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전전자교환기 스위치 네트워크의 트래픽 및 신뢰도 분석

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Trafficability and Reliability Analysis for the Digital Switching Network

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Abstract

As a 'throughput-preferred' system, one of the important performance criteria of the switch network is the blocking probability. In this study, an attempt is made to analyze the switch network blocking probability of the TDX-10, a digital switching system, considering the presence of failure. And the new concept AVBP (Average Blocking Probability) is introduced.

1. Introduction

In complex system which consists of a large number of components, it is very undesirable that a component failure leads to the total system down. The switch network of a switching system is a good example for such system. It is designed to operate at degraded performance level corresponding to the various possible combinations of failures.

As a 'throughput-preferred' system, one of the important performance criteria of the switch network is the blocking probability. The switch network should handle all the traffic from subscriber lines and trunk lines with limited number of service channels. If more call attempts are made than can be accomodated and idle service channel can't be found, the call is said to be blocked. Blocking probability, which is defined as the average channel of no service channel being available [1], varies depending upon the degree of failures in the switch network.

To consider the effect of failures, we must identify the failure states where the switch network is still operational but with much higher blocking probability. At each failure state the correspondng blocking probability can be evaluated. By analyzing the Markov reliability model, the limiting probability of being in each failure state is derived. And average blocking probability can be obtained from the multiplication of the blocking probability and the limiting probability of each failure state.

In this study, an attempt is made to analyze the switch network blocking probability of the TDX-10 [2,4], a digital switching system, considering the presence of failure. Followed by the system description of the switch network, this paper consists of three major parts ; 1) calculation of the blocking probability under the presence of failure, 2) derivation of the average blocking probability by analyzing the Markov reliability model, 3) illustrative example and discussion.

2. System Description

As shown in the figure 1, the group switch of TDX-10 has the typical T-S-T structure : time switch (T-SW) of 4096 time slots and space switch (S-SW) of 32K time slots with 64x64 matrix structure. The time switches of both directions (transmitting and receiving) reside in Access Switching Subsystem (ASS). The ASS accomodating subscriber and trunk lines can be extended to maximum 60. Two space switches are located in Interconnection Network Subsystem (INS), while only one space switch can be employed for the small capacity TDX-10. Each T-SW is linked to the S-SW with 512 time slots. Hence 1024 time slots (512x2) are available for the connection of T-SW and S-SW. Maximum 32 out of 512 time slots can be allocated for the inter processor communication (IPC). Therefore, the least number of time slots are 960 (480x2) for the communication path between T-SW and S-SW's [3].

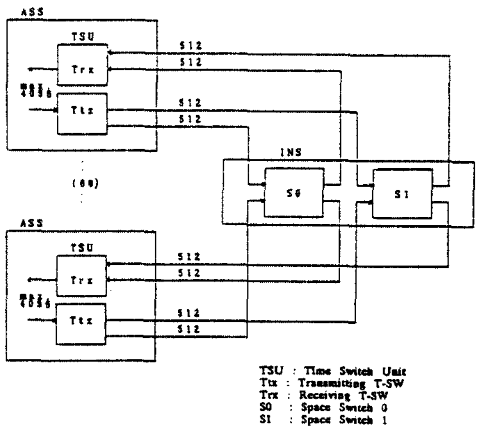

Figure 1. The Structure of TDX-10 Switch Network

Path Searching Algorithm

For a call completion, two speech paths should be established through the switch network in both directions of the originating and the terminating. Out of 960 time slots available only n($\leq$960) time slots are searched for a speech path under the control of switch processor. A speech path can be established only when the same numbered idle time slots are available in the transmitting T-SW (Ttx) and the receiving T-SW (Trx). The call is blocked if the idle time slots can't be found in any direction. Symmetric path searching algorithm is employed to search for the idle time slots in both direction. It searches for same numbered idle time slots in any one direction, and the time slots in other direction is symmetrically determined.

Suppose k^{th} time slots are allocated in the first Ttx and the second Trx for building up the speech path from subscriber A to B. Let c denote the number of available time slots between a T-SW and S-SW's. If $k \leq c/2$, $(k+c/2)^{th}$ time slots are allocated in the second Ttx and the first Trx for the speech path from subscriber B to A. In the case of $k > c/2$, $(k-c/2)^{th}$ time slots are employed.

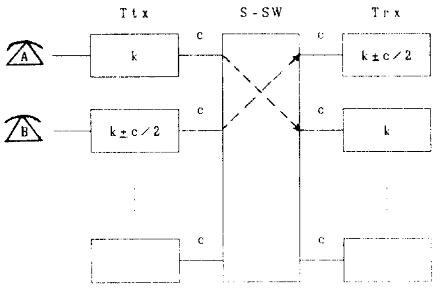

Figure 2. Symmetric Path Searching Algorithm

Reliability

The failures in the T-SW or S-SW affect the blocking probability in the switch network. The failure effect can be summarized as follows.

S-SW failure : Any one failure of two S-SW's causes the traffic to be concentrated to the alive S-SW. Under the failure of both S-SW's, no speech path can be established.

T-SW failure : According to the path searching algorithm, either Ttx or Trx failure of the T-SW does not allow to constitute the speech path. A T-SW failure blocks all the call attempts from and to the subscribers linked to this T-SW.

Failures in the switch network can be classified into several states depending on the number of failures of T-SW's and S-SW's. Let (i,j) denote the number of operating S-SW and T-SW at a particular time, and P(i,j) be the steady state probability that the switch network system is in state (i,j). This probability can be obtained by analyzing the Markov reliability model of the switch network.

AVBP (Average Blocking Probability)

The blocking probability, which is defined as the probability that idle time slots can't be found for a call requiring switch connection, varies depending upon the failure state of the switch network. Let BP(i,j) denote the blocking probability of the switch network under the failure state (i,j). Then average blocking probability can be calculated as

$$AVBP = \sum_j \sum_i P(i,j) \cdot BP(i,j) \qquad (1)$$

where BP(i,j) will be obtained in the next section under the general set of assumptions.

3. Development of Model

Based on the state transition diagram for the switch network system, Markov reliability analysis is performed for deriving the limiting probability that the system is in a particular failure state. An analytical model for the blocking probability under the presence of failure is also constructed under the general set of assumptions.

3.1 Steady State Probability

Assumptions

1. All failure events are statistically independent.
2. The system is used over an infinite time span.
3. Failures are detected at once during operation (self announcing).
4. Transition rates from one state to another are constant
5. In system inoperable states, no failure event occurs.
6. Repairs are simultaneously made over all the failures.

Notations

λ_T : T-SW failure rate
λ_S : S-SW failure rate
μ_T : T-SW repair rate
μ_S : S-SW repair rate
m : number of T-SW

State Transition Diagram

Under the assumptions given above, the state transition diagram can be drawn as shown in the figure 3.

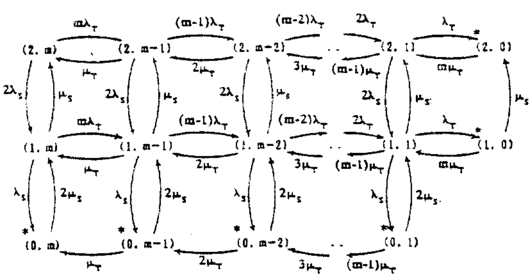

Figure 3. State Transition Diagram of the Switch Network

If failure occurs in S-SW or T-SW, the system still functions but in degradation state. Either two S-SW's failure or m T-SW's failure leads to the inoperable system state. In the figure 3, the states with * denote the inoperable system state, where no failure event occurs and only repairs are made.

Steady State Probability

Based on the transition diagram of the figure 3, the limiting probability P(i,j) can be obtained from the following set of balance equations and $\sum_j \sum_i P(i,j)=1$.

State	Balance Equations
(2,m)	$P(2,m)(m\lambda_T+2\lambda_S) = P(2,m-1)\mu_T + P(1,m)\mu_S$
(2,m-1)	$P(2,m-1)(\mu_T+(m-1)\lambda_T+2\lambda_S) = P(2,m)m\lambda_T + P(2,m-2)2\mu_T + P(1,m-1)\mu_S$
⋮	⋮
(0,1)	$P(0,1)(2\mu_S+(m-1)\mu_T) = P(1,1)\lambda_S$

(2)

3.2 Blocking Probability

Assumptions

1. A S-SW failure causes the traffic to be concentrated on the alive S-SW.
2. The traffic is equally distributed over the operating T-SW's.
3. Busy terminating subscriber or trunk lines are excluded from the consideration.

Notations

- n : Number of searching trials
- d : Number of time slots for inter processor communication
- c : Number of available time slots between a T-SW and S-SW's
- a(i,j) : Occupancy rate of a time slot available at state (i,j)
- T : Offered traffic to the switch network

Blocking Probability

First, consider the blocking probability of the switch network in no failure state, that is, system state (2,m). Let p denote the probability that a pair of time slots is available in one direction and n be the maximum number of time slot searching trials. n is assumed to have the value less than c/2. The searching starts at any point between 1^{st} and c^{th} time slot and is performed cyclically. As discussed previously, if idle time slots are found in any one direction, the communication path can be automatically established by allocating symmetric time slots in other direction. Therefore, the blocking probability of the switch network can be calculated from the probability of no idle time slot being available in one direction. That is,

$$BP(2,m) = (1-p)^n \quad (3)$$

Let us assume that the communication path from subscriber A to B is required through a certain set of Ttx and Trx. For the path to be built up, at least one pair of same numbered time slots should be available. Define event E_1 and E_2 as

E_1 : k^{th} time slot "idle" in the transmitting T-SW
E_2 : k^{th} time slot "idle" in the receiving T-SW

Under the assumption that traffics are equally distributed over the T-SW's, p can be expressed as

$$p = Pr(E_1 \cap E_2) = Pr(E_1) \cdot Pr(E_2 \mid E_1) \quad (4)$$

If a(2,m) denote the average occupancy rate of a time slot in no failure state, then

$$Pr(E_1) = 1-a(2,m) \quad (5)$$

$$Pr(E_2 \mid E_1) = 1-\frac{m-1}{m}a(2,m) \quad (6)$$

In above equation, a(2,m) can be obtained from the carried traffic (2T(1-BP(2,m)) devided by the total number of time slot available. In this equation, 2T stands for the traffic of the both direction in the switch network.

$$a(2,m)=2T(1-BP(2,m))/(2m(512-d)) \quad (7)$$

Finally from the equations (3)~(7), BP(2,m) can be expressed as

$$BP(2,m)=\{1-(1-a(2,m))(1-\frac{m-1}{m}a(2,m))\}^n \quad (8)$$

Now, consider the blocking probability under the presence of failure, that is, system state (i,j), ($1\leq i \leq 2$, $1\leq j\leq m$). Assume that the communication path from subscriber A to B is required. Whether the concerned originating T-SW is alive or in failure state, two cases should be considered.

i) Originating T-SW is in failure state.
This case can happen with the probability of (m-j)/m. If the concerned T-SW is in failure state, all the calls from this T-SW is blocked. Therfore the blocking probability BP(i,j) is defined as 1.

ii) Originating T-SW is alive.
With the probability of j/m, the T-SW can be alive. Two subcases should be also taken into consideration whether the concerned terminating T-SW is alive or in failure state

ii-1) Terminating T-SW is in failure state.
The terminating T-SW can be in failure state with the probability of (m-j)/m. All the calls terminated to this T-SW are blocked. Therefore the blocking probability BP(i,j) is defined as 1.

ii-2) Terminating T-SW is alive.
The terminating T-SW can be alive with the probability of j/m. Now $Pr(E_1)$, $Pr(E_2 \mid E_1)$, and BP(i,j) can be obtained following the same logic as in "no failure state".

$$Pr(E_1) = 1-a(i,j) \quad (9)$$

$$\Pr(E_2 \mid E_1) = 1 - \frac{j-1}{j} \cdot a(i,j) \quad (10)$$

$$BP(i,j) = \{1-(1-a(i,j))(1-\frac{j-1}{j}a(i,j))\}^n \quad (11)$$

Finally BP(i,j) ($1 \le i \le 2$, $1 \le j \le m$) can be expressed as

$$BP(i,j) = (m-j)/m + (j/m)\{(m-j)/m + (j/m)\{1-(1-a(i,j))(1-(j-1)a(i,j)/j)\}^n \quad (12)$$

In above equation, a(i,j) can be expressed as

$$a(i,j) = 2T(j/m)^2(1-BP(2,m))/(i(512-d)j) \quad (13)$$

where $(j/m)^2$ is the correction factor due to the switch network failure in both direction.

In non-operable states, all the call attempts are blocked. That is,

$$BP(i,j) = 1, \text{ for } i=0 \text{ or } j=0 \quad (14)$$

4. Numerical Example

For illustrative purpose, suppose that TDX-10 switch network has 2 S-SW's and 3 T-SW's and accomodates 10,000 subscriber lines whose originating traffic is 0.1 erlang. Other data for the illustrative numerical example are given as follows.

$m = 3$
$\lambda_T = 9.08\times10^{-4}$/hrs
$\lambda_S = 1.83\times10^{-4}$/hrs
$\mu_T = \mu_S = 0.5$/hrs
$d = 32$
$n = 128$
$T = 1{,}000$ erlang

Using the balance equations (2) and equations (8), (12) and (14) the steady state probability (P(i,j)) and blocking probability (BP(i,j)) can be calculated. The results are summarized in table 1.

Table 1. Steady State Probability vs Blocking probability

(i,j)	P(i,j)	BP(i,j)
(2,3)	0.9405	2.4033×10^{-6}
(2,2)	5.1241×10^{-2}	0.5556
(2,1)	9.3054×10^{-4}	0.8889
(2,0)	5.6431×10^{-6}	1
(1,3)	6.8850×10^{-3}	0.2992
(1,2)	3.7485×10^{-4}	0.5574
(1,1)	6.7943×10^{-6}	0.8889
(1,0)	3.0846×10^{-8}	1
(0,3)	1.2830×10^{-7}	1
(0,2)	4.6146×10^{-7}	1
(0,1)	6.2168×10^{-9}	1

Finally AVBP can be obtained as

$$AVBP = \sum_j \sum_i P(i,j) \cdot BP(i,j) = 0.03158$$

5. Summary and Discussion

Analytical model for blocking probability under the presence of failure is derived under a general set of assumptions. The new concept "average blocking probability" is introduced, which combines the limiting probability of each failure state and the corresponding blocking probability. In the past the blocking probability of the switch network has been calculated only under no failure state. Therefore it has been always underestimated. In our numerical example the blocking probability in no failure state, BP(2,3), turns out to be 2.4033×10^{-6}, which is much lower than AVBP= 3.158×10^{-2}. This difference might become serious under high failure rate.

As well as hardware structure, path searching algorithm, and failure or repair rate of the switch network, number of time slot searching trials (n) and number of time slot allocated for IPC (d) have some effects on AVBP, which is shown in Table 2.

Table 2. Effect of "n" and "d" on AVBP

(%)

	32	16	8
128	3.158	3.142	3.135
256	3.151	3.136	3.128
480	3.148	3.132	3.124

The steady state probability P(i,j) obtained in this study is for the switch network of a single unit. Since the switch network of TDX-10 will be duplicated in reality, it has the higher probability of being in no failure state. Therefore AVBP is anticipated to have much lower value.

References

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