Evaluation of End-to-End Latency for Segmented Bursts in OBS Networks

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Abstract— **In Optical Burst Switched (OBS) networks several contention resolution schemes such as wavelength conversion, fibre delay lines (FDLs), deflection routing and burst segmentation have been proposed. To provide the differential quality of service (QoS) for different classes of packets, priority-based segmented burst assembling at the edge nodes coupled with segment level transmission in the core nodes (in the event of congestion or contention) is proposed. All packets are assembled in units called segments according to two priorities, high priority (HP) and low priority (LP). HP segments are always placed at the head end of the composite burst as they are more delay sensitive, whereas the LP segments fill up at the tail end. Only in the event or anticipation of contention/ congestion occurrence, the affected section(s) of the network switch to segment transmission mode in which the composite burst is from this point decomposed into its individual segments and streamed (segment level transmission) along the same route to the destination end. The limited buffering in the core nodes will facilitate temporary buffering of the contending segments as since they are relatively smaller. The queuing at the inputs may lead to differential delays in the core nodes due to possible addition of segments from other links. This ultimately affects the inter-segment-gap between successive data segments ferrying packets of the same source thus leading to increased jittery whose magnitude may compromise the desirable QoS. In this paper we analyze inter-segment delay variations as a function of the number of nodes traversed**.

Keywords— optical burst switched networks, inter segment gap, burst assembly, queuing delays, segment level transmission,

I. INTRODUCTION

Optical Burst Switching (OBS) is promising to become an efficient and flexible switching solution to match the optical plane's ultra transmission speeds in present and future networks. In such networks, the dynamics of traffic can be supported by edge nodes which are equipped with sufficient buffering capabilities and hence can aggregate traffic and assemble data packets into variable length optical bursts as well as by core nodes (with limited buffering capabilities), which asynchronously switch these bursts [1]. Typically, such optical bursts comprise tens or hundreds of packets, which are assembled/disassembled at the edge nodes. During the burst-formation process, each arriving packet must wait until the final burst is complete, which clearly adds an extra delay on each packet in the burst, especially on those arriving earlier. However, such burst-assembly delays may be excessive and thus adversely compromise the acceptable QoS requirements of interactive applications. Burst assembling policies at edge nodes is key in the design and implementation of OBS networks with pre-settable QoS. The strategy implemented will determine the end to end performance of the network. The primary focus of any burst assembly strategy/mechanism is to minimize the packet burstification delays thus ensure that the end-to-end delays fall within acceptable bounds. It should also reduce the rate of control packets generation by maximizing the burst sizes, otherwise overhead processing loads at the intermediate /core nodes may increase drastically and eventually lead to congestion. On the other hand, increasing the burst sizes leads to burstification delays especially in low traffic scenarios. Hence a trade-off between the two is thus desirable. To date several burst assembly schemes have been proposed and are all geared towards improving QoS, e.g., [2]. Generally these are broadly classified into different schemes such as; time based, volume-based, as well as hybrid schemes. An example of a time based scheme is the Fixed Time-based scheme [3].With this scheme a timer is started immediately upon arrival of the first packet and when it reaches a pre-set time threshold $T_{\max}$, a burst under assembly is dispatched. The timer is reset again and only re-initiated upon next packet arrival at the burstification queue. Hence, the edge router generates bursts each of duration $T_{\max}$, independently of the yielding burst size. The pre-setting of a fixed interval time will create drawbacks such as increasing the loss rate in case of high traffic or reaching the interval time $T_{\max}$ before aggregation of enough packets in the burst. In this case padding may be necessary if the resultant burst is below a minimum threshold $L_{\min}$ [4]. In contrast to time-based schemes, a volume-based scheme, which is non-adaptive, sets a minimum burst size value $B_{\min}$ before the burst can be dispatched. Alternatively to that is whereby a threshold $B_{\max}$ is used to determine the end of the assembly process. As soon as that value is reached, the assembling is dispatched. A minimum burst size $B_{\min}$ scheme will favour

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real time applications during relative low traffic loads, as low delays will be experienced whereas a maximum threshold $B_{\max}$ scheme will reduce the frequency of control packets especially when $B_{\max} >> B_{\min}$. This however will attract delays for real time applications during low traffic conditions. A hybrid scheme is proposed and analyzed in [5]. That is, the burst is created either by reaching a maximum value of the timer $T_{\max}$ or by reaching the minimum or maximum burst size. Since this scheme combines the benefits of the time-based and the minimum /maximum length-burst based schemes, it is considered to be the default burst assembly scheme. Nonetheless, the low traffic load problem remains unsolved since the packets that arrived earlier still have to wait till the minimum burst length size is reached. In the process, this might lead to unacceptable delays and jitter for delay sensitive applications. Other example contributory factors to the delays and jitter include propagation delays as well as contention resolution mechanisms in the core nodes. In this paper, we limit ourselves to the evaluation and investigation of the delays incurred by the bursts when transmitted as a series of data segments. The remainder of this paper is structured as follows: in section 2, we briefly describe segmented burst assembling and segment level transmission. This is followed, by analysis and evaluation of inter-segment gap delays in section 3. Section 4 concludes the paper.

SEGMENTED BURST ASSEMBLING FRAMEWORK OVERVIEW

In the introductory section, we noted the stringent QoS requirements for delay sensitive applications, in particular, delay. At the same time we highlighted the need for any burst assembly policy to satisfy both the size and time constraints, with the earlier ensuring acceptable utilization of network resources (links) whilst the latter affects possible renderable QoS to delay sensitive applications. As such all traffic can be classified into either LP (delay non-sensitive applications) or HP (delay sensitive applications).

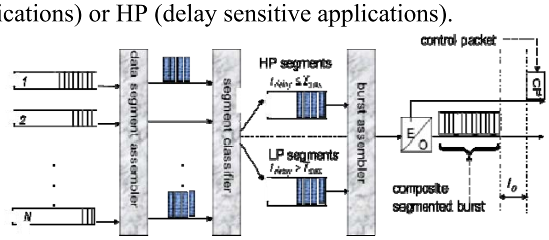

Fig. 1.Model of the segmented burstification process.

All packets can now be assembled into low priority (LP) and high priority (HP) data segments respectively each of fixed size, on a time slotted basis. In assembling a composite segmented burst, the HP data segments will normally be placed at start end (head) of the burst while the LP segments fill up the burst in order to satisfy the size constraint in the event of a packet average time delay threshold (T_{av}) timeout. A framework for creating a composite segmented burst aggregating two or more priority classes is illustrated in figure 1. As seen from the same figure, prior to burstification in the burstification/scheduling buffers, the packets destined for a particular destination end are assembled into class based segments. For that reason HP segments will always be placed at the head end. A gap between segments is necessary to allow for relative easy separation at the core nodes in the event of anticipated or actual /contention state.

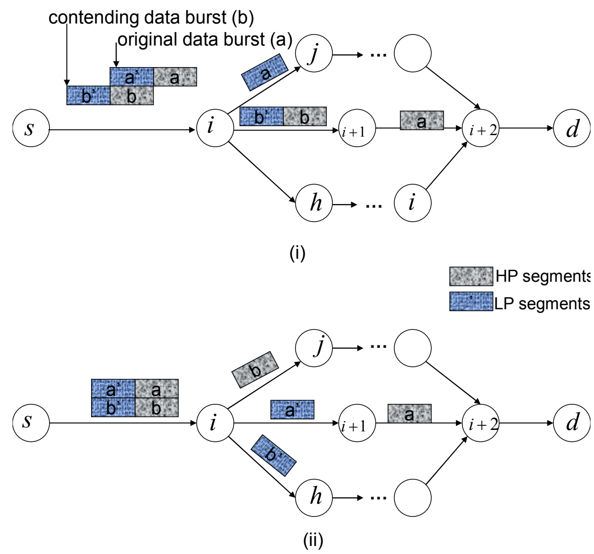

Fig.2. Contention resolution

Figure 2 illustrates, contention resolution at a core node by way of deflecting one of the contending sections (HP or LP) to alternate routes [2]. A drawback with such an approach is that alternate routing may incur more delays as well as jittery. Hence in this paper, we propose that the composite be decomposed into individual segments which are in turn streamed on the same path till destination end. The limited buffering in the core nodes will facilitate queueing of segments from several links at their inputs and consequently leading to differential queuing delays. However loss is significantly minimized.

II. End-To-End Delay Analysis

Model Description

On the onset of congestion/contention, composite burst transmission switches to transmission at data segment level. They are all queued consecutively in the queue of Node 0. All data segments are of the same length and hence equal service times T, and thus they arrive at Node 1 at regular intervals of magnitude T. Within this interval, arrivals from other links are possible and may be queued in Node 1's input queue between data segments of a given burst as illustrated in figure 3. This will cause an additional delay to form between data segments of a given burst. Thus the inter-segment gap will keep on fluctuating along the path as one data segment has to queue longer that the next one or its predecessor. In this analysis we will assume that all the data segments belonging to the same data burst follow the same path from the point of contention/congestion up to destination as illustrated in figure 3.

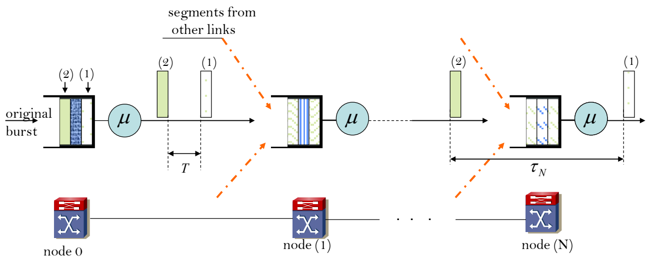

Fig. 3.. Delays experienced by two consecutive segments of the same burst

The nodes are numbered 0 to N If the mean delay between the arrival of two consecutive data segments at the destination node (Node N) is $\overline{T}_N$, the mean delay of a burst comprising M data segments is [6]:

$$\overline{T}_M = \overline{T}_S + (M-1) \times \overline{\tau_N} \quad (1)$$

where $\overline{T}_S$ is the mean delay of a single data segment. We assume that two consecutive segments of the same burst have the same mean gap $\overline{\tau}_N$ and also neglect any correlations between them.

Mean Delays Through a Succession of Nodes

We start with the evaluation of this delay through a single node. We proceed by first letting two data segments from the same burst be separated by an initial delay τ_o , upon arrival at the transmission queue of a node. This queue is modeled as an M/G/1 system, (Poisson input with mean rate λ) representing the sum of all the data segment arrivals at this queue from the rest of the network. Let the arrival time of the first data segment be set to 0; we assume that the first segment sees the transmission queue in the stationary state at its arrival time. The mean waiting time $\overline{W}_1(0)$ of this first segment is then given by [6]:

$$\overline{W_1}(0) = \frac{\rho \overline{T}}{2(1-\rho)}\left(1 + C_T^2\right), \ \rho = \lambda \times \overline{\mathrm{T}} \quad (2)$$

Where C_T is the coefficient of variation of the distribution of the service durations (of mean value $\overline{T}$). Due to the first arrival which has perturbed the M/G/1 system in stationary state, the departure time of the second segment will depend on the effect of the first one. Indeed the second segment comes to the queue at an instant $\tau_o > 0$ when the system is no longer in stationary state. Let $\overline{W}_2(0)$ be the waiting time of the second data segment. Their relationships are shown in the next figure from which it is evident that the inter-delay between the two segments is simply;

$$\tau_1 = W_2(\tau_o) - W_1(0) + \tau_o \quad (3)$$

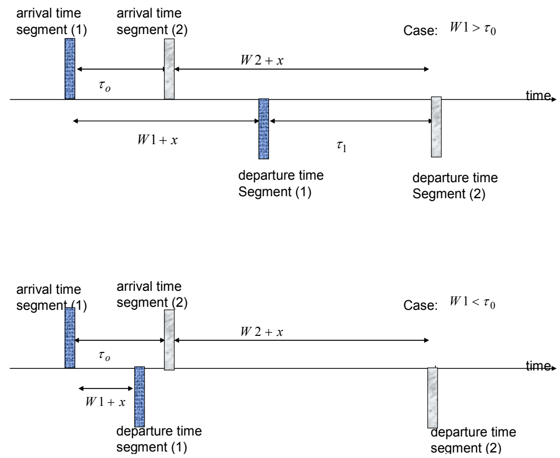

Fig. 4.. Relationship between inter-delay τ_1 and $\tau_o, W_1(0), W_2(\tau_o)$

Given a fixed value τ_o , the mean inter segment gap once the two segments crossed the queue is then:

$$\overline{\tau}_1(\tau_o) = \Delta(\tau_o) = \overline{W}_2(\tau_o) - \overline{W}_1(0) + \tau_o \quad (4)$$

Δ is the function giving the mean gap through one single node.

Mean Inter Segment Delays Through a Succession of Nodes

We first let τ_K , $1 \le K \le N$ be the gap between two (initially consecutive) segments, after they have both crossed node K . The distributions of the random variables τ_{K-1} and τ_K are very tedious to obtain analytically. We propose here a heuristic approach in order to compute the mean delay $\overline{\tau}_N$ at the destination node. We set:

$$\overline{\tau}_K = \Delta\left(\overline{\tau}_{K-1}\right), \quad 1 \le K \le N \quad (5)$$

. In other words, we only take the mean value of τ_{K-1} into account in order to compute $\overline{\tau}_N$ through formula (4). Through N iterations we thus have:

$$\overline{\tau}_N = \Delta^{(N)}(\tau_o) \quad (6)$$

with initial value set to $\tau_o = T$.

III. Simulation And Analysis

To analyze the end-to-end delays, the, simulation tool used is an event simulator based on OMNET.

We made quite a number of assumptions. For the simulation network (topology) we created a 24 node network, 4 of which are edge nodes. The maximum number of nodes that can be traversed end to end is limited to 22. We also used a single wavelength as all data segments traverse the same path.

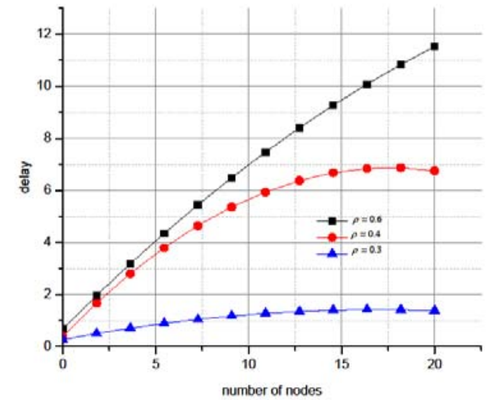

Fig. 5. Variation of the mean inter-segment gap $\bar{\tau}_N$ with number of nodes (N).

The input network traffic is in the form of data segments from composite bursts and follows a Poisson distribution.
The offset time is sufficiently large enough to exclude the data segments of any burst from pacing up with their associated control packet. No deflection is allowed, neither is there provision for wavelength conversion at all nodes in the network. Just-Enough-Time (JET) signaling protocol is used to reserve network resources from each source to destination. Control packet processing time is $9\mu s$. Switch fabric configuration time is $5\mu s$ µs. Each link has a propagation delay of $2.5ms$, thus all are of equal length, and support same speed. As seen in figure 5 the gap tends to decrease with increasing number of nodes (N).

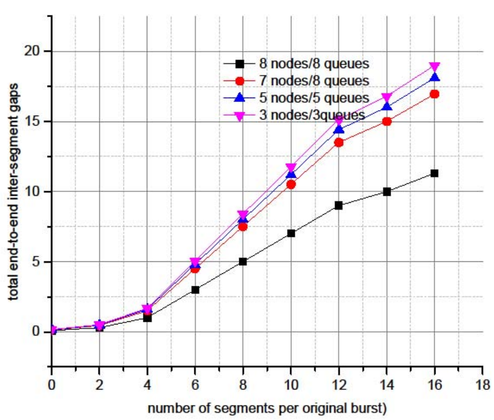

Fig. 6. Mean total inter-segment gap $\bar{\tau}_N$ versus path length .

In figure 6, the mean inter-segment gap varies more- less linearly (at a steady gradient) with the number of data segments per burst, and it is slowly decreasing as the M increases.

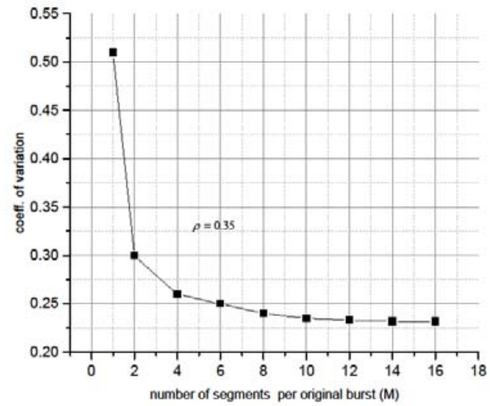

Figure 7. Coefficient of variation of $\bar{\tau}_N$ the total inter-segment gap versus M.

The coefficient of variation of the mean inter-segment gap tends to decrease with an increase in the number of data segments per burst M. This is shown in figure 7.

IV. Conclusions

In this paper, we presented an analysis of the end-to-end delay when the burst are transmitted in segments form.. The coefficient of variation of the mean inter-segment gap tends to decrease with an increase in the number of data segments per burst M.

References

[1]. T. Chen, C. Qiao, and X. Yu, Optical burst switching (OBS): A new area in optical networking research, IEEE Network, vol. 18, pp. 1623, May 2004.

[2]. Nail Akar , Ezhan Karasan , Kyriakos G. Vlachos b, Emmanouel A. Varvarigos b, Davide Careglio c, Miroslaw Klinkowski c,d, Josep Solé-Pareta . A survey of quality of service differentiation mechanisms for Optical Burst Switching Networks. Elservier, 2010.

[3]. A.K Garg, Analysis of burst/packet assembly techniques in high-speed optical switching networks. Op tik-International Journal for Light and Electron Optics, Vol, 122, Issue. 7, pp. 616-619, 2011.

[4]. M.Vokkarane, Karthik Haridoss, and Jason P.Jue. Threshold-Based Burst Assembly Policies for QoS Support in Optical Burst-Switched Networks. Centre for Advanced Telecommunications Systems and Services. The University of Texas at Dallas. Richardson, TX 75083-0688.

[5]. Hernandez, J. A., Aracil, J., Lopez, V., and de Vergara, J. L. (2007). On the analysis of burst-assembly delay in OBS networks and applications in delay-based service differentiation. *Photonic Network Communications.* 14(1), 49-62.

[6]. Patrick Brown , Alain Simonian. Evaluation of Inter-packet delay in a packet switched network. Data Communication Systems and THoer Peformance, Elsevier, 1988.