A Novel Node Architecture for Optical Packet-switched Networks

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Abstract: *we proposed a novel node architecture, which independent of wavelength conversion and optical buffer, for optical packet-switched networks. This node* can decrease drop probability in terms of orders of magnitude.

Introduction

Optical packet-switched networks (OPN) transfer data in separate, small blocks—switching entities--based on the destination address in each entity. When received, switching entities are reassembled and/or disassembled in the proper sequence to make up the message. In recent years, a number of research groups have reported various OPN approaches. Among these approaches, optical burst switching (OBS) [1] and optical packet switching (OPS) [2] technologies are expected to the promising technologies for the optical wavelength division multiplexing (WDM) network. They can be efficient, flexible and transparent transport bursty IP and Ethernet traffic over optical WDM networks and provide statistical multiplexing gains.

However, whether OBS or OPS, under the current and foreseeable limitations of optical technology, network performance is mainly hampered at the network node by resource contention. Due to optical random access memory (RAM) is not available so far, contention will occur when two or more switching entities (bursts or packets) from different input ports wanting to be forwarded on the same wavelength, on the same output port, at the same time. Therefore, many contention resolutions are proposed, such as fiber delay lines (FDL), wavelength conversion (WC), and deflection routing are studied in [3].

In this paper, we proposed a novel node architecture for OPN. This study stems from practical observation that viable wavelength converters are expensive and the optical RAM is not available so far. The proposed node architecture supports dual-fiber link to erase contention. We also proposed a relative media access control (MAC) protocol. Simulation results show that the proposed node architecture can decrease packet drop probability in terms of orders of magnitude.

Node Architecture

The proposed node has two important function parts: edge aggregating and core switching. The former is in charge of traffic aggregation. The latter is in charge of switching. It has an optical cross connect (OXC) to add, drop, and switch the switching entities (e.g. bursts), as well as to provide optical bypass for traffic that does not need to drop at the node. The node supports 2 input fibers connected the same upstream node and 2 output fibers connected the same downstream node. Both the two fibers have the same wavelength channels, as the parallel fiber link in [4].

The proposed node is different from conventional OPN nodes. The conventional node with statistical multiplexing poses problems that are more similar to those faced in legacy packet-switched networks, such as resource allocation and congestion resolution, but again the problem has some peculiar characteristics due to the absence of optical RAM. So, they require deploying large numbers of wavelength converters to erase contention. In contrast, the proposed node can forward a contending entity to another wavelength channel at the other fiber, which connecting the same downstream node. One of the two fibers acts the function of a set of FDL or a set of partial WC.

Take OBS as an example, the proposed node architecture is shown in figure 1. The two output fibers (fiber 0 and fiber 1) have the same wavelengths (λ_0, λ_1,…, λ_m). The wavelength λ_0 is used as control channel. The others are used as data channels. We defined the wavelength of output fiber 1 as master use wavelengths (MUW), and the wavelength of the output fiber 0 as slave use wavelengths (SUW). A MAC protocol is proposed as follows. All new add bursts must be transmitted into MUW to transmission. All control packets of pass-by bursts must reserve the MUW first. If the reservation is unsuccessful, then they reserve the SUW. That is, all new add bursts use MUW to enter the network, and the SUW are always ready for the contending burst. Figure 1 traces the switching process for four bursts, labeled 1 to 4 respectively. Burst 1, 3, 4 are pass-by burst, and burst 2 is a new add burst. The contending burst 4 was switched to SUW (λ_1) in the output fiber 0.

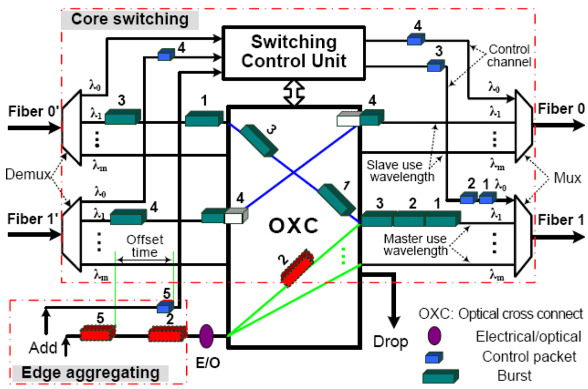

Figure 1: The proposed novel node architecture

Performance Evaluation

To evaluate the node architecture, three scenarios, namely the proposed node, conventional node (CN) and conventional node support two simple link (CNT), are developed in networks as shown in figure 2. The numbers on the links represent the link lengths in kilometers. We defined the injected traffic volume of unit time divide by channel speed and channel numbers as normalized load ρ. The following assumptions are made in the simulations: the node has no wavelength converter and any other contention resolution devices; the switching and processing time of a control packet is 5 us; the Offset time is set to 0.5 ms; using first-in first-out schedule strategy and static shortest path routing; using just enough time [1] signaling; using 4 data channels in each fiber and at a 10 Gbps transmission rate; and the input traffic is uniformly distributed to all nodes.

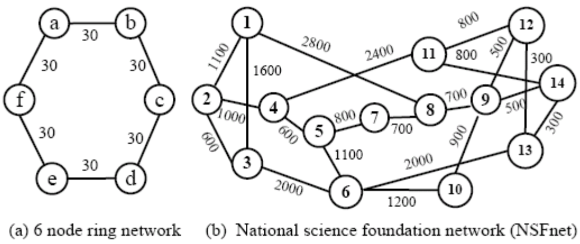

Figure 2: Simulation topologies

In figures of this section, the notation CN and CNT mean the curve for the CN and CNT scenarios respectively. The acronym SS indicate the source produces Self-Similar traffic with Hurst parameter H=0.75 and PS means Poisson traffic. Figure 3 shows the burst drop probability (BDP) of the ring network. There is an obvious difference between these scenarios. The proposed node gets the BDP about two orders of magnitude less than that of the CNT when the load is less than 0.4, and one order of magnitude less than that of the CNT when the load is large than 0.4 and less than 0.7. Figure 4 shows the BDP of the NSFnet. As the results of the ring network, the BDP is also exhibits an evident difference, whether Poisson source or Self-Similar source.

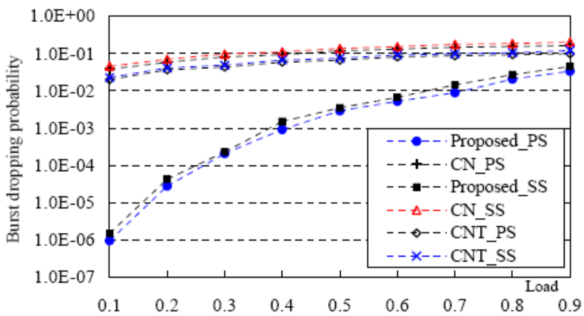

Figure 3: Burst drop probability of the ring network

From figures 3 and 4, one can easy to see that there is an obvious difference between the results of the proposed node and CNT scenarios. Though the two scenarios are identical in terms of total consumed transmission capacity, the contrast is remarkable. The following reasons may give you a clear picture about the visible difference. First, the proposed node has two output fibers with the same wavelengths. The same wavelengths act as the functions of a set of partial wavelength converter. Second, one of the dual-fibers acts as the function of a set of FDL and a series of deflection routing. This is helpful to improve the switching capacity of the node. Finally, the new add bursts use MUW to enter the network guarantees a mild access process. From the point of view of nodes, this process restricts the node throughput. It is this restriction that improves the network throughput in the absence of optical buffer.

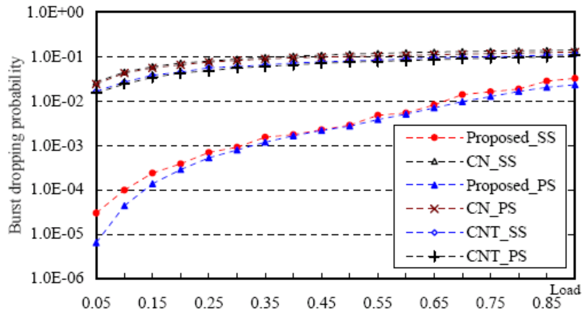

Figure 4: Burst drop probability of the NSFnet

Figure 5 shows the link utilizations of the ring network. One can see that the utilization of MUW is about 10~40% higher than that of the SUW in the proposed node scenario. And the utilization of MUW is a litter less than those of the CN and CNT scenarios at the same load. The proposed node scenario achieves a high entire network throughput at the sacrifice of the utilization of SUW.

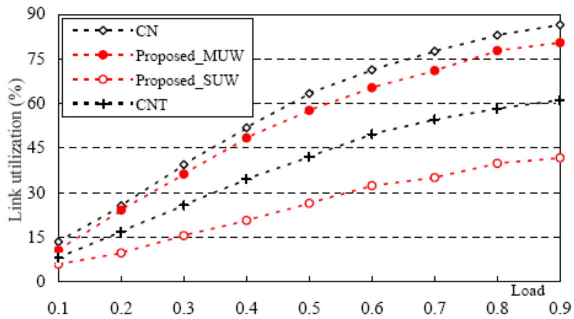

Figure 5: Link utilization of the ring network

Conclusions

In this paper, we proposed a novel node architecture for OPN. This node architecture is more cost-effective than the conventional node architectures because it requires much less WCs to achieve a commercially viable packet drop performance. If we make a trade-off among costs, performances, and devices, it is feasible to deploy this architecture in OPN at low cost.

References

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