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Performance analysis of a novel traffic scheduling algorithm in slotted optical networks

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Abstract

This paper considers the scheduling problem in a new slotted optical network called Time-Domain Wavelength Interleaved network (TWIN). The TWIN architecture possesses interesting properties, which may offer solutions for next-generation optical networks. Besides, better Quality of Service (QoS) could be achieved in TWIN by minimizing two parameters: queueing delay and delay variance. However, to the best of our knowledge, most of the existing scheduling algorithms in TWIN ignored consideration of QoS and focused mainly on maximizing the throughput. In this paper, we formulate the scheduling problem into an Integer Linear Programming (ILP) problem and propose a novel heuristic – Destination Slot Set (DSS) algorithm to solve it fast and efficiently. Besides, we derive an analytical model for TWIN and investigate the performance of DSS in it. By means of simulations, we demonstrate that our analytical model approximates the TWIN network very well; moreover, DSS incurs smaller queueing delay and delay variance, which ensures better QoS.

Keywords: Wavelength division multiplexing; Quality of Service; Traffic scheduling

1. Introduction

As more and more multimedia traffic is going to be transmitted on the Internet, there is a growing need to upgrade current networks to a greater capacity. The wavelength division multiplexing (WDM) is a very effective technique in optical networks for utilizing the huge bandwidth of an optical fiber without spending extra cost on hardware upgrade. However, the traffic on current end-to-end wavelength connections has not scaled to the full capacity, and thus the end-to-end wavelength services are not cost-effective. A number of traffic grooming studies have been reported in the optical networking literature, but they require add-drop multiplexers (ADMs) or need to resort to some electronic operations [1]. Optical Packet Switching (OPS) [2] and Optical Burst Switching (OBS) [3] have also been proposed as solutions, but both of them need ultra-fast optical switches for forwarding packets (bursts) and optical buffering for resolving packet contention (in OBS, using optical buffering is an option but can improve performance). Although researchers are striving to develop faster optical switches and better optical buffers, they are not as operable as the electronic counterparts, and these technical barriers are not likely to be easily overcome in the near future.

Recently, Bell Laboratories proposed a new optical transport network called Time-Domain Wavelength Interleaved Network (TWIN) [4]. TWIN performs efficient traffic grooming without resorting to electronic operations. In TWIN a number of practical difficulties in building optical networks, in particular the lack of optical buffers and fast optical switching, can be effectively dealt with. TWIN provides a thin-layered and cost-effective optical network architecture.

Briefly speaking, TWIN defines an optical network consisting of a simple core based on wavelength-selective

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cross-connects capable of merging incoming signals of the same wavelengths to the same outgoing fiber, and an intelligent edge that uses fast tunable lasers to emulate fast switching of data in the core. Fig. 1 shows a simple TWIN architecture with node G and F being two different destinations. In TWIN, each destination node j is assigned a unique wavelength ξ_j, and other source nodes need to tune to ξ_j in order to transmit to node j. The routes in TWIN are preprovisioned so routing is trivial. Signals are aggregated at the *aggregate devices* (ADs) and routed in the network by passive components such as the *wavelength-selective cross-connects* (WSXCs). Once preprovisioned, each WSXC performs self-routing of various optical signals on-the-fly based on their wavelengths. Compared to OPS [2] and OBS [3], TWIN physically eliminates the need for fast optical switching and optical buffering. Tunable lasers at the sources emulate fast switching in the network core and enable efficient traffic grooming by tuning the signal at designated times. With the initial design, TWIN has a physical limitation that the number of nodes in the network is restricted by the number of wavelengths available in a single fiber. This issue has been addressed in a recent work called TWIN with wavelength reuse (TWIN-WR) [5]. By dividing the problem into several subproblems and solving them in order, it successfully achieved the goal of supporting N nodes with roughly $(N)^{1/2}$ wavelengths.

The scheduling problem in TWIN is somewhat particular. Let us illustrate it by an example. Fig. 1 shows traffic on two different wavelengths (represented by dashed and dotted line) destined for two destination nodes (F and G). The wavelength connections from various sources to a particular destination form a multipoint-to-point tree called destination tree [6]. Bursts from various sources to a destination cannot collide at the destination or at any intermediate node, otherwise they will be dropped. Since time in TWIN is slotted, it requires that no two or more bursts can arrive at the destination or at any intermediate node in a same slot on a same channel. For example, in Fig. 1 there is a burst from node A arriving at node G in time slot 1. If there is another burst from node E also arriving at node G in time slot 1, conflict occurs and transmission fails. In TWIN we rely on scheduling to coordinate the transmission of data bursts.

This scheduling problem is quite different from previous ones. In the packet networks, scheduling takes place in a single node when multiple packets compete for a common outgoing link. The well-known scheduling algorithms such as Virtual Clock [7], Generalized Processor Sharing (GPS), packetized GPS (PGPS) [8] and Worst-case Fair Weighted Fair Queueing (WF^2Q) [9] belong to this category. Another kind of schedulers is the switch schedulers, generally setting up connections between a number of input and output ports. The iSLIP [10], iSKIP [11] are good representatives of this kind. We can consider TWIN as a big switch, with its input and output ports spreading throughout the net-

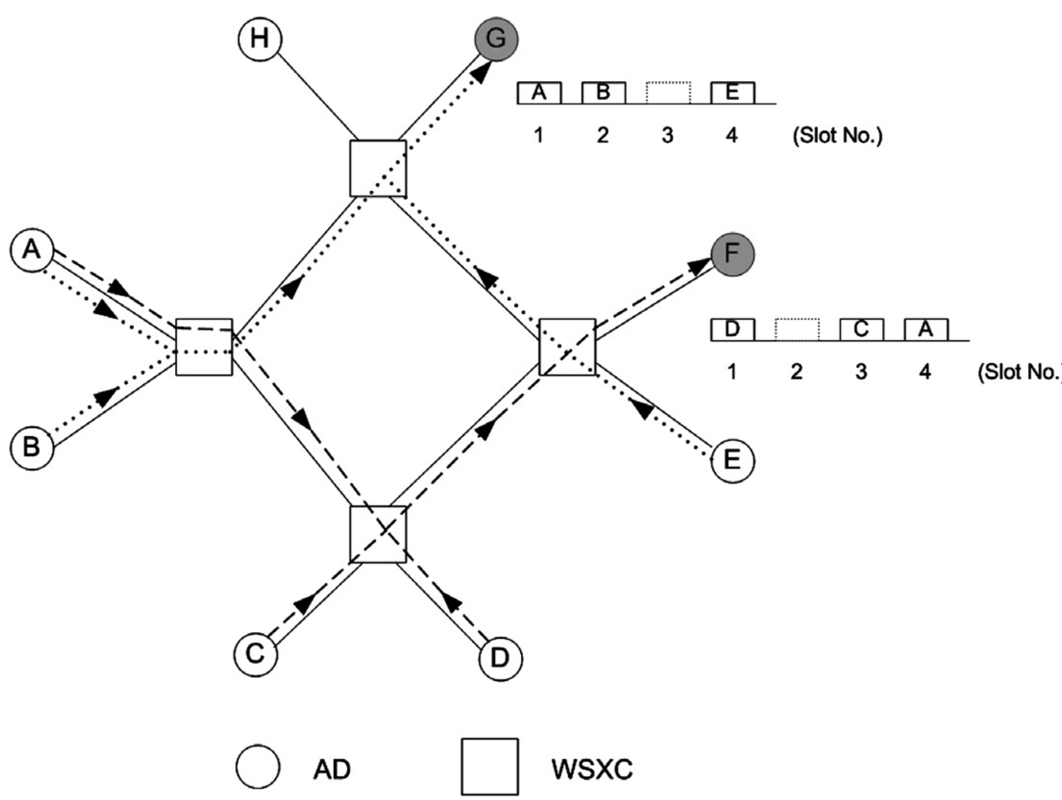

Fig. 1. Illustration of the TWIN architecture.