User Behaviour Based Probability Analysis of Internet Traffic Distribution in Two-Market Environment in Computer Networks

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Abstract

Consider two markets and two operators having different networks operators Both operators are in competition for capturing more and more the internet traffic. The users have presumptive behaviour like faithful, impatient and completely impatient. This paper presented markov chain model based analysis of user behaviour for selecting any one operator. It is found that blocking probability of network plays important role for determining the user's behaviour towards choosing an operator as internet service provider. Also it contains analysis of initial share over the blocking probability varying probability of the rest-state.

Keywords : Markov chain model, Blocking probability, Call-by-call basis, Internet traffic, Quality of Service (QoS), Users behavior.

1. Introduction

Markov Chain Model is a technique of exploring the transition behavior of a system. Naldi [13] has opened up the problem of internet traffic sharing evaluation. Shukla and Gadewal [5] have shown the application of Markov Chain model to the modelling of space division switches. Shukla and Thakur [9] have predicated useful contribution for modelling of internet traffic sharing phenomena between two operators in competitive markets. Vern Paxson [16] has discussed the experiences with different measurement and analysis of the Internet Traffic.

Shukla et. al. [17] have given a share loss analysis of internet traffic distribution in computer networks. Medhi [11],[12] contains the foundational aspects of Markov chains in the context of stochastic processes. Dorea and Rajas [4] have shown the application of Markov chain models in data analysis. Aggarwal and Kaur [15] have proposed reliability analysis of fault-tolerant in a multistage interconnection on computer networks. Shukla, Tiwari and Thakur [20] have shown the effects of disconnectivity analysis for congestion control in internet traffic sharing. Yuan and lygevers [6] obtained the stochastic differential equations and proved the criteria of stabilization for Mrakovian switching.

Shukla, Tiwari et. al. [18],[19] have disucussed a comparison of methods for internet traffic sharing in computer network. Newby and Dagg [13] presented a maintenance policy for stochastically deteriorating systems, with the average cost criteria. Shukla, Pathak and Thakur [7] have useful contribution on the use of Markov chain model based approach to explain and specify the behavior of internet traffic users. Shukla, Saurabh et. al. [6] have given analysis using a markov model for same problem. Babikur Mohd. et.al [1] has shown the flow ased internet traffic classification for bandwidth optimization. Some other useful similar contributions are due to Perzen[10] and Agarwal [5].

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2. User's Behavior And Markov Chain Model

Let O_i and O_j $(i=1,3; j=2,4)$ be operators (or ISP) in two competitive locations Market-I and Market–II. Users choose first to a market and then enters into cyber cafe (or shop) situated in that market where computer terminals for specific operators are available to access the Internet. Let $\{X^{(n)}, ne''0\}$ be a Markov chain having transitions over the state space $O_1, O_2, O_3, O_4, R_1, R_2, Z_1, Z_2, A, M_1$ & M_2 where

State O_1: first operator in market-I
State O_2: second operator in market-I
State O_3: third operator in market-II
State O_4: fourth operator in market-II
State R_1: temporary short time rest in market-I
State R_2: temporary short time rest in market-II
State Z_1: success (in connectivity) in market-I
State Z_2: success (in connectivity) in market-II
State A: abandon to call attempt process
State M_1: market-I
State M_2: market-II

The $X^{(n)}$ stands for state of random variable X at n^{th} attempt $(ne''0)$ made by a user. Some underlying assumptions of the model are:

(a) User first selects the Market-I with probability q and Market-II with probability $(1-q)$ as per ease.

(b) After that User, in a shop, chooses the first operator O_i with probability p or to next O_j with $(1-p)$.

(c) The blocking probability experienced by O_i is L_1 and by O_j is L_2.

(d) Connectivity attempts of User between operators are on call-by-call basis, which means if the call for O_i is blocked in k^{th} attempt $(k>0)$ then in $(k+1)^{th}$ user shifts to O_j. If this also fails, user switches to O_i in $(k+2)^{th}$.

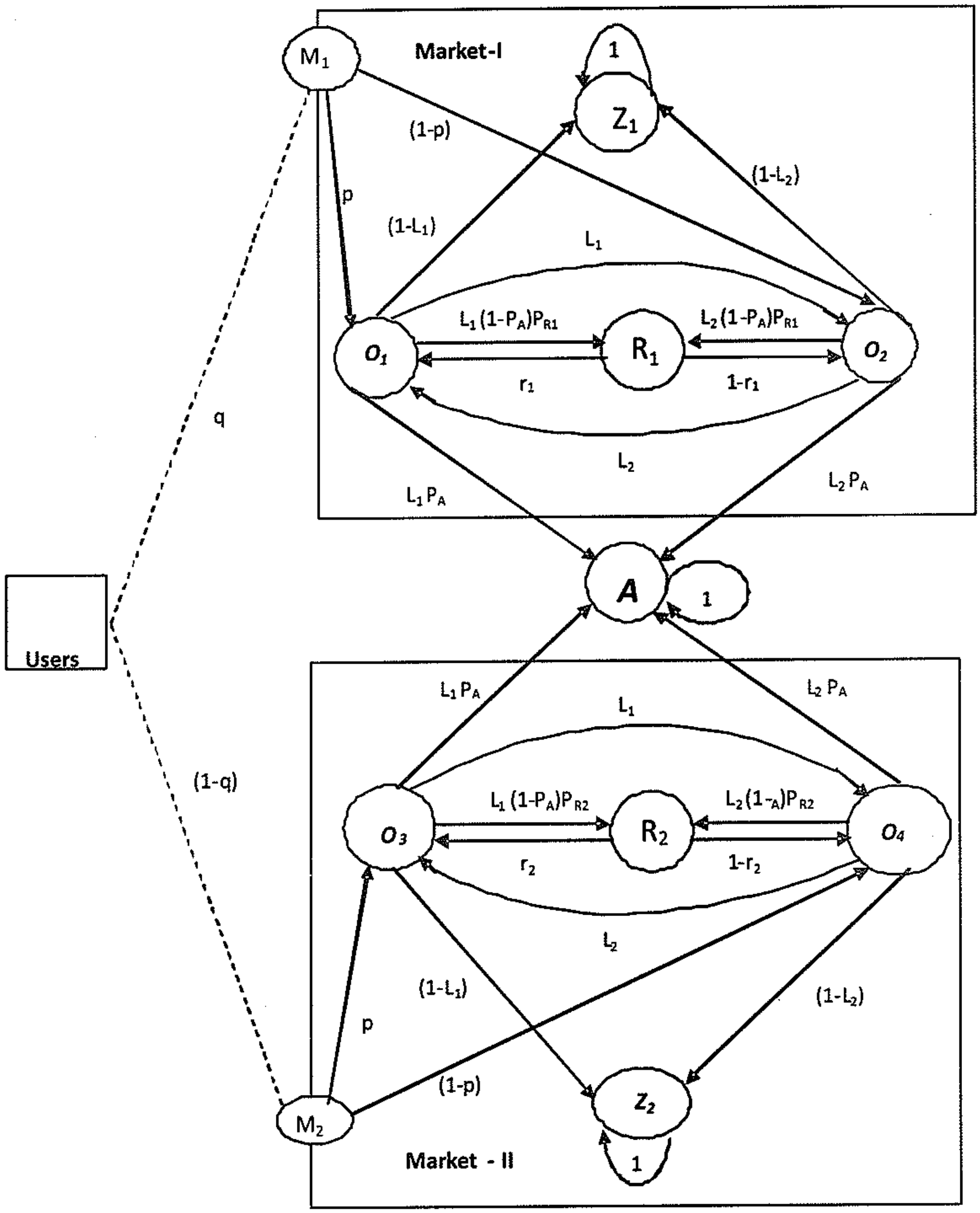
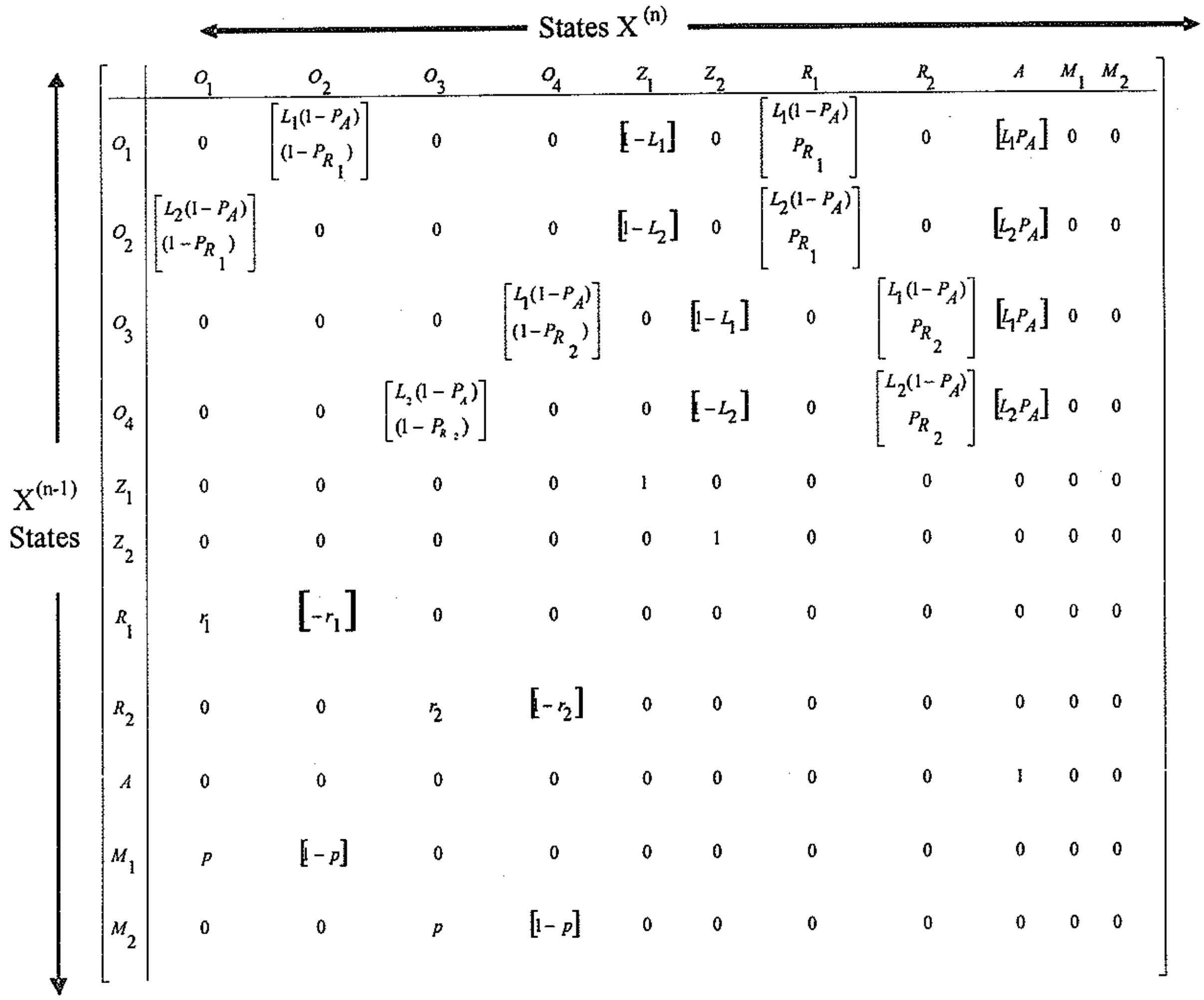


Figure 1: Transition Diagram of model.

2.1 The transition probability matrix



	O_1	O_2	O_3	O_4	Z_1	Z_2	R_1	R_2	A	M_1	M_2
O_1	0	$\begin{bmatrix} L_1(1-P_A) \\ (1-P_{R_1}) \end{bmatrix}$	0	0	$[1-L_1]$	0	$\begin{bmatrix} L_1(1-P_A) \\ P_{R_1} \end{bmatrix}$	0	$[L_1P_A]$	0	0
O_2	$\begin{bmatrix} L_2(1-P_A) \\ (1-P_{R_1}) \end{bmatrix}$	0	0	0	$[1-L_2]$	0	$\begin{bmatrix} L_2(1-P_A) \\ P_{R_1} \end{bmatrix}$	0	$[L_2P_A]$	0	0
O_3	0	0	0	$\begin{bmatrix} L_1(1-P_A) \\ (1-P_{R_2}) \end{bmatrix}$	0	$[1-L_1]$	0	$\begin{bmatrix} L_1(1-P_A) \\ P_{R_2} \end{bmatrix}$	$[L_1P_A]$	0	0
O_4	0	0	$\begin{bmatrix} L_2(1-P_A) \\ (1-P_{R_2}) \end{bmatrix}$	0	0	$[1-L_2]$	0	$\begin{bmatrix} L_2(1-P_A) \\ P_{R_2} \end{bmatrix}$	$[L_2P_A]$	0	0
Z_1	0	0	0	0	1	0	0	0	0	0	0
Z_2	0	0	0	0	0	1	0	0	0	0	0
R_1	r_1	$[1-r_1]$	0	0	0	0	0	0	0	0	0
R_2	0	0	r_2	$[1-r_2]$	0	0	0	0	0	0	0
A	0	0	0	0	0	0	0	0	1	0	0
M_1	p	$[1-p]$	0	0	0	0	0	0	0	0	0
M_2	0	0	p	$[1-p]$	0	0	0	0	0	0	0

Figure 2 : Transition Probability Matrix.

(a) Whenever call connects through either O_i or O_j we say system reaches to the state of success *(Z_1, Z_2)*.

(b) The user can terminate call attempt process, marked as system to abandon state A with probability P_A (either from O_i or from O_j).

(c) If user reaches to rest state R_k ($k=1,2$) from O_i or O_j then in next attempt he may either with a call on O_i or O_j with probability r_k and $(1-r_k)$ respectively.

(d) From state R_k user cannot move to states Z_k and A.

The transition diagram is in fig.1 to explain the details of assumptions and symbols. In further discussion, operator $O_1=O_3$ and $O_2=O_4$ is assumed with network blocking parameter $L_1=L_3$, $L_2=L_4$.

2.2 Logic For Transition Probability In Model

(a) The starting conditions (state distribution before the first call attempt) are

$$P[X^{(0)} = O_1] = 0,$$
$$P[X^{(0)} = O_2] = 0,$$

$$P[X^{(0)} = R_1] = 0,$$
$$P[X^{(0)} = R_2] = 0,$$
$$P[X^{(0)} = Z] = 0, \quad \ldots(2.2.1)$$
$$P[X^{(0)} = A] = 0,$$

$$P[X^{(0)} = M_1] = q,$$
$$P[X^{(0)} = M_2] = 1-q,$$

(b) If in $(n-1)^{th}$ attempt, call for O_i is blocked, the user may abandon the process in the n^{th} attempts.

$P[X^{(n)} = A / X^{(n-1)}=O_i] = P$ *[blocked at* O_i*].P[abandon the process]*$=L_i.P_A$ ...(2.2.2)

Similar for O_j,

$P[X^{(n)} = A / X^{(n-1)}=O_j] = P$ *[blocked at* O_j*].P[abandon the process]*$=L_j.P_A$ ...(2.2.3)

(c) At O_i in n^{th} attempts call may be made successfully and system reaches to state Z_k from O_i. This happens only when call does not block in $(n-1)^{th}$ attempt

$P[X^{(n)} =Z_k / X^{(n-1)}=O_i] =P$*[does not blocked at* O_i*]* $= (1-L_i)$ ...(2.2.4)

Similar for O_j,

$P[X^{(n)} =Z_k /X^{(n-1)}=O_j] =P$*[does not blocked at* O_j*]* $= (1-L_j)$ ...(2.2.5)

(d) If user is blocked at O_i in $(n-1)^{th}$ attempts, does not want to abandon, then in n^{th} he shifts to operator O_j.

$P[X^{(n)} =O_j / X^{(n-1)}=O_i] = P$ *[blocked at* O_i*].P[does not abandon]*$=L_i.(1-p_A$ ...(2.2.6)

Similar for O_j,

$P[X^{(n)} =O_i / X^{(n-1)}=O_j] = P$ *[blocked at* O_j*].P[does not abandon]*$=L_j.(1-p_A)$ ...(2.2.7)

(e) For operator O_i.

$P[X^{(n)}=O_i / X^{(n-1)}=R_k] =r_k$ ...(2.2.8)

Similar for O_j,

$P[X^{(n)}=O_j / X^{(n-1)}=R_k] =1-r_k$ ...(2.2.9)

(f) For M_k, (k=1,2) for O_i, O_j

$P[X^{(n)}=O_i / X^{(n-1)}=M_k] =p$ ...(2.2.10)

Similar for O_j,

$P[X^{(n)}=O_j / X^{(n-1)}=M_k] =1-p$ ...(2.2.11)

3. Categories Of Users

Define three types of users as

(i) Faithful User (FU).

(ii) Partially Impatient User (PIU).

(iii) Completely Impatient User (CIU).

4. Some Results For n^{th} Attempts

At n^{th} attempt, the probability of resulting state is derived in following theorems for all $n=0,1,2,3,4,5....$ for market-I.

$$A = \left[L_1(1-P_A)P_{R_1} r_1\right], \quad B=\left[L_2(1-P_A)P_{R_1}(1-r_1)\right],$$

$$C=\left[L_1L_2(1-P_A)^2(1-P_{R_1})^2\right], \; D=\left[L_1^2L_2(1-P_A)^3(1-P_{R_1})^2P_{R_1}\right],$$

$$E=\left[L_2^2(1-P_A)^2(1-P_{R_1})P_{R_1}\right]$$

THEOREM 4.1: If user is FU and restrict to only O_1 and R_1 in M_1 then n^{th} step transitions probability is

$$\left.\begin{array}{l} P[X^{(2n)}=O_1]=pA^n \\ P[X^{(2n+1)}=O_1]=qpA^n \end{array}\right\}$$

THEOREM 4.2: If user is FU and restrict to only O_2 and R_1 then n^{th} step transitions probability is

$$\left.\begin{array}{l} P[X^{(2n)}=O_2]=(1-p)B^n \\ P[X^{(2n+1)}=O_2]=q(1-p)B^n \end{array}\right\}$$

THEOREM 4.3: If user is PIU and restricts to attempt between O_1 and O_2 and not interested to state R in M_1 then

$$P[X^{(2n)}=O_1]=\frac{[q(1-p)C^{(n)}]}{[L_1(1-p_A)(1-p_{R_1})]}$$
$$P[X^{(2n+1)}=O_1]=[qpC^{(n)}]$$

$$P[X^{(2n)}=O_2]=\frac{[qpC^{(n)}]}{[L_2(1-p_A)(1-p_{R_1})]}$$
$$P[X^{(2n+1)}=O_2]=[q(1-p)C^{(n)}]$$

THEOREM 4.4: If user is CIU and attempts among O_1, O_2 and R only in M_1 then at n^{th} attempt the approximate probability expression are

$$P[X^{(2n)}=O_1]$$
$$=\frac{[q(1-p)C^{(n)}]}{[L_1(1-p_A)(1-p_{R_1})]}+\frac{[pC^{(n)}p_{R_1}r_1]}{[L_2(1-p_A)(1-p_{R_1})^2]}$$
$$P[X^{(2n+1)}=O_1]$$
$$=[qp.C^n]+\frac{[(1-p).C^{(n)}L_2p_{R_1}.(1-r_1)]}{[L_1(1-p_{R_1})]}$$

$$P[X^{(2n)}=O_2]$$
$$=\frac{[qp.C^{(n)}]}{[L_2(1-p_A)(1-p_{R_1})]}+\frac{[(1-p).C^{(n)}p_{R_1}(1-r_1)]}{[L_1(1-p_A)(1-p_{R_1})^{(2)}]}$$
$$P[X^{(2n+1)}=O_2]$$
$$=[q(1-p)C^{(n)}]+\frac{[pC^{(n)}L_1p_{R_1}r_1]}{[L_2(1-p_{R_1})]}$$

5. Behavior Over Large Number Of Attempts For Traffic Sharing

Suppose n is very large, then $\overline{P_k}=\left[\lim_{n\to\infty}\overline{P_k}^{(n)}\right]$, $k=1, 2$ and we get final traffic shares,

$$[\overline{P_1}]_{FU}=\left\{\frac{(1-L_1).p}{1-[A^2]}\right\}+\left\{\frac{(1-L_1).qp[A]}{1-[A^2]}\right\}$$

$$[\overline{P_2}]_{FU}=\left\{\frac{(1-L_2).(1-p)}{1-[B^2]}\right\}+\left\{\frac{(1-L_2).q(1-p)[B]}{1-[B^2]}\right\}$$

$$[\overline{P_1}]_{PIU}=\left\{(1-L_1).p+\frac{(1-L_1).pq[C]}{1-[C^2]}\right\}+\left\{\frac{(1-L_1).qp[C]}{1-[C^2]}\right\}$$

$$[\overline{P_2}]_{PIU}=(1-L_2)(1-p)+\left\{\frac{(1-L_2)(1-p)q[C]}{1-[C^2]}\right\}$$
$$+\left\{\frac{(1-L_2).q(1-p)[C]}{1-[C^2]}\right\}$$

$$[\overline{P_1}]_{CIU}=(1-L_1)p\left\{1+\left[\frac{q[C]}{1-[C^2]}\right]+\left[\frac{[Dr_1]}{1-[C^2]}\right]\right\}$$
$$+\left\{\left[\frac{q(1-L_1)L_2(1-P_A)(1-P_{R_1})[C]}{1-[C^2]}\right]+\left[\frac{(1-L_1)(1-r_1)[E]}{1-[C^2]}\right]\right\}$$

$$[\overline{P_2}]_{CIU}=(1-L_2)p\left\{1+\left[\frac{q[C]}{1-[C^2]}\right]+\left[\frac{[D(1-r_1)]}{1-[C^2]}\right]\right\}$$
$$+\left\{\left[\frac{q(1-L_2)L_2(1-P_A)(1-P_{R_1})[C]}{1-[C^2]}\right]+\left[\frac{(1-L_2)r_1[E]}{1-[C^2]}\right]\right\}$$

6. Average Blocking Probability Experience By Users:

The user experiences varying average blocking probability, at n^{th} attempt, described as:

$$B_i^{(n)} = \frac{P[X^{(n-1)} = O_1]L_1 + P[X^{(n-1)} = O_2]L_2}{P[X^{(n-1)} = O_1] + P[X^{(n-1)} = O_2]}$$

[See Naldi (2002)]

In case of faithful user, by using theorem 4.1 and 4.2.

$$\left\lfloor B_i^{(n)} \right\rfloor_{FU} = p\mathrm{L}_1 + (1 - p)\mathrm{L}_2$$

[See Naldi (2002)]

For Partially Impatient User (PIU), using theorem 4.3

$$\left[B_i^{(n)}\right]_{PIU} = \frac{1}{pL_1 + (1-p)L_2} \qquad \textit{for n even}$$

$$\left\lfloor B_i^{(n)} \right\rfloor_{PIU} = pL_1 + (1-p)L_2 \qquad \textit{for n odd}$$

7. Comparisons Among Users:

(a) $\left\lfloor Bi^{(n)} \right\rfloor_{PIU} < \left\lfloor Bi^{(n)} \right\rfloor_{FU}$ when $p < 1$ along with $L1 > L2$

(b) $\left\lfloor Bi^{(n)} \right\rfloor_{CIU} < \left\lfloor Bi^{(n)} \right\rfloor_{FU}$ when $p < 1$ along with $L1 > L2$ --- (3.6.1)

(c) $\left\lfloor Bi^{(n)} \right\rfloor_{CIU} < \left\lfloor Bi^{(n)} \right\rfloor_{PIU}$ when $p < 1$ along with $L1 > L2$

8. Initial Triffic Share Analysis

According to fig. 8.1-8.3 with the increase of blocking probability of operator O_l the initial traffic share depends highly on opponents blocking probability L_2. If L_2 is high the initial traffic share of faithful users of O_l is high.

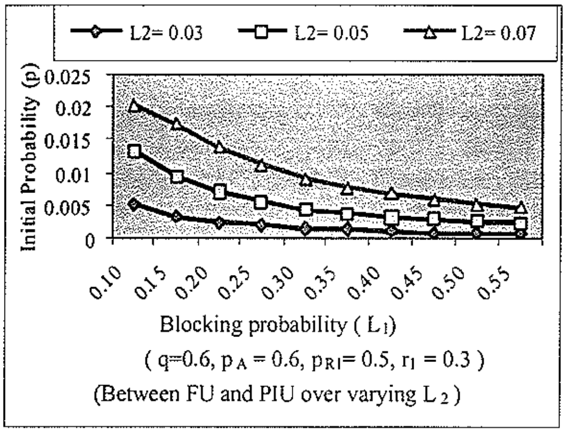


Figure 8.1

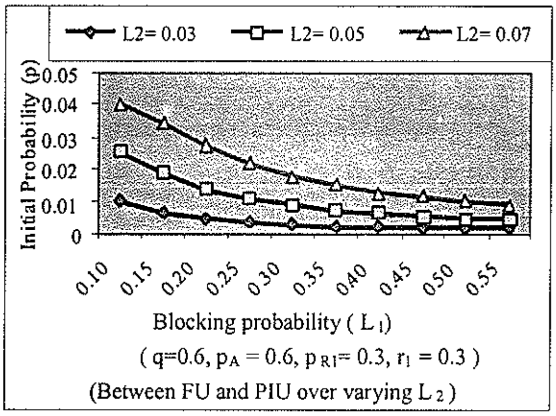


Figure 8.2

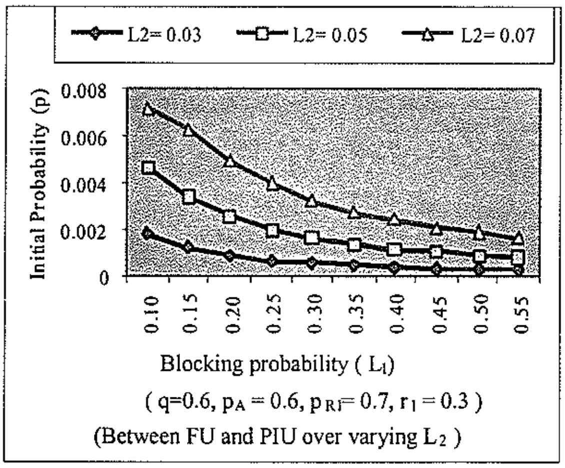


Figure 8.3

When rest state probability p_{Rl} is high then correspondly the traffic share of faithful users reduces for O_l. The rest state r_l has negative impact over the group of partially impatient users (PIU).

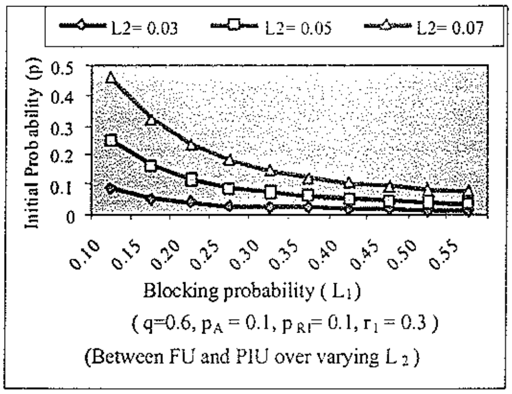


Figure 8.4

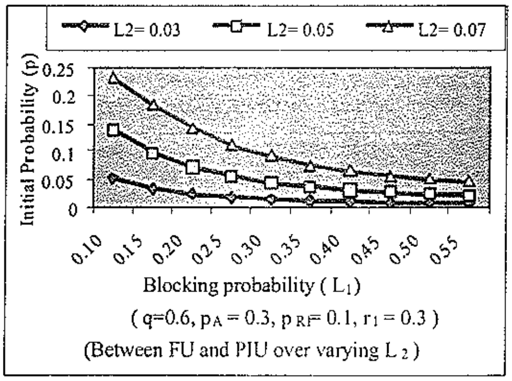


Figure 8.5

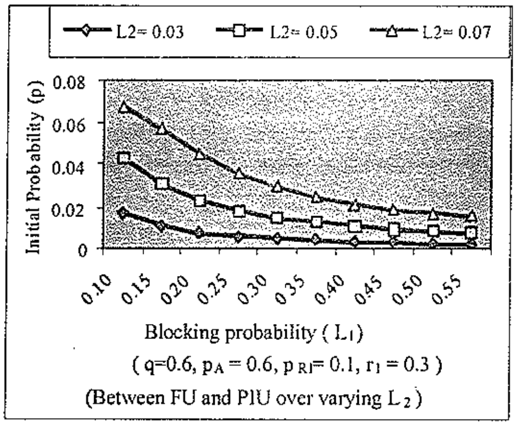


Figure 8.6

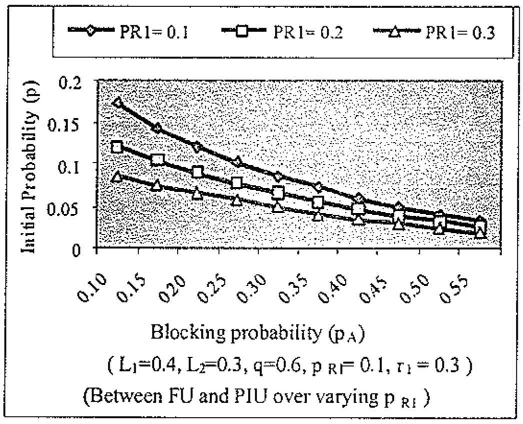


Figure 8.7

With the change of P_A probability which is the abandoning chance if high, reduces the initial traffic share of faithful users for operator O_I. Moreover, opponent blocking level, if high, then the loss of PIU users group is also high.

9. Concluding Remarks

The initial traffic share depends on the amount of faithful user that an operator bears. The self blocking probability of an operator, if high, reduces the initial traffic share. Moreover, if opponent blocking of network is high, than faithful user proportion for O_I is also high. Therefore, in multi-market system a network operator is suggested keep attracting sources and try to reduce the network blocking in order to increase his faithful user group.

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