Traffic Analysis of Message Flow In Three Crossbar Architecture Space-Division Switches

D. Shukla[1] R. Singhai[2]

Abstract

In computer networks the space division switches are used to transmit the messages in order to reach its destinations. These switches are based on cross bar technology. Actually, it is built up of several smaller rectangular crossbars and less cross points is needed than the traditional cross bar switches. According to Tananbum (1996) if we increase the number of cross points, the outgoing reaching probability of messages also increases accordingly with the high cost and low congestion in the network. In this paper we considered the architecture of a three crossbar space-division switch and with the help of Markov chain theory, an L-dependent mathematical model is proposed and used to calculate reaching probabilities of message flow.

Keywords : Space-Division Switch, Cross-Bar Technology, Markov Chain Model, Reaching Probabilities, Transition Probability Matrix, Simulation Study, Message Flow .

1. Review Of Literature

Ko and Davis [3] proposed a protocol known as space-division multiple access (SDMA) which is useful for a satellite switched communication network. Abott [1] discussed a new technique for switching system using digital Space-Division concept for dealing with high-speed data signals. Yamada et al. [16] derived the high-speed digital switching technology with the help of space-division switches. Karol et al. [8] presented an input versus output analysis of queuing on a space-division packet switching. In a contribution Li [5] performed analysis for non-uniform traffic in the setup of Space-Division switches. Yamanka et al. [17] expanded space-division (SD) switch architecture and suggested a bipolar circuit design for gigabit-per-second cross-point switch LSIs. Lee and Li [4] have studied the performance of a non blocking space-division packet switch using finite-state Markov chain model, given the traffic intensities changes as a function of time. Li [6] derived the performance of a non blocking space-division packet switch in a correlated input traffic environment. Wang and Tobagi [14] suggested a self-routing space-division fast packet switch architecture achieving output queuing with a reduced number of internal path. Cao [2] derived a discrete-time queuing network model for space-division packet switches. Pao and Leung [10] used space-division approach to implement a shared buffer in an ATM switch which does not require scaling up the bandwidth of the shared memory. Shukla, Singhai & Gadewar [12] presented Markov Chain analysis for reaching probabilities of message flow in space division switches.

[1]Deptt. of Maths. and Statistics, H.S. Gour Sagar University, Saga, M.P-470003. E-mail : diwakarshukla @rediffmail.com

[2]International Institute of Professional Studies (IIPS), D.A.V.V., Indore. E-mail:singhai_rahul@hotmail.com

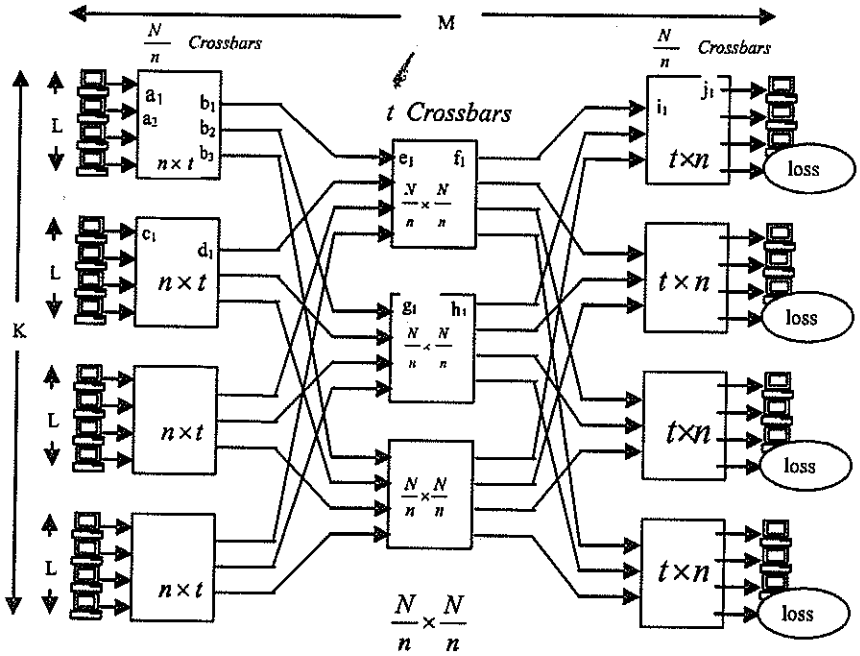

Figure 1 : Three Cross Bar Space Division Switch

2. Motivation

Shukla and Gadewar [11] have suggested a Markov chain model for the transitional analysis of message flow in a two crossbar space division switches. We extend this model, in this paper, from two-crossbars to three crossbar setup and with the help of a simulation study, the impact on reaching probabilities of message is analyzed.

3. Introduction And Assumptions

In what follows, we consider a space-division switch [11],[12] with parameters $N = 16, n = 4, t = 3$ shown in fig. 1 and assume the followings:

a) The left side of switches is input and the flow of information is from left to right.

b) Each input line, on left side, is attached with a computer having different initial probabilities of selection by users. This level is the stage 1.

c) The middle crossbars are stage 2 containing three crossbars with each having four inputs and four output lines.

d) The third stage contains four crossbars, each with three inputs and four output lines. At this, three output lines are with computers and the fourth one, in each crossbar, is a loss state.

e) The term I(M,K,L) denotes an input state at M^{th} stage in K^{th} crossbar and at L^{th} input line where M=1,2,3;K=1,2,3,4;L=1,2,3,4. For example, in fig. 1 the term a_1 is input state I(1,1,1), a_2 is state I(1,1,2), c_1 is I(1,2,1), e_1 is I(2,1,1), g_1 is I(2,2,1), and i_1 is I(3,1,1).

f) The term *O(M,K,L)* denotes output state at M^{th} stage, in K^{th} crossbar and L^{th} output line like the term b_1 is output state O(1,1,1), b_2 is O(1,1,2), b_3 is O(1,1,3), d_1 is O(1,2,1), f_1 is O(2,1,1), h_1 is O(2,2,1) and j_1 is O(3,1,1).

As special, the output states O(3,1,4), O(3,2,4), O(3,3,4) and O(3,4,4) are loss states and when a message reaches to them, it is assumed lost or reached to the known destinations.

3.1. Markov Chain Model

Let $\{X_n, n = 0,1,2,3....\}$ be a Markov chain with state space I(M,K,L) and O(M,K,L), M=1,2,3 and K,L = 1,2,3,4. The X_n denotes the state of message at the n^{th} step transition over states I(M,K,L) and O(M,K,L). The unit-step transition probabilities over states are:

$$\left.\begin{aligned} &P[X_{n+1} = O(1,K,1)/X_n = I(1,K,L)] = L_{1K} \\ &P[X_{n+1} = O(1,K,2)/X_n = I(1,K,L)] = L_{2K} \\ &P[X_{n+1} = O(1,K,3)/X_n = I(1,K,L)] = 1-(L_{1K}+L_{2k}) \end{aligned}\right\}$$

When L=1,2,3;K=1,2,3,4

$$P[X_{n+1} = I(1,K,L)/X_n = O(1,K,J)] = P_{LK}, \quad when \quad J = 1,2,3$$

$$P[X_{n+1} = I(1,K,L)/X_n = O(1,K,J)] = 1-\sum_{i=1}^{3} P_{iK}$$

$$when\, L = 4; K = 1,2,3,4; J = 1,2,3$$

$$P[X_{n+2} = O(2,K,L)/X_{n+1} = I(2,K,L)] = P[X_{n+2} = I(2,K,L)/X_{n+1} = O(2,K,L)]$$

$$= Q_{LK}, \; when \; L = 1,2,3; K = 1,2,3$$

$$P[X_{n+2} = O(2,K,L)/X_{n+1} = I(2,K,L)] = P[X_{n+2} = I(2,k,L)/X_{n+1} = O(2,k,L)] = 1-\sum_{i=1}^{3} Q_{iK},$$

$$when\, L = 4; K = 1,2,3,$$

$$P[X_{n+2} = O(2,K,L)/X_{n+1} = I(2,K,L)] = P[X_{n+2} = I(2,K,L)/X_{n+1} = O(2,K,L)]$$

$$= Q_{LK}, \; when \; L = 1,2,3; K = 1,2$$

$$P[X_{n+3} = O(3,K,L)/X_{n+2} = I(3,K,J)] = R_{LK},$$

$$when\, L = 1,2,3; K = 1,2,3,4; J = 1,2,3$$

$$P[X_{n+3} = O(3,K,4)/X_{n+2} = I(3,K,J)] = 1-\sum_{i=1}^{3} R_{iK}, \; when \; L = 4; K = 1,2,3,4; \; J = 1,2,3$$

$$P[X_{n+3} = I(3,K,1)/X_{n+2} = O(3,K,L)] = S_{1K}$$

$$P[X_{n+3} = I(3,K,2)/X_{n+2} = O(3,K,L)] = S_{2K}$$

$$P[X_{n+3} = I(3,K,3)/X_{n+2} = O(3,K,L)] = 1-\sum_{i=1}^{2} S_{iK}$$

$$when\, L = 1,2,3; K = 1,2,3,4$$

The terms L_{iK}, S_{iK}, P_{iK}, Q_{iK}, R_{iK} (i=1,2,3) are the probabilities of transition lying between 0 and 1 and placed as elements of transition probability matrix given on the next page.

Table 1: Transition Probability Matrix (t. p. m.) for Stage 1

← States →

States	$I(1,K,1)$	$(1,K,2)$	$I(1,K,3)$	$I(1,K,4)$	$O(1,K,1)$	$O(1,K,2)$	$O(1,K,3)$
$I(1,K,1)$	0	0	0	0	L_1k	L_2k	$\{1-(L_1k+L_2k)\}$
$I(1,K,2)$	0	0	0	0	L_1k	L_2k	$\{1-(L_1k+L_2k)\}$
$I(1,K,3)$	0	0	0	0	L_1k	L_2k	$\{1-(L_1k+L_2k)\}$
$I(1,K,4)$	0	0	0	0	L_1k	L_2k	$\{1-(L_1k+L_2k)\}$
$O(1,K,1)$	P_1k	P_2k	P_3k	$\{1-(P_1k+P_2k+P_3k)\}$	0	0	0
$O(1,K,2)$	P_1k	P_2k	P_3k	$\{1-(P_1k+P_2k+P_3k)\}$	0	0	0
$O(1,K,3)$	P_1k	P_2k	P_3k	$\{1-(P_1k+P_2k+P_3k)\}$	0	0	0

Table 2 : Transition Probability Matrix For Stage 2

States	$I(1,K,1)$	$I(1,K,2)$	$I(1,K,3)$	$I(1,K,4)$	$O(1,K,1)$	$O(1,K,2)$	$O(1,K,3)$
$I(1,K,1)$	0	0	0	0	L_1k	L_2k	$\{1-(L_1k+L_2k)\}$
$I(1,K,2)$	0	0	0	0	L_1k	L_2k	$\{1-(L_1k+L_2k)\}$
$I(1,K,3)$	0	0	0	0	L_1k	L_2k	$\{1-(L_1k+L_2k)\}$
$I(1,K,4)$	0	0	0	0	L_1k	L_2k	$\{1-(L_1k+L_2k)\}$
$O(1,K,1)$	P_1k	P_2k	P_3k	$\{1-(P_1k+P_2k+P_3k)\}$	0	0	0
$O(1,K,2)$	P_1k	P_2k	P_3k	$\{1-(P_1k+P_2k+P_3k)\}$	0	0	0
$O(1,K,3)$	P_1k	P_2k	P_3k	$\{1-(P_1k+P_2k+P_3k)\}$	0	0	0

Table 3 : Transition Probability Matrix For Stage 3

States	$I(3,K,1)$	$I(3,K,2)$	$I(3,K,3)$	$O(3,K,1)$	$O(3,K,2)$	$O(3,K,3)$	$O(3,K,4)$
$I(3,K,1)$	0	0	0	R_1k	R_2k	R_3k	$\{1-(R_1k+R_2k+R_3k)\}$
$I(3,K,2)$	0	0	0	R_1k	R_2k	R_3k	$\{1-(R_1k+R_2k+R_3k)\}$
$I(3,K,3)$	0	0	0	R_1k	R_2k	R_3k	$\{1-(R_1k+R_2k+R_3k)\}$
$O(3,K,1)$	S_1k	S_2k	$\{1-(S_1k+S_2k)\}$	0	0	0	0
$O(3,K,2)$	S_1k	S_2k	$\{1-(S_1k+S_2k)\}$	0	0	0	0
$O(3,K,3)$	S_1k	S_2k	$\{1-(S_1k+S_2k)\}$	0	0	0	0
$O(3,K,4)$	S_1k	S_2k	$\{1-(S_1k+S_2k)\}$	0	0	0	0

3.2 Model Classification

The probabilities L_{ik}, P_{ik}, Q_{ik}, R_{ik} and S_{ik} may be functions of M, K and L parameters and on this basis the classification of Markov chain models be as below:

(i) *M*-**Dependent model**- where probabilities L_{ik}, P_{ik}, Q_{ik}, R_{ik} and S_{ik} are only functions of M.

(ii) *K*-**Dependent model**- where probabilities L_{ik}, P_{ik}, Q_{ik}, R_{ik} and S_{ik} are only functions of K.

(iii) *L*-**Dependent model**- where probabilities are functions of *K* and *L* parameters both.

4. Calculation Of Reaching (Initial) Probabilities

Let P_{ik} (I = 1,2,3) be the probability of choosing the i[th] input line in K[th] switching element of the space division switch configuration given in fig. 1of the section 1.0. For $i = 4$, the probability is $\left\{1-\sum_{i=1}^{3} p_{iK}\right\}$. For the Markov chain $\{X_n, n = 0,1,2,3....\}$ over the states I(M,K,L), the initial probabilities of choosing a connecting path is

$$P[X_0 = I(1,K,1)] = p_{1K}, P[X_0 = I(1,K,2)] = p_{2K}$$

$$P[X_0 = I(1,K,3)] = p_{3K},$$

$$P[X_0 = I(1,K,4)] = p_{4K} = 1-(p_{1k}+p_{2k}+p_{3k})$$

$$=\left\{1-\sum_{i=1}^{3} p_{iK}\right\}$$

4.1. Outgoing Probabilities at Stage 1, 2 and 3

The O(1,K,L) over varying K and L are the outgoing states, for the stage 1, where the message is ready to route into for the next stage.

$P\ [X_1 = O(1,K,L)]$

=P[message reaches to the state O(1,K,L) at the first step]

The general form for M = 1(stage-1) is

$$P\,[x = O(1,k,L)] = L_{1k} \quad \text{when } L = 1; K = 1,2,3,4$$

$$= L_{1'k} \quad \text{when } L = 2$$

$$= \{1 - L_{1k} + L_{2k}\} \text{ when } L = 3$$

The general form for M = 2 (stage-2) is

$$P\,[x = O(2,k,L)] = Q_{LK} \sum_{i=1}^{4} L_{1i} \text{ when } k = 1, L = 1,2,3$$

$$P\,[x=O(2,k,L)] = \{1-\sum_{i1}^{3} Q_{ik}\} \sum_{i=1}^{4} L_{1i} \text{ when } k = 1, L = 4$$

$$P\,[x= O(2,k,L)] = Q_{LK} \sum_{i=1}^{4} L_{2i} \text{ when } k = 2, L = 1,2,3$$

$$P\,[x= O(2,k,L)] =\{1- \sum_{i1}^{3} Q_{ik}\} \sum_{i=1}^{4} L_{2i} \text{ when } k = 2, L=4$$

$$P[x=O(2,k,L)]=Q_{LK}\{4-\sum_{i=1}^{4} L_{1i} - \sum_{i=1}^{4} L_{2i}\} \text{ when } k=3, L= 1,2,3$$

$$P\,[x = O(2,k,L)] = \{1- \sum_{i1}^{3} Q_{ik}\}\{4 - \sum_{i=1}^{4} L_{1i} - \sum_{i=1}^{4} L_{2i}\} \text{ when } k = 3, L = 4$$

The general form for m = 3(stage-3) is

$$P\,[x = O(3,k,L)] = R_{LK} * \left[Q_{k1}\sum_{i=1}^{4} L_{1i} + Q_{k2}\sum_{i=1}^{4} L_{2i} + Q_{k3}\left\{4-\sum_{i=1}^{4} L_{1i} - \sum_{i=1}^{4} L_{2i}\right\}\right]$$

when k = 1, 2, 3 ; L = 1, 2, 3

$$P[x=O(3,k,L)] = R_{LK} *\left\{1-\sum_{i=1}^{3} R_{ik}\right\}* \left[Q_{k1}\sum_{i=1}^{4} L_{1i} + Q_{k2}\sum_{i=1}^{4} L_{2i} + Q_{k3}\left\{4-\sum_{i=1}^{4} L_{1i} - \sum_{i=1}^{4} L_{2i}\right\}\right]$$

when k = 1, 2, 3 , L = 4

$$P[x=O(3,k,L)] = R_{LK} \left[\left\{1-\sum_{i=1}^{3} Q_{i1}\right\}\sum_{i=1}^{4} L_{1i} + \left\{1-\sum_{i=1}^{3} Q_{i2}\right\}\sum_{i=1}^{4} L_{2i} + \left\{1-\sum_{i=1}^{3} Q_{i3}\right\}\left\{4-\sum_{i=1}^{4} L_{1i} - \sum_{i=1}^{4} L_{2i}\right\}\right]$$

when K = 4 , L = 1, 2, 3

$$P[x=O(3,k,L)]= *\left\{1-\sum_{i=1}^{3} R_{ik}\right\}* \left[\left\{1-\sum_{i=1}^{3} Q_{i1}\right\}\sum_{i=1}^{4} L_{1i} + \left\{1-\sum_{i=1}^{3} Q_{i2}\right\}\sum_{i=1}^{4} L_{2i} + \left\{1-\sum_{i=1}^{3} Q_{i3}\right\}\left\{4-\sum_{i=1}^{4} L_{1i} - \sum_{i=1}^{4} L_{2i}\right\}\right]$$

when k = 4 , L = 4

5. L-dependent Model and Simulation Study

Based on the above equations we considered the following L-dependent Markov chain model with unit-step transition probability. The a,b,c,d and e are constants having values in between 0.00 to 0.5.

$$\left.\begin{aligned} P[X_1 = O(1,K,J)/X_0 = I(1,K,L)] &= L(a)^K & J=1,2 \\ P[X_1 = O(1,K,J)/X_0 = I(1,K,L)] &= \{1-2L(a)^K\} & J=3 \end{aligned}\right\} L=1,2,3,4$$

$$\left.\begin{aligned} P[X_1 = I(1,K,J)/X_0 = O(1,K,L)] &= L(b)^K & J=1,2,3 \\ P[X_1 = I(1,K,J)/X_0 = O(1,K,L)] &= \{1-6(b)^K\} & J=4 \end{aligned}\right\} L=1,2,3$$

$$\left.\begin{aligned} P[X_2 = O(2,K,J)/X_1 = I(2,K,L)] &= L(c)^K & J=1,2,3 \\ P[X_2 = O(2,K,J)/X_1 = I(2,K,L)] &= \{1-6(c)^K\} & J=4 \end{aligned}\right\} L=1,2,3,4$$

$$\left.\begin{aligned} P[X_2 = I(2,K,J)/X_1 = O(2,K,L)] &= L(c)^K & J=1,2,3 \\ P[X_2 = I(2,K,J)/X_1 = O(2,K,L)] &= \{1-6(c)^K\} & J=4 \end{aligned}\right\} L=1,2,3,4$$

$$\left.\begin{aligned} P[X_3 = O(3,K,J)/X_2 = I(3,K,L)] &= L(d)^K & J=1,2,3 \\ P[X_3 = O(3,K,J)/X_2 = I(3,K,L)] &= \{1-6(d)^K\} & J=4 \end{aligned}\right\} L=1,2,3$$

$$\left.\begin{aligned} P[X_3 = I(3,K,J)/X_2 = O(3,K,L)] &= (e)^K & J=1,2 \\ P[X_3 = I(3,K,J)/X_2 = O(3,K,L)] &= \{1-2(e)^K\} & J=3 \end{aligned}\right\} L=1,2,3,4$$

5.1 Effect of *L* And *D*

The fig. 5.1 to 5.3 shows the variations over the reaching probabilities with respect to increasing values of *a,b,c,d* parameters.

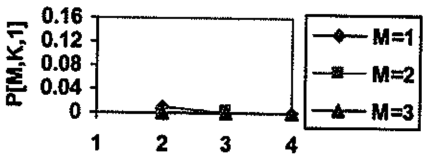

Figure 5.1 : a=0.1,c=0.1,d=0.1, L=1

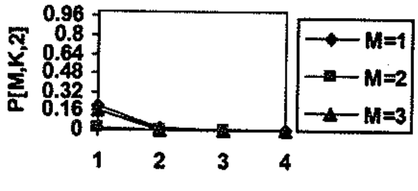

Figure 5.2 : a=0.1,c=0.1,d=0.1, L=2

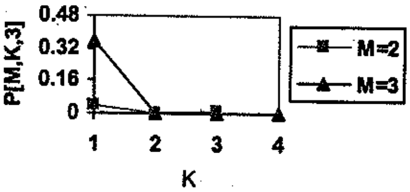

Figure 5.3 : a=0.1,c=0.1,d=0.1, L=3

When L=1 and a=c=d=0.1, the reaching probability P[M,K,1] reduces for the increasing values of K. This connectivity probability is higher for stage 1 and suddenly decreases for other stages. When L=2, the connectivity probability shows different pattern of variations than to compare what shown at L=1. The probability P[M,K,2] is higher for stage 1 and shows sudden decreasing pattern for other stages. When we talk about L=3, the P[M,K,3] has low down tendency over increasing K. The probability of connectivity improves at the third stage in comparison to second.

5.2 Effect of Variation of *C, D and K*

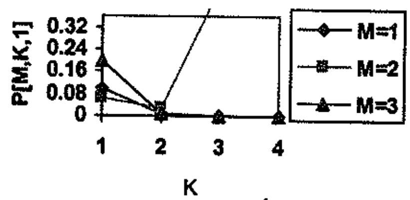

Figure 5.4 : a=0.1,c=0.5,d=0.1, L=1

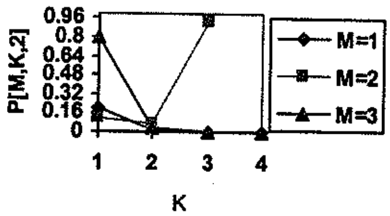

Figure 5.5 : a=0.1,c=0.5,d=0.1, L=2

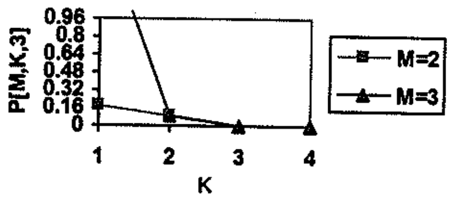

Figure 5.6 : a=0.1,c=0.5,d=0.1, L=3

Fig. 5.4 to 5.6 shows the effect on the reaching probabilities with the increasing values of c and d parameters while keeping the value of a parameter constant. With the increase of C, the probability pattern at stage 2 bears a sudden change.When L=1, the first and third stage has downward trend of probabilities over varying k, but the third stage bears a little increase than the second stage. When L=2, the first stage remains at high probability in comparison to others. At L=3 the chance of reaching probabilities reduces for the third stage with increasing values of K, but this increases for the second stage over the same *K*. The increase in *c* has special impact on the second stage probability of connectivity. When C is high, the probability for M=*2* concentrate entirely near to K=1.

5.3 Effect Of Variation Of *A,C,D and L*

With the increase in parameter a, in comparison to c, d and L has an effect in the connectivity probability. According to figure 5.7 to fig. 5.10, the increase of k produces decreasing Probability P [M.K.L].When L=1 changes to L= 2, keeping fix a, c, d, we observe higher probability P [M, K, 2] than P [M, K, 1]. When L= 3, the K = 2 is an ultimate value.

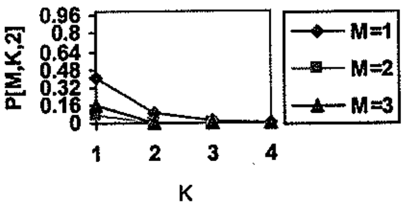

Figure 5.7 : a=0.2,c=0.1,d=0.1, L=2

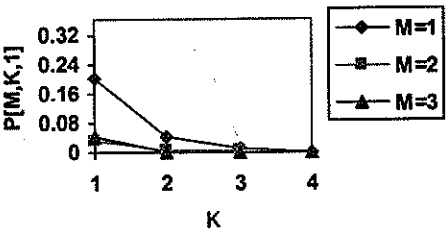

Figure 5.8 : a=0.2,c=0.1,d=0.1,L=1

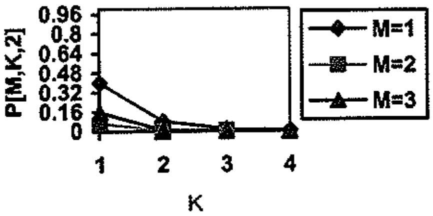

Figure 5.9 : a=0.2,c=0.1,d=0.1, L=2

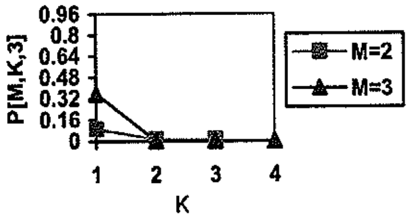

Figure 5.10 : a=0.2,c=0.1,d=0.1, L=3

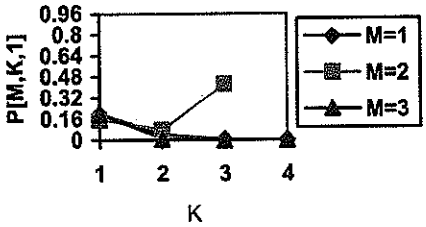

Figure 5.11 : a=0.2,c=0.5,d=0.1,L=1

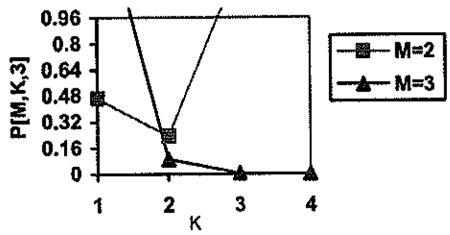

Figure 5.12 : a=0.2,c=0.5,d=0.1, L=3

With the increase in d value, from d= 0.1 to d=0.5, a sudden increase of P[M,K,L] is observed at k=3, k=4.

In this, L=3 bears the largest probability as showing in fig. 5.11 to 5.12. The increase in c Value produces zigzag movement in P [M, K, L] .The L= 1 and L=3 has a sudden jump in connectivity probability. With the simultaneous increase in c and d value, the connectivity with M=3 increases at high rate. In this case, the K=3 bears the highest probability for P [M, K, 3]. The increase in value of a parameter has the most significant, effect in the role of increasing the connectivity probability. According to fig 5.13, when all the parameters a, c, d, L are high than the connectivity chances are also high, for both M =2 and Therefore, the higher values of parameter a, c ,d produces higher chance of connectivity and message passing in space division switches having three cross bar.

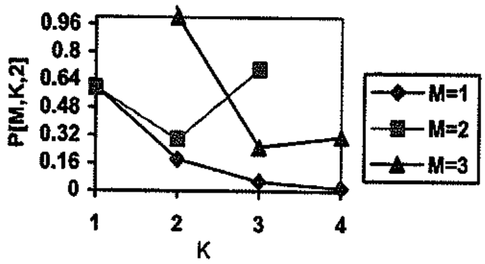

Figure 5.13 : a=0.3,c=0.5,d=0.5, L=2

6. Conclusions

Many interesting highlights are identified after the simulation study on different values of parameters using L Dependent Model, Some concluding remarks are:

(i) When parameters are with smaller values, the outgoing reaching probability for *L=2* is higher than L=1 at K=1, (i.e. (P[M,K,2]>P[M,K,1]). The increase in d values (from 0.1 to 0.5) certainly affects the outgoing probabilities in *L*-dependent model. So one should be optimistic and careful in selecting ***d*** values. However, the variation of parameter ***c*** and ***d*** both affects the reaching probabilities and their high values (e.g.c=0.3orc=0.5,d=0.3ord=0.5) produce a significant change in them. In three cross bars, there is constant exponential decay in P [M, K, L] is found. With the increase of d value this decay process reduces, therefore the higher value of d is recommended in case of three pin cross bars.

(ii) In *L*-dependent model, the increase in parameter ***a*** plays very important role and has significant impact on outgoing probability.

(iii) The parameter has very important role in deciding about the probability pattern of outgoing message. With the increase of c and d values together produces significant increase in message passing probability in case of three crossbar setup. When all values of a, c and d are high i.e. in the range (0.3, 0.6), the L-dependent model shows better performance in this case than two-cross bar setup.

(iv) One interesting observation in three crossbar case is, that for L= 4. The reaching probability is much higher. So, with the help of proposed model, the hardware designers of space division switches can design switches, more effectively & efficiently.

References

[1] Abott. G.F, *"Digital space division –A technique for switching high-speed data signals"*, IEEE Communications Magazine, Vol. 22, No. 4, PP. 32-38 , 1984.

[2] Cao.X.R, *"The maximum throughput of a nonblocking space-division packet switch with correlated destinations"*, IEEE Transactions on Communications, Vol. 43, No.5, PP. 1898-1901, 1995.

[3] K.T. Ko and B.R. Davis, *"A space-division multiple-access protocol for spot-beam antenna and satellite switched communication network"*, IEEE Journal on Selected Areas in Communication 1(1), 126–132, 1983.

[4] Lee.M.J and Li.S.Q, *"Performance of a nonblocking space-division packet switch in a time variant nonuniform traffic environment"*, IEEE Transactions on Communications, Vol. 39, No. 10, PP. 1515-1524, 1991.

[5] Li.S.Q, *"Nonuniform traffic analysis on a nonblocking space-division packet switch"*, IEEE

Transactions on Communications, Vol. 38, No.7, PP. 1085-1096 , 1990.

[6] Li.S.Q , *"Performance of a nonblocking space-division packet switch with correlated input traffic"*, IEEE Transactions on Communications, Vol. 40, No.1, PP. 97-108 , 1992.

[7] M.J. Karol, M.G Hluchyi and S.P. Morgan, *"Input versus output queuing on a space-division packet switch"*, IEEE Transaction on Communications 35 (12), 1347–1356 , 1987.

[8] Medhi. J, *"Stochastic Processes"*, Ed 4, Wiley Eastern Limited (Fourth reprint), New Delhi, 1991.

[9] Naldi. M, *"Internet access traffic sharing in a multi operator environment"*, Computer Network, Vol. 38, PP. 809-824, 2002.

[10] Pao. D.C.W and Leug. S.C, *"Space division-approach to implement a shared buffer in an ATM switch"*, Computer Communications, Vol. 20, Issue 1, PP. 29-37, 1997.

[11] Shukla. D, Gadewar. S and Pathak. R.K, *"A Stochastic model for space-division switches in computer networks"*, Applied Mathematics and Computation (Elsevier Journal), Vol. 184, Issue 2, PP. 235-269, 2007.

[12] Shukla.D, Singhai.R and Gadewar.S.K, *"Markov Chain Analysis for Reaching Probabilities of Message Flow In Space-Division Switches"*, In eletronic proceedings of ICMCS-08,Loyola College, Chennai, India ,2008.

[13] Tanenbaum. A.S, *"Computer Network"*, 3rd Ed., Prentice-Hall, Inc., USA(25th Indian reprint), 1996.

[14] Wang.W and Tobagi.F.A, *"The Christmas-tree switch: an output queuing space-division fast packet switch based on interleaving distribution and concentration functions"*, Computer Networks and ISDN Systems, Vol. 25, Issue 6, PP. 631-644 , 1993.

[15] Yamada.H, Kataoka.H, Sampei.T and Yano. T, *"High-speed digital switching technology using space-division switch LSI'S"*, IEEE Selected Areas in Communications, Vol. 4, No. 4, PP. 529-535, 1986.

[16] Yamanka.N, Kikuchi.S, Suzuki.M and Yoshioka.Y, *"A 2 Gb/s expandable space-division switching LSI network architecture for gigabit-rate broad-band circuit switching"*, IEEE Selected Areas in Communications, Vol. 18, No.8, PP.1543-1550, 1990.

Author's Biography

Dr. Diwakar Shukla is presently working as a faculty member in the Department of Mathematics and Statistics, H.S.Gour Sagar University, Sagar, M.P. and having over 19 years experience of teaching to U.G. and P.G. classes. He obtained M.Sc.(stat.), Ph.D.(stat.) degrees from Banaras Hindu University, Varanasi and served the Devi Ahilya University, Indore, M.P. as a permanent Lecturer from 1989 for nine years and obtained the degree of M.Tech.(Computer Science) from there.He joined Sagar University,Sagar as a Reader in ststistics in the year 1998. During Ph.D. from BHU, he was junior and senior research fellow of CSIR, New Delhi through Fellowship Examination (NET) of 1983. Till now, he has published more than 55 research papers in national and international journals and participated in more than 35 seminars/conferences at the national level. He is the recipient of MPCOST Young Scientist Award, ISAS Young Scientist Medal, UGC Career Award and UGC visiting fellow to Amerawati University, Maharashtra. He also worked as a Professor in the Lucknow University, Lucknow, U.P., for one (from june, 2007 to 2008) year and visited abroad to Sydney (Australia) and Shanghai (China) for conference participation and paper presentation. He has supervised nine Ph.D. theses in Statistics and Computer Science and six students are presently enrolled for their doctoral degree under his supervision. He is a member of 10 learned bodies of Statistics and Computer Science at the national level. The area of research he works are Sampling Theory, Graph Theory, Stochastic Modeling, Data mining, Operation Research, Computer Network and Operating Systems.

Rahul Singhai has obtained M.C.A. degree from H.S. Gour University, Sagar, MP, in 2001 and obtained M.Phil degree in Computer Science from Madurai Kamaraj University, Madurai, Tamilnadu in 2008.. Presently he is pursuing Ph.D in Computer Science from H.S. Gour University, Sagar. His research interest includes Computer Network, Data mining & Software Testing. He has authored and co-authored 8 research papers in proceedings & journals. Currently, he is working on to develop new probability based methods for data preprocessing in data mining .He has worked as contract Lecturer in the Dept. of Computer Science & Applications., H.S. Gour University, sagar from Feb -2005 to July-2009. He is presently working as permanent lecturer at IIPS, Devi Ahilya Vishwavidyalaya, Indore (M.P.) since 7Th July-2009.