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ESTIMATION OF BURSTS LENGTH AND DESIGN OF A FIBER DELAY LINE BASED OBS ROUTER

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Abstract

The demand for higher bandwidth is increasing day by day and this ever growing demand cannot be catered to with current electronic technology. Thus new communication technology like optical communication needs to be used. In the similar context OBS (optical burst switching) is considered as next generation data transfer technology. In OBS information is transmitted in forms of optical bursts of variable lengths. However, contention among the bursts is a major problem in OBS system, and for contention resolution defection routing is mostly preferred. However, deflection routing increases delay. In this paper, it is shown that the arrival of very large bursts is rare event, and for moderate burst length the buffering of contending burst can provide very effective solution. However, in case of arrival of large bursts deflection can be used.

Keywords: OBS, Burst length, Burst loss probability, Optical router and contention.

1. Introduction

In recent years, demand for higher network bandwidth has become a major challenge for service providers due to increasing global popularity of the Internet and the service it offers. The other challenge is to provide high capacities at low cost. From the past few years, optical data communication has been considered as the best solution to meet out the present bandwidth requirements of the users and for supporting future network services. This is possible because; theoretically a single piece of optical fiber has the ability to support bandwidth demand of up to 50 THz [1]. In addition to this, optical fibers are very cheap in cost and provide extremely low bit-error rates [1]. But as the optical technology advances and the OBS vision come closer to reality, a number of other challenges will emerge. One such challenge is the design of an efficient contention resolution technique.

Nomenclatures

B	*Buffer size*
b	Number of bits in single burst
c	Speed of light, (m/s)
E[*t*]	Mean
F(t)	*Cumulative distribution function of t*
f(*t*)	Probability distribution function of t
L	Burst Length
l	Length of fiber loop
N	Switch size
n	Refractive index of fiber
P	Probability
R	Bit rate, Gbps
Std[t]	Standard Deviation
t	Random time
$t_{\circ}$	Specified time
X	Random Variable
x	Value assigned to random variable

Greek Symbols

λ	Packet arrival rate
π	Row vector in Markov chain model
ρ	Offered load
τ	Time when first packet arrives

Abbreviations

BHP	Burst Header Packet
BL	Burst Length
BPF	Band Pass Filter
CCG	Control Channel Group
CDF	Cumulative Distributive Function
DB	Data Burst
DCG	Data Control Group
FDL	Fiber Delay Line
IP	Internet Protocol
OBS	Optical Burst Switching
OPS	Optical Packet Switching
PDF	Probability Distribution Function
RWA	Routing and Wavelength Assignment
TWC	Tuneable Wavelength Converter

A. Optical burst switched networks

OBS network consists of two types of node: edge nodes (ingress and egress nodes) and core nodes [2] as shown in Fig. 1. The IP packets from the access network are collected by the ingress node in the form of bursts. Ingress node also generates control packets for setting up the light path to the egress node. Burst assembly, routing and wavelength assignment (RWA), signaling, generation of the BHP, as well as determination of the offset time is the main functions of an ingress node. At the core nodes, all optical DBs are switched from one input port to another depending on the information contained in the BHP. The core node takes the decision regarding the routing of the burst to resolving the contention among multiple bursts. The egress node disassembles the large size burst into IP packets and forwards them to the appropriate IP access network [2].

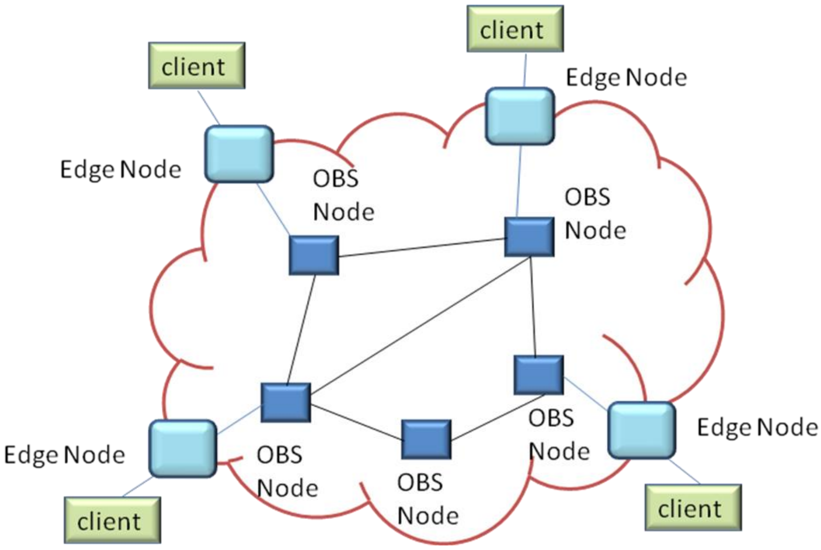

Fig. 1. Generic layout of the OBS networks.

Within OBS, optical switches provide optical paths through each router, in which data can pass optically without any electronic processing. In order to obtain the switching information needed for switching and scheduling tasks, electronic processing of the header is required in each router node [3]. To have an efficient processing of the header's routing and switching information, without disturbing the data transport, the header is removed from the data and sent in advance of the data part, on a separate control channel.

In OBS, the wavelength of a link used by the burst will be released as soon as the burst passes through the link, either by an explicit release packet or automatically according to the reservation made. This means that bursts from different sources to different destinations can effectively utilize the bandwidth of the same wavelength on a link in time-shared statistical multiplexed manner. If the control packet fails to reserve the wavelength at an intermediate node, the burst is not rerouted and it is dropped.

To avoid contention of control information, the channels inside in a fiber are divided in data channels and a few separate control channels. The Burst Header Packet (BHP) is sent in front of the Data Burst (DB) on a separate control channel. These control channels are grouped together in the Control Channel Group (CCG). The DB is scheduled on one of the data channels by a scheduler. All the different data channels form the Data Control Group (DCG) for a single fiber.

B. Deflection routing

To mitigate the burst contention problem, researchers have proposed solutions based on deflection (or alternative) routing. The main idea is to re-route the contending bursts from primary to alternative routes. With these means, it alleviates congestion on bottleneck links and achieves dynamic load balancing in the network [4].

C. Optical buffer

In telecommunications, an optical buffer is a device that is capable of temporarily storing light. Similar to a regular buffer, it is a medium of storage that enables to compensate for a difference in time of occurrence of events [4]. More particularly, an optical buffer serves to store data that was transmitted optically. In optical domain RAMs does not exists. Therefore, optical fiber delay lines are used for the buffering of the contending bursts.

In the previous work, burst buffering is not considered as good option for contention resolution, as burst size is unknown. This problem has been addressed in this paper, and possible solution is proposed.

This paper is organized into five sections; section 2, of the paper discusses the mathematical formulation for the estimation of bursts. The description of the architecture is elaborated in section 3. In section 4, simulation results are presented and major conclusions of the paper are discussed in section 5 of the paper.

2. Burst Length Estimation

In optical network traffic arrival pattern is random in nature. However, in most of application the arrival of packets is considered to be Poisson in nature [5]. Assuming that packet arrival (X) occur in time according to a Poisson process with parameter λ. Let τ denote the Length of time until the first packet arrive. The cumulative distribution function (cdf) of τ can be written as:

$$F(t) = P(\tau \le t) = 1 - P(\tau > t) = 1 - P(X = x = 0) \tag{1}$$

The probability of no arrival in time *t* using the Poisson distribution is given by

$$P(X = x) = \frac{e^{-\lambda t}(\lambda t)^x}{x!} \tag{2}$$

The probability of no arrival is given by

$$P(X = x = 0) = e^{-\lambda t} \tag{3}$$

Then the probability of arrival of at-least one packet is

$$F(t) = 1 - e^{-\lambda t} \tag{4}$$

To find the pdf of τ we take the derivative of the cdf w.r.t to *t* get:

$$f(t) = F'(t) = \lambda e^{-\lambda t} \tag{5}$$

A. Relation of Poisson and gamma distribution

Using the above analogy, the probability that we observe the L^{th} arrival after time *t* is the same as the probability that we observe less that *L* arrivals from now until time *t*. But *X* is poisson with parameter λ which has parameter λt over the time interval $(0,t)$. We compute the above using.

$$F(t) = 1 - P(X \le L-1) \tag{6}$$

$$F(t) = 1 - \sum_{x=0}^{L-1} \frac{(\lambda t)^x e^{-\lambda t}}{x!} = 1 - e^{-\lambda t} \sum_{x=0}^{L-1} \frac{(\lambda t)^x}{x!} \tag{7}$$

To find the pdf of τ we take the derivative of the cdf w.r.t to get:

$$f(t) = F'(t) = e^{-\lambda t} \lambda \sum_{x=0}^{L-1} \frac{(\lambda t)^x}{x!} - e^{-\lambda t} \sum_{x=0}^{L-1} \frac{x(\lambda t)^{x-1} \lambda}{x!} \tag{8}$$

Using the elementary algebra we get,

$$f(t) = e^{-\lambda t} \lambda \frac{(\lambda t)^{L-1}}{(L-1)!} = \frac{t^{L-1} \lambda^L e^{-\lambda t}}{\left(L-1\right)!} \tag{9}$$

The above obtained p.d.f. known as Gamma distribution and defined as

$$\Gamma_t(L,\lambda) = \frac{\lambda^L t^{L-1} e^{-\lambda t}}{(L-1)!}, t \ge 0 \tag{10}$$

With mean $E[t] = \frac{L}{\lambda}$ and standard deviation

$$Std[t] = \sqrt{\frac{L}{\lambda^2}} \tag{11}$$

The probability to actually have *L* packet arrivals before release time t_0 is given by [6, 7]:

$$P(t < t_0) = \int_0^{t_0} \frac{\lambda^L t^{L-1}}{(L-1)!} e^{-\lambda t} dt = \frac{\gamma_{inc}(L, \lambda t_0)}{(L-1)!} \tag{12}$$

where γ_{inc} refers to the incomplete gamma function.

In network packets arrives in bunch and they show self similar feature. Additionally, aggregating streams of self-similar traffic typically intensifies the self-similarity ("burstiness") rather than smoothing it. The queue length distribution of self-similar traffic decays more slowly than with Poisson sources. Still a fair comparison is possible with Poisson arrivals.

The probability distribution function vs. time is plotted for different burst length, ranging from 1 to 15; it is observable form Fig. 2, as the burst length increases the pdf becomes flattened.

In Fig. 3, the probability of generation of burst length *L* vs CDF is plotted for low arrival rates. For burst length of 14, at the arrival rates of λ of 0.2, 0.6 and 1, the probability is $\approx 10^{-11}, \approx 10^{-5}$ and $\approx 10^{-3}$ respectively.

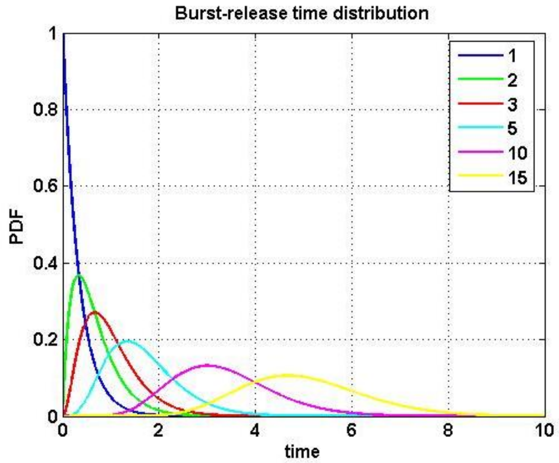

Fig. 2. PDF vs. time.

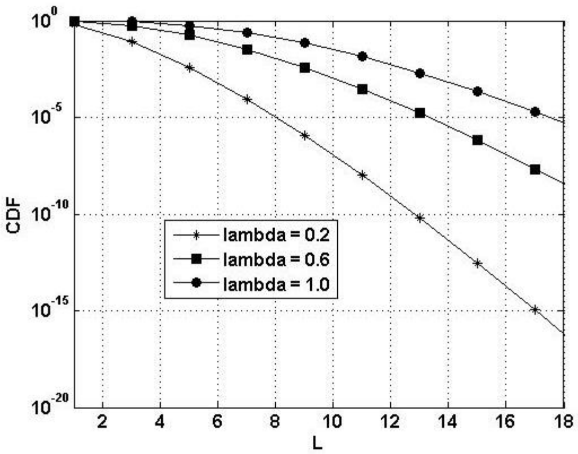

Fig. 3. CDF vs. Burst Length for various value of lambda.

In Fig. 4, CDF $P[t < t_0]$, the probability of assembling a burst of length *L* in time less than or equal to t_o. It is clear from Fig. 4, the probability of assembling larger burst is smaller in comparison to smaller burst length. For $t_0 = 4, \lambda = 3$, the probability of getting a burst length 10 is 0.7576, while for *L*=40, the probability is $\approx 10^{-10}$. It is obvious form the figure, the probability of getting burst length greater than 30 is very less.

It is shown in Fig. 5 that as the arrival rate increases, the burst assembly time decreases. The results is drawn for the burst length of 6 and $t_0 = 4$. For lambda 2, the probability is 0.8088 and for lambda 3, the probability is 0.9797. Therefore it is very obvious that the probability of generation of larger size bursts is smaller in comparison to smaller size bursts.

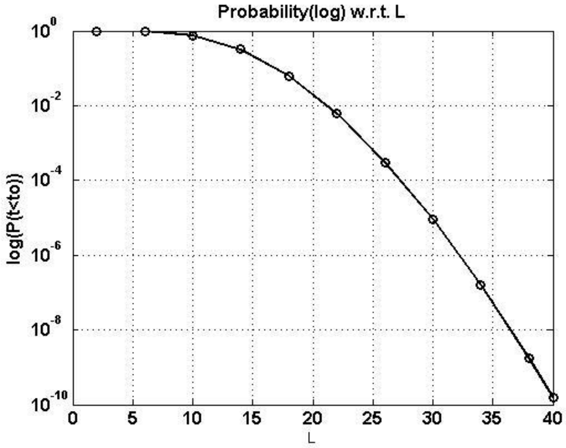

Fig. 4. CDF vs. Burst Length for fix value of lambda.

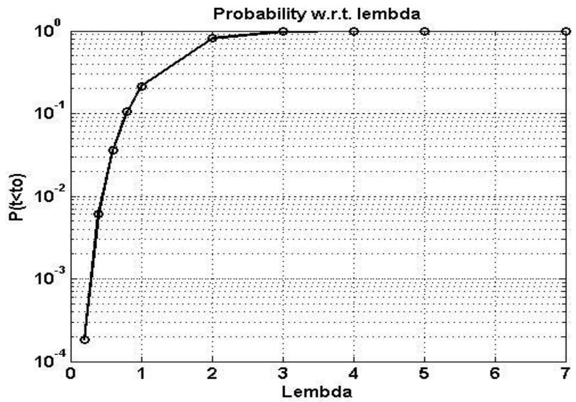

Fig. 5. CDF vs. lambda for fixed time *t*.

In Fig. 6, CDF vs. burst length is plotted with varying time'*t'* with $\lambda = 3$. As expected for the larger '*t'* the probability of generation of larger bursts is larger. Thus form above two figures it can be concluded that the probability of the generation if burst depends heavily on arrival rate λ and assembly time *t*. From the above two Figs. 5 and 6, it can be concluded that the probability of generation of burst of particular length L heavily depends on the product λt , if this product is higher than the probability is higher.

Therefore form the above discussion it can be concluded that: in any network the generation of larger burst is a rare event, as the assembly time should be very large (means extra delay) for the generation of larger size bursts.

As also suggested in the larger size burst have larger data loss in case burst is loss, and idea of burst segmentation is suggested for larger size bursts. Therefore it is un-necessary to first assemble larger size bursts and then segment them. Moreover, this exercise will increase the delay as well as complex controller design to carry out segmentation process. However, the generation of larger bursts is rare event, but probability of generation of larger size burst is not zero.

Therefore, it is necessary to have provision for both shorter and larger burst length to resolve contention among bursts. So we propose that, for smaller and medium burst lengths contending bursts will be stored at the contending nodes and larger bursts which can't be stored due to the buffer size limitations will be deflected in the network.

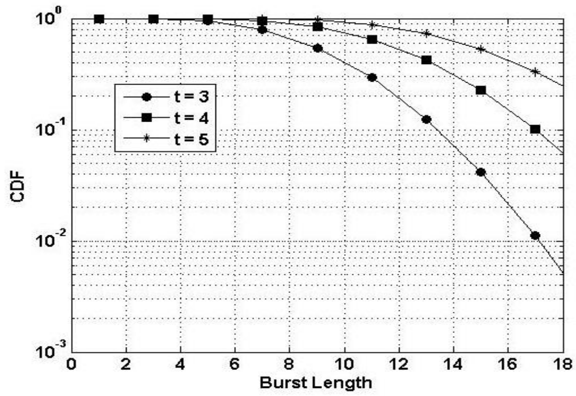

Fig. 6. CDF vs. Burst Length for various value of *t*.

3. Architecture Design

As discussed above that the buffering of the contending bursts at the contending nodes reduces the burst loss probability. The buffering of the bursts at each contending nodes is only possible through the optical switch. The optical switch under consideration is shown in Fig. 7.

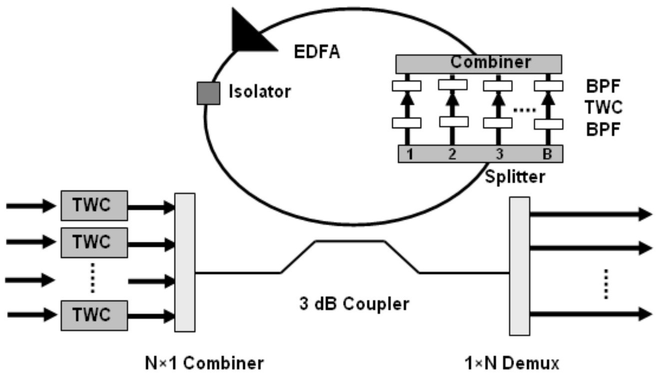

Fig. 7. Switch architecture design.

In this switch, wavelengths inside the fiber loop are grouped and number of such groups (*G*) equal to the number of TWCs in the loop buffer (*T*) plus one i.e. $G = T+1$, with each group containing *N* wavelengths [8]. Thus the total number of wavelengths used by the switch is $(T+1)\ N$. In worst case delay situation, the TWCs at the input of the switch tunes the packet to wavelength in group *T* which is permitted to enter the TWC in branch number *T* due the BPF just after the splitter (Fig. 7). It converts the packet wavelength to a wavelength belonging to the $(T\text{-}1)^{th}$ group. The packet shift from one wavelength to another after each circulation; thus by changing the group every time and finally getting assigned to the output wavelength, which is passed by the fixed filter at the output. Depending on the amount of delay required, the TWC at the input of the switch tune the packet wavelength to appropriate group. The wavelength selection within the group is decided by the output port to which packet is destined.

The length of the fiber loop will be decided by the Burst length, as discussed above, the burst length will be equal to the integral multiple of the single packet duration.

$$l = cb / nR \tag{13}$$

where '*c'* is the speed of the light, '*b*' is then number of bits in a single burst, '*n'* is the refractive index of the fiber and '*R*' is bit rate.

$b = LP$, *b* is burst length *L* is the number of packets and *P* is unit packet length.

In Fig. 8, length of the fiber delay lines is plotted vs. burst length at various data rates. It is clear from the figure as the as the burst size increases the FDL also increases. However as the data rates increase the FDL length decreases.

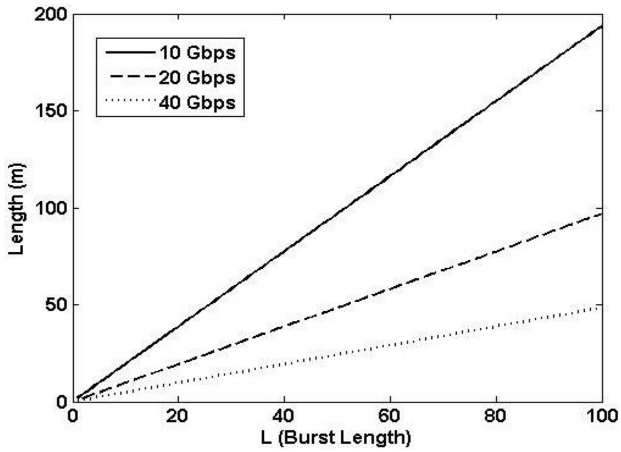

Fig. 8. Burst Length vs. buffer FDL at different data rates.

4. Simulation and Results

In reality data traffic is usually bursty in nature. In the bursty traffic arrivals are correlated, i.e., packets arrive in the form of bursts. It is characterized by the offered load (ρ) and burst length (*BL*) [8]. Each burst of packets is equally likely to be destined to any of the output with probability *1/N*.

The probability that particular burst have *K* packets is

$$\Pr(K) = (1 - P_b)(P_b)^{K-1} \qquad K \geq 1 \tag{14}$$

Thus the average burst length can be obtained as

$$BL = \sum_{K=1}^{\infty} K.\Pr(K) = \frac{1}{1-P_b} \qquad (15)$$

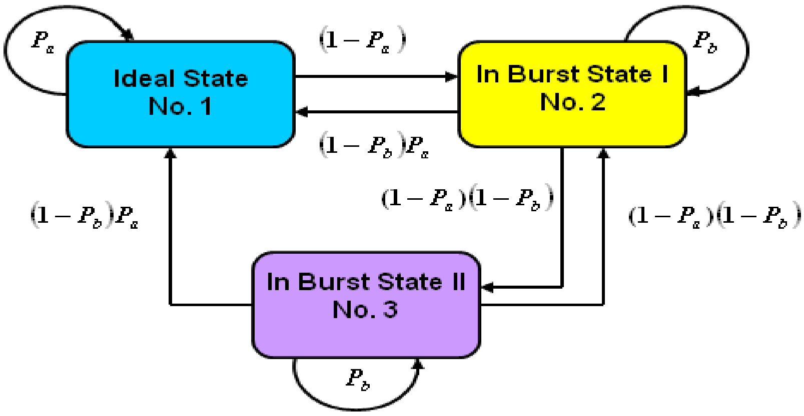

Fig. 9. Markov chain model for the bursty traffic.

A. Results

In Fig. 10, loss probability vs. load on the system is plotted for various values of *N* i.e., number of inputs. the buffering of zero, i.e., at the contending node no burst will be stored, and in case of contention it will be defected to some other node, form where it will come back again to the contending node and if contention is resolved it will be served. In the simulation the bursty traffic model is considered. Here, the switch size is varied form 4, 8 and 16. Here, as no buffering is assumed at each node, therefore a large number of bursts ~ 35% will be deflected. Therefore as suggested previously [7] that in case of OBS contention the defection of burst is a very good viable option is not correct due to the following reasons:

- The deflection of packet will generate many dummy packets in the networks.
- The network will easily be congested, and therefore further enhances the contention of bursts.
- Due to the alleviated contention the throughput of the network decreases and the average latency can be very huge.

In Fig. 11, loss probability vs. Load for fixed switch size *N*=4, different buffer sizes for burst length *L*=4. In this figure B =2 denotes that only two burst of length 4, can be stored. It is clear from Fig. 11, even very small buffer space significantly reduces the Burst loss probability. For B=8, at the load of 0.6 Burst loss probability is as low as 3×10^{-4}.

Loss Probability vs. Load for fixed switch size *N*=4, different burst length with buffer sizes *B*=64. It is clear from Fig. 12, as the burst length increases the burst loss probability increases as now lesser number of burst can be stored. At the load of 0.8 the burst loss probability is very low for *L*=4, and at the similar load for *L*=16 the BLP is as low as 4×10^{-2}.

In Fig. 13, loss probability vs. Load for fixed switch size *N*=4, different buffer sizes for burst length *L*=20. In this figure *B* =4 denotes that only four burst of length 20, can be stored. It is clear from Fig. 13 even very small buffer space significantly reduces the Burst loss probability. For *B*=8, at the load of 0.6 Burst loss probability is as low as ~ 10^{-3}. Moreover for the larger buffer space burst loss probability decreases.

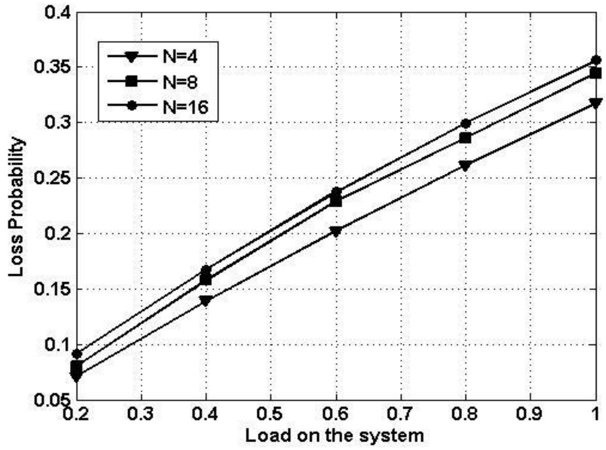

Fig. 10. Loss Probability vs. Load for different numbers of inputs without buffer with burst length of 2.

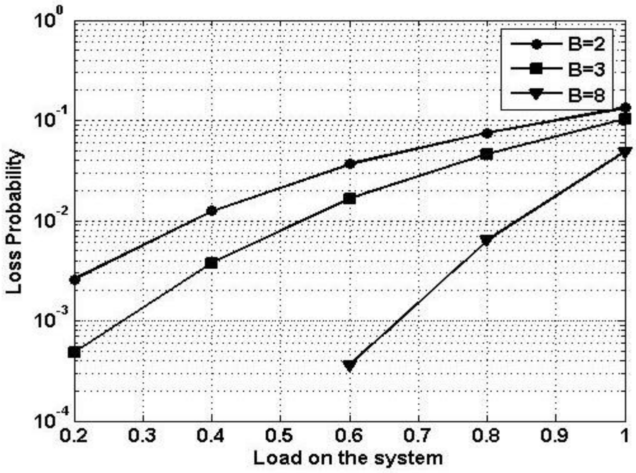

Fig. 11. Loss Probability vs. Load for fixed switch size *N*=4, different buffer sizes for burst length *L*=4.

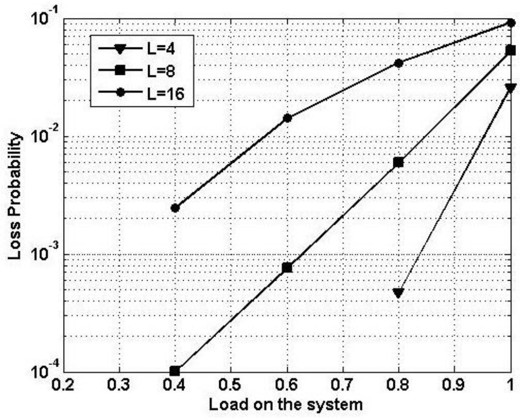

Fig. 12. Loss Probability vs. Load for fixed switch size *N*=4, different burst length with buffer sizes *B*=64.

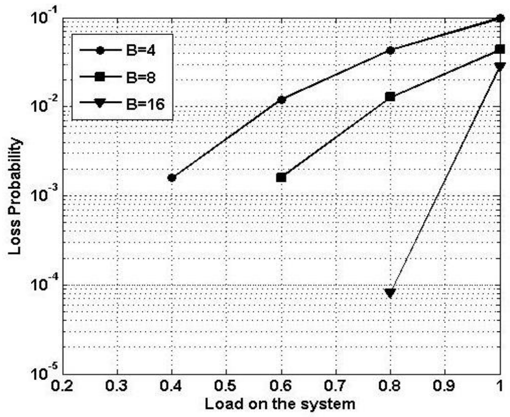

Fig. 13. Loss Probability vs. Load for fixed switch size *N*=4, different buffer sizes for burst length *L*=20.

5. Conclusions

In this article a novel paradigm called the optical burst switching (OBS) as an efficient way to resolve the problem of congestion that the Internet is suffering from is discussed. The major issue in the OBS is the estimation of the burst length before it arrives to the destination nodes. Due to this un-certainty, the deflection routing was assumed to be only feasible option for the contention resolution of the bursts. In this paper, we have discussed that the arrival of very large burst is very rare event; hence network cannot be designed on the basis of very large bursts. The theoretical results are presented to validate our hypothesis. Finally, we conclude that the storage of burst at the contending node for smaller and average size burst along-with the deflection of the larger size burst is the more suitable option rather than deflect all the contending bursts. The suggested methodology will increase the network throughput while reducing the average delay.

Hence, in shell following conclusions can be made

- Defection routing alone is not good idea as burst loss probability is very high.
- The buffering of burst at the contending node improves the burst loss probability. In case of no buffering is assumed at each node, a large number of bursts ~ 35% will be deflected.
- As the burst size increases while keeping the buffering capacity fixed the burst loss probability increases.
- The increase in buffering capacity improves the Burst loss probability.
- If very large sizes burst arrives (more than the buffering capacity) then these burst can be deflected to avoid loss of data.
- Thus for smaller of medium size burst in case of contention the burst can be buffered while for the larger size burst the deflection routing can be considered. For B=8, at the load of 0.6 Burst loss probability is as low as $\sim 10^{-3}$.
- Hence, in conjunction of both buffering and deflection of burst provide more realistic and effective solution.

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