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Performance Improvement in Optical Burst-Switching Networks

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Abstract - The emergence of the Internet has revolutionized the computer, and communications world like nothing before, and has permanently changed the lifestyle of human beings. The Internet is committed to providing at once a world-wide broadcasting capability, a mechanism for information dissemination and a medium for collaboration and interaction between individuals, irrespective of the geographical distance separating them. As a result Internet traffic has skyrocketed, and is consuming increasing network bandwidth. At the same time, new time-critical multimedia applications such as Internet telephony, video conferencing, video-on-demand, and interactive gaming are consuming large amounts of bandwidth. All these facts are imposing tremendous strain on the underlying telecommunication networks, forcing us to search for alternative means to satisfy the demand.

Keywords - optical burst switched networks, burst aggregation schemes, burst limit

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1. Introduction

The emergence of the Internet has revolutionized the computer, and communications world like nothing before, and has permanently changed the lifestyle of human beings [1]-[2]. The Internet is committed to providing at once a world-wide broadcasting capability, a mechanism for information dissemination and a medium for collaboration and interaction between individuals, irrespective of the geographical distance separating them. As a result Internet traffic has skyrocketed, and is consuming increasing network bandwidth [3]. At the same time, new time-critical multimedia applications such as Internet telephony, video conferencing, video-on-demand, and interactive gaming are consuming large amounts of bandwidth. All these facts are imposing tremendous strain on the underlying telecommunication networks, forcing us to search for alternative means to satisfy the demand. There is however a number of issues concerning optical networks that needs to be addressed. Some of the prominent issues are switching techniques, routing and wavelength assignment strategy, etc. Optical networks have come a long way today from the legacy wavelength-routed networks, IP-over-WDM networks, to the current state of art in optical packet switched and optical burst switched networks.

1.1 Optical Burst Switching (OBS)

OPS has a number of attractive advantages, such as faster speed, finer granularity, and more efficient bandwidth utilization, that have made it a promising switching technology for the next-generation optical Internet. However, this technology is still a dream at the current stage [4]. Commercial deployment of OPS in the short term is still limited by several obstacles in enabling technologies in terms of switch architectures, packet synchronization, contention resolution, etc.

An alternative to OPS is optical burst switching (OBS). In OBS, the basic switching unit is a burst of data, which is of a variable length that can range from one packet to several packets. A burst is usually assembled at an ingress node by aggregating several packets that may come from a single or multiple users in the same or different access networks and are destined for the same egress node. A control packet is first transmitted to reserve the bandwidth over the path and configure the switches. The data burst is transmitted following this control packet. As soon as the burst passes through a link, the bandwidth or wavelength reserved for the burst on that link will be released either automatically or by an explicit release packet [5]. This allows different bursts to share the bandwidth of the same wavelength on a link in a time multiplexing manner, and thus increases the bandwidth utilization. Optical burst switching has been proposed as an optical switching paradigm to combine the best of optical circuit and packet switching while avoiding their shortcomings.

One may employ optical burst switching (OBS) for optimal IP routing. However, the problems of optical switching control, design of efficient switching architectures, data burst contention resolution are to be resolved to ensure sustainable network load and reasonable burst forwarding performance. Future optical IP routers exploiting DWDM could achieve a higher degree of

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statistical multiplexing and lower blocking probability, but the optimum number of wavelengths per inlet of the router also depends on the physical layer performance.

1.2 Objectives and Motivation

It is well known that with the proliferation of Internet usage and more demand in the traffic growth, the next generation of Internet will require real bandwidth-efficient transmission and switching schemes for the needed networking infrastructure. Both optical packet switching and optical burst switching will occupy considerable research efforts till their successes are met in practice. The following is a list of the exact nature of investigations carried out related to OBS networks:

1. A study of burst aggregation techniques for IP traffic in optical burst switched networks
2. Impact of self-similarity of aggregated burst on the performance of OBS networks.
3. Offset-time adjustment based on traffic self-similarity in OBS networks.
4. A comparison between Path and Span protection in JET based OBS networks

2. Description of research work modules: Performance Improvement in OBS Networks

General OBS Network Configurations

The concept of Optical Burst Switching (OBS) was proposed for voice communications in the early 1980s. OBS is an adaptation of an International Telecommunication Union standardization Sector (ITU-T) standard for burst switching in ATM networks [6]. To avoid padding and to give the burst assembly mechanism freedom to optimize burst lengths, which typically are based on timers, fixed length schemes

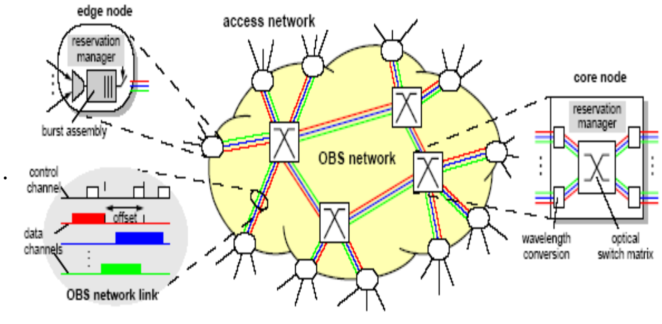

Fig 2.1 Node and network architecture for OBS

OBS is a fast circuit switching technique providing granularity in between wavelengths and packets. Client layer packets are assembled in edge nodes, and transported through the optical network in optical bursts. A key characteristic is the hybrid approach: control information is signaled out-of band using a control packet ("burst header") and processed electronically, while data bursts stay in the optical domain until they reach the egress node [7]-[8]. Another key concept of OBS is one pass reservation, i.e. burst transmission is initiated shortly after the burst was assembled and the control packet was sent out.

The arriving IP packets are assembled to bursts at the edge of the OBS network. Transmission and switching resources for each burst are reserved according to the one-pass reservation scheme. On the other hand, bursts may be released into the network although there are not enough resources available and therefore lost. This yields extremely low latency as propagation delay usually dominates transmission time in a wide area networks. The reservation request (control packet) is sent on a dedicated wavelength some offset time prior to the transmission of the data burst. We classified this as separate-control delayed transmission (SCDT). This basic offset has to be large enough to electronically process the control packet and set up the switching matrix for the data burst in all nodes.

3. Work module I: Study of burst aggregation techniques for IP traffic in optical burst switched networks

3.1 Burst aggregation Schemes

We shall now look at four different burst assembly algorithms. These algorithms can be time-based, burst-size based, packet-count based [6] or based on a combination of one or more strategies [9]. Since most OBS networks are purported to be deployed in the Internet, it shall be assumed that the input traffic to the burst assembler is IP traffic having a tri-modal distribution [10]. Further, it is assumed that the traffic is bursty and self-similar in nature [11]. These packets are segregated according to their destinations and directed to the respective queues. The bursts are assembled following one of the assembly algorithms described below.

3.1.1 Burst aggregation strategy with buffer-limit

Incoming IP packets with the same destination edge node (and optionally QoS class) are collected in a buffer. Whenever the total length of current buffered packets, L, exceeds a threshold B_{max} (i.e. $L > B_{max}$), the buffer contents are queued for transmission on the data channel. According to this algorithm the maximum burst size will be $B_{max} + S_{max}$, where S_{max} is the maximum IP packet size and the minimum burst size is $(B_{max} + 1)$ byte. In this strategy the burst assembly time is not constant and depends on the input load (i.e. packet arrival rateλ). This is a possible drawback of this technique because a packet may have to suffer a large amount of delay before it is transmitted into the network. An advantage of this technique is the uniform burst size that facilitates design of FDL buffers at the nodes.

3.1.2 Burst aggregation strategy with time-limit

In this strategy the burst formation time is constant and is equal to the aggregation time T. Each burst aggregation queue is equipped with a time counter. When a packet arrives at an empty burst aggregation queue, the time counter is started with t = 0. Further incoming IP packets are collected in the burst aggregation queue until the time counter reaches the value t = T. The time counter is reset to zero and remains so until the next packet arrives to the queue. The aggregation strategy must guarantee that no segmentation of IP packets takes place when the timeout is triggered before an IP packet has completely arrived at the aggregation buffer. The formation time of all the bursts is the same and its value is equal to the constant T. This is advantageous because the higher layer protocols have an estimate of the maximum delay that the packet will encounter before it is transmitted. The variable burst size is however a problem for the design of buffers to accommodate different sized bursts.

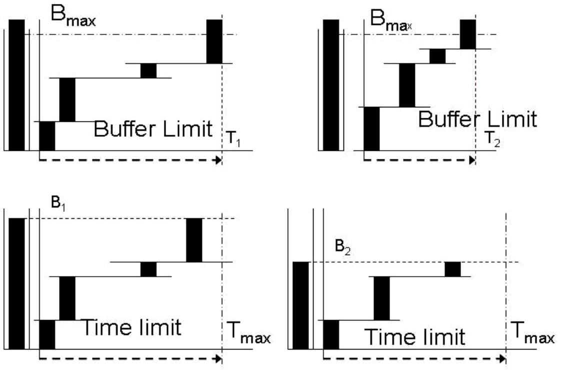

Fig.3.1 Buffer-limit scheme and time-limit scheme

Fig.3.1 shows two aggregation schemes based on buffer-size and time-out limits. We see that in the buffer-limit scheme, the burst aggregation time is not constant while in the time-out strategy, the burst size is not constant.

3.1.3 Mixed time/burst length aggregation strategy

To address the deficiency with each type of assembly algorithm discussed above a mixed time/burst-length based scheme such as the Fixed-Time-Min-Length burst assembly algorithm was proposed [11] which uses a fixed assembly time (T) as the primary criterion. It also requires that each burst be larger than a minimum length, B_{min}. Normally, $B_{min} < T\lambda$, where λ is the average traffic arrival rate. The burst assembly algorithm is described as follows:

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    • When a packet arrives in an empty burst assembly queue, start the time counter at t = 0, which increases with time;
    • When t=T
      if
        assembled burst ≥ $B_{min}$ then send all the collected data as a burst immediately
      else
        increase the data size to $B_{min}$ with padding and send the data out as a burst immediately
• Flush the burst assembly queue and go back to the first step.
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3.1.4 Burst aggregation with packet-count limit

Incoming IP packets with the same destination edge node (and optionally QOS class) are collected in a buffer. Whenever a buffer receives n IP packets, its contents are queued for transmission on the data channel. According to this algorithm, the number of IP packets per burst is constant and is equal to n. This technique considers the number of packets over which the control packet overhead is distributed.

3.2 Simulation Model:

We have evaluated the performance of four burst-assembly algorithms with self-similar IP traffic as input to the burst assembler. The self-similar traffic has been generated as bursts of IP packets with an average on-time α_{on}=1.25 and load varying from 0.2 Erlang to 0.8 Erlang. The average off-time has been computed using the expression in [12]. Each burst is composed of IP packets having one of the four sizes 44 bytes, 512 bytes, 576 bytes and 1500 bytes. It has also been assumed that the destination of each packet is randomly chosen among M edge routers or possible destinations within the burst switch cloud. Each arrival from the merged traffic was given a destination drawn randomly and it was then queued in the buffer associated with that destination in the edge router. Bursts are assembled according to the previously explained algorithms and queued in a common FIFO queue for transmission on the data link. Burst sizes in our simulation are measured in bytes and burst inter-arrival times are measured in terms of time-slots, with one time-slot corresponding to the time

3.3 Results and discussion

We can easily appreciate that in case of the buffer-limit strategy the burst inter-arrival time is nearly uniformly distributed about mean. Also with an increase in load; the peak value of the burst inter-arrival time probability density function (PDF) decreases. This is to be expected because as the load is increased, more packets are generated in a shorter time, and hence the bursts at each node will be assembled faster and consequently the inter-arrival time between bursts will reduce. Burst sizes on the contrary are exponentially distributed between a minimum size of B_{max}+1 and a maximum burst size of (B_{max}+1500)-1 as shown in Fig.3.2 We also observe that with a change in load the packet count distribution does not change because the average number of packets required to make up a given burst is independent of the load.

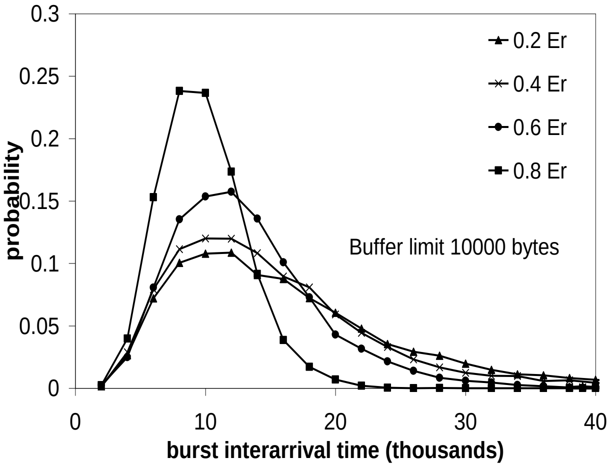

Fig. 3.2 : Burst inter-arrival time distribution using buffer limit scheme (B_{max} = 5000 bytes)

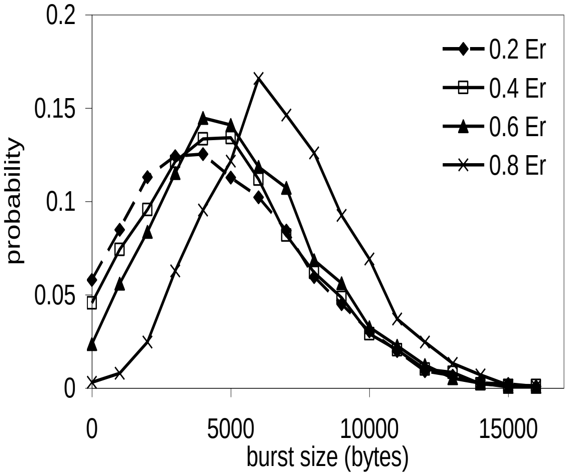

Fig.3.3: Burst size distribution for different loads using time limit scheme (T= 40,000)

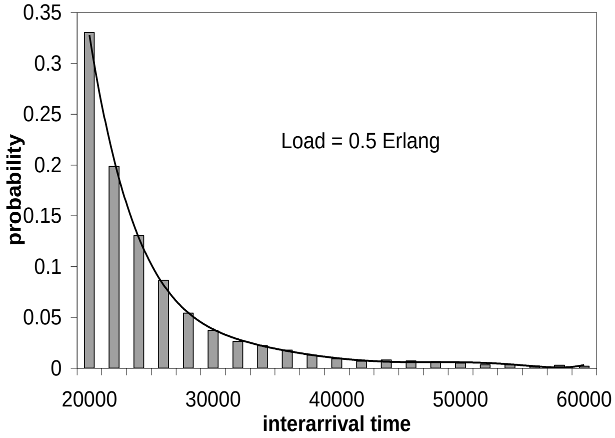

Fig. 3.4 Burst interarrival distribution using mixed scheme (T = 20,000, B = 5000)

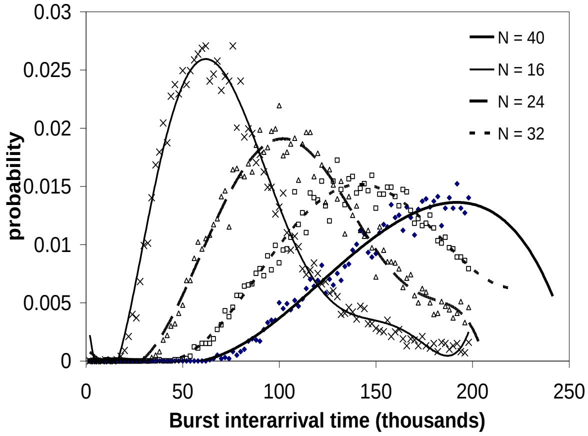

Fig.3.5 Burst inter-arrival time distribution using packet count limit scheme (load= 0.4 Er)

In the burst-assembly scheme with time-limit policy, the burst inter-arrival times have an exponential distribution similar to that of burst size in the burst-size limit aggregation strategy as shown in Fig. 3.3. The exponential distribution is shifted to the right by the timeout value. The offered load affects the fall-off rate of the exponential distribution as can be observed in Fig.3.3. At higher loads, the burst inter-arrival times are on an average smaller than those at lower loads. This is because with an increase in load, the packets arrive more rapidly and hence the time between the end of one burst and the beginning of the next burst goes on decreasing. Thus, even if the bursts are allowed to accumulate for the same amount of time, the packet inter-arrival time affects the burst inter-arrival time.

The mixed scheme also throws up some interesting results. The burst inter-arrival times as shown in Fig. 3.4 are exponentially distributed as in the case of buffer-limit strategy. We may observe from Fig. 4.8 that the burst sizes follow a uniform distribution or a truncated uniform distribution if the timeout value has been set too low as compared to the burst size. In the final scheme studied i.e. burst aggregation with packet-count limit, both the burst size and the burst inter-arrival times are uniformly distributed. With an increase in the load the burst inter-arrival time reduces as shown in Fig. 3.5. This is to be expected because as the load increases, a given number of IP packets are assembled faster.

4. Conclusion

We have investigated few important issues related to optical burst-switched optical networks in an attempt to improve their performances. Our study mainly focused on the performance improvement on optical burst switched network. The following are the highlights of our investigations:

A systematic study of four burst assembly mechanisms used in optical burst switching for very high speed routing in the next generation Internet backbone has been carried out. The Internet Protocol (IP) packets that are assembled into bursts are considered to be self-similar. Detailed simulations have been performed to analyze the impact of burst assembly mechanisms on the burst inter-arrival time and burst size distributions. In the case of optical burst-switched networks we have fully implemented the JET signaling protocol and using this protocol have carried out detailed investigation on several burst aggregation schemes. The studies reveal that a wide variation of burst traffic statistics occurs depending on the burst assembly policy and such results would be of practical value in optimizing the scheduling as well as the QOS-based reservation policies in OBS network for performance improvement.

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