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Analysis of an optical hybrid switch

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Abstract
In this paper, we study a genetic design for an optical hybrid switch composed of both slow and fast switching fabrics, and present a performance analysis to provide deeper insight in its behavior.

Keywords: Optical Hybrid Switch

Introduction

Optical networks have a proven track-record in the context of long-haul, point-to-point networking, where large amounts of data are transported in a cost-effective way. However, interest is growing to use optical networks in edge and even access networks; mostly because of the predictable performance of photonic technology (i.e. high bandwidth, low latency). A major issue is O/E/O (optical/electronic/optical) conversions in the network, mostly because the speed of electronic processing cannot match the bandwidths currently offered in the form of 40 Gbps and higher. For this reason, current research is focusing on all-optical networking solutions. As of today, it is possible to create all-optical networks through the use of circuit-switched paths, which essentially reserve one or more full wavelengths between end points.

In this paper, we propose a generic hybrid optical switch architecture, which supports both circuits and 'bursts. We show through simulation analysis of a single node that this architecture has improved performance over single technology nodes (e.g. a circuit-only node).

Analysis

The basic function of an optical switch is straightforward: it must create a path between an input and an output port for each incoming data packet. The decision which output port a data packet should be directed to is usually made in a control unit available at each optical switch. The time between the control packet and the actual data transfer is denoted by T_{offset}, and is the time available to the switch to reconfigure its internal cross-connections. Each switching fabric (see [4] for current technologies) is limited by its switching speed T_{switch}, and thus a data burst can only be switched successfully if $T_{swich} < T_{offset}$. A related parameter is the switch utilization, and is bounded by:

$$\frac{T_{data}}{T_{data} + T_{switch}}$$

As shown in Figure-1 shows a generic design of a hybrid optical switch, which is composed of two separate switching fabrics. The signaling plane. Depicted out-of-band in the figure, informs the Control Unit of the imminent arrival of a data burst.

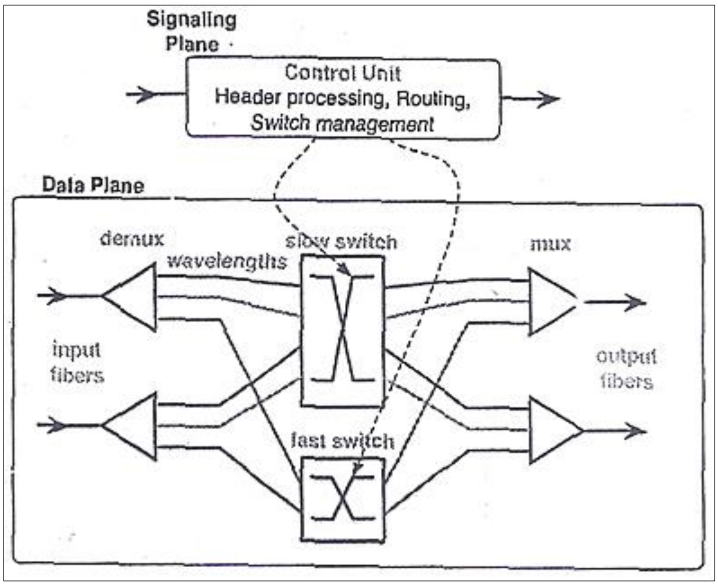

Fig 1: A generic design of a hybrid optical switch

If optical signaling is used, additional O/E and E/O conversions are necessary before and after the Control Unit.

We propose two algorithms; simple as shown in Figure-2 and greedy Figure-3 scheduling.

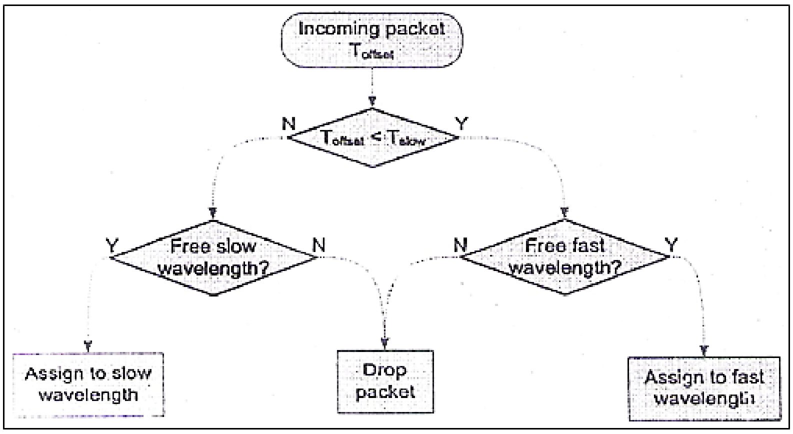

Fig 2: Two algorithms

The simple scheduling algorithm works by looking up the requested switching time of the burst, and if it is possible to switch slow (i.e. offset between header and data (T_{offset}) is larger than the switching time of the slow switch T_{slow}), the burst is assigned to a slow wavelength in case one is free, otherwise the burst is dropped. In case fast switching is required, a fast wavelength is used if one is free. Greedy scheduling also allows slow packets on the fast wavelengths in case no slow wavelength is available. It uses available bandwidth more aggressively, at the risk of assigning valuable fast wavelength to slow data bursts. The other option, where fast packets are allowed on the slow wavelength was not implemented because of its obvious non-optimal use of wavelength capacity; fast packets on the slow wavelengths cannot be switched in most cases, and additionally consume capacity required for slow packets.

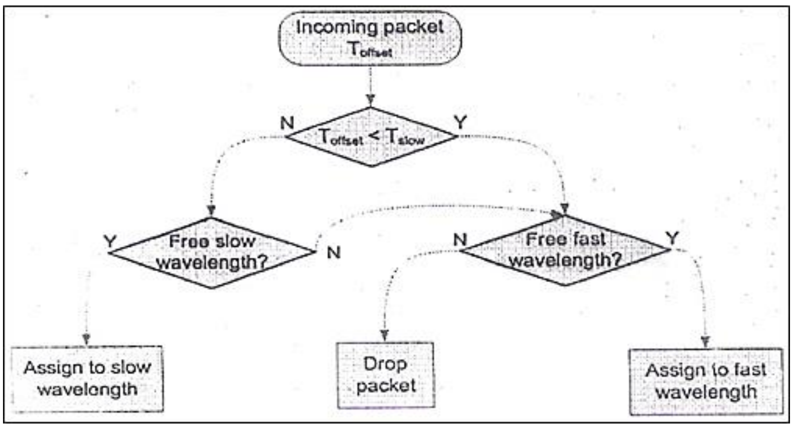

Fig 3: Scheduling

To evaluate the influence of the scheduling algorithm on the traffic offered to the switch, we implemented a scenario when: generated traffic is composed of 50% fast and 50% slow bursts, and the wavelengths consists of 5 slow and 5 fast wavelengths.

Result and Discussion

Through simulation analysis, we showed the possible performance improvements of the hybrid switch over a wide range of traffic and switch parameters. The generated network load is composed of 20% fast traffic and 80% slow.

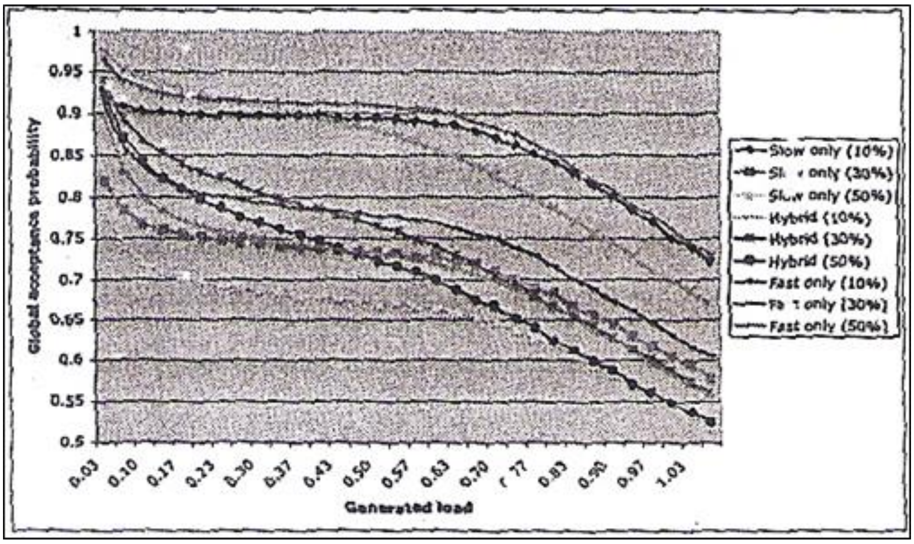

Fig 4: The details of this traffic directionality for all switch designs

Clearly, having a high probability of choosing the same output port for two consecutive burst (case 10%-90%) results in the highest acceptance probability. For this specific case, the slow-only is even able to outperform the hybrid approach, although when switching gains importance (i.e. directionality values closer to 50%), we show the influence of the ratio of fast/slow wavelengths, for a fixed ratio of last/slow traffic. This latter ratio is held constant throughout the following simulations, and equal to .5. Obviously these results show the performance of the hybrid switch design, and' we discuss the performance of the simple scheduling separately from the greedy scheduling, such as

a) Simple scheduling

The best performance is achieved by the hybrid switch with a number of fast/slow ports that, corresponds to the fast/slow traffic ratio. We also see that cases for corresponding fast/slow port counts (e.g. 6 fast, 2 slow and 2 fast, 6 slow) show very similar behaviour. In these cases, the design with the highest number of fast ports has slightly better performance. The acceptance probability of packets which are actually offered to the switch shows the best performance for the combination of fast/slow ports which corresponds to the ratio of fast and slow traffic (i.e. 50% fast, 50% slow). Performance degrades as the number of fast/slow ports differs more from the ratio of fast and slow traffic.

b) Greedy scheduling

The greedy scheduling method clearly makes better use of the available capacity, by allowing slow bursts access to the fast wavelengths. In contrast to the simple scheduling algorithm, the corresponding fast/slow wavelength counts (e.g. 6 fast, 2 slow and 2 fast, 6 slow) do not have similar performance. Instead, higher number of fast wavelength counts are used more effectively by the greedy scheduling and ultimately lead to higher performance.

Conclusion

In this paper we presented a generic model for a hybrid optical switch, to support all-optical switching in future transport networks.

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