2R/3R Optical Grooming Switch with Time-Slot Interchange


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Abstract

We demonstrate a regenerative optical grooming switch for interconnecting 130 Gbit/s and 40 Gbit/s networks with switching functionality in time, space and wavelength domain. Q-factors are above 21 dB.

Introduction

Recent advances in long haul transmission and switching technology have shifted the operational and bandwidth bottleneck from the core to the edge of the network [1][2]. Replacing expensive OEO equipment with scalable all optical solutions promises significant capital and operational cost savings due to the reduced power requirements and the service transparent provisioning flexibility [3][4][5]. However, any new all-optical solution must be competitive in terms of both performance and cost compared to legacy SONET/SDH expansions. These should offer not only the traditional switching-routing functionalities but also transparent mechanisms for sub-rate traffic grooming.

Optical Grooming Switch Description

The architecture of the grooming switch is depicted in Fig. 1. The switch interconnects two access rings, each carrying 3 × 43 Gbit/s WDM signals, with a metro core ring carrying 2 × 130 Gbit/s signals generated with mode-locked lasers. The switch itself comprises a Wavelength Selective Switch (WSS), a MEMS switch, an OTDM-to-WDM unit [6][9], a WDM-to-OTDM unit [7] and a 2R multi-wavelength signal regenerator [8]. Traffic from any of the access rings is switched by means of the MEMS switch to either access ring or via the Add path to the core ring. Within the WDM-to-OTDM unit each 43 Gbit/s input is retimed to a local clock and wavelength converted to a signal comprising suitably short pulses of the OTDM channel at the desired wavelength. The retimed waveforms are then time interleaved to form the OTDM signal and launched onto the core ring using the WSS. Each add-port of the MEMS switch relates to a particular time-slice of the OTDM tributaries. Time-slot interchanging (TSI) functionality is thus obtained by mapping of add ports within the MEMS. Conversely, an OTDM channel may be dropped via the WSS to the OTDM-to-WDM unit which maps the OTDM onto distinct wavelength channels. We have implemented both a scheme with wavelength interchangeability where tributaries are mapped onto clocks from tuneable sources [9] or a scheme with wavelength interchangeability limited within a permutation [6]. The three low bit-rate WDM tributaries then are guided into the MEMS switch and can be switched to either one of the access rings or back to the core ring. By proper selection of the ADORE path, time slot interchange may also be performed for any looped back tributaries, if required. Finally, to guarantee the quality of the traffic in the core ring, an all-optical multi-wavelength regenerator, operating at 130 Gb/s traffic, is also included.

Experimental Results

To demonstrate the functionality of the grooming switch we show partial Add, Drop and TSI functionality by means of the following switching scenario (Fig. 2). The metro core path supports two 130 Gb/s signals (λcore1, λcore2) with signal qualities of 18.7 and 20.0 dB, respectively. Each one of them consists of 43 Gbit/s tributaries TS1, TS2 and TS3. Coordinates (x, y) are indicated in the legend for each signal. The signals are dropped and switched back to the core ring using the MEMS switch. The output signals are monitored with an OSA at the core ring. Signal quality is observed to be the same as at the input and after the switching every channel is dropped back to the access ring.
In the selected network scenario we drop TS$_2$ from channel 2 of the metro ring onto drop$_2$ and add access channel access$_2$ instead. This is implemented as follows: core$_2$ is dropped to the OTDM-to-WDM unit where its tributaries are simultaneously extracted using by choosing the appropriate time delays in a single nonlinear optical time gate (here an EAM). The time slot to wavelength mapping is determined by arranging the delays. Here, the following scheme is adopted: TS$_1$→drop$_1$, TS$_2$→drop$_2$, TS$_3$→drop$_3$. The qualities of the corresponding drop channels are 18.3 dB, 19.2 dB, and 19.8 dB, respectively (Fig. 2C). Channels drop$_1$ and drop$_3$ are subsequently switched along with the wavelength access$_2$ to the WDM-to-TDM unit. It comprises three ADORE units, each unit converting one WDM channel to an OTDM tributary, by performing asynchronous retiming and pulse-width adaptation. Fixed delay lines at the output stages of the WDM-to-OTDM interleave the tributaries to form the OTDM channel, thus associating each ADORE with a certain tributary (e.g. drop$_1$→TS$_3$, access$_2$→TS$_2$, drop$_3$→TS$_1$). By reordering the WDM channel connections to the ADORE units through the MEMS switch, also TSI functionality has been obtained. The OTDM channel generated this way has a quality of $Q^2 = 20.2$ dB (Fig. 2D). Finally, the WSS maps both the through core$_1$ and the newly formed core$_2$ channel to the multi-wavelength regenerator subsystem. After regeneration, core$_1$ and core$_2$ exhibit a $Q^2$ improvement of 2.5 dB and 2.6 dB, respectively, compared to their inputs A and D. All Q-factors were measured with random signal polarization using an all-optical sampling scope (Picosolve$^\text{TM}$), and were cross-checked with a BERT. In our scenario, damaged packets due to bit-slips from synchronization onto the common local clock will be resent. Many more arrangements have been tested, two of which are shown in Fig. 3. We found similar results for all switching scenarios.

**Fig. 3:** Eye diagrams and Q-factors at regenerator output for switching scenarios 2 and 3 showing TSI.

**Conclusion**

A novel optical switching node with sub-rate traffic grooming and multi-wavelength regenerative capabilities has been successfully demonstrated. It provides interconnection of high bit-rate 130 Gbit/s core / metro networks with lower bit-rate 43 Gbit/s metro / access rings.

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**References**

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