Quality-of-Service Encoding Scheme for Optical Packet-Switched Fabrics

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The future Internet architecture will require a clean-slate design in order to successfully accommodate the exploding bandwidth demand. Next-generation networking applications should support a bidirectional cross-layer information exchange in which the physical-layer performance, characteristics, and impairments can be extracted for higher-layer routing decisions. The dynamic cross-layer mechanisms should further be aware of the packet's quality-of-service (QoS). By invoking QoS requirements and classes directly on the optical physical layer, the end-to-end network performance may be optimized [2]. The architecture should also exploit optical packet-switched (OPS) fabrics as a low-latency, high-bandwidth approach to switch optical messages with low power. Embedding QoS guarantees on the physical layer through QoS and priority levels may constitute an important requirement for achieving significant performance gains within the scope of broadband message routing. An optimal coding protocol must be designed and experimentally implemented to demonstrate the feasibility of creating QoS-aware routing of optical packets.

Here, we present an optical encoding scheme for an experimental OPS network test-bed that allows for message routing decisions to account for the QoS classes that are encoded directly within the optical packets [3]. The QoS/priority encoding mechanism specifically addresses contention resolution in future OPS fabrics. Contending optical packets are dropped and later retransmitted. The QoS-aware routing scheme prevents the dropping of high-priority packets, resulting in an overall reduction in the packet retransmission penalty for critical data flows. 8×10-Gb/s wavelength-striped optical messages are correctly routed with error-free performance; verified bit-error rates (BERs) less than 10^{-12} are achieved.

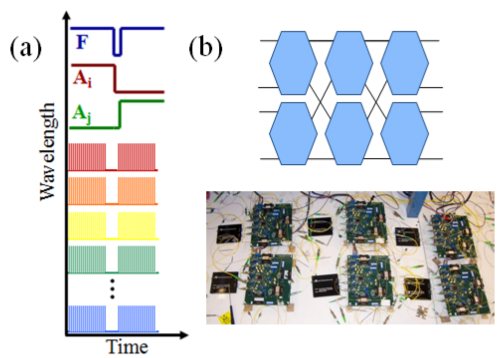

Fig. 1: (a) Wavelength-striped packet; (b) 3-stage switching fabric network topology and test-bed photograph.

The OPS fabric design and architecture [3] is based on a multistage topology using 2×2 photonic switching nodes comprised of semiconductor optical amplifiers (SOAs) (Fig. 1). Due to the unique reprogrammability of the routing control logic, the OPS network test-bed is adapted to support QoS priority-encoded packet transmission. The QoS encoding mechanism is the result of a simple modification of the electronic routing control logic, as well as the supported optical message format. Depending on the high or low service class assigned to the packet, the corresponding priority class is mapped directly to the optical header. The optical frame header's signal incorporates a one-bit priority, which is sampled with a low-duty electronic pseudo-clock that consists of two pulses per timeslot (i.e. message duration) to determine the presence of a packet and its QoS class (Fig. 2). The implemented routing control is based on control logic that samples the frame on the two pulses of the pseudo-clock. The subsequent message routing decision at each switching node can then be made according to the two high/low levels detected by the control logic. In the situation of contention, the adapted routing logic and circuitry switches on the SOA associated with the high-QoS packet, while dropping the contending low-QoS packet.

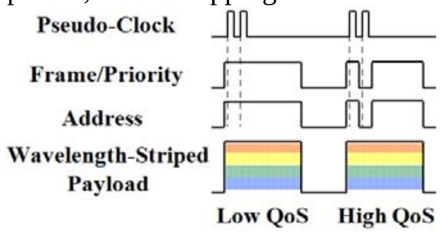

Fig. 2: Diagram depicting the implemented QoS encoding scheme for the supported wavelength-striped packet.

The experimental OPS fabric test-bed is constructed using commercially-available discrete components (SOAs, passive optical elements, optical receivers, and digital electronics). To demonstrate the QoS-encoded routing, a pattern of wavelength-striped packets is injected via three input ports with high and low priority encoded packets. This demonstration supports 57.6-ns timeslots, containing 51.2-ns duration packets with 10-Gb/s modulated data on eight payload wavelengths. All optical packets are created using a single $LiNbO_3$ modulator using a 2^7-1 NRZ PRBS. The optical header of each packet is comprised of a frame signal encoding a one-bit QoS, one-bit distribution address (selecting one of two possible paths through the test-bed), and two-bit routing address. Fig. 3 provides the input and output waveforms of the pseudo-clock and optical packets, and verifies correct routing. Error-free transmission all high and low QoS packets is confirmed at the network test-bed's output using a DC-coupled 10-Gb/s p-i-n-TIA receiver. BERs less than 10^{-12} are obtained for all eight payload wavelengths.

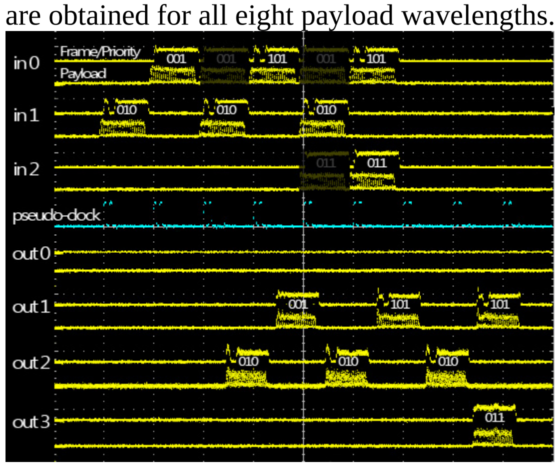

Fig. 3: Input and output waveform traces validating the correct routing of the encoding scheme.

Next-generation Internet and optical packet routing networks will necessitate accounting for the QoS/priority of the end users in high-bandwidth message routing algorithms. Thus, the optical physical layer should directly support a varying set of QoS classes. Here, a QoS encoding scheme is proposed for routing high-QoS wavelength-striped optical messages for OPS networks. Experimental demonstrations of the priority encoding scheme illustrate two distinct classes of packet priority through a frame-based protocol. In the case of optical message contention, prioritize routing is given to high-QoS optical packets. Correct routing of the 8×10-Gb/s wavelength-striped optical packets is verified with error-free transmission through the test-bed; BERs less than 10^{-12} are achieved. This exploration verifies the feasibility of realizing QoS-aware routing protocols for the future Internet.

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[2] A. G. P. Rahbar, and O. Yang, Journal of Optical Networking **5**, 1056 (2006).
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