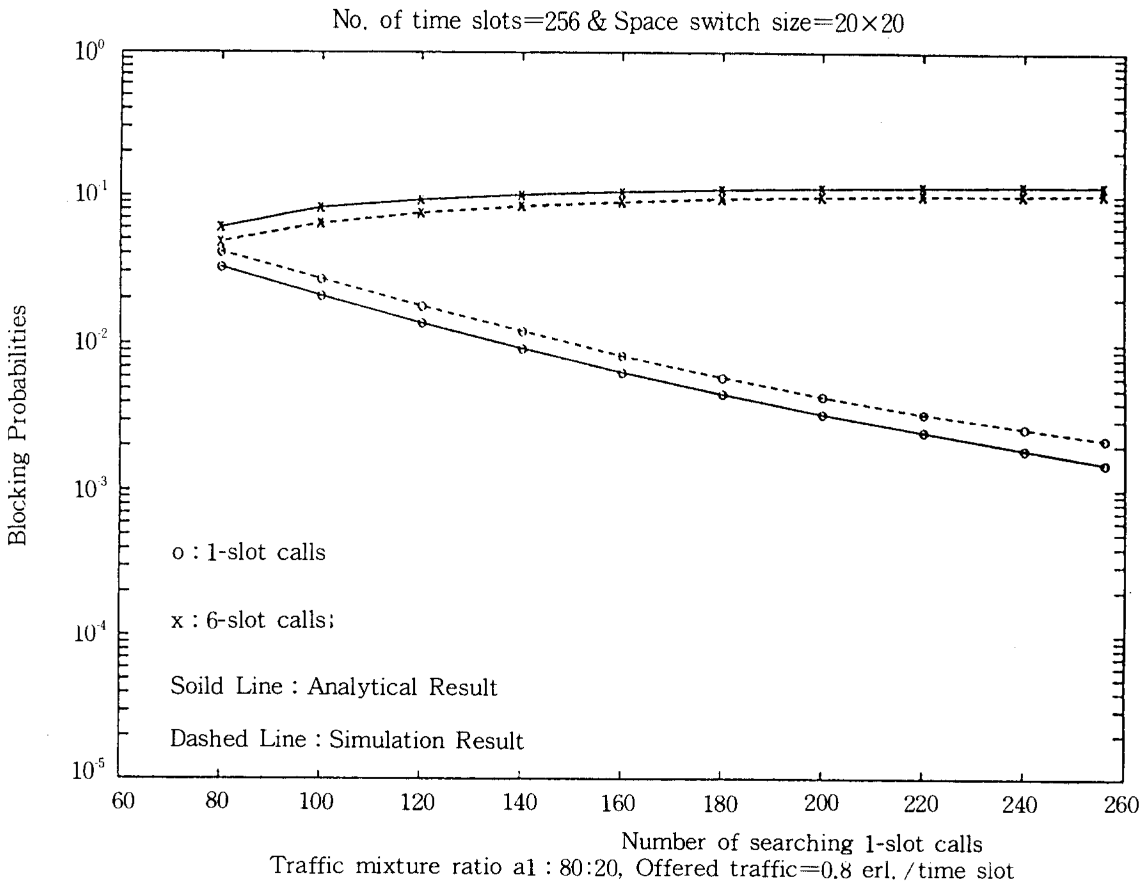

Figure 2. Blocking probabilities when the number of searching idle time slots for single-slot calls is varied

Figure 3 shows blocking probabilities of both single-slot calls and 6-slot calls under varying offered traffic when we use two different methods, i.e. the full-searching method(α_1=m) and the partial-searching method(α_1=100<m), where α_1 is the number of searching idle time slots for single-slot calls. The result shows that the blocking probability for 6-slot calls improves by using the partial-searching method, while the blocking probability for single-slot calls becomes worse.

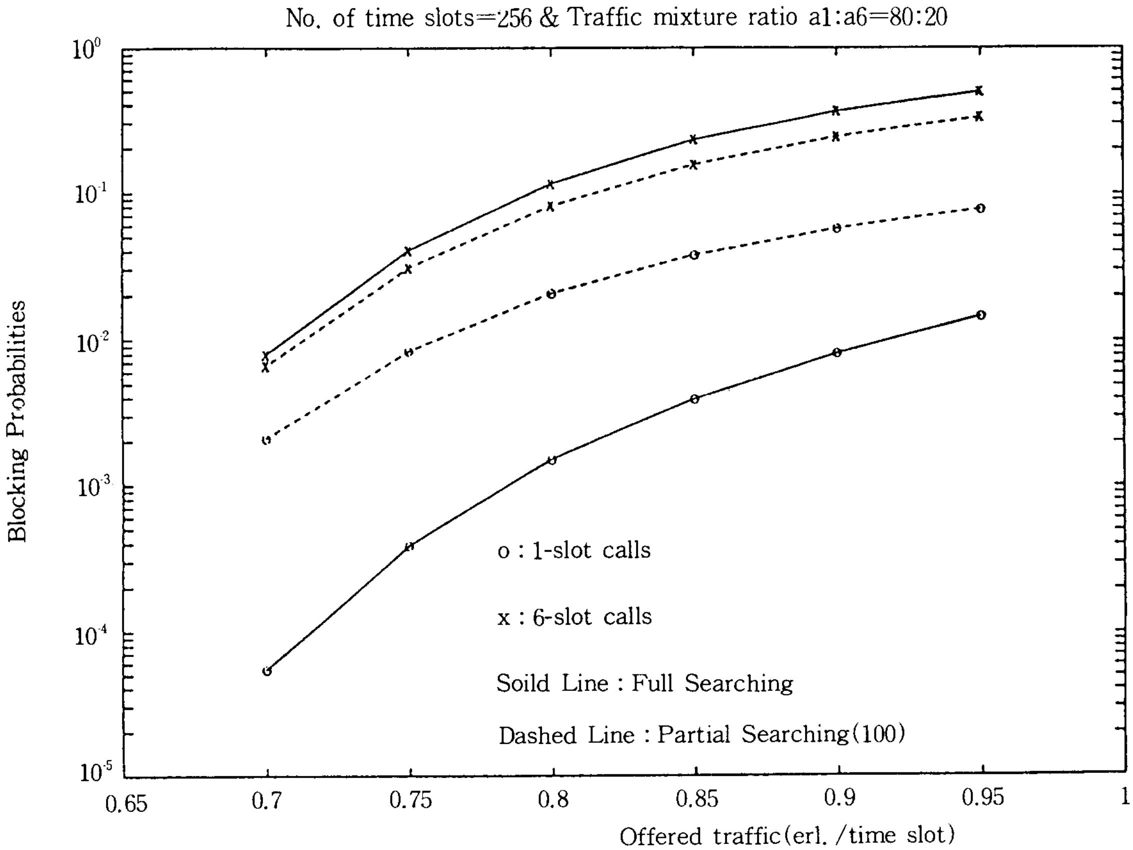

Figure 3. Blocking probabilities under varying offered traffic

We now compare the performance of the proposed method in terms of traffic handling capacity with those of the conventional full-searching method and the Beshai and Manfield's method. In the Beshai and Manfield's method, calls are blocked if the number of busy time slots in the time switch is greater than or equal to △. The traffic handling capacity is defined as the maximum carried traffic satisfying grade-of-service(GOS) requirement of each type calls. Since the GOS requirements for multi-slot calls have not been specified by the CCITT(The International Telegraph and Telephone Consultative Committee), we consider the blocking probability of single-slot calls b_1=0.01 and the blocking probability of 6-slot calls b_6=0.05, 0.02, and 0.01, for convenience. Table 1 shows a performance evaluation in terms of the carried traffic for three different call allocation methods. The proposed method exhibits best performance in the traffic handling capacity.

Table 1. Performance evaluation in traffic handling capacity

Reqired Blocking Probability	Complete Sharing Method	Beshai and Manfield's Method	Proposed Method
b1 = 0.01 b6 = 0.05	C = 192.0 O = 0.758×256 = 194.048	C = 192.7 O = 0.766×256 = 196.096 (△ = 231)	C = 193.1 O = 0.768×256 = 196.608 (α_1 = 109)
b1 = 0.01 b6 = 0.02	C = 184.8 O = 0.725×256 = 185.6	C = 185.6 O = 0.732×256 = 187.392 (△ = 228)	C = 186.6 O = 0.738×256 = 188.928 (α_1 = 85)
b1 = 0.01 b6 = 0.01	C = 180.1 O = 0.705×256 = 180.48	C = 180.8 O = 0.709×256 = 181.504 (△ = 232)	C = 182.2 O = 0.719×256 = 184.064 (α_1 = 73)

We now evaluate the blocking probabilities under varying offered traffic with the fixed traffic mixture ratio ($a_1 : a_6 = 80 : 20$) for the proposed method and the Beshai and Manfield's method. The result is shown in Table 2. The proposed method generally yields better performance in blocking probabilities than the Beshai and Manfield's method even in case of varying offered traffic.

We now compute the processing load in terms of the mean number of searching idle time slots. The probability that there exist k_i matching time slots within α_i time slots, when there exist k matching time slots between the corresponding incoming and outgoing highways, can be obtained by the hypergeometric distribution

$$h_{k,\alpha_i,k_i} = \binom{\alpha_i}{k_i}\binom{m-\alpha_i}{k-k_i}\Big/\binom{m}{k}, \qquad k_i \le k,\ k_i \le \alpha_i,\ m-\alpha_i \ge k-k_i. \tag{8}$$

Table 2. Blocking probabilities under varying offered traffic

(a1+a6) /m	Mixture Ratio	Proposed Method (α_i = 84)	Beshai and Manfield's Method (△ = 224)
0.70	80 : 20	b1=3.77864e-03 b6=5.93686e-03 b6 / b1=1.57116	b1=4.96752e-03 b6=8.00259e-03 b6 / b1=1.61098
0.75	80 : 20	b1=1.31191e-02 b6=2.65594e-02 b6 / b1=2.02448	b1=1.52390e-02 b6=3.04462e-02 b6 / b1=1.99792
0.80	80 : 20	b1=2.94960e-02 b6=6.97349e-02 b6 / b1=2.36422	b1=3.20993e-02 b6=7.50112e-02 b6 / b1=2.33685
0.85	80 : 20	b1=5.04769e-02 b6=0.131718 b6 / b1=2.60948	b1=5.34166e-02 b6=0.137341 b6 / b1=2.57114

Let $\Phi_{n,k_i,j}$ denote the probability of finding n matching time slots after searching j time slots when there exist k_i matching time slots between the corresponding incoming and outgoing highways. The probability of finding n matching time slots after searching j time slots is equal to the probability of finding n-1 matching time slots within searching j-1 time slots multiplied by the probability that the j-th time slot is a matching time slot, and it can be determined by

$$\Phi_{n,k_i,j} = \left\{ \binom{k_i}{n-1} \binom{\alpha_i - k_i}{j-n} \Big/ \binom{\alpha_i}{j-1} \right\} \left\{ \frac{(k_i - n + 1)}{(\alpha_i - j + 1)} \right\}, \quad k_i \geq n-1,\ n \leq j \leq \alpha_i + n - k_i. \tag{9}$$

The expected number of searching idle time slots until n matching time slots are obtained when there exist k_i matching time slots becomes

$$\Psi_{n,k_i} = \sum_{j=n}^{\alpha_i + n - k_i} j \Phi_{n,k_i,j} = n(\alpha_i + 1) / (k_i + 1). \tag{10}$$

The expected number of searching idle time slots to find n matching time slots at state (x, y) can be obtained by

$$W_{n,x,y} = \sum_{k=n}^{m} g_{k,x,y} \left(\sum_{k_i=n}^{\min(k,\alpha_i)} n(\alpha_i+1)/(k_i+1) h_{k,\alpha_i,k_i} + \alpha_i \sum_{k_i=0}^{n-1} h_{k,\alpha_i,k_i} \right) + \alpha_i \sum_{k=0}^{n-1} g_{k,x,y} \qquad (11)$$

Finally, the overall mean number of searching idle time slots for type i calls requiring n matching slots, E_n, can be computed as follows

$$E_n = \sum_{x=0}^{m-n} p_x \sum_{y=0}^{m-n} p_y W_{n,x,y} \qquad (12)$$

We now evaluate the mean number of searching idle time slots for 2 types of calls. Figure 4 shows the mean number of searching idle time slots of both single-slot calls and 6-slot calls under

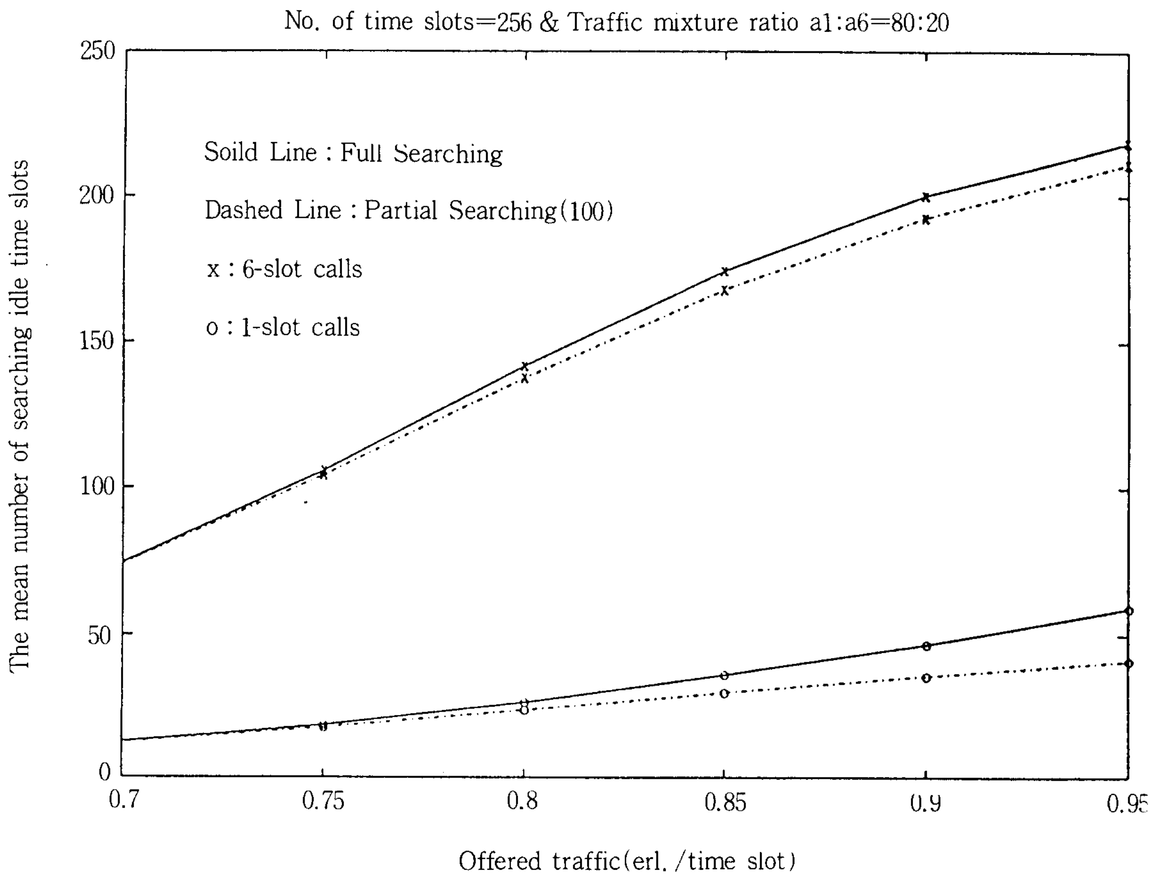

Figure 4. The mean number of searching idle time slots under varying offered traffic

varying offered traffic when we use two different methods, i.e. the full-searching method and the partial-searching method. The result shows that the mean number of searching idle time slots of single-slot calls and 6-slot calls under the partial-searching method($\alpha_1=100$) are less than that of full-searching method($\alpha_1=256$) and the degree of improvement becomes greater as the offered traffic increases. Suppose that the offered traffic is 0.8 erlang/time slot, the BHCA(Busy Hour Call Attempts) of both single-slot calls and 6-slot calls are 32768 and 1365, respectively. At this offered traffic load the total number of searching idle time slots of both single-slot calls and 6-slot calls can be reduced by about 91095 and 5678, respectively, compared with that of full searching method. The proposed method yields a reduction in the mean number of searching idle time slots because the maximum number of time slots searched for single-slot calls can be reduced.

4. CONCLUSION

The blocking probabilities of nx64Kb/s multi-slot calls are generally much higher than that of single-slot calls. In this paper we proposed a method in which type i calls search up to α_i time slots to find the required matching time slots in order to improve the blocking probabilities of multi-slot calls. We analyzed the performance of the double-buffered time-space-time switching network in terms of the processing load, the blocking probabilities and the traffic handling capacity, and compared the performance of the proposed method with other methods. The results show that the overall performance in blocking probabilities of multi-slot calls and the traffic handling capacity of the proposed method is better and the CPU processing load could be reduced by limiting the number of searching idle time slots for some types of calls, compared with those of other methods.

REFERENCES

1. Beshai, M. E. and Manfield, D. R., "Multichannel services : performance of switching networks", *Proc. ITC 12*, (1988), 5.1A7.1.
2. Kroner, H., Kuehn, P.J. and Willmann, G., "Performance comparison of resource sharing strategies between last-calls-cleared and reserved traffic", *Proc. ITC 13*, (1991).
3. Liary, Y., Liao, K. and Simonian, A., "Queueing models for reserved setup telecommunication services", *Proc. ITC 12*, (1988).
4. Masuda, E., "Evaluation of traffic characteristics of nx64Kb/s calls in a time division switching network satisfying the sequence integrity between n time-slots", *Trans. of IEICE* (Japan), Vol. J69-B, No. 10(1987), pp.919-927.
5. Sung, D. K., Chung, M. Y., and Oh, S. Y., "Traffic characteristics of time slot allocation with time slot sequence integrity for nx64Kb/s multislot connection calls", *Proc. ITC 13*, (1991), *Discussion Circle*, pp.105-110.
6. Takahashi, T., "Time-slot sequence integrity for (Nx64)Kb/s connection", *Trans. of IEICE* (Japan), Vol. J69-B, No. 10(1986), pp.1038-1045.