Optical Packet Ring Network Offering Bit Rate and Modulation Formats Transparency

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Abstract: *We demonstrate the feasibility of a bit rate transparent ring packet network based on a Packet-OADM technology. A lab network has been successfully evaluated at 10, 40 and 100G.*

OCIS codes: (060.1155) All-optical networks; (060.6719) Switching, packet

1. Introduction

The foreseen increase of network bandwidth is pushing equipment vendors to investigate different network solutions. The improvement of the network efficiency (ratio between the offered load and the incoming load) by adopting a finer switching granularity together with the exploitation of optical transparency represents one research direction. We proposed an optical packet ring network based on a Packet-Optical Add/Drop Multiplexer (P-OADM) technology [1,2] that benefits from a packet technology with time multiplexing and optical transparency to deflect the node transit traffic in the optical domain in a ring topology. With the predictable increase in bit rates, it is critical to validate that any network concept could easily support a bit rate evolution with different modulation formats. To reach this goal, we proposed a separation of the data packets and the control packets, including the headers used to route the packets. In this paper we will analyze the possibility for this network to operate at 10G, 40G and 100G with different modulation formats in a 40-wavelengths configuration.

2. Technical choices adopted for the Packet OADM

The proposed solution is a synchronous optical packet ring network based on Packet-Optical Add/Drop Multiplexers managing fixed duration optical data packets in a time-slotted approach. The data packets include the useful data and additional bits (guard band, preamble and bits for synchronization) for adaptation to the optical switching time. Control packets including the headers of the data packets are encoded on a different wavelength and used to control and process the data packets. The optical interface that bridges between the client legacy boards and the ring is a P-OADM. Active semiconductor optical amplifier (SOA) elements are used in the transit path of the P-OADM to allow the local management of the data packets, to support different Classes of Services of data, and to guarantee the bandwidth when required. A time-slotted format for the data packets (useful packets interleaved with empty packets) has been adopted to have no impact on the fiber infrastructure, including the optical amplifiers. Figure 1 illustrates the ring network concept with a zoom on the data packets and on the control channel, and Figure 2 gives the structure of the P-OADM. The P-OADM is composed of amplification stages (at its input and output), an optical demux and mux, couplers, and SOA gates for the transit part, burst mode receivers for the drop part, and fast tunable lasers [3] for the insertion line.

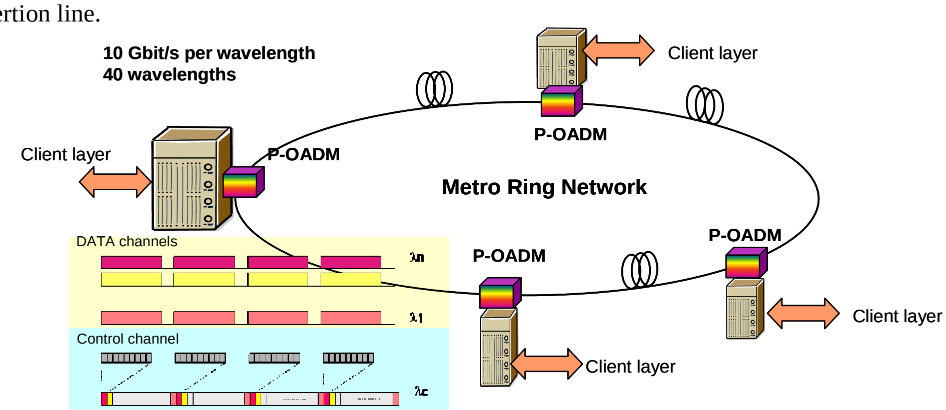

Fig. 1: Metro Ring Network basics

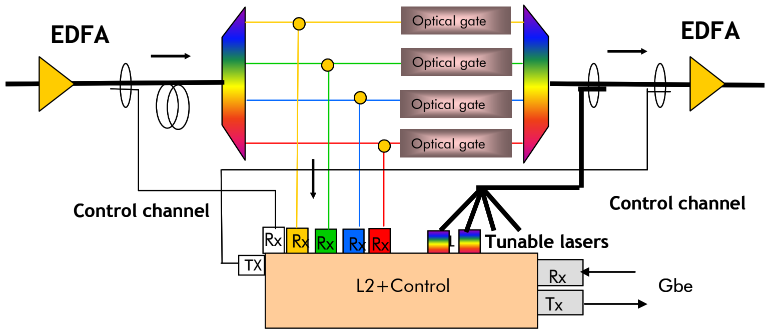

***Fig. 2**: Packet Optical Add/Drop Multiplexer structure*

3. Optical Packet Ring demonstrator

To evaluate the potential of the network, we built a sub-equipped rack-mounted packet ring network. It includes a 40 wavelengths WDM source, 4 spans of 50 km of Standard Single Mode Fiber (SMF), 3 nodes (P-OADMs) and a burst mode receiving chain to evaluate the quality of the transmitted data. Figure 3 illustrates the experimental set-up previously described whereas figure 4 shows the structure of the transmitter/receiver used for the tests at 100G.

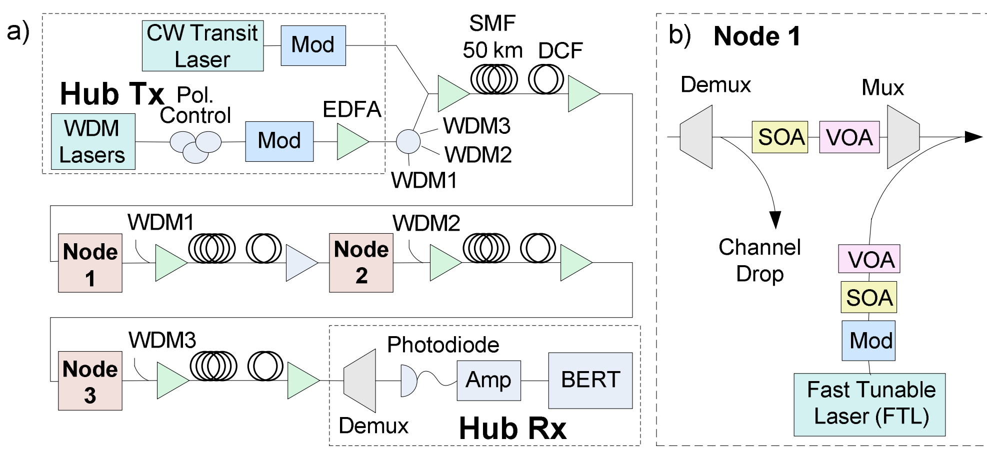

***Fig. 3**: Experimental set-up*

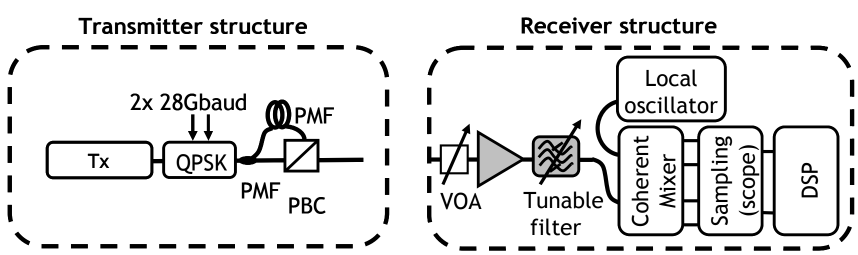

***Fig. 4**: PDM DQPSK Transmitter/Receiver*

4. Experimental results and discussion

The objective of this study is to evaluate the network at different bit rates: 10 Gb/s On-Off Keying (OOK), 40 Gb/s Partial-Differential Phase Shift Keying (P-DPSK) and 112 Gb/s Polarisation Division Multiplexing – Differential Quadrature Phase Shift Keying (PDM-DQPSK). Figure 5, 6 and 7 show the performance at 10G, 40G and 100G respectively. We assume that the packet format does not impact the transmission since the switching time is masked with an adaptation layer including a guard band, a preamble to mitigate transient effects at the Receiver (Rx) or an impact of the guard band on the data sequence, and bits for synchronization. Therefore, a characterization using a PRBS at 40G and 100G is representative of the expected physical performance.

All the BER measurements were made on a probe channel at different wavelengths passing through 3 POADMs, with 39 additional channels modulated with 10Gbit/s Pseudo-Random Binary Sequences (PRBS).

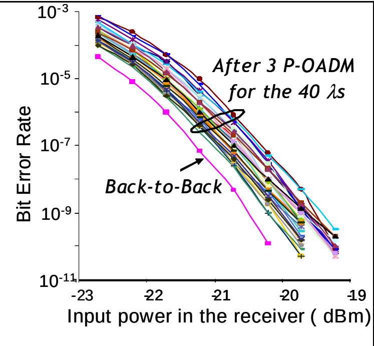

Fig. 5: Bit Error Rate at 10G for optical packets detected after 200 km, and crossing 3 POADM + one HUB

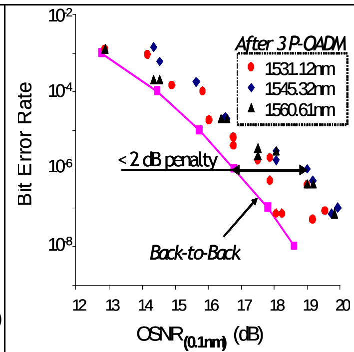

Fig. 6: Bit Error Rate at 40G for three wavelengths covering the C-band

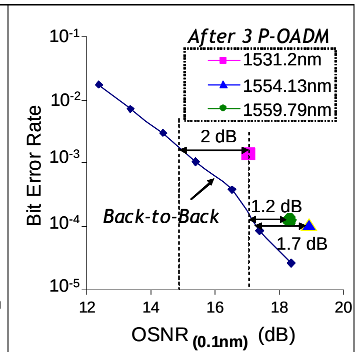

Fig. 7: Bit Error Rate at 100G for three channels crossing the packet ring network

Results and Discussion

For the 10G characterizations made in burst mode operation, using optical packet generation from the fast-tunable laser and a burst mode receiver, we observe that the network has a sensitivity penalty close to 1 dB over the full C-band with measurements made on one packet stemming from the Hub transmitter among a packet stream switched along the network. Similar measurements made on other packets, inserted at different points of the network, show the same tendency. The sensitivity penalty is mainly due to a cross-gain modulation effect of the SOA gate of the first P-OADM and the penalty stabilizes for subsequent P-OADMs .

We made the 40G characterizations on three probe-wavelengths covering the C-band and crossing the three network sessions using the following setup. The 43Gb/s channel was modulated with P-DPSK format with 2^{31}-1 PRBS sequence, P-DPSK filtering at the transmitter with a 50 GHz interleaver and at the Rx, the channel was detected through a 50 Ghz Wavelength Selective Switch followed by a 66 GHz-bandwidth Delay Line Interferometer and balanced photodiodes. The dispersion was optimized at the Rx for each wavelength. We observe an Optical Signal to Noise Ratio (OSNR) penalty lower than 2 dB with respect to the back-to-back.

For the 100G characterizations we used a data stream at 112 Gbit/s (including FEC overhead) with 2^{7}-1 PRBS sequences and based on PDM-DQPSK [4] format in the packet ring network. Three wavelengths of the C band are analyzed: 1531.2 nm, 1554.13 nm and 1559.79 nm. We observe an Optical Signal to Noise Ratio (OSNR) penalty of 2 dB with respect to the back-to-back.

5. Conclusion

Network efficiency is a key requirement for next generation networks. In addition, the bit rate and modulation format evolution pushes equipment vendors to propose network concepts offering easy upgrades.

We thus proposed a packet ring network concept, providing a response to the network requirements [2]. In this paper, a lab demonstrator was built to test the performance of the network at different bit rates and modulation formats. We have reported the results of the network characterization at 10G in with packet switching, and at 40G and 100G using PRBS sequences. The results show no more than 2dB penalty over the C-band for the three bit rates. By combining bit-rate transparency with a network-efficient packet granularity, we demonstrated for the first time that the network infrastructure of the optical packet ring network can support a large range of bit rates up to 100G.

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6. References

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