ARTEMIS: A New Architecture for All-Optical Asynchronous Self-Routing Network with Efficient Contention Protection and QoS Differentiation

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Abstract *We present a new architecture for bufferless, asynchronous all-optical self-routing network combining an efficient physical layer structure and conflict-preventing signaling protocol for providing lossless communication with optimum resource utilization and QoS differentiation.*

Introduction

Optical self-routing gives potential for migrating from circuit-switched WDM networks to OTDM or hybrid WDM/OTDM optical packet switching [1]. MPLS has initiated new self-routing concepts, but their applicability is still restricted due to design challenges related to buffering, efficiency and contention. Self-clocking and serial-to-parallel conversion [2] require special transmitters or electronic header processing. In [3] optical header processing is used, but the scheme is only suitable for slotted operation and requires multilevel signals that increase the susceptibility to signal distortions. On the network level, only deflection routing (DR) has been proposed for congestion control of such networks [4]. However, using the network itself as a distributed buffer can lead to complex routing by raising the network load. In this work, we propose a 40 Gb/s asynchronous, all-optical, self-routing network. The subsystems employed are designed especially for on-the-fly bit and packet-mode processing posing minimal guardbands and no special coding formats. The node inherently resolves jitter accumulation while amplitude distortions are removed using 2R regeneration. At network layer, we employ a new time-slot reservation protocol that uses timing network state information for scheduling flows providing contention protection.

Physical layer modeling

Fig. 1 shows the two-layer, self-routing network on the NSFNET topology and the node structure. MPLS-compatible packet routing is realized on the physical layer using “optical tag containers”. Each tag corresponds to a specific node [5], but also contains bit-level information for intra-node routing. Flow control and contention protection is provided by the network layer negotiating the exact timing of the transmissions. The building blocks of the node are the self-synchronizer (SS), the all-optical processor (AOP) and the optically-controlled switching matrix. The SS provides packet and bit-rate clock signals and is based on the 40 Gb/s packet-mode Optical Clock Recovery (OCR) and the Single Pulse Extraction (SPE) experimentally demonstrated in [6]. In the AOP processing of the first tag and generation of the control signals is performed.

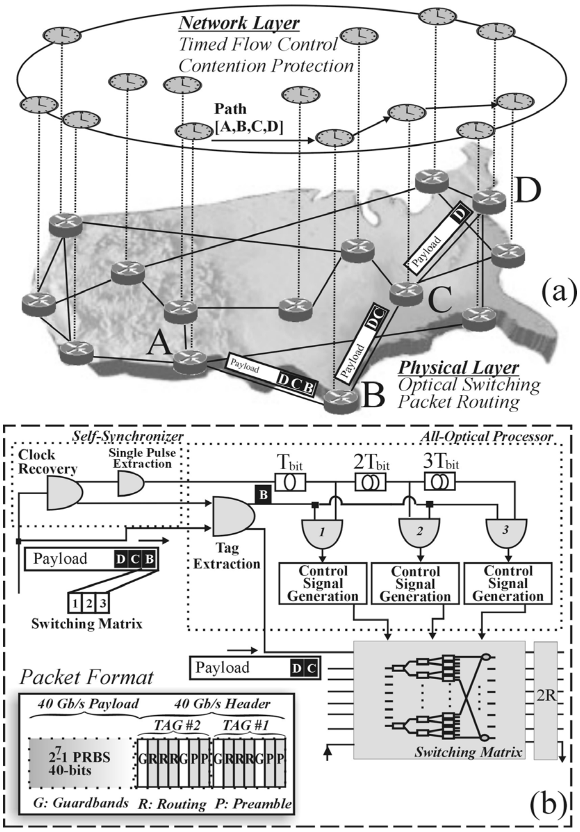

Figure 1. All-optical self-routing network concept and physical layer node design

The first tag is extracted in an optical gate by sampling the data with the clock packet having differential delay equal to a tag length. Similarly, AND operations between the output of the SPE and the extracted tag are used to segregate the embedded routing bits. These bits trigger the control signal generator which can be an optical flip-flop [6] or a finite memory element [7]. The switching matrix employs 1x2 switches arranged in a strictly non-blocking configuration. Fig. 2 shows the results obtained with VPI simulation using a high accuracy, time-domain analysis of bi-directional optical fields within all active devices (SOA-based MZIs). Fig. 3(a) shows the output signals of the SS. The recovered clock has 277 fs and 0.25 dB timing and amplitude jitter respectively and the SPE exhibits 14 dB extinction ratio. Fig. 3(b) shows the outputs of the AOP; the extracted tag#1, the remaining payload with

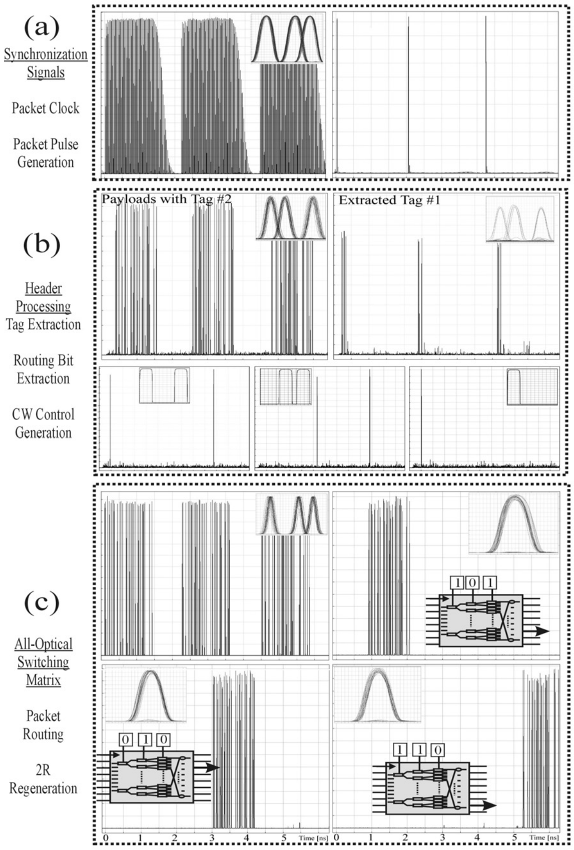

Figure 3: Simulation results for an ARTEMIS node

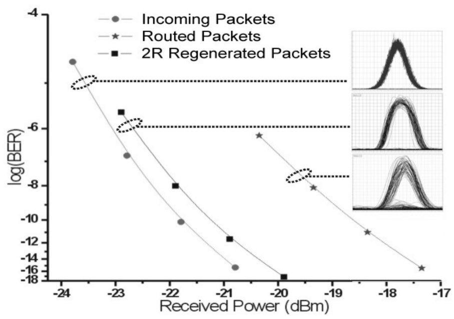

Fig. 4. BER and eye results for an ARTEMIS node

tag#2, the segregated routing bits for all packets and finally the CW controls driving the switching matrix. To reduce complexity of the model, the control signal generator was implemented using a photodiode and a pulse generator triggered by the SPE. Using the low jitter clock to extract the tag retimes the data relaxing the requirement for 3R regeneration stages. Fig. 3(c) shows the incoming data with 500 fs and 0.8 dB timing and amplitude jitter. The figure shows the three packets at the 8x8 output ports after routing in the switching matrix. The three curves in Fig. 4 are the BER results revealing 3.8 dB penalty for the routed packets reduced to 0.5 dB after reshaping (2R).

Network layer modeling

The two-way signaling protocol relies on negotiation of the starting time and the duration of the reservation overcoming the requirement of classic OBS schemes for reservation only at fixed time instances. Timed reservations are relaxed and can be made "in-advance" [8] to increase acceptance probability. The reservation horizon can be customized by defining an appropriate reservation duration (RD) allowing QoS differentiation. We assume the NSFNET topology, Poisson arrival and exponential burst size distribution with mean 10 MB. Fig. 5(a) reveals superior blocking performance against classic two-way reservation protocols without "in-advance" and RD features at the expense of only slightly increasing holding time. JET can provide a minimal holding time though is not efficient for single channel OTDM networks. Fig. 5(b) shows that by granting higher priority transmissions with larger RD, lower blocking and holding time can be achieved enabling QoS differentiation.

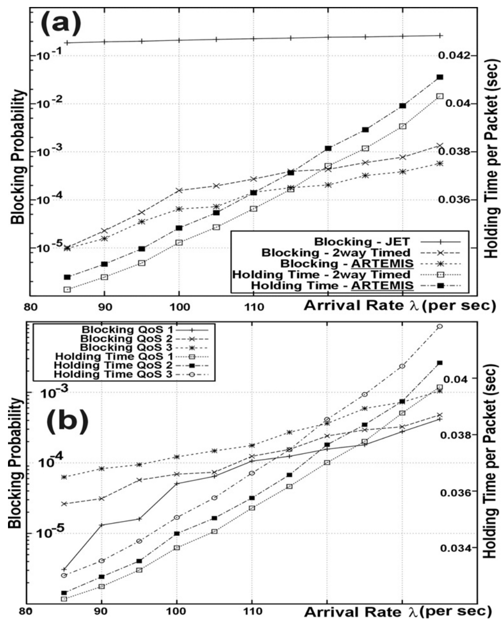

Fig. 5. Simulated network protocol performance

Conclusions

We have presented a new network architecture and for the first time we showed that all-optical self-routing can be a viable solution in terms of bandwidth efficiency providing contention protection and QoS.

Acknowledgements

This work was performed within the frames of IST European projects E-Photon/ONe and LASAGNE.

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