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Iso-Share Analysis of Internet Traffic Sharing in the Presence of Favoured Disconnectivity

Thakur Sanjay[1] and Shukla Diwakar[2]

[1]Department of Computer Science & Applications., Sagar University, Sagar M.P. 470003, India.
e-mail: drsanjay2009@rediffmail.com
[2]Department of Mathematics. and Statistics, Sagar University, Sagar M.P. 470003, India.
e-mail: diwakarshukla@rediffmail.com

Abstract

During the Internet utilization one common problem observed is the lack of constant of connectivity of Internet. On many occasions, user faces disconnectivity in a prefixed working duration. This factor affects the market share of customers of an operator. Disconnectivity is classified as favoured and non-favoured according to restart call attempt criteria. This paper presents the Iso-share analysis of Internet traffic between the two operators in the presence of favoured disconnectivity as a cause. A Markov chain model is used for analysis and simulation study is performed to support the findings.

Keywords*: Markov chain model, Initial preference, Call-by-call basis, Internet Service Provider [operators], Internet access, Quality of service (QoS), Simulation, Transition probability matrix, Users behavior.*

1.0 Introduction:

According to [2] considered quality of service (QoS) component as a function of network blocking probabilities whose high level leads to poor quality. Apart from blocking, another quality aspect is 'disconnectivity' which directly relates to the network efficiency. When a call attempt is successful through dialup setup, the probability of disconnectivity starts and user feels the fear due to this event. He has option to choose to other operator as his favourate if it is frequent. Suppose L_1, L_2 are network blocking probabilities and s_1, s_2 are disconnectivity probabilities then according to [2] the quality of service is a function of blocking parameters.

$$QoS = f(L_1, L_2)$$

We consider a modified form of this function as

$$QoS = f(L_1, L_2, s_1, s_2)$$

A model of traffic distribution is drawn in fig 1.1 where first choice (p) and Internet traffic share both are assumed related through disconnectivity parameters.

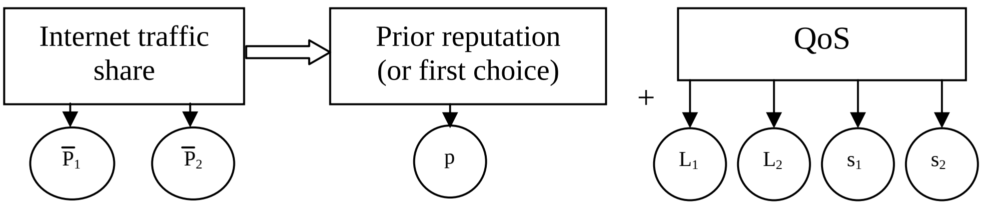

Fig. 1.1

The [9] produced an analysis of Space Division switches using Markov chains. Moreover, the [8] used Markov chain model for Knockout Switch explaining the packet flow phenomenon. Deriving motivation from all these, this paper presents an analysis of traffic distribution in light of QoS offered by operators with special reference to the disconnectivity event. A Markov chain

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model is used to explain the system behavior and to derive the mathematical expressions. Some useful contributions are due to [1], [3], [4], [5], [6], [7], [10].

1.1 User's Behavior as a System:

Consider following hypotheses for the behavior of a user, with network blocking, disconnectivity and initial choice as parameters.

- A competitive market has a café, containing Internet facility of two operators O_1 and O_2.
- A user enters into café with initial choice in mind (first choice) as p for O_1 and (1-p) for O_2.
- During the repeated connectivity call attempts, the blocking probability of O_1 is L_1 and of O_2 is L_2. Blocking implies the event when call attempt process fails to connect.
- After each fail call attempt, the user has two choices: he can abandon with probability p_A or switch over to other operator for a new attempt.
- Switching between O_1 and O_2 on a call-by-call basis depends just on the latest attempt. The two successive call attempts are not on same operator.
- When call connects, the success appears and user performs Internet surfing through connected operator. Suddenly, due to lack of quality of service, the call disconnects with probability s_1 for O_1 and s_2 for O_2.
- For re-connectivity, the user bears a favoured attitude for earlier operator and retries with the same. This results into favoured disconnectivity with probability parameter s_i (i = 1, 2).

2.0 Markov Chain Model:

These models are used by [8], [9] in switch system analysis of computer network.

Under hypotheses of section 1.1, the user's behavior is modeled through a four-state discrete-time Markov chain $\{D^{(n)}, n \geq 0\}$ such that $D^{(n)}$ stands for the state of random variable D at n^{th} call attempt made by user over state space $\{O_1, O_2, Z, A\}$, where

State O_1: First operator
State O_2: Second operator
State Z: Success obtained in call connection
State A: User leaving (abandon) the call attempt process

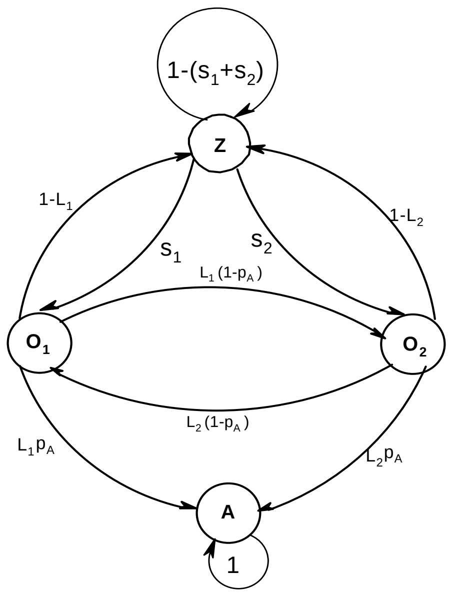

Fig. 1.2 [Transition Diagram]

Some other assumptions and their interpretations related to model are:

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(a) The connectivity attempts of user between operators are on call-by-call basis, which means if the call for O_1 is blocked in k^{th} attempt $(k > 0)$,and does not abandon, then in $(k+1)^{th}$ user shifts to O_2 . If this also fails, user switches to O_1 (or abandon).
(b) Whenever call connects through either of O_i $(i = 1,2)$, we say system reaches to the state of success after n attempts.
(c) If connected with operator O_i successfully and disconnected thereafter, the user is back to O_i again for a retry, which is faithfulness.
(d) From state Z user can not move to the abandon state A.
(e) State Z and A are absorbing state.

Incorporating above all, the transition probability matrix is in the form in fig. 1.3

$$
\begin{array}{cc}
 & \text{States} \\
 & \xleftarrow{\hspace{3em}} \quad X^{(n)} \quad \xrightarrow{\hspace{3em}} \\
 & \begin{array}{cccc} \quad O_1 \quad & \quad O_2 \quad & \quad Z \quad & \quad A \quad \end{array} \\
X^{(n-1)} \begin{array}{c} O_1 \\ O_2 \\ Z \\ A \end{array} &
\left(\begin{array}{cccc}
0 & L_1(1-p_A) & 1-L_1 & L_1 p_A \\
L_2(1-p_A) & 0 & 1-L_2 & L_2 p_A \\
s_1 & s_2 & 1-(s_1+s_2) & 0 \\
0 & 0 & 0 & 1
\end{array}\right)
\end{array}
$$

Fig. 1.3 [Transition Probability Matrix]

3.0 Results for n^{th} Attempts:

The probabilities of ultimate state n^{th} attempt are derived in the following theorem.

Theorem 3.1: If user attempts between O_1 and O_2 , then the n^{th} step state probability, for n = 1, 2, 3, - - -, is:

$$P[D^{(2n)} = O_1] = p[(L_1L_2)^n(1-p_A)^{2n} + (L_1L_2)^{n-1}(1-p_A)^{2(n-1)}(1-L_1)s_1]$$
$$P[D^{(2n+1)} = O_1] = (1-p)L_2[(L_1L_2)^n(1-p_A)^{2n+1} + (L_1L_2)^{n-1}(1-p_A)^{2n-1}(1-L_1)s_1]$$
$$P[D^{(2n)} = O_2] = (1-p)[(L_1L_2)^n(1-p_A)^{2n} + (L_1L_2)^{n-1}(1-p_A)^{2(n-1)}(1-L_2)s_2]$$
$$P[D^{(2n+1)} = O_2] = pL_1[(L_1L_2)^n(1-p_A)^{2n+1} + (L_1L_2)^{n-1}(1-p_A)^{2n-1}(1-L_2)s_2]$$

4.0 Computation of Traffic Share and Call Connection:

The traffic is shared between O_1 and O_2 and we wants to calculate the probability of call connection achieved in n^{th} attempt with O_i. The symbol $\overline{P_i}^{(n)}$ denotes the traffic division after n^{th} successful call attempt when initial share at n = 0 was p [or (1-p)]

$\overline{P_1}^{(n)}$ = P[call completes in n^{th} attempt with operator O_1]

$\overline{P_1}^{(n)}$ = P[at $(n-1)^{th}$ attempt on O_1] P[Z at n^{th} attempt when was at O_1 in $(n-1)^{th}$ attempt]

$$= P\left[X^{(n-1)} = O_1\right] P\left[X^{(n)} = Z \middle/ X^{(n-1)} = O_1\right]$$

$$\overline{P_1}^{(n)} = (1-L_1)\left\{\sum_{i=0}^{n-1} P\left[X^{(i)} = O_1\right]\right\}$$

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$$\overline{P_1}^{(n)} = (1\text{- }L_1)\left[\sum_{\substack{i=0\\ i=even}}^{n-1} P\left[X^{(i)} = O_1\right] + \sum_{\substack{i=0\\ i=odd}}^{n-1} P\left[X^{(i)} = O_1\right]\right] \tag{4.1}$$

$$\overline{P_1}^{(n)} = (1\text{- }L_1)\left[\left\{p\sum_{\substack{i=0\\ even}}^{n-1}\{(L_1L_2)^i(1-p_A)^{2i} + (L_1L_2)^{i-1}(1-p_A)^{2(i-1)}(1-L_1)s_1\}\right\}\right.$$

$$\left.+\left\{(1-p)L_2\sum_{\substack{i=0\\ odd}}^{n-1}\{(L_1L_2)^i(1-p_A)^{2i+1} + (L_1L_2)^{i-1}(1-p_A)^{2i-1}(1-L_1)s_1\}\right\}\right] \tag{4.2}$$

$$\overline{P_1}^{(2n)} = (1\text{- }L_1)\left[\{p+(1-p)L_2(1-p_A)\}\frac{1-[L_1L_2(1-p_A)^2]^n}{1-L_1L_2(1-p_A)^2}\right.$$

$$\left.+(1-L_1)s_1\{p+(1-p)L_2(1-p_A)\}\frac{1-[L_1L_2(1-p_A)^2]^{n-1}}{1-L_1L_2(1-p_A)^2}\right] \tag{4.3}$$

$$\overline{P_1}^{(2n+1)} = (1\text{- }L_1)\left[\left\{\frac{p\{1-[L_1L_2(1-p_A)^2]^{n+1}\} + (1-p)L_2(1-p_A)\{1-[L_1L_2(1-p_A)^2]^n\}}{1-L_1L_2(1-p_A)^2}\right\}\right.$$

$$\left.+(1-L_1)s_1\left\{\frac{p\{1-[L_1L_2(1-p_A)^2]^n\} + (1-p)L_2(1-p_A)\{1-[L_1L_2(1-p_A)^2]^{n-1}\}}{1-L_1L_2(1-p_A)^2}\right\}\right] \tag{4.4}$$

Similar for O_2

$$\overline{P_2}^{(2n)} = (1\text{- }L_2)\left[\{(1-p)+pL_1(1-p_A)\}\frac{1-[L_1L_2(1-p_A)^2]^n}{1-L_1L_2(1-p_A)^2}\right.$$

$$\left.+(1-L_2)s_2\{(1-p)+pL_1(1-p_A)\}\frac{1-[L_1L_2(1-p_A)^2]^{n-1}}{1-L_1L_2(1-p_A)^2}\right] \tag{4.5}$$

$$\overline{P_2}^{(2n+1)} = (1\text{- }L_2)\left[\left\{\frac{(1-p)\{1-[L_1L_2(1-p_A)^2]^{n+1}\} + pL_1(1-p_A)\{1-[L_1L_2(1-p_A)^2]^n\}}{1-L_1L_2(1-p_A)^2}\right\}\right.$$

$$\left.+(1-L_2)s_2\left\{\frac{(1-p)\{1-[L_1L_2(1-p_A)^2]^n\} + pL_1(1-p_A)\{1-[L_1L_2(1-p_A)^2]^{n-1}\}}{1-L_1L_2(1-p_A)^2}\right\}\right] \tag{4.6}$$

5.0 Computation of Traffic Share Over Large Attempts:

When number of attempts are infinitely large before getting call connected, then $\overline{P_1} = \lim_{n\to\infty}\overline{P_1}^{(2n)} = \lim_{n\to\infty}\overline{P_1}^{(2n+1)}$; $\overline{P_2} = \lim_{n\to\infty}\overline{P_2}^{(2n)} = \lim_{n\to\infty}\overline{P_2}^{(2n+1)}$ which provides

$$\overline{P_1} = (1\text{- }L_1)\left[\frac{p+(1-p)L_2(1-p_A)+(1-L_1)s_1\{p+(1-p)L_2(1-p_A)\}}{1-L_1L_2(1-p_A)^2}\right] \tag{5.1}$$

$$\overline{P_2} = (1\text{- }L_2)\left[\frac{(1-p)+pL_1(1-p_A)+(1-L_2)s_2\{(1-p)+pL_1(1-p_A)\}}{1-L_1L_2(1-p_A)^2}\right] \tag{5.2}$$

6.0 Iso-Share Equations :

The expression (5.1) and (5.2) establish a trade-off between the investments needed to acquire the first choice rank (p) and those on the network infrastructure needed to maintain an adequate

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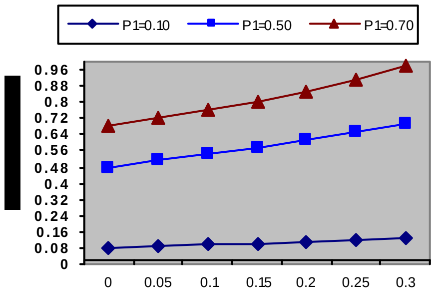
blocking and disconnectivity probability (L_1,L_2 and s_1,s_2).The same value of final share can be reached through different choices as to these parameters. The couples of points (p, L_1, L_2, s_1, s_2) that lead to the prefixed final share $\overline{P_1}$ could be obtained by rewriting expression (6.1) so as to get p as

$$p=\frac{L_1L_2(1-p_A)[1-\overline{P_1}(1-p_A)+(1-L_1)s_1]+\overline{P_1}-L_2(1-p_A)-(1-L_1)L_2s_1(1-p_A)}{L_1[L_2(1-p_A)-1+L_2(1-L_1)s_1-(1-L_1)s_1]+1-L_2(1-p_A)+(1-L_1)s_1-(1-L)L_2s_1(1-p_A)} \qquad (6.1)$$

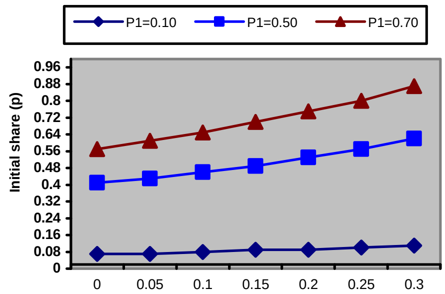
7.0 Simulation of Iso-Share Equation:

Looking into fig. 7.1 - 7.5, we observed that curves are iso-share for paired input (p, L_1) on X-axis and initial share p of operator O_1 at Y-axis. The iso-share curves are slightly concaved upward showing that in order to achieve the final prefixed share level, the operator has to compensate his initial share in the market. If the blocking L_1 is high then operator O_1 has to raise-up his initial share



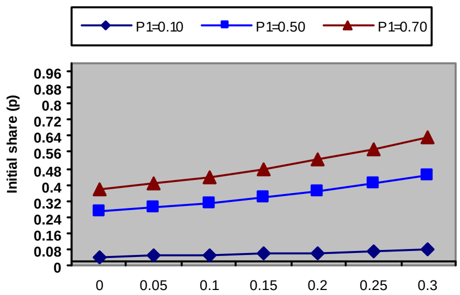
Blocking probability (L_1)

Fig 7.1(p_A= 0.05, L_2 = 0.01, s_1 = 0.02)



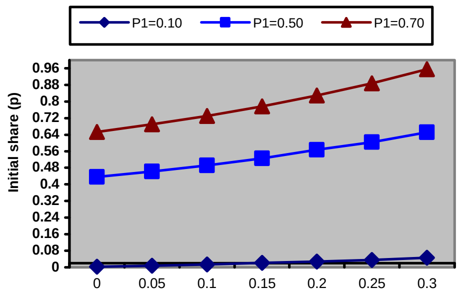
Blocking probability (L_1)

Fig 7.2(p_A= 0.05, L_2 = 0.01, s_1 = 0.2)



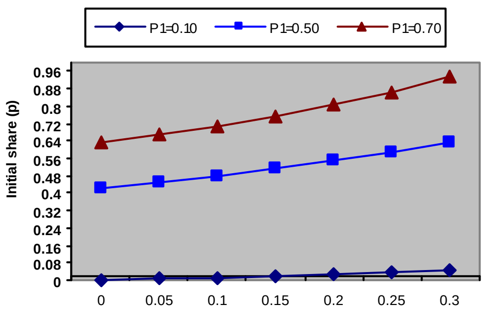
Blocking probability (L_1)

Fig 7.3(p_A= 0.05, L_2 = 0.01, s_1 = 0.8)



Blocking probability (L_1)

Fig 7.4 (p_A= 0.05, L_2 = 0.10, s_1 = 0.02)

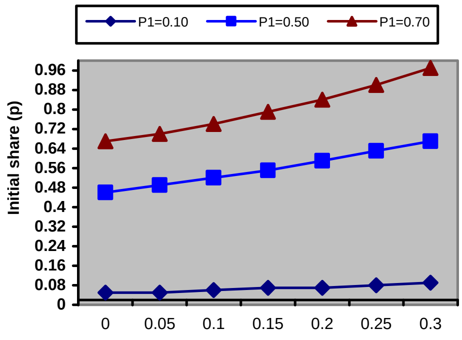


Blocking probability (L_1)

Fig 7.5 (p_A= 0.05, L_2 = 0.10, s_1 = 0.05)

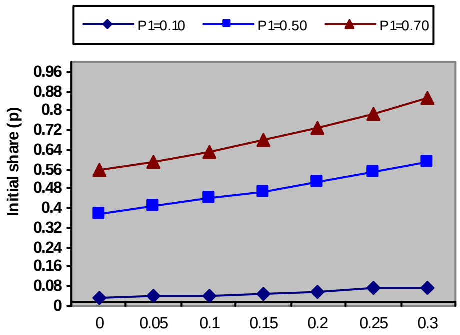
more in order to achieve the pre-desired level of final share. The increasing favoured disconnectivity s_1 plays a significant role in reducing this like compensation .If s_1 = 0.02, the initial level has to be 0.72 to get final output 0.70. But if s_1 = 0.8, the initial level needed only 0.45 to get pre-fixed final output 0.70 while fixed L_1 = 0.1 in both cases. Therefore, the increase in s_1

parameter which is favoured disconnectivity has significant effect in controlling the initial share on iso-share curves. Looking over to fig. 7.6 - 7.8, one can arrive at the same conclusion.



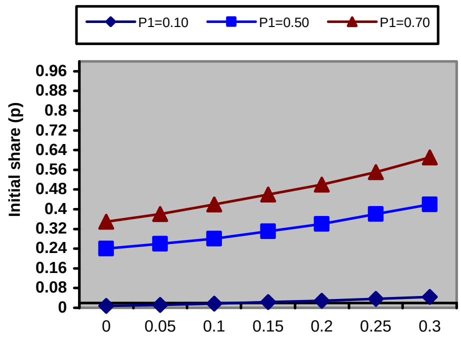
Blocking probability (L_1)

Fig 7.6(p_A=0.05, L_2=0.05, s_1=0.02)



Blocking probability (L_1)

Fig 7.7(p_A=0.05, L_2=0.05, s_1=0.2)



Blocking probability (L_1)

Fig 7.8(p_A=0.05, L_2=0.05, s_1=0.8)

8.0 Concluding Remarks:

The proposed Markov chain model explains the user behavior in presence of two new parameters s_1, s_2 related to quality-of-service offered by an operator. Iso-share curves prove this fact that favoured disconnectivity has strong effect in controlling and reducing the initial share p of customers in the market in order to achieve a prefixed final share. It is observed further that the favoured disconnectivity controls traffic share loss when self blocking in the network of an operator is high.

It is therefore recommended for Internet service providers (or operators) to incorporate favoured disconnectivity as factor in their quality-of-service package and develop related marketing plans to uplift the value of this parameter to get better traffic share in the competitive market. If an operator offers a small time slot free of cost for Internet access for each call drop then it results into favoured disconnectivity and certainly leads to better share.

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