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LETTER

Novel scheduling algorithm for hybrid buffer structured optical packet switch

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Abstract

We propose a novel scheduling algorithm for the optical packet switch (OPS) with a hybrid buffer consisting of a fiber delay line (FDL) buffer and a shared electronic buffer, for contention resolution of asynchronous variable length packets. By employing the end of each channel together with the time intervals between the scheduled packets of each channel in the output line, simulation results showed that packet loss might be reduced significantly, resulting in a powerful reduction of the number of FDLs in the hybrid buffer. Also, the optimum number of electronic buffer inputs/outputs accompanied by O/E/O conversion was confirmed to be obtained for various loads.

Keywords: Scheduling algorithm; Optical packet switch (OPS); Hybrid buffer; Fiber delay line (FDL) buffer; Electronic buffer

1. Introduction

In optical packet switching, contention occurs in cases where more than one packet arrives from different input fibers and simultaneously leaves for the same output port [1]. To resolve these contentions, the fiber delay line (FDL) buffers consisting of a set of FDLs have been introduced to buffer optical packets. Contending packets are sent to travel an FDL and thus are delayed for a specific amount of time. However, they did not guarantee a low packet loss probability for asynchronous variable length packets. For this reason, various types of buffer structures have been proposed including the non-degenerated FDL buffer, which are well-adapted to void-filling scheduling algorithms, and the multistage FDL buffer with fine granularity and long delays [2,3]. In terms of practical implementation, however, they need to be improved in dealing with the real IP traffic model.

Recently, a hybrid buffer structure which consists of a FDL buffer and a shared electronic buffer, was introduced to the optical packet switch (OPS) as an alternative for the contention resolution of asynchronous variable length packets [4]. Here, the electronic buffer was employed to provide continuous time delays. The packets not being served by the FDL buffer were stored into the electronic memory and then could be retrieved at any time, if available time intervals between the scheduled packets (i.e., voids) in each channel were found. A modified void-filling algorithm to decrease packet loss probability based on a hybrid buffer was also proposed for the contention resolution [4]. However, overflow packets (i.e., the packets that failed to find available channels by using FDLs) larger than available voids in the output line were still not served.

In this respect, we propose a new algorithm to decrease packet loss regardless of the overflow packet sizes, which

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uses the end of each channel (hereafter, the end of wavelength queue) as well as voids in each channel, for channel allocation of overflow packets.

2. The hybrid buffer structure for variable length packets

The FDL buffer generates inevitable voids in the output line for variable length packets due to its discrete step delay property, which results in the excess load to each channel of the output line [1,4]. Although a void-filling scheduling algorithm had been introduced to reduce this excess load and to improve packet loss, it did not guarantee low packet loss probability [1]. To decrease packet loss probability significantly, longer delays accommodating the excess load are required and this can be realized by using a number of FDLs [1]. Unfortunately, the fiber itself is very sensitive to temperature fluctuation and mechanical stress [4]. Thus, the fluctuation in time delay due to long length of the fiber severely degrades system performance. For this reason, the number of FDLs (buffer depth) needs to be limited within a certain value (e.g., around 10 delay lines [1]) in the OPS. The hybrid buffer structure was introduced to enhance buffer capacity under the limited number of FDLs [4]. In this structure, overflow packets can be efficiently served by the electronic buffer, which provides longer and continuous time delays, making it possible to minimize voids efficiently in the output line [4]. Although optical processing is a general trend for buffering of data payloads in the OPS, we have adopted the electronic buffer together with the FDL buffer for asynchronous variable length packets, for the above reasons [4]. On the other hand, the optical-to-electrical (O/E) conversion and the reverse (E/O) conversion limit the speed of signal processing and, therefore, the electronic buffer needs the optimized number of inputs/outputs.

An OPS architecture with a hybrid buffer is shown in Fig. 1 [4]. The FDL buffer has a degenerate buffer structure of $\{D_1, D_2, \ldots, D_i, \ldots, D_B\}$, where each D_i has a time delay given as multiple of basic delay line length D, i.e., i times D. And, all packets carrying on the wavelengths of $\{\lambda_0, \lambda_1, \ldots, \lambda_{n \cdot N-1}\}$ can be delayed through each FDL. The shared electronic buffer with k inputs/outputs is used as a supplementary buffer to store the optical packets that fail to find available channels using only FDLs [4]. Tunable wavelength converters (TWCs) with the conversion range of $\{\lambda_0, \lambda_1, \ldots, \lambda_{n \cdot N-1}\}$ were employed to provide internal wavelengths of nN for incoming packets, which enable each incoming packet to exploit one of nN WDM channels in the FDL buffer. Therefore, we could only evaluate the influence of scheduling algorithms on the packet loss due to the lack of buffering space. Since there are internal wavelengths of nN, the packet loss due to the lack of internal wavelengths can be avoided, even though the event that nN arrival packets from input fibers want to use the same FDL at the same time occurs. Spatial switches perform routing function to a selected buffer (FDL buffer or shared electronic buffer) for scheduled packets. Fixed wavelength convertors perform wavelength conversion to a scheduled channel in a destination output fiber for each buffered packet [4]. The switch control unit (SCU) controls each switching element by

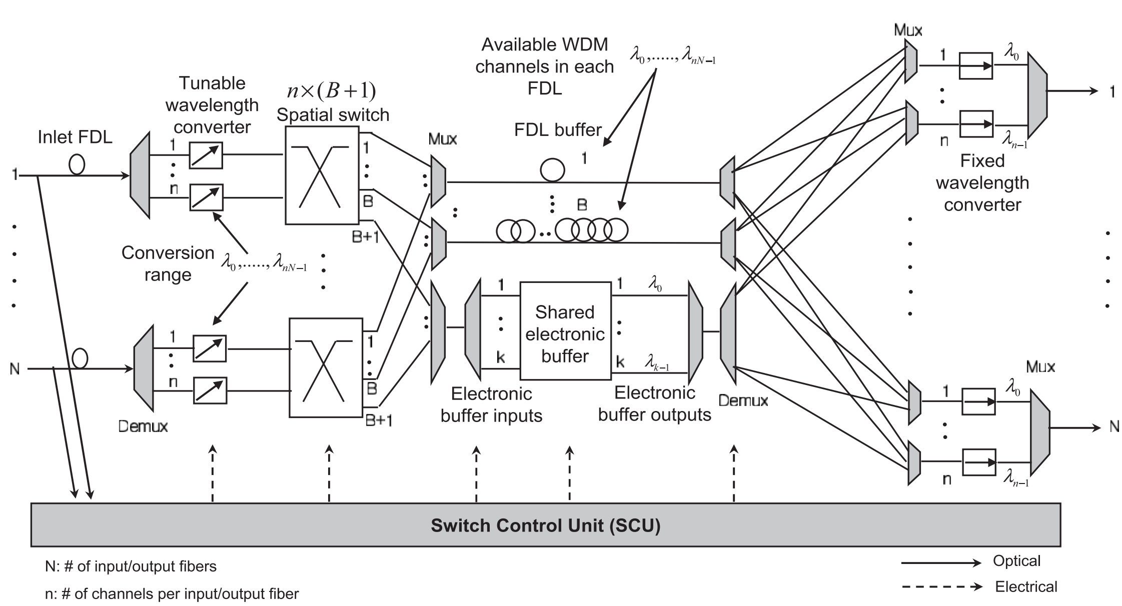

Fig. 1. OPS architecture with a hybrid buffer.