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Comparison analysis of optical burst switched network architectures

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Abstract

Optical burst switching (OBS) is a promising paradigm for the next-generation Internet infrastructure. In this paper, a novel efficient network architecture for OBS has been presented and compared with conventional OBS architectures. To enhance OBS system performance, the architecture employs a novel proposed burst assembly algorithm, fiber delay lines (FDLs) and dynamic route selection technique. A queuing model is used to predict the system behavior for both classless and prioritized traffic. Simple closed-form expressions are obtained for the burst-loss probability of both classless and prioritized traffic. Numerical results show that the proposed architecture provides an accurate fit for the performance of the highest traffic class and lower bounds for the other traffic classes that are tighter than earlier known results.

Keywords: Optical burst switching; OBS architectures; Burst assembly; Route selection

1. Introduction

The exponential growth of the Internet traffic demands a high speed transmission technology to support rapidly increasing bandwidth requirements. Currently, the dense wavelength-division multiplexing (DWDM) technology achieves multiplexing of 160–320 wavelengths in one fiber with 10–40 Gb/s transmission rate per wavelength. In order to efficiently utilize the raw bandwidth in DWDM networks, an all-optical transport system that can avoid optical buffering while handling bursts traffic, which can also support fast resource provisioning and asynchronous transmission of variable sized packets, must be developed. Optical burst switching (OBS) [1] is a switching technique that occupies the middle of the spectrum between the well-known circuit switching and packet switching paradigms, borrowing ideas from both to deliver a completely new functionality (as shown in Table 1).

OBS is a compromise between optical circuit switching (OCS) and optical packet switching (OPS), since it allows for a data burst to be sent in an all-optical manner over the network, although the network switching and input/output resources are reserved by a signaling message electronically interpreted at each node, sent prior to the burst in a separate channel named control channel. Network resources such as wavelength converters or data channels (λ channels) are reserved at a node after the setup message is processed following a given signaling protocol. These protocols may be classified as one-way reservation, termed

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Table 1. Comparison of optical switching schemes.

Optical switching (paradigm)	Bandwidth utilization	Latency (setup)	Optical buffer	Traffic adaptivity
Circuit	Low	High	Not required	Low
Packet/cell	High	Low	Required	High
Burst	High	Low	Not required	High

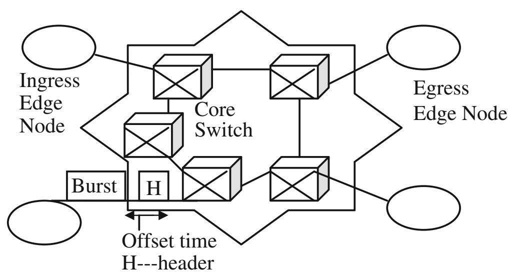

Fig. 1. Optical burst switched (OBS) network architecture.

tell-and-go (TAG–OBS), such as just-in-time (JIT) and just-enough-time (JET), or two-way reservation, termed tell-and-wait (TAW–OBS) [1–3]. TAG protocols are faster since they do not wait for a resource reservation confirmation message, but have performance problems caused by concurrent attempts to reserve the same network resources. TAW protocols need a longer setup time and the packets in the burst experience a longer delay, but the probability of burst loss is smaller since transmission of the burst is done only after all the resources have been successfully reserved. In OBS networks, the traffic management decisions are performed at the edge nodes, keeping the core nodes as simple as possible. Thus, when an edge node transmits a burst into the network, its control packet (CP) already includes information on the path for the burst. The information in OBS nodes is used only locally; thus the network as a whole system does not benefit from the information available on each of the individual nodes. Some attempts have been made to solve this problem, such as the architecture using centralized management model to optimize the utilization of the network information.

2. OBS, issues and related work

Fig. 1 shows the basic procedure of sending one burst from an ingress node to an egress node in an OBS network. At the ingress nodes of an OBS network, all TCP/IP packets are assembled into bursts. The ingress node sends out a control (or setup) packet before sending out the data burst. There is an offset time between the CP and the data burst to give the intermediate OBS nodes enough time to configure their switching fabrics and reserve channel for the following data burst. The CPs are sent out on one or more dedicated control channels (e.g. wavelengths) and go through O/E/O conversion at each intermediate node to provide information about the coming burst. However, the data burst will go through each intermediate node in the optical domain without any O/E/O conversion. There are many interesting issues in OBS, such as burst scheduling, burst assembly, offset time setting and contention resolution [1,2]. Currently, how to efficiently assemble IP packets to bursts in an OBS network is still an open issue. Although fiber delay lines (FDLs) are not mandatory in OBS architecture, the system performance can be significantly improved by employing them. Thus, it is of interest to evaluate the system dynamics considering FDLs. Study of OBS with FDLs is a challenging task due to the unique behavior of FDLs.

Assume that the maximum delay that can be provided by an FDL is τ seconds. Unlike conventional electronic buffers, where a packet can stay in the buffer for an indefinite amount of time, the amount of time that an optical burst can stay is constrained to be less than τ. This is known as buffering with bounded delay. In addition, unlike electronic buffers, where a packet can use a buffer as long as it is available, an optical burst can occupy an FDL only if the FDL is idle and the requested delay is less than τ. There are a few papers in the literature dedicated to the study of OBS with FDLs. Turner [2] applied the M/M/k/D queuing model to study the performance of OBS. Yoo et al. [4] used the M/M/k/D queuing model to find lower and upper bounds on the performance and indicated unique behavior of FDLs. The basic OBS architecture is based on the premise that data are aggregated into bursts and transported from an ingress point to an egress point in the network by setting up a short-life light path in the network in such a way that the burst finds the path configured when it crosses the network nodes. This light path is set in such a way that it maximizes the utilization of the network's resources. If the light path is to be explicitly destroyed then either the ingress or the egress node will issue a control packet with a message that will remove the configured status for that data channel in each of the nodes; otherwise, in the implicit release scenario, each node will compute (in the case of estimated release) or assume (in the case of reservation for a fixed duration)