An effective buffering architecture for optical packet switching networks

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Abstract A novel optical buffering architecture for Optical Packet Switching (OPS) networks is proposed in this article. The architecture which adopts a fiber-sharing mechanism aims at solving the problem of using a large number of fiber delay lines that are used to solve resource contention in the core node in OPS networks. The new architecture employs fewer fiber delay lines compared to other simple architectures, but can achieve the same performance. Simulation results and analysis show that the new architecture can decrease packet loss probability effectively and achieve reasonable performance in average packet delay.

Keywords Optical packet switching · Optical buffering · Fiber delay lines · Packet loss probability · Average packet delay

1 Introduction

The exponential growth of Internet traffic is requiring more and more network capacity every day. Wavelength-division multiplexing (WDM) technology is currently used to multiply network capacity. Besides the huge amounts of bandwidth, all-optical WDM networks also allow high-speed data transmission without electronic converters at core switching nodes and transparency with respect to data format to be achieved. Therefore, network nodes have to process a large amount of incoming data, which is becoming difficult by electrical processing alone. To overcome the bottleneck of the electrical processing technology and enhance the signal processing speed in the switching node, it is desired that optical signals be routed without being converted to electrical signals, that is, they should be routed directly in the optical layer.

Wavelength-routed networks have been extensively studied in the recent years. Additionally, Optical Packet Switching (OPS) which is one technology based on WDM [1], is attracting more and more interest. The OPS network layer will bridge the gap between high-speed wavelength channels in the optical WDM transport network and the electrically switched network partitions.

In general, OPS networks can be divided into two categories: synchronous OPS and asynchronous OPS. Synchronous OPS networks require that all optical packets must have the same length, and enter into a switching node synchronously. This results in less contention, but is difficult to implement. While asynchronous OPS networks do not confine the length of optical packets and do not care whether or not packets arrive at a switching node synchronously. Thus it can be easily implemented, but has a larger probability of resource contention than synchronous OPS networks, which is one of the most critical issues in asynchronous OPS networks.

This article consists of five sections. Section 2 presents some solutions of resource contention. In Sect. 3, we describe how a fiber delay matrix solves the problem of resource con-
tention, and present a novel optical buffering architecture. Simulation results are given to prove the performance of the new architecture, in the fourth section. Section 5 provides some brief concluding remarks.

2 Solutions statement

There are two situations that result in resource contention in a core node of asynchronous OPS networks, as can be seen in Fig. 1. One is two or more optical packets compete for the same channel at the same output port at the same time. Another situation is that the selected leaving channel by a packet is exactly being used by other packet.

Three methods are used to solve this problem [2]: wavelength conversion, deflection routing, and optical buffering. Fixed wavelength converters (FWC) and tunable wavelength converters (TWC) are both used to transform contending packets to an idle channel at the same port. But FWC is not efficient enough, while TWC is costly and not reliable. In the second method, optical packets are transferred to another output port which has an idle channel, but that may result in a chaos in networks. Comparably speaking, optical buffering using fiber delay lines (FDLs) has been proved to be a best choice to handle resource contention by providing fixed length and finite delay [3–5]. The length of FDLs is measured in terms of a delay unit, called granularity. But optical buffering using a larger number of FDLs makes the cost unacceptable. To solve this problem, a novel architecture is proposed in this article. It adopts a fiber-sharing mechanism to improve the utilization of FDLs while reducing the cost.

3 New architecture

We shall assume the first-in first-out (FIFO) discipline, which means incoming packets are always placed in the buffer after the last one in output time, with the shortest possible delay.

The purpose of FDLs is to resolve the problem of resource contention, so optical packets in one channel will not overlap to each other after passing through the fiber delay matrix. By using FDLs, contending packets which are destined to the same channel can be sent to different inputs of a fiber delay matrix, according to the time they arrive, as can be seen in Fig. 2. In different delay fibers, packets travel a different distance before arriving at a particular output port. This means that all packets are separated from each other in their output port, in time.

Though the problem of resource contention is solved, a large number of FDLs are needed in most of simple architectures. Fortunately, in Fig. 3a, a novel architecture called the Segmented Shared Buffer Architecture (SSB) is proposed [6], based on the fact that packets appeared in the same channel at the same time will not overlap with each other after passing through the fiber delay matrix. In the SSB architecture, every segment of fiber has two inputs, one connects to the output of up-step segment, and another directly connects to the switching matrix of the core node. It senses that the up-step segment can share all of its down-step segments. The number of FDLs can be reduced visibly in the fiber delay matrix, just because of this sharing mechanism. And there is no overlapping delay fibers, so all FDLs are employed with high efficiency.

Figure 3b illustrates the time relation of the SSB architecture. For example, in the output buffering architecture (OB) [5], the number of FDLs units needed is $B(B + 1)/2$, if delay