Performance analysis of a novel architecture for contention resolution of OPS

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Optical packet switching (OPS) technology can rapidly deliver the enormous network bandwidth and offer high-speed data rate and format transparency. In this paper we propose a novel architecture using all-optical tunable wavelength converters (TWCs) and fiber delay-lines (FDLs) to address the contention problem for OPS in wavelength and time domains. This architecture improves packet switching speed but significantly decreases the number of optical switches comparing with existing architectures. A simulation is also conducted to evaluate the performance of the architecture. The simulation results show that the packet loss probability of this architecture is lower than general architectures.

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The increasing data traffic demands on Internet and recent optical components innovation are two most important forces pushing the emergence and maturation of advanced switching technology. In recent years, optical packet switching (OPS) and optical burst switching (OBS) technologies have become hot research areas in the field of optical communications, but they are also the technologies just meet the today's level of components and concepts, and their disadvantages decided they are maybe only the intergradation technologies. So the research works are needed as the optical components, especially the all optical store and optical logic circuits, will be matured[1−3].

In this paper we propose a novel architecture to contention resolution for OPS using tunable wavelength converters (TWCs) and fiber delay-lines (FDLs) in wavelength and time domains. This architecture improves packet switching speed and significantly decreases the use of optical switches in comparison with general architecture. The simulation results show that the network throughput can be increased and the packet loss can be decreased.

In an OPS networks, each packet has to go through a number of switches to reach its destination. Contention occurs whenever two or more packets are trying to leave the switch from the same outgoing port. How to resolve the contention has a very great effect on the network performance. The general methods of contention resolution are three types: optical buffering, deflection routing and wavelength conversion.

In this paper a novel architecture of an optical cross connect (OXC) switching node using optical buffers and wavelength converters is proposed to resolve the contention. The structure of the OXC switching node is shown in Fig. 1, each wavelength uses two all-optical TWCs and several MUX, DEMUX and FDLs to resolve the contention. The lengths of FDLs between the MUX and DEMUX are in turn T, KT, $2KT$, $\cdots$, and nKT. Here T is the average transport time of a packet, n and K are constant. When contention occurs, one of competed wavelengths forwards to the next node directly and others enter the different length FDLs and are simultaneously changed to the corresponding wavelength by TWC, then forward to the next node through optical switching matrix after being changed to the right wavelength by the next TWC. There are still contentions will occur at the FDLs in this architecture. When a packet enters one of FDLs, then the next packet enters other FDLs, after time delay, they will go out to the TWC at the same time section, but the TWC can't deal with them at one time, and the worst situation is that several packets arrive to TWC at the same time although it is a low probability event. That is the main reason of the network packet loss. Optimizing the combination of different lengths of FDL in one wavelength channel can efficiently decrease the packet loss probability[4,5].

The all-optical TWC is the key component of this scheme. If we select the suitable tunable laser the all-optical TWC can get high convert speed. Today, for the tunable laser, such as grating assisted codirectional coupler with rear sampled grating reflector (GCSR) laser,

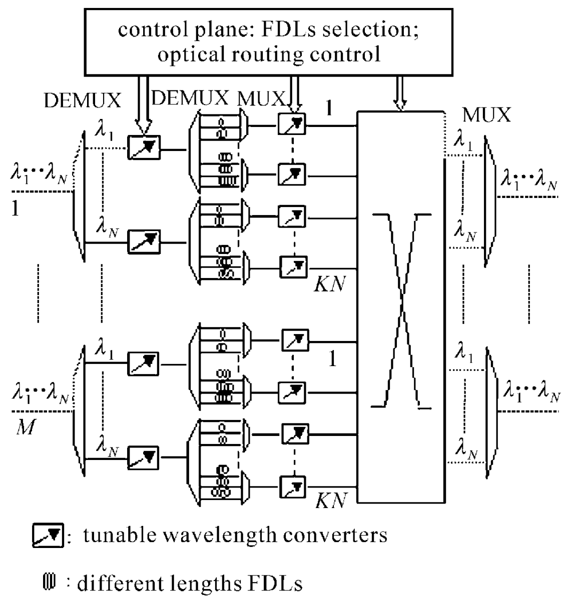

Fig. 1. A novel architecture for contention resolution.

tunable time can finish below 5 ns, which is a good selection[6].

An algorithm of using the FDLs for the severalty mode (SM) given as following:

1. A packet with the length L arrives.
2. If the destination output port is free, the packet is transmitted to the port. No contention exists. Go to step 6. Otherwise, if the port is used or reserved, contention appears.
3. Calculate all of the output periods for each FDLs at the output port and then determinate the candidate FDLs that can be employed according to L.
4. Make sure that no contention exists between the candidate FDLs with other FDLs at each MUX. Then the remained FDLs can be selected continuously.
5. If no FDLs are selected, the packet should be discarded. Go to step 6. Otherwise, a candidate FDL is selected and the wavelength converters (WCs) are adjusted to use the selected FDL.
6. The packet process ends.

Performance of this algorithm for contention resolution of OPS is evaluated by discrete-event simulation. The experimental setup for the simulation is based on the following assumptions.

- The arrival of packets at a node follows a Poisson distribution with rate λ and the packets are equally likely to be destined to any other nodes.
- Packet duration follows an exponential distribution with unit mean.
- Packet lengths are variable. L and D represent the average length of a packet and the granularity of FDLs, respectively.
- The node has M single fiber input and output ports and N wavelength channels per fiber. We assume that $M = 16$, $N = 8$ and $L = 50$ μs.

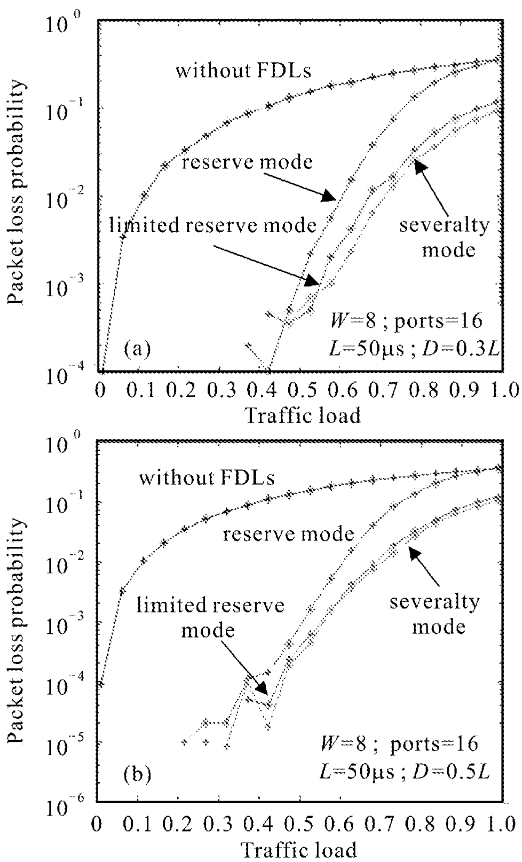

Fig. 2. Packet loss probability versus traffic load for different FDLs modes.

We give different values of L, node switching matrix ports numbers, and D to simulate the performance of the FDLs. Two modes, full-reservation mode (FRM) and limited-reservation mode (LRM), are used to compare the performance of the SM proposed in this paper. The FRM is the basic mode of the most used FDLs and the LRM modified from reserve mode is proved to have better performance than FRM. In Fig. 2, the plot of packet loss probability versus traffic load is shown for four different modes, i.e. without FDLs, FRM, LRM and SM, and D is set to $0.3L$ and $0.5L$ in Figs. 2(a) and (b), respectively. Similarly, the packet loss probability increases with the offered load for all of the four modes. The simulation results also indicate that the packet loss probability of the SM is obviously lower than that of the other three modes. Even when the traffic load becomes high, the SM still achieves better performance than the others. The packet loss probability of the other three modes is in descending order of without FDLs, FRM and LRM. Through the comparison between Figs. 2(a) and (b), it is also shown that the performance in $D = 0.3L$ is better than the one in $D = 0.5L$. So we should choose an appropriate mode and an optimal delay granularity of FDLs to attain the good performance.

We also give the effect of the number of wavelength channels on the performance in Fig. 3, where the packet loss probability versus traffic load for four different modes is illustrated for both 8 and 16 wavelength channels. It is indicated that increasing the number of wavelength channels is able to improve the performances for FRM, LRM and SM except for the case without FDLs. The case without FDLs has very little difference for two cases with different wavelength channels. With the increment of the number of wavelength channels, the performance of the network will be improved significantly. However, the architecture will be more complicated. Therefore, a trade-off between the performance and the complexity of architecture should be considered.

In this paper, we proposed and evaluated a SM for FDLs based on novel node architecture for OPS networks.

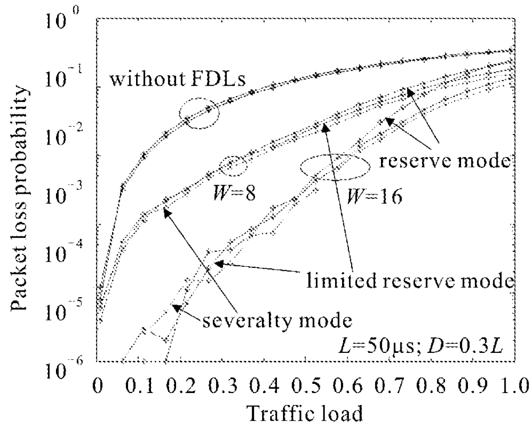

Fig. 3. Comparison of different wavelength number.

Simulation results show that the scheme proposed in this paper has the low packet loss probability than the modes both with no FDLs and with shared FDLs. This scheme can reduce the number of optical switches used, shorten the switching time and use FDLs independently in each wavelength channel. Although it takes low packet loss probability, its disadvantages are the large number of FDLs and its low efficiency. However, the main considered problems in OPS node are its switching time, the packet loss probability and physical performance. Thus, this novel architecture for contention resolution is a practicable scheme. In addition, we should choose an appropriate mode and an optimal delay granularity of FDLs to attain the good performance.

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