MULTICAST-CAPABLE ACCESS NODES FOR SLOTTED PHOTONIC RING NETWORKS

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Abstract: Different multicast-capable access node architectures for a slotted photonic ring network are proposed and investigated. Simulations show that $LiNbO_3$ switch configurations should be preferred over nodes employing a 3-state switch with respect to network scalability.

Introduction

Slotted packet-switched photonic ring networks (Fig. 1) are highly attractive due to their inherent robustness against link and node failures and their ability to slot synchronization even at ultra-high transmission rates. In order to achieve data rates in the upper Gbit/s range, optical compression along with the Optical Time Division Multiplexing (OTDM) technique can be used at the ring access nodes /1//2/.

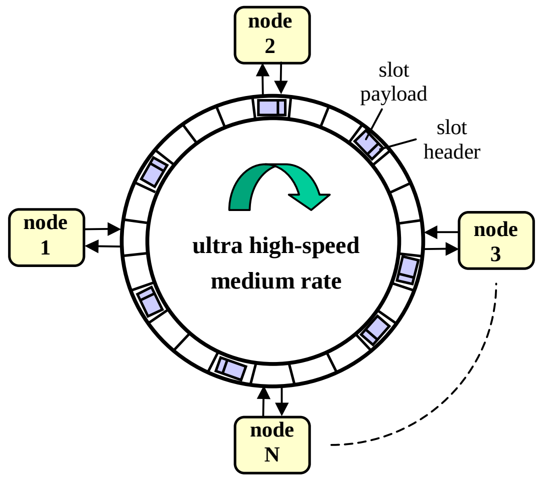


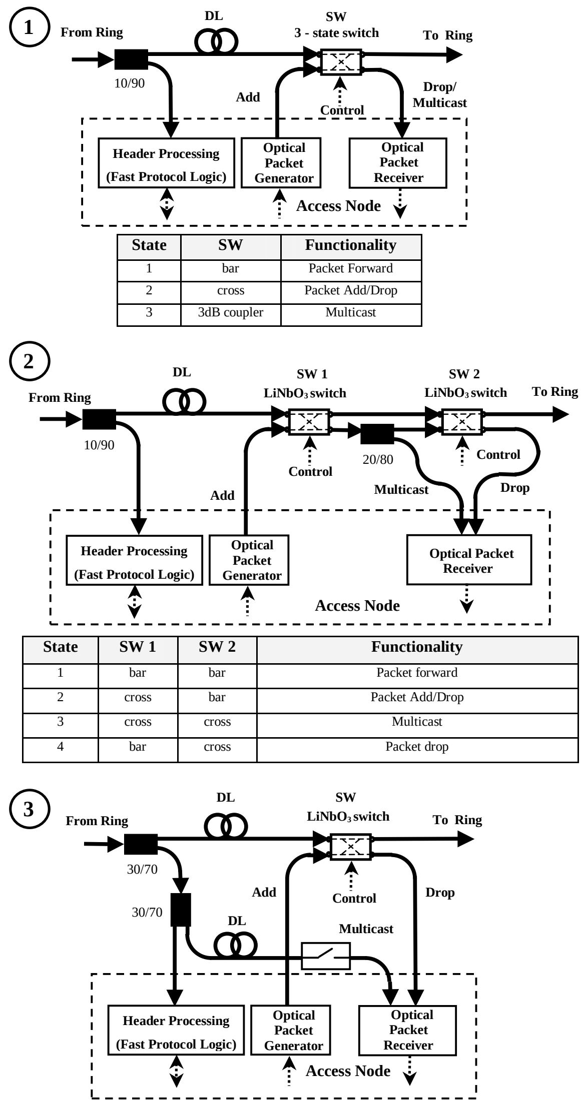
Figure 1: Slotted ring architecture

In general, multicasting is one of the most important issues in optical networking. Basically, multicasting in such a slotted ultra high-speed ring network can be realized by transmitting individual copies of a multicast packet to all the destination nodes belonging to the multicast group (multicast-by-unicast). However, this scheme obviously leads to inefficient bandwidth utilization.

Alternatively, in order to deliver multicast packets more efficiently, each node of a multicast group may copy a multicast packet before forwarding it to the downstream nodes, while the last multicast node is responsible for dropping the corresponding packet (multicast-by-copy&forward). In this paper, three different access node architectures supporting such a multicast scheme are proposed, and their impact on the network scalability is investigated by simulation.

Access Node Architectures Supporting Multicast

In Fig. 2, the schematics of the proposed node configurations are illustrated. All of them are equipped with a *header processing unit* for evaluating the header section of the incoming optical packets after tapping off a fraction of the optical power by passive splitters. Moreover, an *optical delay line* (DL) is employed compensating the header processing latency of the nodes.



State	SW	Functionality
1	bar	Packet Forward
2	cross	Packet Add/Drop
3	3dB coupler	Multicast

State	SW 1	SW 2	Functionality
1	bar	bar	Packet forward
2	cross	bar	Packet Add/Drop
3	cross	cross	Multicast
4	bar	cross	Packet drop

Figure 2: Multicast-capable access node architectures

In the first architecture, a *3-state switch* /3/ is used to achieving both: add/drop and copy&forward in the optical path. The switch reported in /3/ represents a polymer waveguide thermo-optic 2x2 switch showing an interferometric behavior like a coupler when the electrodes are not heated (3rd state). This third state is used for the multicast mode. Thus, all the required switching modes may be performed in a single component. However, the response time of this switch is on the order of 1 ms making this switch less suitable in ultra high-speed systems. In the second configuration, two $LiNbO_3$ switches are deployed in the optical path. There are four different scenarios possible with this switch cascade as shown in the corresponding table. Unlike the first case, the switching time lies in the ps-range (10–15 ps). Lastly, the third architecture consists of only one $LiNbO_3$ switch and an additional on/off switch for the multicast mode.

Note that the optical receivers in all three cases must be adapted to unequal signal powers because of different received signal power in multicast and dropping mode. Now, it is particularly important to find out whether the deployment of the node architectures 2 or 3 (Fig. 2) enabling multicasting with a low switching latency is justified in terms of the network scalability compared to the low cost 3-state switch.

Simulation Results

Simulations are carried out in order to investigate the network scalability of the presented access node architectures. A 1.55 µm optical pulse source generating 6-ps pulses was externally modulated by a Mach-Zehnder modulator to insert (2^{23} – 1) PRBS RZ (Return to Zero) signals into the ring. The system input power was adjusted to 1dBm throughout the simulations. The fiber segments were assumed to be pre-compensated SSMF with a length of 250 m between two neighboring nodes. After each 4^{th} node an EDFA was placed for compensating the losses in switches and fiber segments. Also, the crosstalk in the switches has been taken into account. Further note that all transit nodes were set to be in the multicast mode. Finally, the optical RZ signal was filtered by an optical bandpass filter and received by a PIN-diode (10^{-12} A/Hz$^{(1/2)}$ thermal noise and 1 A/W responsivity) located at the last multicast node.

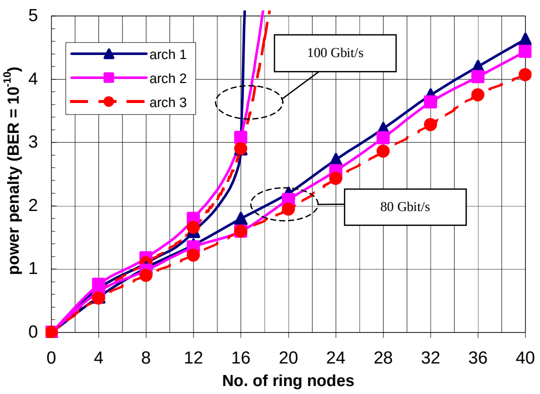


Figure 3: Power penalty vs. number of ring nodes

In principle, the number of supported nodes in the considered ring network is limited by crosstalk and losses in the switches, losses in the splitters, chromatic dispersion in the fiber segments and signal distortion due to ASE in the amplifiers. Fig. 3 shows the power penalties over the number of ring nodes related to the different access node configurations for a transmission rate of 80 Gbit/s and 100 Gbit/s, respectively. Though only slight differences in the penalties may be seen, it can be observed that the 3-state switch architecture results in the worst results for an 80 Gbit/s network, while its performance for 100 Gbit/s behaves similar to that of the other cases.

Furthermore, Fig. 4 demonstrates the ring scalability in dependence of the medium bit rate, where remarkable differences can be seen for lower data rates but not for very high transmission speeds (> 40 Gbit/s).

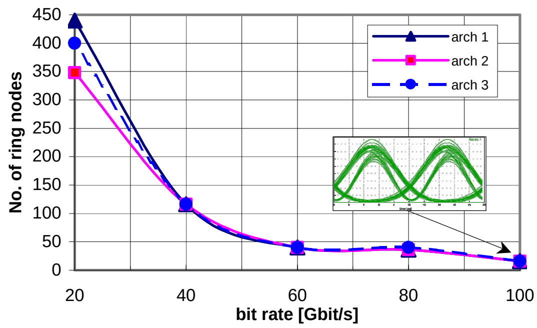


Figure 4: Ring scalability versus transmission rate

Conclusions

In this paper, three access node architectures with multicast capability are proposed and discussed. We can conclude from the above simulation results that the 3-state switch configuration corresponding to a cost-effective solution for multicast transmission in a slotted photonic ring network is not preferable over its $LiNbO_3$ counterparts regarding the network scalability. Taking also into account the relatively large switching latency and the impairment of the signal on the ring due to large response times of the 3-state switch, either the $LiNbO_3$ cascade or the $LiNbO_3$ plus on/off switch configuration should be preferred for implementing multicast-capable access nodes.

Acknowledgements

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References

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