ESTIMATION OF THE BURST LENGTH IN OBS NETWORKS

Pallavi S.
Department of CSE, Sathyabama University
Chennai, Tamilnadu, India
pallavi.das12@gmail.com

M. Lakshmi
Department of CSE, Sathyabama University
Chennai, Tamilnadu, India
laks@icadsindia.com

Abstract

This paper presents an overview of the optical burst switching (OBS) and discusses the major components. In OBS, the length of the burst arriving at a particular node is unknown, and hence, node design is very complex. In OBS first control, packet is transmitted and reserve the path as in circuit switching, thereafter, the data bursts is transmitted. In this paper, a poisson arrival of packets is considered and estimation is made on the size of the burst length. The results presented in the paper clearly reveal that, the very large burst length is un-common. Therefore, most of the times, very short or average length burst is expected. Therefore it is concluded in this paper, buffering of burst at the contending nodes is a good option which increases the throughput and reduces the average delay. Finally, the buffering in conjunction with deflection of bursts will provide very effective solution.

Keywords— OBS; Burst length; Poisson Arrival; Cumulative distribution function.

1. INTRODUCTION

Optical burst Switching (OBS) is a switching paradigm, which can provide very high speed data transmission [1]. The concept of OBS is not new; however, due to the complexity of the OBS,this area of research is very challenging. In OBS, it is assumed that the information is transmitted in the form of bursts of packets, and a single burst may be of any length.As the burst length is not fixed, it is very difficult to design a system with such a large variation of the burst length [2]. Therefore, in the available literature, it is assumed that at any node either burst will be served or it will be deflected to some other node in case of contention. However, due to the deflection of bursts, a large number of bursts simultaneously can exist in the network and may become bottleneck for the network.

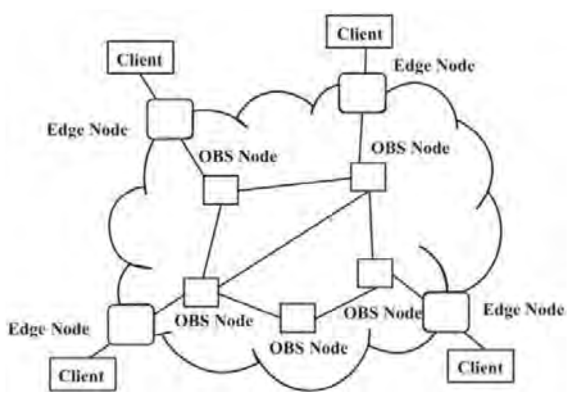

Fig. 1.General layout of an OBS network architecture

Fig. 1shows an OBS network with three components: an ingress node, an egress node anda network of core nodes. In OBS network, different types of data from the access networkare combined to form a single large size data burst at an ingress node (an edge node), and that burst is transmitted inoptical domain. Bursts destined to the same egress node which will lead to correct destination (destination edge node) and requiringthe same level of service (if supported) are aggregated into a burst at the burst assembly queue.

A controlpacket i.e. burst header packet (BHP) havingvarious information like; the information of the length and arrivaltime of the data burst is sent in advance to avoid buffering and processing of data burst (DB)at intermediate core nodes[3]. As shown in Fig. 2, the BHPs are transmitted ona dedicated control wavelength, whereasDBs are sent on a separate wavelengthafter some delay [3].

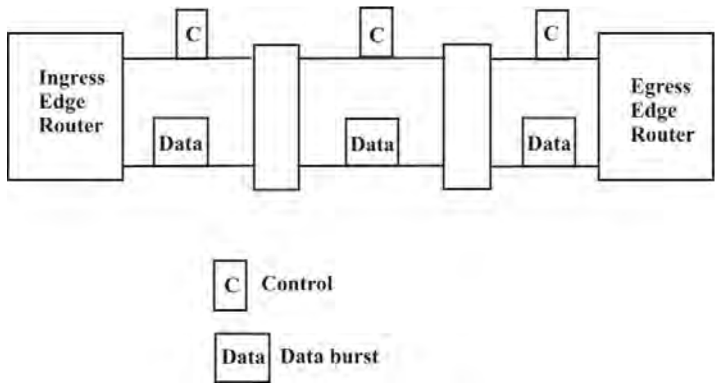

Fig.2.Transmission of Burst and control packet

As the data remainsin optical form in core network, it is transported much faster as compared to the header. This results in too much overhead for the electronic processing with respect to the data part of IP packets. Therefore, it is proposed by researcher, notto transport the data as separate IP packets, ratherthan to group the packets together to form bursts of variable length. Packets with same edge nodes and Quality of Service (QoS) requirements will be put in the same burst and thus will have only one BHP. The remainingDB is transmitted unchanged through the network, until it reaches the edge of the network (Fig. 2). At the edge, the DB will be separated back into IP-packets.

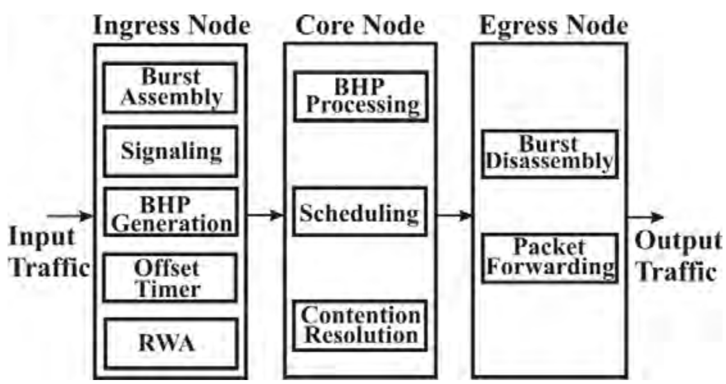

Fig. 3.Block diagram of functionalities of different nodes in an OBS network.

The time lag between a BHP and the corresponding DB is known as the offset time, which is kept high enough to enable the processing of BHP at the core nodes. Once a burst reaches the egress node where it exits the core network, it is disassembled into packets which are further routed through the access networkto the appropriate output [3].

OBS network consists of two types of node: edge nodes (ingress and egressnodes) and core nodes [3] as shown in fig. 3. The IP packets from the access network are collected by the ingress node in the form ofbursts. Ingress node also generates control packets for setting up the path to theegress node. Burst assembly, routing and wavelengthassignment (RWA), signaling, generation of the BHP, as well asdetermination of the offset time is the main functions of an ingress node. At the core nodes, all optical DBs areswitched from one input port to another depending onthe information contained in the BHP. The core node takes the decision regarding the routing of the burst to resolving the contentionamong multiple bursts. The egress node disassembles the large size burst into IP packets and forwardsthem to the appropriate IP access network [3].

Optical Burst Switching (OBS) is distinguished from other optical switching technologies due to its two features: 1) the OBS allowed the transmission of large data bursts, which are aggregated at the edge nodes of the network, and 2) the possibility to establish a path dynamically and on-the-fly (i.e. without acknowledgment of the availability of transmission resources). As the optical buffering capability in the core nodes is not available hence, the main challenge of OBS networks is to deal with high burst losses due to the contention of bursts transmitted in the network.

To combat the burst contention problem, many solutions based on deflection (oralternative) routing was proposed [4-5]. All of these methods allow re-routing contending bursts from primary route to alternative routes, and by employing these methods, alleviating congestion on bottleneck links and achieves a dynamic balancing of the load in the network.

In principle, the transmission of optical bursts is asynchronous in nature, or in other words, the arriving bursts are not time aligned to each other, and thus they can arrive at a core switching node in any instances of time. It is shown in the past that the performance can be improved if synchronous operation is applied: in fact, in such a case contention may occur only between entire data units (at the slot boundary) and thus better utilization of transmission resource can be obtained with simple contention resolution mechanisms [6].

As the burst length is not fixed, the concept of buffering of burst at the intermediate/ destination node was assumed to be non-feasible solution. However, in the recent past, some researcher looked into the concept of the buffering of the contending burst at different nodes, between the source and destination.

Typically, the Burst control packet (BCP) is generated and transmitted straightafter the data burstis assembled at the border node, since it must know the exact burst size andrelease time to inform the intermediate nodes' scheduler, under Just-Enough-Time (JET) scheduling [1, 7]. Hence, in addition to the delay suffered by thedata packets during the burst assembly process, the packets suffer an extradelay given by the offset-time between the BCP and the data burst. In certainsituations, such delay may be excessive.

To alleviate such long delay, this work proposes a mechanism to overlap theburst-assembly delay and the offset delay suffered by the data packets. Essentially,after the first packet has arrived at the burst assembler, the algorithm presented in [8] generates and sends off the BCP to the next hop in the path. Such early BCPcarries out a given burst-release time (which is equal to the offset time) anda rough estimation of the final size of the optical burst.However, the size of the buffer at each node cannot be fixed until unless we have rough estimate of the burst length. In this paper we extending the work presented in [8] and an estimate is presented on the burst length and how buffering of burst can be made possible.

2. Traffic Arrival and Pattern

In the network, traffic arrival is random in nature, and in general, the arrival is considered Poisson in nature. In the similar context, it is assumedthat events (X) occur in time according to a Poisson process with parameter λ .Let *T* denote the length of time until the first arrival so that *T* is a continuous random variable. To find the probability density function (PDF) of *T*, we begin with the cumulative distribution function (CDF) of *T* as follows:

$$F(\mathrm{t}) = \mathrm{P}(\mathrm{T} \le \mathrm{t}) = 1 - P(\mathrm{T} > \mathrm{t}) = 1 - P(\mathrm{X} = 0) \quad (1)$$

In words, the probability that we observe the arrival after time *t* is the same as the probability that we observe no arrivals from now until time *t*. But,*X* is Poisson with parameter λ which has parameter λt over the time interval $(0,t)$. Eq. 1 can be computed as

$$F(\mathrm{t}) = 1 - \frac{(\lambda\,\mathrm{t})^0 e^{-\lambda t}}{0!} \Rightarrow F(\mathrm{t}) = 1 - e^{-\lambda t} \quad (2)$$

To find the PDF of *T*, we take the derivative of the CDF w.r.t *t* get:

$$f(\mathrm{t}) = F'(\mathrm{t}) = \lambda e^{-\lambda t} \quad (3)$$

We observe that if $X \sim \mathrm{Poisson}(\lambda)$ the time until the first arrival is exponential with parameter λ .

2.1. *Relation of Poisson and gamma distribution:*

Suppose that the event occurs in time according to a Poisson process with parameter λ so, $\sim \mathrm{Poisson}(\lambda)$ .Let *T* denotes the length of time until *L* arrivals. Then *T* is a continuous random variable. To find the PDF of *T*, we begin with the CDF of *T* as follow.

$$F(t) = P(T \le t) = 1 - P(T > t) \quad (4)$$

$$F(t) = 1 - P(X < k) = 1 - P(X \le k-1) \quad (5)$$

In word,the probability that we observe the k^{th} arrival after time *t* is the same as the probability that we observe less than*k* arrivals from now until time *t*. But,*X* is poisson variable with parameter λ which has parameter λt over the time interval $(0,t)$. We compute the above Eq. 4 and 5:

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

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

To find the PDF of *T* we take the derivative of the CDF w.r.t *t*.

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

Eq. 8 can be expressed as:

$$\begin{aligned} f(t) &= e^{-\lambda t} \lambda \left[\sum_{x=0}^{k-1} \frac{(\lambda t)^x}{x!} - \sum_{x=1}^{k-1} \frac{x(\lambda t)^{x-1}}{x(x-1)!} \right] \\ &= e^{-\lambda t} \lambda \left[\sum_{x=0}^{k-1} \frac{(\lambda t)^x}{x!} - \sum_{x=1}^{k-1} \frac{(\lambda t)^{x-1}}{(x-1)!} \right] \end{aligned} \tag{9}$$

Since,

$$\begin{aligned} &\left[\sum_{x=0}^{k-1} \frac{(\lambda\, \mathrm{t})^x}{x!} - \sum_{y=0}^{k-2} \frac{(\lambda\, \mathrm{t})^y}{\mathrm{y}!} \right] = \\ &1 + \frac{(\lambda\, \mathrm{t})}{1!} + \frac{(\lambda\, \mathrm{t})^2}{2!} + \frac{(\lambda\, \mathrm{t})^3}{3!} + \ldots + \frac{(\lambda\, \mathrm{t})^{k-2}}{(\mathrm{k}-2)!} + \frac{(\lambda\, \mathrm{t})^{k-1}}{(\mathrm{k}-1)!} \\ &-1 - \frac{(\lambda\, \mathrm{t})}{1!} - \frac{(\lambda\, \mathrm{t})^2}{2!} - \frac{(\lambda\, \mathrm{t})^3}{3!} - \ldots - \frac{(\lambda\, \mathrm{t})^{k-2}}{(\mathrm{k}-2)!} \end{aligned} \tag{10}$$

Hence,

$$f(\mathrm{t}) = e^{-\lambda t} \lambda \frac{(\lambda\, \mathrm{t})^{k-1}}{(k-1)!} = \frac{t^{k-1} \lambda^k e^{-\lambda t}}{k-1!} \tag{11}$$

But, *k*is an integer (number of *k* arrivals), $\Gamma(\mathrm{k}) = (\mathrm{k}-1)!$ .The Eq. 11 can be written as:

$$f(t) = \frac{t^{k-1} \lambda^k e^{-\lambda t}}{\Gamma(k)} \tag{12}$$

2.1. ***Probability distribution of the burst-release time***

Under the assumption of Poisson packet arrival, the assembly time *t* for a*L*-sized burst follows a Gamma distribution with *L*- 1 degree of freedom and parameter λ, the PDF for such assembly can be obtained by substituting $K = L - 1$ in above equation [8].

$$\Gamma_t(L-1, \lambda) = \frac{\lambda^{L-1} t^{L-2} e^{-\lambda t}}{(L-1)!}, t \ge 0 \tag{13}$$

with mean $E[t] = \frac{L-1}{\lambda}$ and standard deviation

$$Std[t] = \sqrt{\frac{L-1}{\lambda^2}} \tag{14}$$

Since, the BCP is released after the first packet arrival with information t_0 and *L*, the probability to actually have *L-1* additional packet arrivals before release time t_0 is given by [5]:

$$P(t < t_0) = \int_0^{t_0} \frac{\lambda^{L-1} t^{L-2}}{(L-1)!} e^{-\lambda t} dt = \frac{\gamma_{inc}(L-1, \lambda t_0)}{(L-1)!} \tag{15}$$

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

It is worth noticing here that such probability depends not only on the choice of t_0 but, also on the value of *L*. Clearly, it is easier to complete L_1 packet within time [0, t_0] than $L_2 > L_1$ within the same amount of time.Hence, the choice of *L* relatively being small is a conservative estimation, that is high probability of complete *L* packet before time t_0. Moreover, the choice of small *L* would probably lead to a situation at which data burst are completed in a time *t* much earlier than t_0, thus requiring to allocate them in memory for time $t_0 - t$. However, the opposite (relatively large *L* values) leads to high probability to transmitting data burst with fewer packets than predicted, thus over-loading the network [8].

3. Results

In this section, results are presented under various conditions. In fig. 4, the CDF is presented by considering the fixed arrival rate of 3, and varying the burst assembly time as 3,4 and 5. This figure clearly reveals that the probability of getting larger burst length is relatively small.

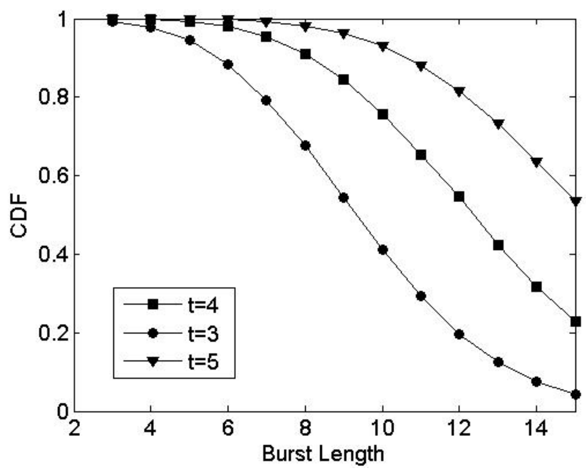

Fig.4.CDF vs the burst length with fixed arrival rate 3, and variable burst assembly time.

The above figure is drawn by considering the arrival rate (λ) of 3 and assuming *t*=3, the product λt is 9. Hence, the probability of having a burst of length 8 is 0.6761.

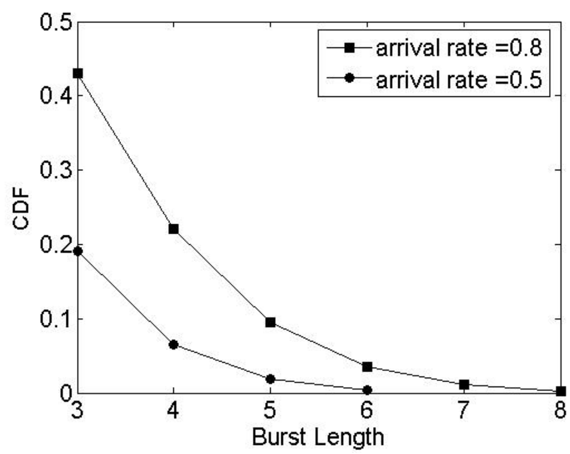

Fig.5.CDF vs the burst length with fixed arrival rate 0.5 and 0.8 and variable burst assembly time.

In fig. 5, same results are presented by considering the arrival rate of 0.8 and 0.5 while burst length varying from 3 to 8.Considering the arrival rate (λ) of 0.8 and assuming t=3, the product λt is 2.4. Hence, the probability of having a burst of length 8 is 0.0016. Hence, as the product λt decreases, the probability of getting the larger burst length decreases. These are obvious results that if arrival rate is low than the probability of getting larger burst will be small as timer would expire, before a larger burst can be generated. To prove this, the mean waiting time with different burst length is plotted in fig.6. The obtained results clearly shows that for a lesser arrival rate, the mean waiting time is very large and sometimes, it can be much higher than the timer expiry time. The mean waiting time for larger arrival rate is very less.

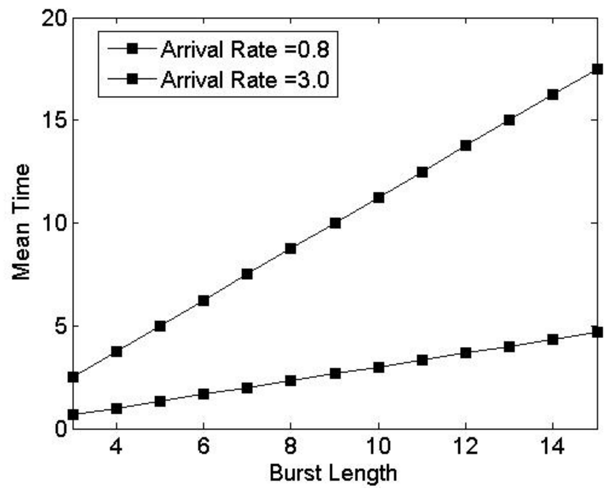

Fig.6.the mean waiting time vs the burst length with fixed arrival rate 0.8 and 3.

The standard deviation in the waiting time is larger for the lesser arrival rate and hence, the prediction is poor in case of lesser arrival rate (Fig.7). Moreover, the probability of getting very large burst is very small. Hence, most of the time, the average size burst will arrive. Therefore, from the above results we can conclude that:

1. The probability of getting smaller size burst length is larger; however, the prediction about the burst size is very in-accurate.
2. The probability of getting larger size burst length is small; however, the prediction about the burst size is well accurate.
3. Most of the time, it is expected that the average size burst will arrive.
4. For average size burst, the buffer can be easily employed using the fiber delay lines of 16, 32 or 64 packets burst.

As stated above, the probability of having a burst of length 8 is 0.0016. This states that out of 10000 bursts, only 16 will be of length 8. As in fig. 5, it is also clear that even for higher arrival rate the probability of getting very large burst is below 0.1, means out of 100 bursts only 10 burst will have large burst size. Therefore, as suggested previously [5], that in case of OBS contention, the deflection of burst is a very good viable option, is not correct due to the following reasons:

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

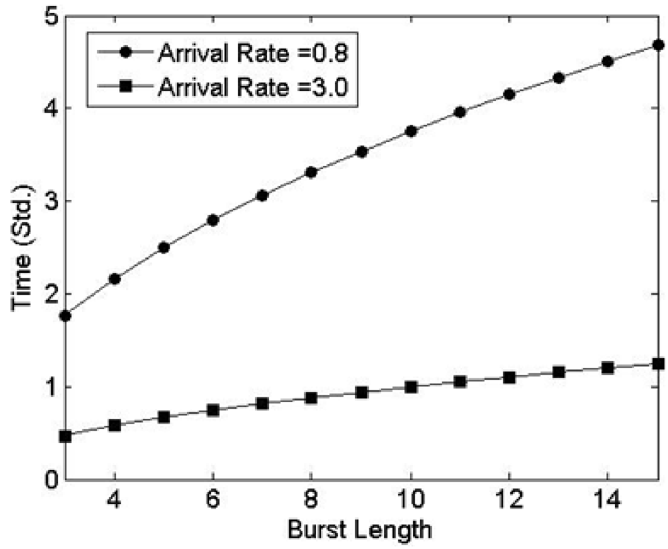

Fig.7.The standard deviation in waiting time vs the burst length with fixed arrival rate 0.8 and 3.

As discussed above, most of the time, we will get either small or average size bursts.Hence, they can be easily stored in contending nodes as in packet switching. If larger size burst (more than the size of the buffer) arrives, then it can either be deflected or it can be segmented as suggested in [1]. As the burst will be stored at the contending node only, hence dummy burst will not flowin the network, the throughput will increase and the average delay will also be greatly reduced.

4. Conclusions

In this paper, OBS is discussed in details. 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 alongwith the deflection of the larger size burst is more suitable option rather than deflecting all the contending bursts. The suggested methodology will increase the network throughput while reducing the average delay.

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