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USER BEHAVIOUR ANALYSIS OF IPTV CHANNELS USING MARKOV CHAIN MODEL

P L SRINIVASA MURTHY[1], Dr.T.VENU GOPAL[2]

[1] *Associate Professor, Gokaraju Rangaraju Institute of Engineering & Technology, Hyderabad, India.*

[2] *Associate Professor, JNTUH College of Engineering Sultanpur, Hyderabad, India.*

ABSTRACT

Due to the emergence of innovative technologies over Internet, the traditional broadcasting of TV is changed to use IPTV for next generation networks. IPTV is the delivery of multimedia content to multiple subscribers through multicasting over well known IP. The IPTV depends on the Internet and telecommunications. Therefore, the inherent issues are to be identified and resolved for the success of IPTV. In this paper we proposed a Markov chain model that characterizes the user behaviour. Markov model a stochastic model that expresses a sequence of events. In the set of events, the probability of each event is likely based on the state gained from previous event. We considered two IPTV channels. Users may prefer any one. However, user switches to other channel if the channel fails. The Markov chain model used for modelling user behaviour includes states and transition probabilities. Quitting from a channel is the variation parameter over the popularity of channels. The more of quitting behaviour pertaining to a channel reflects the deteriorated quality of services and popularity of that channel. The results of the study reveal probable inter relationship between user behaviour parameters and channel's popularity in the market.

Index Terms – *IPTV, Markov chain, transition probability, user behaviour modelling*

INTRODUCTION

In the wake of technological advancements Internet Protocol (IP) is being used for delivering multimedia content over Internet. In fact, leveraging IP for global communications became a cheaper alternative for reliable and instant communication over global communication medium such as information super highway. It is wise idea to utilize already established public network such as Internet for public communications. With IP v6 and security considerations, IP became a viable alternative for cost effective global communications. Many technologies such as Voice over IP (VoIP) are already in place to exploit delivery of voice communications and multimedia content over Internet Protocol. This has motivated broadcasting networks like Television to adapt IP based content delivery as its next generation broadcasting method. The phenomenon which facilitates deliverance of multimedia services of Television via Internet Protocol is known as Internet Protocol Television (IPTV). Thus the TV network can leverage the advantages of well established public network (Internet) and its underlying protocols for broadcasting content. IPTV when realized fully can bestow plethora of advantages like interactive TV, personalization, low bandwidth requirement, and accessibility on multiple devices besides a low-cost service.

Traditionally TV is a telecommunications medium for delivering broadcasting content like text and moving images. Right from the inception TV had undergone many changes such as mechanical television, electronic television, colour television, digital television, smart television, and 3D television. With respect to broadcasting medium TV is categorized into terrestrial television, cable television, satellite television, and Internet television [26]. With the emergence of IPTV, there will be revolutionary changes in the way TV works as next generation mass communication medium with many benefits as said before. However, IPTV can throw many challenges as it is based on the public network Internet and over IP which is considered an untrusted public network. The challenges are pertaining to security, service quality, privacy and content quality. Reducing risk of unauthorized access to digital services rendered via IPTV is the major concern that needs to be addressed for taking the TV services to the next generation network IPTV successfully.

This paper throws light into user behaviour analysis with respect to IPTV services. We proposed Markov chain model for the said analysis. The results of such stochastic model can help in understanding the probable ground realities and make well informed decisions. The remainder of the paper is structured as follows. Section II provides related works. Section III presents the proposed Markov model for user behaviour analysis with respect to IPT services. Section IV presents the results of the study while section while V concludes the paper and provide directions for future work.

RELATED WORK

According to Obele*et al.* [1] bandwidth – hungry applications like IPTV and High-Definition Television (HDTV) have been around for some time and they keep on driving even for higher bandwidth in the networks. Habib [2] proposed a method to evaluate QoS evaluation in IPTV networks. The research was carried out on the QoS evaluation of bandwidth scheduling. Traffic policing and Call Admission Control (CAC) were applied to evaluate the QoS performance of IPTV networks. QoS differentiation is explored in [7] for having diversified traffic handling mechanism to accommodate service classes that need different quality. There must be different approaches for traffic classes like delay-sensitive and delay-insensitive traffic. Caching strategies as explored in [8] can help commercial IPTV to have high quality content delivery. For improving quality of services for IPTV, Ethernet networks have built in broadcasting capabilities [9]. IPTV is one of the transport layer protocols that needs high bandwidth besides quality of service networks [10]. Real Time Transport Protocol (RTP) is the underlying protocol for various bandwidth intensive applications like IPTV.

Link functioning under such applications were explored in [11]. For high QoS delay-oriented analysis of networks that demand high bandwidth is essential. This is explored in [12] with respect to the design and implementation of optimal scheduling algorithms. This will help in improving quality of applications like IPTV for broadcasting multimedia content. Distortion and Error Propagation modelling are explored by Chakareski [13] in the presence of predictive video coding. Loss of packets leads to distortion of video generally. These are all capable of affecting quality communications in IPTV. Similar kind of research was carried out in [18].The underlying Hidden Markov Process can take into account bandwidth variations at run time and the application layer encoding constraints and strikes balance between then for improving quality of services [14]. Gopalakrishnan*et al*. [3] explored the behaviour of consumers with respect to interactive viewing of videos in the context of IPTV. Mirtchev*et al*. [4] reviews different models for managing IP traffic in the context of IPTV. They focused on experimenting on the traffic measures on different traffic types like VoIP flows, TV, Point-to-Point (P2P), and HTTP transfer.

According to Tawnier and Perros [5], the VBR video traffic models [16] can be classified into autoregressive models, and models that are based on Markov process. Hossfeld [6] focused on how Internet applications and users behave in future. The investigation was made on emerging user behaviour in the context of next generation Internet applications. . Lee *et al*. [15] proposed a predictive tuning method that can reduce channel zapping time. This model is based on user behaviour.When the TV channels are not much popular, the content delivery is made using P2P networks while the TV channels with high popularity are given multicasting capabilities. Thus it is possible to optimize bandwidth besides improving QoE [17]. Other contributions towards IPTV include modelling multiplexed traffic [19], exploring challenges in future Internet applications [20], P2P streaming in distributed fashion [21], Push-to-Peer VoD systems [22], VoIP [23] and quality of service management approaches in IPTV content delivery.

ASSUMPTIONS AS PER THE USER BEHAVIOR

With respect to user behaviour the following are the assumptions made.

1. User tries to use the IPTV channels. If there are connectivity or quality issues, the probability of quitting user is Pc.
2. Users choose IPTV channels such as C1, C2 with probability of P and 1-P.
3. User views any one of the channels at a given time when the connectivity and quality is as expected.
4. Ci (i=1,2) failure occurs when user is not able to access channel and not satisfied with minimum quality of the channel.
5. There is possibility of switching between channels through attempts represented as n=1,2,3...
6. Users give preference to quality of services.
7. Failure probability of any IPTV channels C1 and C2 are considered to be c1 and c2.
8. Transition probability of users accessing services through C1 is 1-c1.

9. Absorbing state (self transition) probability is 1. From this state no transition to other states is expected.

MARKOV CHAIN MODEL

Under the assumptions described in the previous subsection, we proposed Markov chain model that that explores transition possibilities stochastically.

The states identified are as follows.

When {Xn, n>=0) is considered a Markov chain with state space {O, C, C1, C2, S}. The Table 1 shows the description of the states involved while Figure 1 shows the states and transitions between states with dynamic behaviour.

Table 1 – States and description

STATE	DESCRIPTION
O	Connecting state
C	Closing or quitting state
C1	User attempts to make use of IPTV channel C1
C2	User attempts to make use of IPTV channel C2
S	User gets services successfully and with good quality of service.

nWith equations (3.1) & (3.4) the average blocking (congestion) probabilities of faithful user (Bf) are equal. Since the geometric mean of the blocking probabilities b1 and b2 is smaller than their weighted sum (if $b1 \neq b2$) i. e.

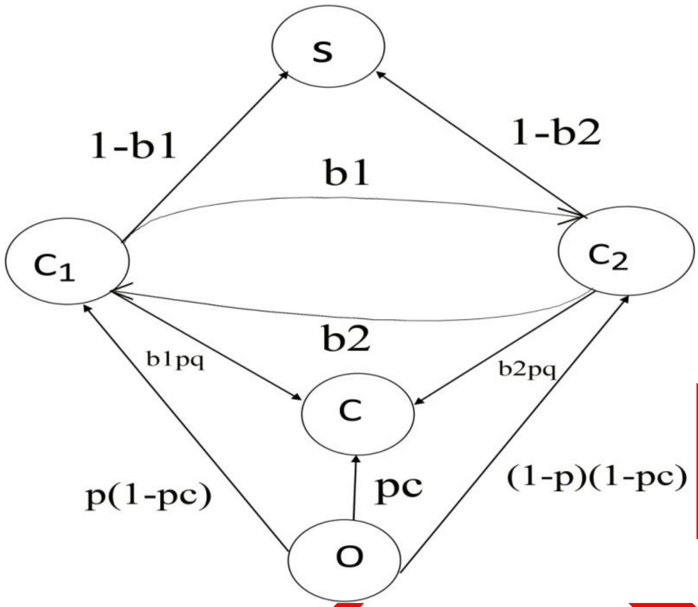

Figure 1 – Markov chain representation of the problem showing state dynamics

As can be seen in Figure 1, it is evident that the circles represent states in the Markov chain while the arcs represent transition probabilities besides connecting the states. The states represented include O, C, C1, C2, and S. The connecting state can transition to quitting state and User attempts to make use of IPTV channel C1 and User attempts to make use of IPTV channel C2. C1 and C2 can transition to quitting sate. C1 and C2 can also transition to a state which represents user gets services successfully and with good quality.

The prior conditions (n=0) which respect to state probabilities are as given here.

$P[x^{(0)}=0]=1$
$P[x^{(0)}=C1]=0$
$P[x^{(0)}=C2]=0$
$P[x^{(0)}=S]=0$
$P[x^{(0)}=C]=0$ - (1)

Afterwards, the transition probability matrix is shown in Table 2.

Table 2 – Shows transition probability matrix

$c_1 c_2$ s c

c_1 $0 b_{1(1-b_1)} (1-b_1) b_1 p_q 0$

c_2 $b_{2(1-p_{q1})}$ $0 (1-b_2) b_2 p_q 0$

$s 00\ 10\ 0$

$c00\ 010$

$op(1-p_c)(1-p)(1-p_c)0p_c\ 0$-(2)

With multiple attempts in which users try to switch to different channel, the transition possibilities are as given here.
When user makes first attempt to switch to different channel, its attempt is denoted as n=1.

$P[x^{(1)}=C1]$

$=P[x^{(0)}=o]P[x^{(1)}=C1|x^0=o]$

$=p.(1-Pc)$ - (3)

$P[x^{(2)}=C2]$

$=P[x^{(0)}=o]P[x^{(1)}=C2|x^0=o]$

$=p.(1-pc)$ - (4)

$P[x^{(1)}=C]$

$=P[x^{(0)}=C]P[x^{(1)}=C1|x^0=o]$

$=pc$ - (5)

For n is equal to 3:

$P[x^{(3)}=C1]$

$=P[x^{(2)}=C2]P[x^{(3)}=C1|x^{(2)}=C2]$

$=P[x^{(1)}=C2]P[x^{(2)}=C1|x^{(1)}=C1][b_2(1-p_q)]$

$=p[1-p_c]b_1(1-p_q)[b_2(1-P_q)]$ -(7)

$= b_1b_2p(1-p_c)(1-P_q)^2$

$P[x^{(2n)}=C1]$ - (6)

$=b_1^{n-1}b_2^{n}(1-P)(1-P_C)]b_2(1-p_q)^{2n-1};n>0$

$P[x^{(2n)}=C1]$

$=(b_1b_2)^np(1-P_C)](1-p_q)^{2n};n>0$ - (8)

In the same fashion, for channel C2:

$P[x^{(2n)}= C2]$

$=b_{1\,(}^{\,n-1)} b_2^{\,n}(1-P_C)]b_2(1-p_q)^{2n-1};n>0$ - (9)

When n is odd

$P[x^{(2n+1)}=C2]$

$=(b_1b_{2)}^{\,n}(1-P_C)]b_2(1-p_q)^{2n};n>0$ (10)

$CH=pb_1(1-p)b2$ - (11)

$B_{f=}pb_{1+}(1-p)b_2$ - (12)

Since the state probability for B1& B2 at the nth attempt depends whether n is even or odd, we can have two expressions.

$B1(n)=\frac{p[x^{(n-1)}=C1]b1+p[x^{(n-1)}=C2].b2}{[x^{(n-1)}=C1]b1+p[x^{(n-1)}=C2]}$ - (13)

$P_1(n)=p[x^{(n-1)}=C1]\ P[x^{(n)}=S|\ x^{(n-1)}=C1]$ - (14)

With equations (11) & (14) the average blocking (congestion) probabilities of faithful user (Bf) are equal. Since the geometric mean of the blocking probabilities b1 and b2 is smaller than their weighted sum (if $b1 \neq b2$) i. e.

$n>0$ - (15)

$P_1^{(n)}=(1-b_{1)}\sum_{i=1}^{n}\ p[x^{(i-1)}=C1]$ - (16)

Let $b_1b_2\,(1-p_q)^2=r$

$P_1^{(1)}=(1-b_1)\sum_{i=0}^{n}\ p[x^{(i)}=Bi]=(1-b_1)=0$ - (17)

$P_1^{(2)}=(1-b_{1)}\sum_{i=0}^{n}\ p[x^{(1)}=B1]$

$=(1-b1)[p(x^{(0)})=C1)+p(x^{(1)}=C1)]$

$=(1-b1)[p(1-pc)]=(1-b_1)p(1-p_c)]$ - (18)

$P_1^{(3)}=(1-b_{1)}\sum_{i=0}^{n}\ p[x^{(1)}=C1]$

$=(1-b_1)[p(x^{(0)})=B1)+P(x^{(1)}=C1)]+P(x^2=C1)$

$=(1-b_1)[P(1-Pc)]=(1-P)(1-P)p(1-P_c)b_2(1-P_q)]$

$=(1-b_1)\ P(1-Pc)+(1-P)(1-P_c)b_2(1-P_q)]$ - (19)

In similar fashion, for n is greater than zero and it is even:

$P^{(2n)}=(1-b_1)$

$$\begin{bmatrix} p(1-PC)\left\{1-r^{n}/_{1-r}\right\} \\ +(1-p)(1-pc)(1-\mathrm{Pq}))\mathrm{b}2\left\{1-r^{n-1}/_{1-r}\right\} \end{bmatrix} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(20)$$

For n>0; when n is Odd

$P^{(2n+1)}=(1-b_1)\{\frac{1-r^n}{1-r}\}$

$P(1-p_c)+ P(1-Pc)+(1-P)(1-P_c)b_2(1-P_q)b_2]$……………………………………(21)

When is even

$P_1=\lim_{n\to\infty}(p1)^{2n}$

$(1-b_1)(1-Pc)[\frac{P+(1-p)(1-\mathrm{Pq})\mathrm{b}2}{1-\mathrm{b}1\mathrm{b}2\ (1-\mathrm{Pq})^2}]$…………………………(22)

When is Odd

$\lim_{n\to\infty}(p1)^{2n+1}$

$(1-b_1)(1-Pc)[\frac{P+(1-p)(1-\mathrm{Pq})\mathrm{b}2}{1-\mathrm{b}1\mathrm{b}2\ (1-\mathrm{Pq})^2}]$………………(23)

Based on the user behaviour, the users are categorized into two types. They are known as faithful user and impatient user. The faithful user generally sticks a channel that provides quality of services with respect to given program. The impatient user generally switches between the available channels.

RESULTS ANALYSIS

The results of our analysis using Markov chain model are presented in this section. The proposed model is used to investigate user behaviour with favoured strategies, traffic share, failure probability that help in determining the ultimate user behaviour analysis.

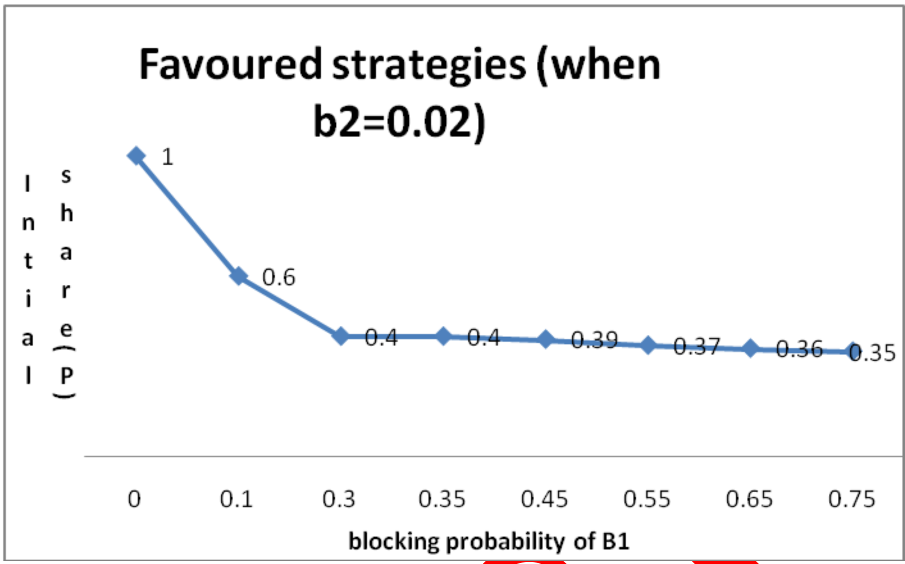

Figure 2 –Blocking probability analysis

As can be seen in Figure 2, it is evident that the blocking probability of IPTV channel is inversely proportional to initial choice of user. This clearly indicates that the users' choice is based on the quality of service.

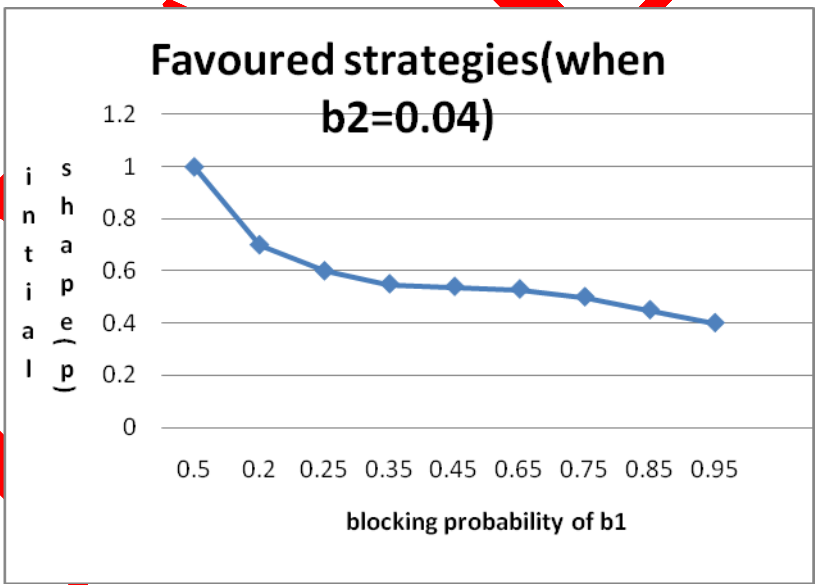

Figure 3 – Blocking probability analysis

As can be seen in Figure 3, it is evident that the blocking probability of IPTV channel is inversely proportional to initial choice of user. This clearly indicates that the users' choice is based on the quality of service. The results reveal the user behaviour dynamics when b2=0.04.

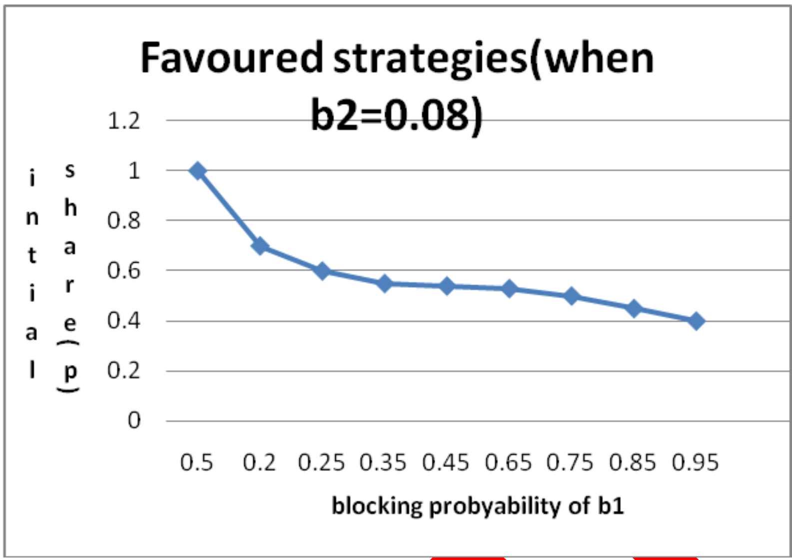

Figure 4 – Blocking probability analysis

As can be seen in Figure 4, it is evident that the blocking probability of IPTV channel is inversely proportional to initial choice of user. This clearly indicates that the users' choice is based on the quality of service. The results reveal the user behaviour dynamics when b2=0.08.

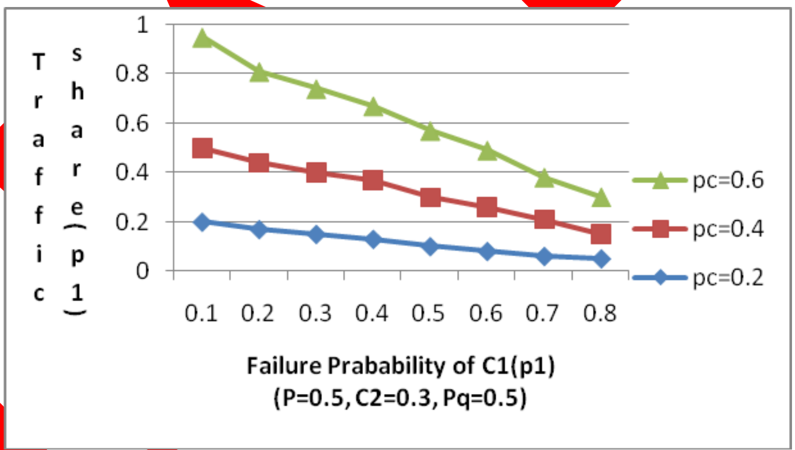

Figure 5 –Failure probability versus traffic share

As can be seen in Figure 5, it is evident that the traffic share is inversely proportional to the failure probability. The results are captured with pc=0.2, 0.4 and 0.6 and P=0.5, C2=0.3 and Pq=0.5.

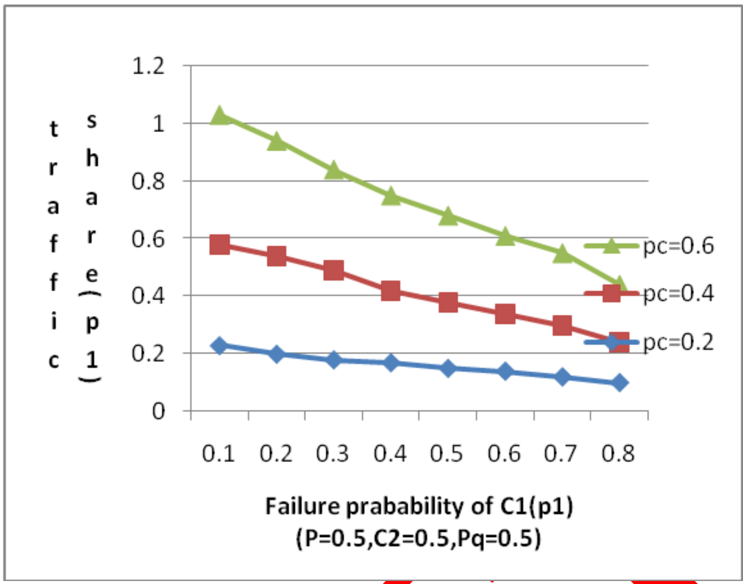

Figure 6 – Failure probability versus traffic share

As can be seen in Figure 6, it is evident that the traffic share is inversely proportional to the failure probability. The results are captured with pc=0.2, 0.4 and 0.6 and P=0.5, C2=0.5 and Pq=0.5.

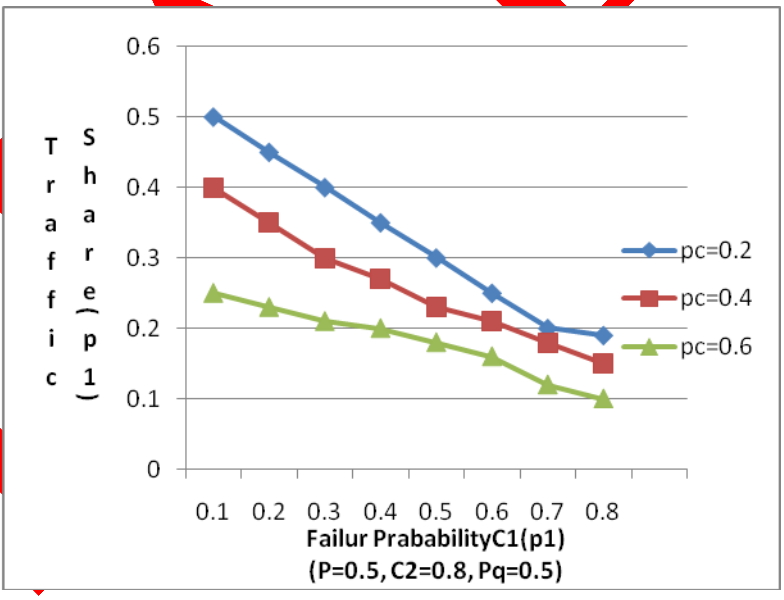

Figure 7 – Failure probability versus traffic share

As can be seen in Figure 7, it is evident that the traffic share is inversely proportional to the failure probability. The results are captured with pc=0.2, 0.4 and 0.6 and P=0.5, C2=0.8 and Pq=0.5.

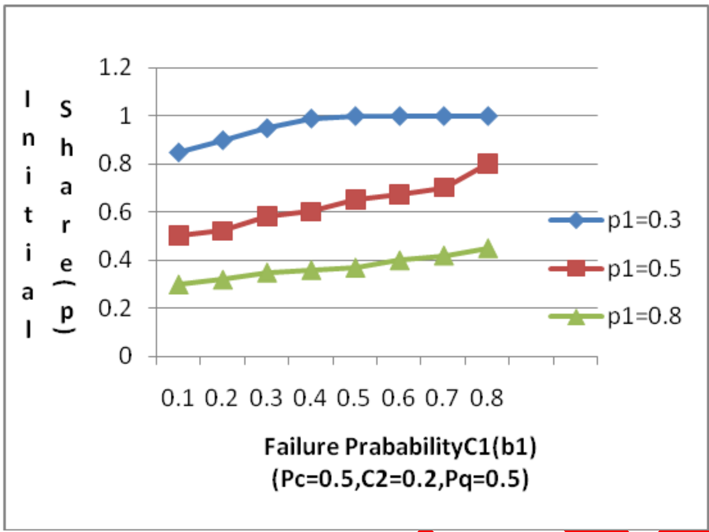

Figure 8 – Failure probability versus initial share

As can be seen in Figure 8, it is evident that the initial share is inversely proportional to the failure probability. The results are captured with pc=0.2, 0.4 and 0.6 and P=0.5, C2=0.2 and Pq=0.5.

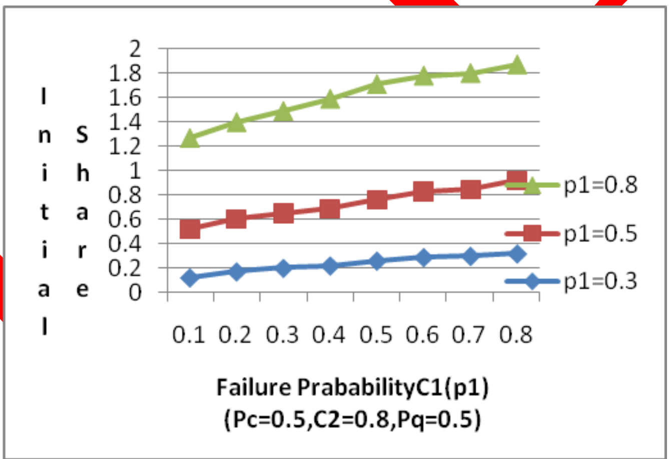

Figure 9 – Failure probability versus initial share

As can be seen in Figure 9, it is evident that the initial share is inversely proportional to the failure probability. The results are captured with pc=0.2, 0.4 and 0.6 and P=0.5, C2=0.8 and Pq=0.5.

CONCLUSIONS AND FUTURE WORK

With respect to IPTV broadcasting the failure in rendering quality services has impact on user behaviour. It inversely affects market share of channel service provider. If user’s quitting probability is increased, the reputation of the service provider decreases. Low failure rate and rendering highest quality can attract new customers besides influencing the level of loyalty from existing customers. In this paper, we studied the customer behaviour with respect to IPTV channel services. Characterization of customer behaviour can be modelled using many tools. In this paper we used Markov chain model which can present various states and the transition probabilities. Since the Markov model is a stochastic model which is suitable for predicting probability distributions by using a random variable. The random variation of the variable affects the prospects of service providers and thus is the important area of study. In this paper we considered two IPTV channel service providers and the random variable is the user behaviour of quitting the channel. From the analysis it is revealed that if the service providers' failure rate and quitting behaviour of customer, that service provider can enjoy relatively an increased loyalty and market share. An IPTV service provider can improve market share by constantly studying failure rates of its own and competitors besides taking necessary steps to have a sustainable quality of services.

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