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تقدير طول انفجار في شبكات انفجار التحول الضوئية القائمة على الإفراج المبكر عن حزمة السيطرة

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الخلاصة

في العقد الماضي، شاهدنا نمو هائل في حركة المرور على الإنترنت. وتطلب هذا النمو المزيد والمزيد من النطاق الترددي من وسائل الاتصال، والسرعة الهائلة لأجهزة الاتصال. ولتلبية هذه الاحتياجات، يمكن استخدام الاتصال بالألياف البصرية. في سياق مماثل، يعتبر تحول الانفجار البصري (OBS) بديل جيد للنظام الإلكتروني الحالي. في تحول الانفجار البصري، OBS، يفضل اختيار توجيه الانحراف، ولكن الخسارة في أداء التوجيه سيئة جدا. وكبديل لذلك، يمكن استخدام التخزين المؤقت للانفجار، ولكن كما أن حجم الانفجارات عشوائي وبالتالي لا يمكن أن يكون حجم المخزن المؤقت ثابتا من البداية. لحل هذه المشكلة، في هذه الورقة، يقدم تحليل طول تقدير الانفجار مع الاحتفاظ على حد سواء الإفراط في التحفظ ومتوسط وقت الانتظار في الحد الأدنى. وباستخدام مقار بطول تحليل انفجار ثابتة، يمكن تصميم طول الموجة الثابت بسهولة جدا للحصول على الاحتمال المطلوب من الفاقد من الانفجار.

Estimation of burst length in optical burst switching networks based on early release of control packet

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ABSTRACT

In the past one decade, an explosive growth has been seen in internet traffic. This growth has demanded for more and more bandwidth of communication media, and very fast configurability of connecting devices. To meet these requirements, optical fiber communication can be used. In the similar context, optical burst switching (OBS) is considered as a good alternative for the current electronic system. In OBS, for contention resolution, deflection routing is the preferred choice, but the burst loss performance in deflection routing is very poor. As an alternative, buffering of contending burst can be used, but as the size of bursts is random, thus the buffer size cannot be fixed in advance. To solve such a problem, in this paper, a burst length estimation analysis is presented, while keeping both over-reservation and average waiting time at minimal and using the asymptotic analysis, the burst length is fixed. For the fixed burst length, buffer can be designed very easily to obtain the required burst loss probability.

Key Words: Optical burst switching;, buffering;, burst length estimation;, over-reservation;, waiting time.

INTRODUCTION

Optical burst switching (OBS) is an important switching technology in the future of optical WDM networks and Internet. In OBS, IP packets with a common destination, arriving at the same ingress node, are aggregated into large bursts, each being switched and routed as one unit (Zeng, 2003). In OBS system, the length of data burst varies from L_{Min} to L_{Max} (L_{Min} and L_{Max} are minimum and maximum burst lengths, respectively). In OBS system, as the exact length of each burst is not known, so first of all, the control signal is sent on a separate channel;, this reserves the bandwidth and then different switches are configured from source to destination; then after this, the burst follows the same path and traverses from one node to the other. In the optical communication system, the aggregate data packets (burst) will traverse, that i's why, it is mandatory that both the signal quality degradation and burst loss should be very minimal and at each node so that bursts can traverse a large distance in optical networks (Levense, 2002;, Yu, 2002;,Srivastava, 2009;,Yawei, 2013;&Jingyan, 2015).

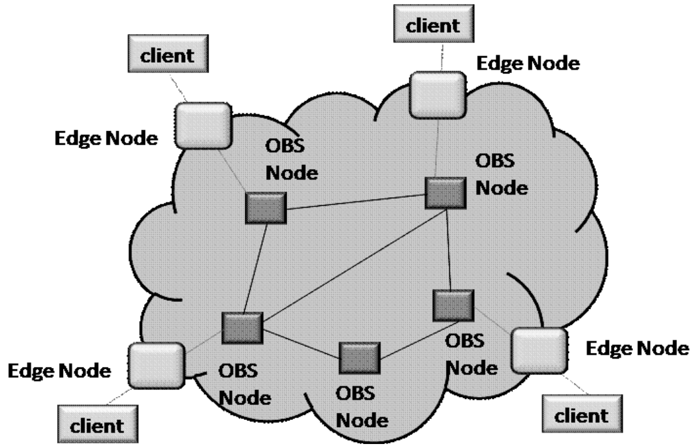

Figure 1. Generic layout of the optical network.

The generic layout of optical burst switching network is shown in Figure 1. Edge routers are an integral part of OBS and for each egress node, a separate queue is required. Moreover, buffering and, clocking should match with the core bit rate, which is very challenging. Moreover, in OBS, a very large amount of traffic is desirable to avoid excessive delays. In Optical Packet Switching (OPS), no reservation is needed; thus, a common buffer will do the same job. In OPS, the length of the packets is fixed;, thus, the buffer can be easily designed, and the performance of OPS in terms of packet loss rate is much better in comparison to OBS (Shukla, 2016;&Shukla, 2016).

As in OBS, the burst size is not fixed;, therefore burst assembly algorithms are used. The burst assembly algorithms are either time or size based. In time-based approach, after a fixed definite amount of time, burst will be transmitted irrespective of size of bursts; however, sometime padding is required to have a burst of minimum size. This scheme restricts the delay (Figure 2).

In size-based assembly algorithm, the burst will not be transmitted until it reaches its size. Delay is a major concern in this approach (Figure 2). This approach considers the self-similarity of traffic, and a packet will arrive in a hurry and bursts will gain it's size in a very less time;, however, self-similarity has not always been the case.

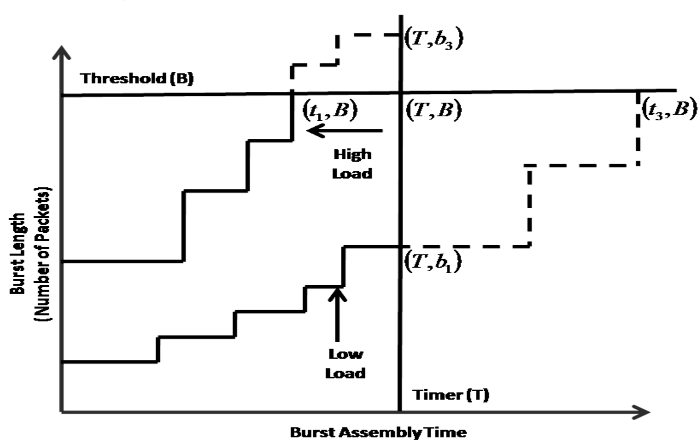

Figure 2. Burst assembly mechanisms.

In OBS, at any node, the arriving burst can be of any length, but in general, this ranges from some minimum length L_{Min} to some maximum length L_{Max}. Still the exact length of the arriving burst is not known;, thus, there is some wastage of resources. Another major issue in the OBS core network is the contention among bursts. The situation of contention arises when two or more bursts arrive at the same output port, at the same time, with the same destination address. For the contention resolution of bursts, various schemes are proposed. The primary schemes are optical buffering, wavelength conversion, deflection routing (Stefano, 2010), and burst segmentation (Vinod, 2003). In the optical buffering schemes, for contention resolution among the bursts, FDL (Fiber delay lines) are used to delay the contending bursts for a specified amount of time, which is proportional to the length of the occupied delay line (Shukla, 2015; Shukla, 2016). In wavelength conversion method, if two bursts, with the same wavelengths are destined to the same output port at the same time, then, by modifying the wavelengths, one of the two bursts will be routed to the correct output port (primary) and the other will go towards any alternative output port (secondary). This is also an example of deflection routing where contending burst provided an alternative route to reach its destination. Some of the major drawbacks of the deflection routing method is that the burst arrive in this method are in out of order, and the deflected bursts may end up following a longer path to reach their destination. This introduces higher end to end delay among bursts. Moreover, extra traffic is created in the network as contending bursts will traverse in the network unnecessary. To provide high throughput, low delay, and low burst loss probability, a combination of contention resolution techniques may be used. In the third approach, which is a burst segmentation scheme, the whole burst is divided in to small units of burst called burst segments. Each of these segments contains a single IP packet or multiple IP packets, with each segment defining the possible partitioning points of a burst when the burst experiences the contention in the optical network. Initially, all the segments in a burst are transmitted as a single burst unit. However, in the situation when contention among bursts occurs, then only those segments of a given burst that overlap with segments of another burst will be dropped (Vinod, 2003).

Generally, in OPS, for contention resolution, optical switches are used. These switches consist of fixed numbers of input and outputs lines. Contending packets are placed in the buffer with the help of tunable wavelength convertor (TWC). The contending packets can be buffered optically using fiber delay lines, but the storage is limited due to the noise accumulation (Srivastava, 2009; Shukla 2014). On the other hand, some switch designs (Yawei, 2013;&Jingyan, 2015) are available, in which, packets traverse in the optical domain while when a packet needs to be buffered, it is converted in electronic domain and can stay in the buffer for longer duration. In this method, O/E conversion for placing a packet in the buffer and E/O conversion for the retrieval of the packet from the buffer is are extra overhead.

In OBS, as the burst size is unknown, therefore, buffering is not considered as a good solution. A few designs have been proposed where the variable length buffer is used for the contending bursts (Rogiest, 2013). As in the OBS, the first control packet is transmitted, then burst flows;, therefore, some researcher has proposed buffering of control packets in case of contention; this will save the re-transmission of control packets, which are in contentions.

In this paper, an analysis has been carried out for proper estimation of the burst length. Burst estimation will help in deciding the buffer size required for the storage of burst if contention occurs. Also, due to burst estimation, it is possible to send the Burst Header Packet (BHP) (BHP contains the routing information and information about the data burst) before full burst aggregation and by this, the delay can be decreased as the aggregation time is overlapped with the waiting time.

RELATED WORK

Due to the unavailability of network resources, during path reservation, the burst drop is an important issue in the optical burst switching system. In the paper by (Stefano,(2010), a numerical evaluation has been performed for different buffering characteristics of OBS nodes. In order to reduce the inherent technical restrictions of implementing optical buffers, classical deflection routing strategies are considered, as an additional alternative way to handle with output node contention. Authors evaluated different mechanisms that control the burst loss events, which are input buffering, deflection routing, or and the shared buffering. A simulation model is presented that shows how different parameters affect the network performance, where the network is composed of a number of optical burst nodes, which are mutually connected in a mesh topology. From the results presented in the paper by (Stefano,(2010), it can be observed that a better performance is achieved with a larger buffer capacity. If α is defined as the ratio between the number of links in the network and that of a full mesh network, then they defined eight node networks that are characterized by a connectivity factor α=0.29, 0.43, 0.71, 1.0. Further, a study shows that increasing the meshing degree from α=0 .71 to 1 gives a small performance improvement if the offered traffic level is low. On the other hand, if the meshing degree is small (α=.029 to 0.43), the performance improvement provided by larger input buffers becomes more negligible for the loads above than a certain threshold. Finally, in the paper, it was concluded that both buffering and deflection routing are essential in OBS systems.

In the paper by (Vinod,(2003), the author investigated a number of different policies with and without segmentation and deflection. The study in the paper shows that, in comparison to standard dropping policies, the performance of segmentation policies are is much better and these policies offer the best performance when the load is high. On the other hand, the policies which uses deflection perform better at low loads. In the paper by (Vinod,(ICC; 2003), the authors uses the concept of fiber delay lines and burst segmentation for scheduling burst in the OBS network, and a number of new channel scheduling algorithms with burst segmentation perform well in comparison to the existing scheduling algorithm, with and without void filling (Tomohiro, 2003). Based on the FDL architectures, two categories of scheduling algorithms are proposed. The first algorithm, which is a delayed first algorithm, first algorithm is suitable for transmitting packets which have higher delay tolerance and strict loss constraints, for example, internet data, while, on the other hand, the segment first algorithm is good enough for data with strict delay constraints and higher loss tolerance such as video and voice traffic.

For achieving high quality service in optical burst switching system, a burst pre-emption scheme is proposed (Zeng, 2003;&Zeng, 2004), in which there is a high priority burst pre-empt low priority one if there is no available output channel. A conservation law is used for analyzing the performance of prioritized pre-emption scheme. The results presented in the paper shows that the approximation model can yield accurate solutions under different traffic conditions.

In (Zeng,(2003) &and Zeng,(2004) show that the distribution of the arriving burst is exponentially distributed when the burst is treated as a single entity. In this paper, we have further extended the work, and it is shown that if, in a burst, numbers of packets are counted, then the distribution is an incomplete Gamma function.

BURST LENGTH ESTIMATION

Generally, the traffic arrival in the network is a random process, and this arrival of traffic In the network can be modelled as Poisson process. If X represents an event occurring in time, according to Poisson process with parameter λ, then X has parameter λt over the time interval (0, t). Now the arrival of k^{th} packet after times t can also be interpreted as that in time t or less;, less than k packets have been arrived. So, the probability of arrival of k^{th} packet after time t from now is the same as the probability of arrival of less than or equal to $(k\text{-}1)^{th}$ packets from now. Let F (*t*) denotes the cumulative distributive function, which represents that till time *t, k* packets have arrived, or in other words, it states the probability of arrival of *k* packets in time t;, then we can written as:

$$F_k(t) = P(X > k) = 1 - P(X \le k-1) = 1 - \sum_{x=0}^{k-1} \frac{(\lambda t)^x e^{-\lambda t}}{x!} \tag{1}$$

As eq. (1) gives cumulative distribution function (cdf), we can find the probability density function (pdf) of a continuous random variable *t*; which denotes the time required for *k* arrivals by calculating the derivative of eq. (1) w.r.t. *t* and it will be represented by (2)-(3):

$$f(t) = F'(t) = e^{-\lambda t}\lambda \sum_{x=0}^{k-1} \frac{(\lambda t)^x}{x!} - e^{-\lambda t} \sum_{x=0}^{k-1} \frac{x(\lambda t)^{x-1}\lambda}{x!} \tag{2}$$

Therefore, we have

$$f(t) = e^{-\lambda t}\lambda \frac{(\lambda t)^{k-1}}{(k-1)!} = \frac{t^{k-1}\lambda^k e^{-\lambda t}}{(k-1)!} \tag{3}$$

The pdf obtained in eq.3 in known as gamma distribution.

BURST–RELEASE TIME DISTRIBUTION

If the arrival of burst is Poisson distributed, then, the assembly time t for an L-sized burst follows a Gamma distribution eq. (3) (Hernandez, 2007). In order to find the pdf for such assembly, we substituted K=L in eq. (3) and it is represented by eq. (4):

$$\Gamma_t(L,\lambda) = \frac{\lambda^L t^{L-1} e^{-\lambda t}}{(L-1)!},\ t \ge 0 \tag{4}$$

With mean $E[t] = \frac{L-1}{\lambda}$ and standard deviation $Std[t] = \sqrt{\frac{L-1}{\lambda^2}}$. It is noticeable that, if L is taken to be 1, then equation 4 follows exponential distribution. Thus, if the burst is taken as a single entity, then it follows exponential distribution as discussed in the work by (Zeng,(2004).

As the BCH is released after the arrival of the first packet of burst with the information of burst release time (t_0) and Burst length (L), the probability that in time t_0 from the release of BCH next L-1 packets actually arrive and, is given by eq. (5):

$$P(t < t_0) = \int_0^{t_0} \frac{\lambda^L t^{L-1}}{(L-1)!} e^{-\lambda t} dt$$
$$P(t < t_0) = \frac{\gamma_{inc}(L, \lambda t_0)}{(L-1)!} \tag{5}$$

Where γ_{inc} , refers to the incomplete gamma function.

In this scenario, where Burst Control Header (BCH) is released after the arrival of the first packet, only then BCH can over-reserve the resource if the burst length provided by BCH is more than the actual buffer size and if the last packet of burst arrives before the release time of burst; then the burst have to wait (Rogiest, 2013; &Tomohiro, 2003).

Case 1: Actual burst size is less than $\hat{L}$

In this section, we have considered the first case, in which the BCH reserves the resources for $\hat{L}$ - sized optical burst, but the actual size of burst is l, where $l < \hat{L}$.

So, BCH over-reserves the resources. Let $Y = \hat{L} - l$; then Y is a random variable, which is representing the over reservation at the intermediate node. The probability mass function of Y is given by:

$$\mathrm{P}(Y = p) = \mathrm{P}\left(l = \hat{L} - p \text{ Poission arrivals in } [0, \mathrm{t}_0)\right)$$
$$\mathrm{P}(Y = p) = \frac{(\lambda t_0)^{\hat{L}-p}}{(\hat{L}-p)!} e^{-\lambda t_0} \qquad 0 \le l \le \hat{L} - 1 \tag{6}$$

Here, in eq. (6),the random variable Y is Poisson (shifted) distributed.

Now, the over-reservation (average) of resources in terms of packets will be given in eq. (7):

$$\mathrm{E}[Y] = \sum_{p=1}^{\hat{L}-1} (\hat{L} - p) \frac{(\lambda t_0)^{\hat{L}-p}}{(\hat{L}-p)!} e^{-\lambda t_0} \tag{7}$$

The asymptotic value of over reservation can be found using the relation, assuming $\hat{L} \to \infty$,

$$\mathrm{E}[Y] = \sum_{p=1}^{\infty} (\hat{L} - p) \frac{(\lambda t_0)^{\hat{L}-p}}{(\hat{L}-p)!} e^{-\lambda t_0} = \hat{L} - \lambda t_0 - 1$$

Case 2: Waiting time of Burst

In this case, we have considered the scenario in which $\hat{L}^{\text{th}}$ packet, that is the last packet of the burst, arrives before the release time of burst; that is, the last packet arrives at time $t<t_0$. Thus, buffer holds the data burst for some time Z. So, Z is a random variable that represents the waiting time in buffer, that is $Z = t_0 - t$ Then it is evident that the pdf of Z is a shifted gamma distribution, which is given by eq. (8):

$$f_Z(t) = \Gamma_{t_o - t}\left(\hat{L}, \lambda\right)$$
$$f_Z(t) = \frac{\lambda^{\hat{L}}\left(t_o - t\right)^{\hat{L}-1}}{\left(\hat{L}-1\right)!} e^{-\lambda(t_o - t)}, \quad 0 \le t \le t_o \tag{8}$$

The average waiting time can easily be obtained and is represented in eq. (9):

$$\mathrm{E}\left[t_o - t\right] = \int_0^{t_0} \left(t_o - t\right) \frac{\lambda^{\hat{L}}\left(t\right)^{\hat{L}-1}}{\left(\hat{L}-1\right)!} e^{-\lambda t} dt$$
$$\mathrm{E}\left[t_o - t\right] = \frac{\lambda t_o}{\left(\hat{L}-1\right)!} \gamma_{\mathrm{inc}}\left(\hat{L}, \lambda t_0\right) - \frac{1}{\left(\hat{L}-1\right)!} \gamma_{\mathrm{inc}}\left(\hat{L}+1, \lambda t_0\right) \tag{9}$$

The asymptotic value of the average waiting time can be found using, assuming $t_0 \rightarrow \infty$,

$$\mathrm{E}\left[t_o - t\right] = \int_0^{\infty} \left(t_o - t\right) \frac{\lambda^{\hat{L}}\left(t\right)^{\hat{L}-1}}{\left(\hat{L}-1\right)!} e^{-\lambda t} dt = t_0 - \frac{\hat{L}}{\lambda}$$ with minimum value of zero.

Based on above mentioned estimates, the obtained results for the typical values are detailed in the next section.

ANALYTICAL RESULTS

In this section, the analytical results have been generated for the analysis done above, and these results are shown in graphs under various conditions.

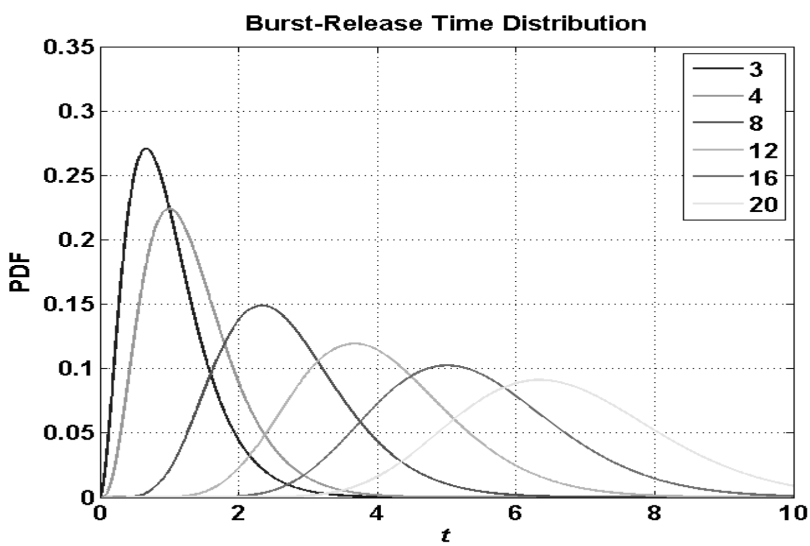

Figure3. Burst release time distribution for various burst lengths.

Figure 3, shows burst release time distribution for different burst lengths (L). It is obvious form the result that as the burst length increases, the burst release time also increases for the same arrival rate. As for the same arrival rate, the time in which a greater number of packets will arrive is more so as the burst size increases the time for forming burst also increases and hence, as the burst size increases, then, for same arrival rate, the pdf becomes more and more flattened.

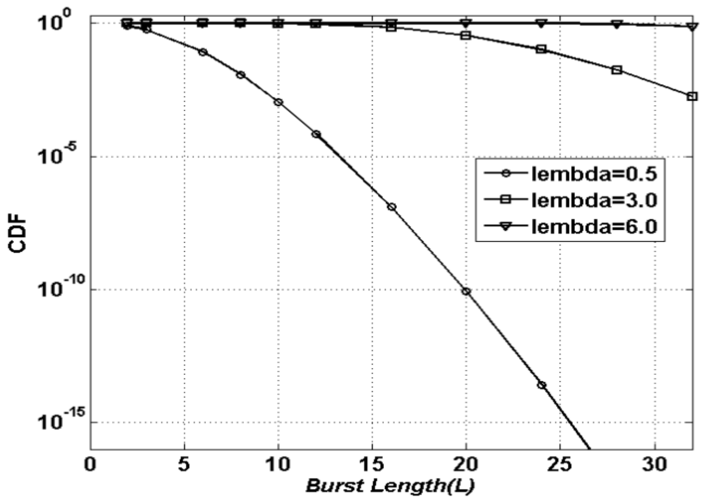

Figure 4. Probability that $t<t_0$, w.r.t. burst length for t_0=4, in case of packet arrival rate of 0.5, 3, and 6.

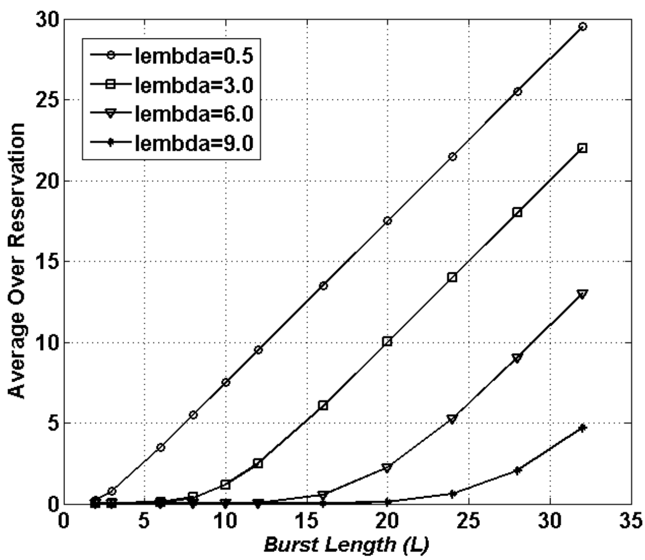

Figure 5. Average over reservation vs. burst length for packet arrival rate of 0.5, 3, and 6.

In Figure 4, the probability of generation burst of different lengths at different arrival rates at fixed burst assembly time '3' is shown. For low arrival rate of 0.5, the probability of generation is that the generation of a larger burst is nearly zero; as for the burst length of 20, the probability is 10^{-10}. As the arrival rates increase (3.0 and 6.0), the probability of generation of larger bursts also increases. For lambda equals 3.0, a burst of length 12 is generated with probability 1. Similarly, for lambda 6, a burst of length 24 can be generated with unity probability.

In Figure 5, the average over-reservation is plotted vs. the burst length at different arrival rates. For lesser arrival rates, over-reservation is very large, and this result is obvious; as for the lower value of the burst generation time, a burst of a larger size will not be framed. However, for larger arrival rates, average over-reservation is less. For lambda equals 9.0 till a burst length of 20, over-reservation is zero. Using asymptotic value, for arrival rate (λ) equals 9, t_0 equals 3, and for is 32, and then over-reservation is 4, which is very close to the value obtained in the exact analysis. For other values, The difference inthe results is not much.

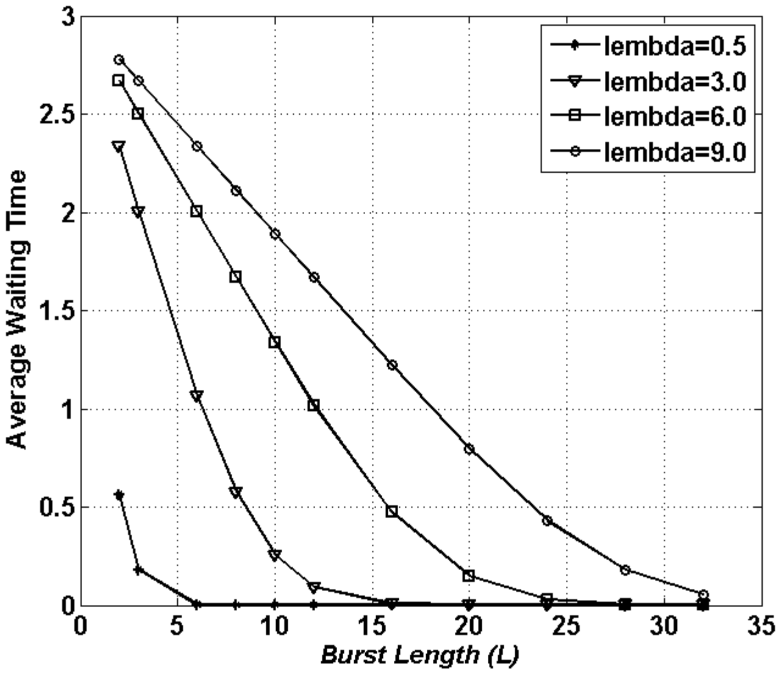

Figure 6. Average waiting time vs. burst length for packet arrival rate of 0.5, 3, and 6.

In figure 6, the average waiting time vs. the burst length is plotted under various arrival rates. It is clear from the figure that as arrival rates increases, the average waiting time increases. It is due to the fact that, for larger arrival rates, the burst achieves its desired length sooner, and as the burst assembly time is fixed, therefore, for the Left –over time, the burst waits before it releases. However, over here, the asymptotic results does not match much, as in the results where t_0 equals 3, which is not in agreement of with the asymptotic value of t_0 as infinite. Still considering the following: let burst length is be16, lambda is 6, then average waiting time form asymptotic formula is nearly 0.4;, however, the exact value is zero. It is desirable that, both over-reservation and average waiting time should be ideally zero.

From fgures5 and 6, it is clear that if one increases, then the other decreases. Therefore, both cannot be minimized simultaneously. Therefore, an optimal value should be selected. If, then both over-reservation and average waiting time can be minimized.

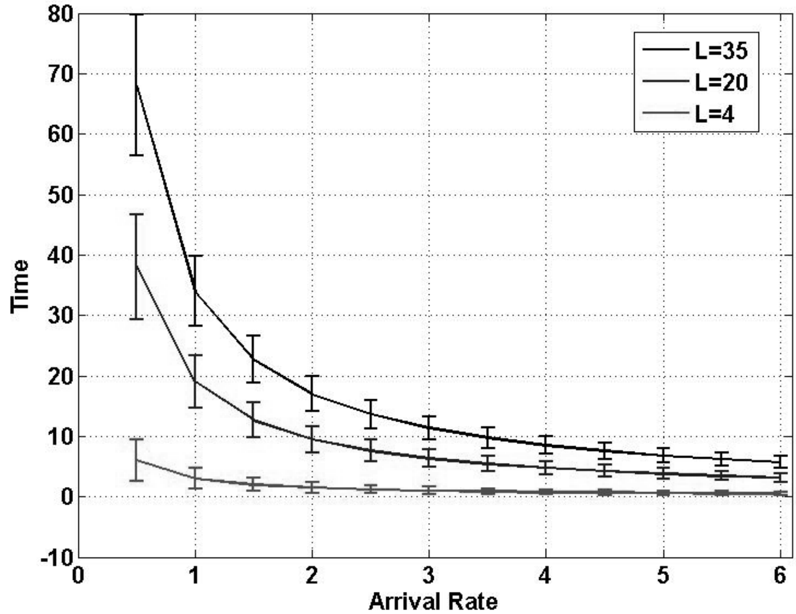

Figure 7. Arrival rates vs. time for different burst lengths with error bars.

In Figure 7, arrival rate vs. time is plotted for different burst lengths with error bars. When the arrival rate is very low, let us say 0.5, for the generation of a burst of a length of 35, the assembly time would be of 68 units with an error of ±11.66 units. Thus, at a lower arrival rate, the prediction is not accurate. At lower load, similar trends is are also observed for L=4 and 20. However, for the an arrival rate of 5, for the generation of a burst of a length of 35, the assembly time would be of 6.8 units with an error of ±1.16 units. For the same arrival rates, for a burst of 20 packets, the assembly time would be of 3.8 units with an error of ±0.87 units. However, for the a burst length of 4, the assembly time is less that the unit, and the error time is negligibly small. In general, it can be inferred from the graph that, at the higher arrival rates, the assembly time is lesser and in turn, the associate prediction error is also lesser. It is also noticeable that, in bursty traffic, arrival rates are higher, so a very accurate prediction of the burst length can be made using the above analysis.

CONCLUSIONS

This paper explores OBS in detail, with physical and network layer issues. In this paper, burst length estimation analysis is presented;, average over-reservation and average waiting time is are also obtained for different arrival rates and burst assembly time. It has been found that both over-reservation and waiting time cannot be minimized simultaneously. However, with the proper choice of burst length, both over-reservation and waiting time can be kept minimal. Once the burst length is fixed, buffering of contending bursts is possible using fiber delay lines with very minimal additional resources.

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