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Performance of Optical bursts with Retransmission in OBS Networks

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Abstract: Optical Burst Switching (OBS) is the promising switching technology for demand of bandwidth requirement and technical constraints of internet traffic. Major constraint in OBS network is burst contention. Burst loss is prominent in OBS due to inadequate contention resolution techniques. Several analytical models focussing on contention resolution protocols have been developed earlier. A single server retransmission queueing system including impatient bursts, link failure and maintenance activity is analysed in this paper. Simulation experiments are performed to validate the model. Numerical results show the effect of impatience and link failure on the number of processed bursts in the network.

Index Terms: Optical Burst Switching; Impatience ; Burst retransmission; Buffering; Link failure.

1. INTRODUCTION

For the past several years a significant amount of research has been conducted in the area of Optical Burst Switching (OBS) networks. This research has been motivated by the need for the promising solution for all optical Wavelength Division Multiplexing (WDM) networks, which combines the advantages of Optical Circuit Switching (OCS) and Optical Packet Switching (OPS) techniques. The basic entity in OBS network, called burst, is the collection of packets. A burst has 2 parts called control packet (header) and data packet (payload). The control and data packets of a burst are sent separately with a time gap called offset time. The offset time is based on the number of hops the burst has to travel to reach the destination [1] and it allows the control packet to reserve the resource for data transmission**.** A major problem in OBS networks is wavelength contention which is the main reason for burst loss [2]. Contention occurs when more than one data burst try to reserve the same data channel on an outgoing link and it is solved by various approaches.

Optical buffering, wavelength conversion and deflection routing, retransmission, segmentation are few technologies that are mostly used approaches in OBS. By combining two or more of the above techniques give better network performance [3,4]. Due to contention some of the bursts will get dropped. In case of retransmission, retransmitting the dropped bursts takes place. In [5], the Anticipated Retransmission (called AR) concept is explained. The basic idea behind AR is to anticipate retransmission of dropped bursts by sending systematically two copies (primary and secondary) of each burst over two different paths. The simulation results show that AR reduces considerably the burst loss only in moderately loaded networks. The analysed model performs well in heavily loaded networks.

The queuing system proposed in [6] is analysed to find the average number of bursts reaching the destination. In OBS network, for the incoming burst if the server (data channel) is free the burst reserves it and transmission takes place. When contention occurs in source node, bursts are either stored in buffer for retransmission or leaves the system forever as impatient bursts (balking). If contention occurs during

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retransmission then the bursts either comes to the buffer or leave forever (reneging). When there is no burst in the buffer the server goes for maintenance activity. On return from maintenance activity if there is no burst in the network again the server goes for another maintenance activity. This pattern continues until the server returning, finds at least one burst in the network. The number of maintenance activities is limited to J. If there is any link failure, the repair work starts instantaneously and after completion of the repair, the server accepts the new burst only after the successful transmission of available burst (reserved time). In [7], the authors considered a queueing model in which the bursts can stay in the buffer for a limited period of time. In the analysed model we consider both balking and reneging, link failure, reserved time, maintenance activity and generally distributed service times. Impatient bursts are applied in the model to account for burst loss in the OBS. Reserved time is applied to avoid the packet loss in the transmitted burst due to link failure. Maintenance activities are done to update and enhance the performance of the network. This model can describe no impatient bursts, no link failure and no maintenance activity as its special cases.

The rest of the paper is organised as follows. Mathematical modelling is explained in section II. Simulation results are given in section III. Conclusions are presented in section IV.

2. RETRANSMISSION IN OBS NETWORKS

2.1. Mathematical Modelling

A mathematical model is analysed for the proposed scheme over OBS networks. $M^x/G/1$ retransmission queue with second optional service, impatience, repair and modified vacation is used here. This model is for the single-server infinite queuing system with buffer. The model is developed only for number of hops between source and destination is two. In this scenario, retransmission, data channel, buffer, first hop(FH), second hop(SH), link failure, impatient bursts and maintenance activity correspond to the retrial, server, orbit, essential service, optional service, repair, impatience and vacation policy respectively, in queueing terminology.

Consider a single server queueing system in which packets arrive in batches called bursts according to Poisson process with rate λ bursts/second. The burst size Y is a random variable with distribution function $P(Y = k) = C_k$, $k = 1, 2, ...$, the probability generating function $C(z)$ and first two moments m_1 and m_2. If the data channel is free, then one of the arriving bursts reserves the channel immediately and others join the buffer. If the data channel is busy all the bursts join the buffer with probability p or leave the network with probability $\overline{p}$ (= 1 – p). The burst access from the buffer to the network is governed by an arbitrary law with distribution function $A(x)$. If a primary burst arrives first, then the retransmission burst cancels the attempt for reserving channel and either returns to its position in the buffer with probability q or leaves the network with probability $\overline{q}$ $(= 1 - q)$.

There are two available hops, first essential and second optional. First hop is provided to all the arriving bursts. As soon as the FH is completed the bursts may leave the network with probability r_0 or go for the SH with probability $\overline{r}_0 (= 1 - r_0)$. The service time of i^{th} phase follows an arbitrary distribution with distribution function $B_i(x)$ and the first two moments μ_{i1} and μ_{i2}, $i = 1, 2$. There may be link failure in the network while it is working. It is assumed that the lifetime of the channel in i^{th} phase is exponential with rate α_i. The repair time of the network failed during i^{th} phase service is generally distributed with distribution function $R_i(x)$ and the first two moments γ_{i1}, γ_{i2} $i = 1, 2$.

When the link fails during i^{th} hop of the transmission, the interrupted burst remains in the same hop with probability θ_i or joins the buffer with probability $1-\theta_i$ and keeps returning at times exponentially distributed with rate τ_i, $i = 1, 2$. If the interrupted burst is not in the position, then after completion of the repair, the data channel waits for the same burst to continue the transmission. The data channel is not allowed to accept new burst until the interrupted burst leaves the data channel. Whenever the buffer becomes empty, the data channel leaves for maintenance activity of particular period. On return from maintenance activity if there is no burst in the buffer, the data channel go for another maintenance activity. This pattern continues until the data channel returning from maintenance activity finds at least one burst in the network. Number of consecutive maintenance activities is limited to J. At the end of J^{th} maintenance activity even if the network is empty the data channel is readily available in the network. The maintenance activities are generally distributed with distribution function $V(x)$ and the first two moments v_1 and v_2.

The state of the network at time t can be described by the Markov process $\{X(t), t \geq 0\} = \{S(t), N(t)\}$, where $S(t)$ denote the data channel state 0, 1, 2, 3, 4, 5, 6, j+6 according as the channel being idle, busy in first hop, busy in second hop, under link failure during first hop, under link failure during second hop, in reserved time during first hop, in reserved time during second hop and in j^{th} maintenance activity $(1 \leq j \leq J)$.

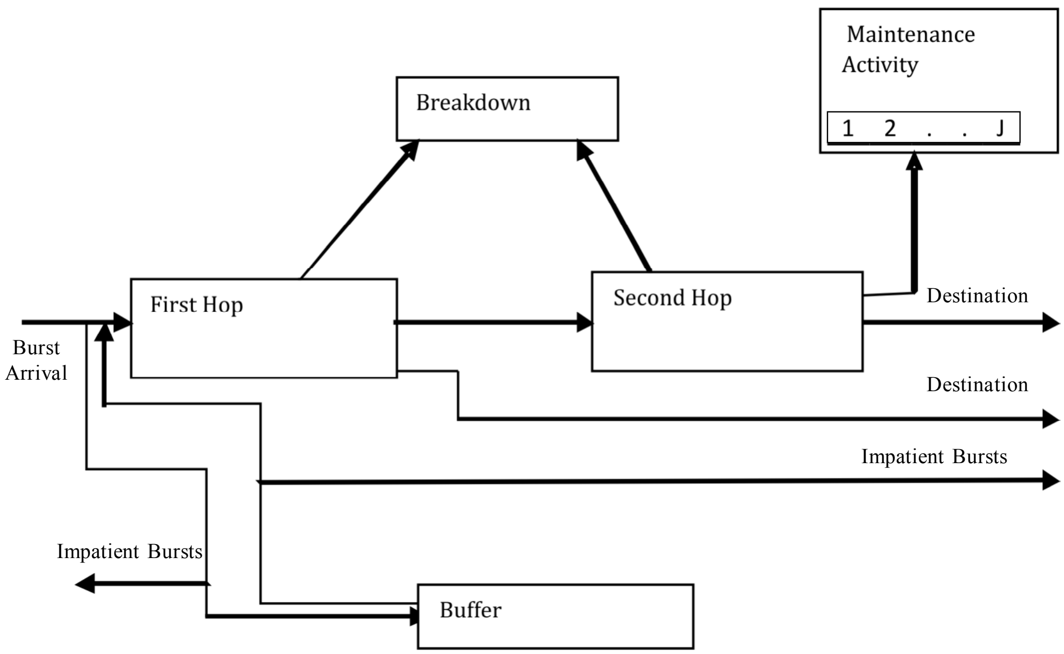

Figure 1: Representation of proposed method

$N(t)$ denotes the number of bursts in the buffer at time t.

The data channel is idle in non empty system with probability

$$I = \frac{I_0\left(1 - A^*(\lambda)[m_1 + p\lambda m_1 \mu_{11}(1+\alpha_1\left(\frac{1-\theta_1}{\tau_1} + \gamma_{11}\right)\right)\right) + \overline{r}_o p\lambda m_1 \mu_{21}\left(1+\alpha_2\left(\frac{1-\theta_2}{\tau_2}+\gamma_{21}\right)\right) + N - 1]}{D_1} \tag{1}$$

The data channel is busy with probability

$$S = \frac{\lambda I_0\left(\mu_{11} + \overline{r}_0\mu_{21}\right)\left[1 + m_1 + N - \left(A^*(\lambda) + 1 - \left(A^*(\lambda)\right)(m_1 + q)\right)\right]}{D_1} \tag{2}$$

The data channel is in link failure with probability

$$F = \frac{\lambda I_0(\alpha_1\mu_{11}\gamma_{11} + \overline{r}_0\alpha_{20}\mu_{21}\gamma_{21}\left[1 + m_1 + N - \left(A^*(\lambda) + 1 - \left(A^*(\lambda)\right)(m_1 + q)\right)\right]}{D_1} \tag{3}$$

The data channel is on maintenance activity with probability

$$V = \frac{1-(V^*(p\lambda))^J}{1-(V^*(p\lambda))(V^*(p\lambda))^J}\lambda I_0 v_1 \tag{4}$$

The availability of the data channel is

$$A = \frac{1-\left[\lambda\left(1+m_1+N-\left(A^*(\lambda)+1-(A^*(\lambda)\right)(m_1+q)\right)\right](\alpha_1\mu_{11}\gamma_{11}+\overline{r}_0\alpha_2\mu_{21}\gamma_{21})+\left(\frac{ND_1}{pm_1}\right)}{D_2} \tag{5}$$

The mean number of bursts in the buffer is given by

$$L_q = \frac{D^2(1)N^3(1)-N^2(1)D^3(1)}{3D^2(1)^2} \tag{6}$$

Where,

$$N^2(1) = 2\left[\left(1-A^*(\lambda)\right)(N(\overline{p}m_1-\overline{q})-2p\overline{q}m_1)-(1+N+pm_1+A^*(\lambda)(g_1+\overline{r}_0 g_2))\right], N^3(1) = 3(h_3+h_4+h_5)$$

$$D^2(1) = -2pm_1D_1, D^3(1) = -3p(m_1g_3+m_2D_1), g_i = p\lambda m_1\mu_{i1}\left(1+\alpha_i\left(\frac{1-\theta_i}{\tau_i}+\gamma_{i1}\right)\right), i=1,2$$

$$g_3 = 2-(h_1+2\overline{r}_0 g_2 g_1+\overline{r}_0 h_2)-2(g_1+\overline{r}_0 g_2)(A^*(\lambda)+(1-A^*(\lambda))(2qm_1+m_2)$$

$$h_i = \mu_{i1}\left[p\lambda m_2+\alpha_i\left(p\lambda m_2\gamma_{i1}+p^2\lambda^2m_1^2\gamma_{i2}+\frac{p\lambda m_2(1-\theta_i)}{\tau_i}+\frac{2p^2\lambda^2m_1^2(1-\theta_i)}{\tau_i}\left(\gamma_{i1}+\frac{1}{\tau_i}\right)\right)\right]$$

$$+p^2\lambda^2m_1^2\mu_{i2}\left(1+\alpha_i\left(\gamma_{i1}+\frac{(1-\theta_i)}{\tau_i}\right)\right)^2, i=1,2$$

$$h_3 = (h_1+\overline{r}_0(2g_2g_1+h_2)+2pm_1(g_1+\overline{r}_0 g_2)+pm_2)\left(\left(1-A^*(\lambda)\right)(m_1-\overline{q})-m_1\right)$$

$$-(g_1+\overline{r}_0 g_2)+pm_1)(m_2+2m_1-(1-A^*(\lambda))(2qm_1+m_2))$$

$$h_4 = \frac{N}{m_1v_1}(m_2v_1+p\lambda m_1^2v_2)(A^*(\lambda)+(1-A^*(\lambda))(q+\overline{p}m_1)-2+N((1-A^*(\lambda))(2qm_1+\overline{p}m_2-4pm_1)-2)$$

$$h_5 = pA^*(\lambda)[m_1(h_1+\overline{r}_0(2g_2g_1+h_2)+2m_1(g_1+\overline{r}_0 g_2)+m_2)-(m_2+2m_1)(1-(g_1+\overline{r}_0 g_2)-m_1)]$$

The mean number of bursts in the network is

$$L_s = L_q + S + F \tag{7}$$

From the above analysis, the number of bursts available in the buffer and in the network with other performance measures are calculated by varying the arrival rate.

3. NUMERICAL RESULTS

Consider NSFnet topology shown in figure 2 to implement the analysed method. This consists of 14 nodes with unidirectional links. The packets arrive in batches and are allowed to go to the source depending upon their size. Bursts are allowed to have maximum of two hops between the source and destination. Any node can randomly act as a source and destination node. For example the source destination pair for two bursts in the network are (2, 4) and (2, 5). Few bursts have source destination pair as (2, 4) and the path is 2-4 (number of hop is 1). For another few bursts source destination pair as (2, 5) and the selected path is 2-4-5 (number of hops are 2). In this case the link 2-4 is called First Hop (FH) for all the bursts and for remaining few bursts 4-5 is called Second Hop (SH). If the data channel is free one burst reserves it, other bursts wait in the buffer and retransmission takes place. If it is not free all the bursts enter the buffer and retransmission takes place or leave with impatience as explained earlier.

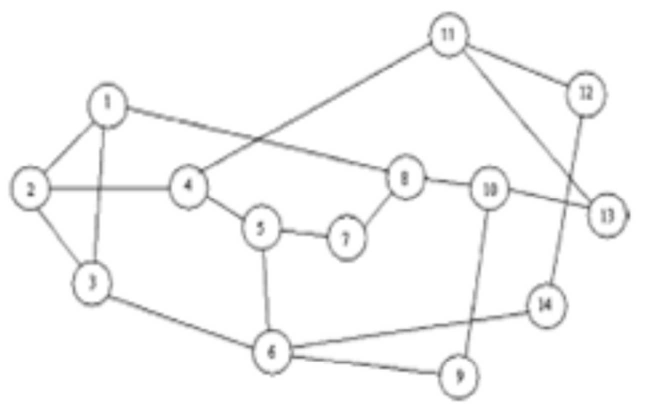

Figure 2: NSFnet topology

For numerical calculations, assume the retransmission time, service time, repair time and vacation time follow exponential distribution with respective rates η, μ_i, β_i and γ for i = 1, 2. The equations have been validated by means of MATLAB simulation. The performance measures such as expected number of bursts processed in the system, probability that the data channel is busy, probability that the data channel is under maintenance activity and the availability of data channel has been presented in the graph. We set the default parameters as $\lambda = 1$; $\alpha_1 = 0.4$; $\alpha_2 = 0.4$; $r_0 = 0.5$; $r_1 = 0.5$; $p = 0.4$; $q = 0.6$; $J = 5$; $\theta_1 = 0.4$; $\theta_2 = 0.4$; $\tau_1 = 0.5$; $\tau_2 = 0.5$; $C_1 = 0.5$; $C_2 = 0.5$; $\mu_1 = 5$; $\mu_2 = 10$; $\beta_1 = 3$; $\beta_2 = 3$; $\gamma = 5$; $\eta = 3$.

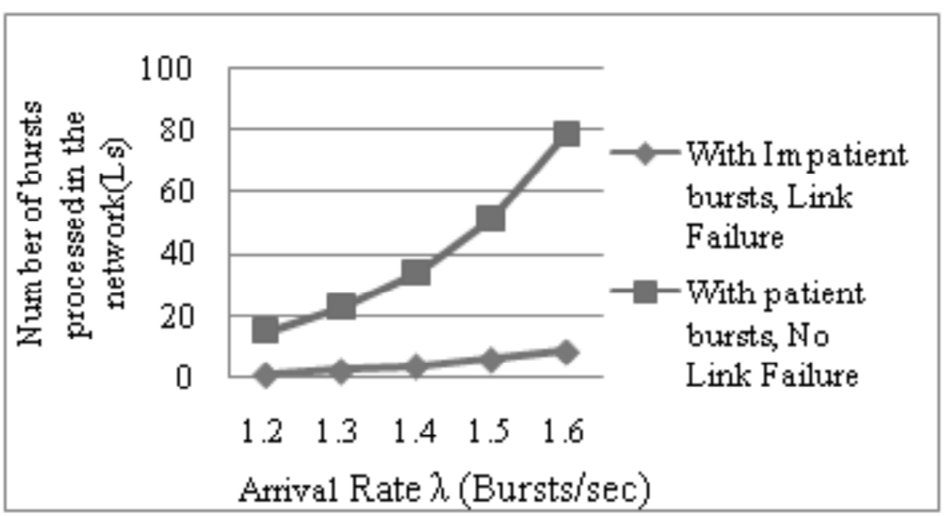

Figure 3.1(a): Comparison of Number of bursts processed in the network with patient and impatient bursts with and without link failure.

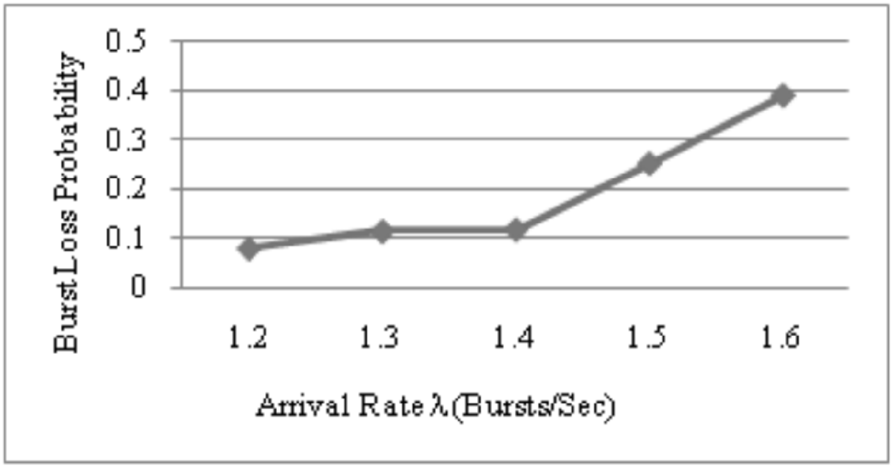

Figure 3.1(b): Comparison of Burst loss probability in the network with patient and impatient bursts with and without link failure.

In the simulation, the mean number of bursts being processed in the network under retransmission with impatient bursts with link failure is compared with retransmission with patient bursts without link failure. From the figure 3.1.a it can be seen that number of bursts processed in the network is more when there is no

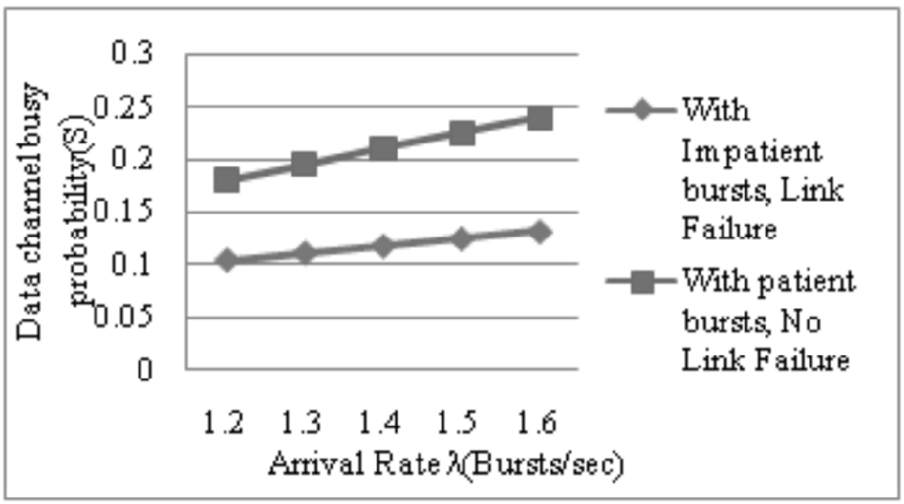

Figure 4: Comparison of probability of data channel is busy under retransmission with and without impatient bursts, link failure and maintenance activities.

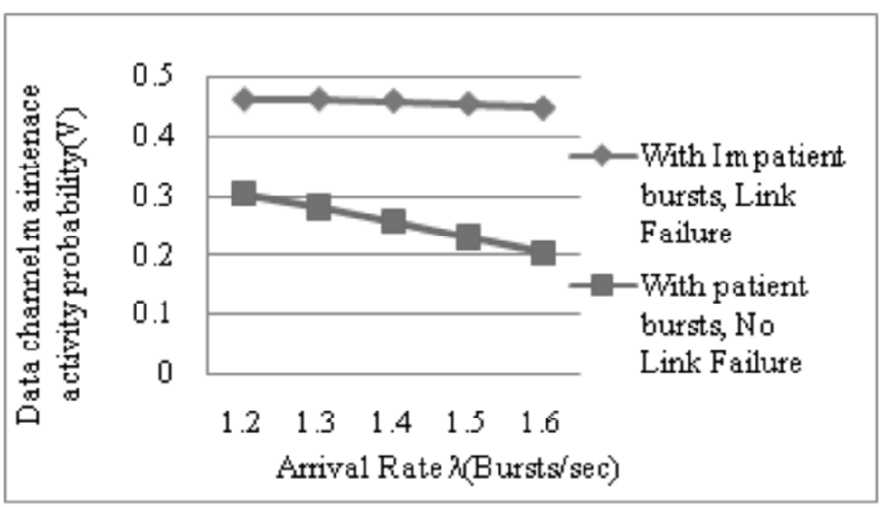

Figure 5: Comparison of probability of data channel is under maintenance activity.

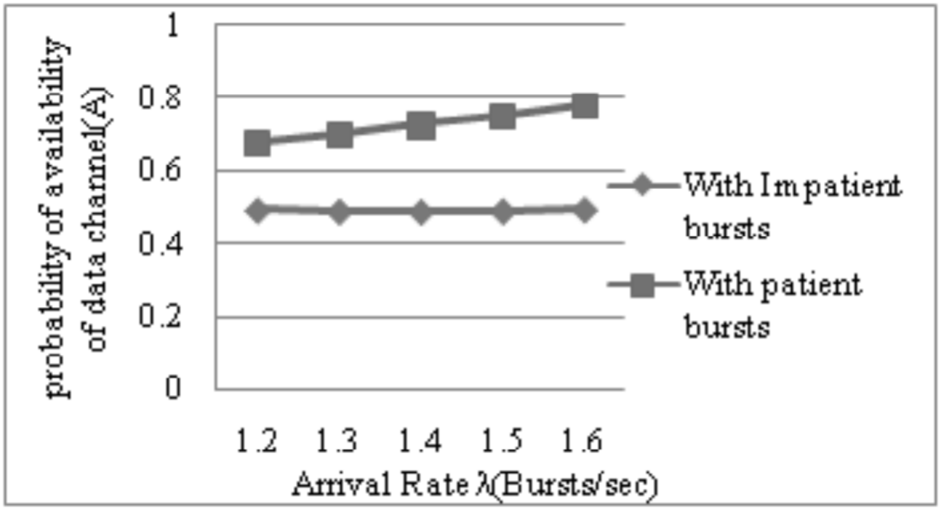

Figure 6: Availability of data channel with and without impatient bursts.

impatient bursts and no link failure. The burst loss probability of the network with maintenance activities due to impatient bursts and link failures is shown in figure 3.1.b

Figure 3.2 proves that the data channel is busier when there is no link failure and there are no impatient bursts. Figure 3.3 depicts that, if the arrival rate increases number of bursts processed in the network also increases which in turn reduces the probability of data channel going for maintenance activity.

Figure 3.4 demonstrates that the availability of the data channel increases with the arrival rate and with patient bursts.

4. CONCLUSION

Efficient contention resolution is a promising solution in OBS network, due to the increasing demand in bandwidth requirement. In this paper contention resolution is analysed with buffering, retransmission, impatience (both balking and reneging), link failure and maintenance activities. Numerical results demonstrate the effect of various performance measures with patient and impatient bursts, with and without link failures.

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