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ScienceDirect

Optik 121 (2010) 274–280

Optik Optics

www.elsevier.de/ijleo

Investigations on burst length in optical burst switched networks

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Received 18 February 2008; accepted 1 July 2008

Abstract

In this paper, we investigate the performance of optical burst switched networks for erbium-doped fiber amplifiers (EDFAs) and semiconductor optical amplifiers (SOAs). We show that EDFAs are more suitable for burst switching as compared to SOAs. We further investigate the burst length for 18, 24.6 and 55 km optical switched network. It is observed that burst length should neither be very small nor very large. If the burst length is small, throughput will be less, and if the burst length is very large, delay will be very large. This is due to higher wait times incurred when packets are formed into larger bursts causing additional overall delay. It is observed that performance decreases up to a small burst length of 1500 μs, which is the minimum burst length required for the creation of the burst. Once this burst is created, there is significant improvement in the quality factor up to 3000 μs. After this burst length, the performance again degrades. Hence the burst length can be optimized for the best quality factor in optical burst switched networks. We further show that by increasing EDFA gain, the quality deteriorates as increasing the EDFA gain results in increased levels of additive phase noise, which can further induce nonlinearities.

Keywords: Optical burst switching; EDFA; SOA; WDM

1. Introduction

Optical burst switching (OBS) has been proposed as a technique to overcome the shortcomings of conventional wavelength-division-multiplexing (WDM) deployment, such as lack of fine bandwidth granularity in wavelength routing and electronic speed bottlenecks in SONET/SDH. The rate of increase in the speed of electronic processing is slower than the rate of increase in fiber capacity. This makes the processing of high-speed data in the electronic domain infeasible and results in the need of optical switching. Three types of optical switching architectures have been reported in the literature: optical circuit switching (OCS), optical packet switching (OPS) and OBS [1]. Existing switching paradigms in optical networks are not suitable for supporting bursty traffic. Specifically, using OCS via wavelength routing, a lightpath needs to be established first from a source node to a destination node using a dedicated wavelength on each link along a physical path. An alternative to OCS is optical or photonic packet/cell switching in which a packet is sent along with its header. While the header is being processed by an intermediate node, either all-optically or electronically (after an O/E conversion), the packet is buffered at the node in the optical domain [2]. However, high-speed

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0030-4026/$ - see front matter
doi:10.1016/j.ijleo.2008.07.009

optical logic, optical memory technology and synchronization requirements are the major problems with this approach.

OBS is a compromise between the demands of forecast traffic (which mandate the statistical sharing of packet switching) and the realities of optical technologies (for which circuit switching is much easier to implement). OBS is a possible stepping stone on the way to OPS and OCS. OBS has recently been proposed as a candidate architecture for the next-generation optical Internet [3]. The central idea behind OBS is the promise of optical technologies to enable switch reconfiguration in microseconds, therefore providing a near-term optical networking solution with finer switching granularity in the optical domain [4]. At the ingress node of an IP over OBS network, the IP packets destined to the same egress node and with similar QoS requirements are segmented into bursts, which are defined as a collection of IP packets, whereas IP packet re-assembly is carried out at the egress OBS node. In OBS, the reservation request for a burst is signaled out of band (e.g., over a separate wavelength channel) as a burst control packet (BCP) and processed in the electronic domain. When the BCP arrives at an OXC toward the egress node, the burst length and the arrival time are extracted from the BCP and the burst is scheduled in advance to an outgoing wavelength upon availability.

In OBS networks, the data packets are assembled into bursts on the WDM channel and transported across the optical core to the destination. This results in the possibility of long inter burst idle intervals, during which transients in erbium-doped fiber amplifiers (EDFAs) can cause gains to greatly exceed the average values. The transient effect in OBS networks results in power variation in different packets, which could potentially cause misrouting and degradation in signal quality at the node and require a high dynamic range for the receiver. Several approaches have been proposed to control EDFA transients, including the use of a continuous-wave (CW) channel to drive the amplifier into saturation or provide constant total power, or using automatic gain control with optical [5] or electronic feedback to control the power into the amplifier. However, these approaches require a high-power laser source [6], have slow response or suffer from relaxation oscillations [5]. Tran et al. [7] studied a simple technique based on envelope detection to significantly control rapid EDFA transients in optical burst switched networks. It was demonstrated that there is 6-dB transient reduction in a 10-Gb/s 80-km-long WDM system with three EDFAs. Further, the OBS amplification with feedback loop was used to control transients [8] and cause amplification.

To precisely demonstrate the OBS networks, one should be properly aware about the burst length in OBS. But yet there are no predictions made with respect to the burst lengths. The burst length plays a vital role in the processing of data in the optical network. If the burst length is small, throughput is less, and if the burst length is very large delay will be very large. This is because higher wait times will be incurred when packets are formed into larger bursts causing additional overall delay. If burst lengths required in OBS networks are not well known, there may be loss of packets and the problem of contention may occur. Thus, main consideration is given towards burst length in OBS networks. Thus, the predictions should be made for the appropriate burst length, gain of EDFAs to be used for transient reductions and the relationship of burst length with other parameters of OBS.

In this paper, we further investigate and simulate a fast and simple scheme based on the envelope detection technique to significantly remove amplifier transients in OBS networks. The scheme results in transient reduction in a 10-Gb/s 80-km-long WDM system with three EDFAs. It is also shown through simulation that the technique can be used at the first EDFA in links with 10 cascaded EDFAs to further reduce transients.

This paper is divided into three sections. Section 2 describes the setup for the new EDFA transient control technique. Section 3 includes the simulation results for the number of amplifier spans, the effect of EDFA gain and effect of transient control on burst length. Section 4 gives the conclusion related to the dependence of various parameters of OBS networks on the burst length and transient control technique using envelope detection.

2. System setup for new EDFA transient control technique

Fig. 1 shows a schematic diagram of the proposed technique to control EDFA transients in OBS networks. The input WDM bursts enter the control module and are first split into two parts using a 9:1 coupler. The first part (10%) of the input signals is detected by a photodiode (PD) and is then fed into a control circuit. The control circuit consists of envelope detection, radiofrequency amplification and laser-driver circuits. The transient control circuit generates an inverted envelope of the input bursts. The time constant of the PD and control circuit needs to be greater than the burst rate to accurately reproduce the envelope of the input bursts, but should be smaller than the response time of the EDFA to generate fast transient control signal. The inverted envelope then directly modulates a laser at wavelength, which is different from the input channel wavelengths. The circuit can be used to adjust the level of the detected envelope depending on the requirement. The second part of the input burst signals (90%) passes