Available online at www.sciencedirect.com
ScienceDirect
Optik 121 (2010) 876–883
Optik Optics
www.elsevier.de/ijleo

Performance enhancement of optical burst switched networks

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Received 2 June 2008; accepted 27 September 2008

Abstract

Optical burst switching (OBS) is an optical switching paradigm which offers a good tradeoff between the traditional optical circuit switching (OCS) and optical packet switching (OPS) since it has the relatively easy implementation of the first and the efficient bandwidth utilization of the second. Hence, OBS is a promising technology for the next generation optical Internet. A buffer-less OBS network can be implemented using ordinary optical communication equipment without the need for either wavelength converters or optical memories. In an OBS network, burst-loss performance is a critical concern. In OBS, the data-burst transmission is delayed by an offset time (relative to its burst control packet (BCP), or header) and the burst follows its header without waiting for an acknowledgment for resource reservation. Thus, a burst may be lost at an intermediate node due to contention, which is generally resolved according to the local routing and bandwidth information. The routing table maintained in each OBS node is generally pre-computed and fixed to forward the data bursts. Such a static forwarding feature might have limited efficiency to resolve contentions. Moreover, a burst may be lost and the network may be congested when a network element (e.g., fiber link) fails. In this paper, an efficient integrated scheme based on dynamic routing and burst segmentation has been proposed to improve reliability of data transport and network load balancing in optical burst switched networks. Simulation results demonstrate that the proposed approach reduces effectively blocking probability and hence contention. Further, it provides end-to-end throughput performance also. Hence, it establishes an appropriate tradeoff between loss rate and end-to-end throughput.

Keywords: Optical network; Optical burst switching; Dynamic routing; Burst segmentation; Quality of service (QoS)

1. Introduction

Optical burst switching (OBS) has been proposed as a promising switching paradigm to efficiently transport dynamic bursty traffic, e.g., IP packets, over wavelength-division-multiplexed (WDM) mesh networks [1]. Under OBS, several IP packets may be assembled at an ingress edge router into a longer entity, called a burst. Each burst has an associated burst control packet (BCP) (i.e., burst header packet), which carries information such as destination address, offset time (between BCP and burst) and quality-of-service (QoS) requirements. The header of a burst is transmitted prior to the data-burst to reserve bandwidth for certain duration at each routing node it will pass through (as shown in Fig. 1). The intermediate nodes process the header packet and configure the optical switches accordingly such that the data-burst passes through uninhibited in the optical domain through intermediate nodes along its route.

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0030-4026/$ - see front matter
doi:10.1016/j.ijleo.2008.09.037

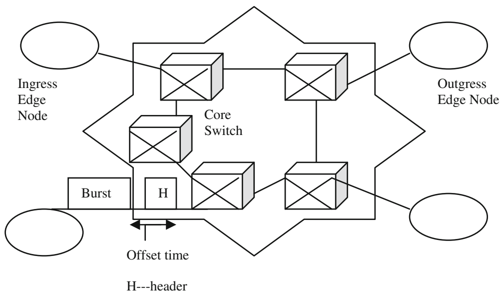

Fig. 1. Optical burst switched (OBS) network architecture.

By providing out-of-band signaling control, OBS needs no data buffering at intermediate nodes, unlike the case with optical packet switching (OPS), while achieving bandwidth efficiency for bursty traffic as in OPS due to its nature of statistical multiplexing of data [2,3]. With the emergence of high-bandwidth applications such as IPTV and videoconferencing, networks need to be designed to support various QoS functions [4,5] that facilitate low data-loss rate, low latency, survivability, etc. Burst-loss is one of the major QoS concerns in OBS networks. Two scenarios causing burst-loss are resource contention and network failures which have attracted much research attention in recent years [6,7]. Under OBS, the data-burst transmission is delayed by an offset time and it follows its header without waiting for an acknowledgment for resource reservation. If the header fails to reserve resources due to a contention along the path, the burst is dropped and the data is lost, unless some contention-resolution techniques are employed to delay/detour the burst. Generally, for OBS as well as OPS, there are three mechanisms to resolve a contention including: using wavelength conversion, fiber delay lines (FDLs) and deflection routing [7]. When competing for the same output channel, multiple contending bursts could be forwarded through different wavelength-channels via the wavelength-conversion technique, or they could be delayed via FDLs that delay the contending bursts for a period of time proportional to the length of the FDL (as in OPS) [8]. With deflection routing, when a contention occurs, a burst could be deflected to an alternative route according to some policies [9,10].

To reduce burst-loss due to congestion, some studies explore proactive contention-avoidance mechanisms through efficient channel scheduling algorithms [11]: burst segmentation [12] or admission control strategies [13]. Moreover, due to the huge capacity of an optical fiber, a large amount of bursts could be lost when a network failure, such as a link failure occurs. How to survive from failures becomes one of the primary objectives in OBS network design. There have been few works on OBS survivability [14–16]. While the restoration mechanism is demonstrated to deal with single-link failure for wavelength-routed OBS in [14], architecture for OBS $1+1$ protection based on the multi-protocol label switching (MPLS) protection is developed in [15]. Ref. [16] applies optimization techniques for static burst traffic to pre-compute explicit backup routes for various failure scenarios. In an OBS network, a contention may be resolved according to the local routing and bandwidth information available at the node where the contention occurs. The routing table maintained in each OBS node is generally pre-computed and fixed to forward the data bursts. Such a mechanism might not be efficient to accommodate dynamic bursty traffic since the congestion could be high on some links when bursts try to travel on the shortest routes which pass through these links.

In this paper, an efficient integrated scheme based on dynamic routing and burst segmentation has been proposed to improve reliability of data transport and network load balancing in optical burst switched networks. Instead of using FDLs and deflection routing when congestion occurs, the objective of proposed integrated scheme is to avoid congestion through an efficient route-computation mechanism for both network scenarios with and without network failures. In the proposed scheme, routing table is dynamically adapted to the current network state. Such a mechanism incorporates the route-distribution and bandwidth-utilization information in route computation and automatically performs load balancing to avoid congestion in advance when setting up the routing table. Further, in the proposed burst segmentation scheme, the control packet contains the burst length and reserves capacity from the first instant when a wavelength becomes available. The initial portion of the burst which is not served before a wavelength becomes free is discarded and lost, i.e. the burst is segmented. The remainder is transmitted successfully as a truncated burst. Simulation results demonstrate the performance enhancement offered by the proposed integrated scheme to optical burst switched networks.

2. Burst segmentation vs. JET scheme

2.1. JET scheme

Since OBS is a buffer-less system, the $M/M/k/k$ queuing model is a standard analysis approach [17,18]. This model assumes that the burst arrival process at a given output port of an optical burst switch is a Poisson process with rate λ. If the burst duration is exponentially distributed with mean $1/\mu$ and the number of wavelengths on the output fiber is k then the Erlang B formula gives the probability of burst blocking:

$$P_B(k, A) = \frac{A^k/k!}{\sum_{m=0}^{k} A^m/m!} \tag{1}$$