Simultaneous high speed OTDM add-drop multiplexing using GT-UNI switch

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MTs, while using the proposed protocol the data transmission as a whole would be kept uninterrupted regardless of the channel state of any single MT.

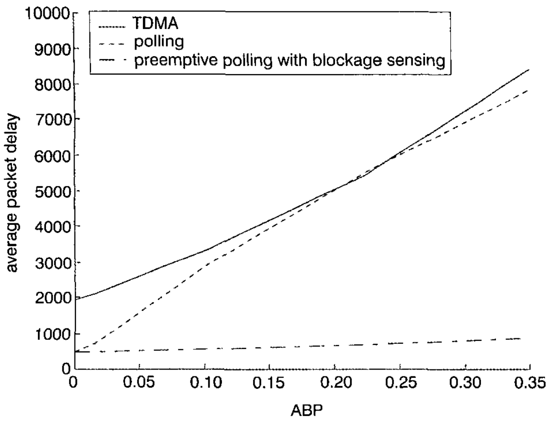

Fig. 3 *Impact of ABP on average packet delay for different MAC protocols*

The improvement of the average transfer delay is also significant, which is shown in Fig. 3. The preemptive polling with blockage sensing protocol has a small and stable average transfer delay, even under a severe degree of beam blockage. Conversely, the average transfer delay of either TDMA or polling increases radically when the ABP rises. The reason is that for TDMA and polling, even if an MT is blocked, the system still allocates a part of the channel resource to it, which inevitably reduces the data transmission of all MTs. The proposed scheme eliminates that inefficiency factor of the standard protocols: only when an MT has a good link state can it access the shared channel.

Conclusion: Classic fixed-assignment and demand-assignment MAC protocols cannot efficiently reallocate the shared channel, which leads to their poor performance under beam blockage circumstances. This motivates us to modify the polling by using blockage sensing and channel reassignment according to individual channel state. This proposed method provides significant improvement in both system throughput and average transfer delay. Therefore, as a candidate MAC protocol for LOS optical WLAN, the preemptive polling with blockage sensing could satisfy the requirements of both system efficiency and user's QoS.

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References

1 EDNEY, J.: '802.11: the new wireless standard [wireless LAN]', *Data Commun. Int.*, 1995, **24**, (12), pp. 77–78, 82, 84, 86
2 SPRAGINS, J.D.: 'Telecommunications protocols and design' (Addison-Wesley, 1991)
3 FANTACCI, R., and SCARDI, M.: 'Performance evaluation of preemptive polling schemes and ARQ techniques for indoor wireless networks', *IEEE Trans. Veh. Technol.*, 1996, **45**, (2), pp. 248–257
4 FANTACCI, R., and NANNICINI, S.: 'Multiple access protocol for integration of variable bit rate multimedia traffic in UMTS/IMT-2000 based on wideband CDMA', *IEEE J. Sel. Areas Commun.*, 2000, **18**, (8), pp. 1441–1454

Simultaneous high speed OTDM add-drop multiplexing using GT-UNI switch

J.P. Turkiewicz, E. Tangdiongga, H. Rohde, W. Schairer, G. Lehmann, G.D. Khoe and H. de Waardt

The authors describe the excellent capability of an all-optical gain-transparent ultrafast nonlinear interferometer (GT-UNI) in dropping, passing through, and adding optical time domain multiplexing (OTDM) channels. Error free operation without significant penalties of a complete OTDM add-drop node at 80 Gbit/s was achieved.

Introduction: The key functionality required in OTDM network nodes is add-drop multiplexing [1]. In an add-drop node a low bit rate single data channel will be separated (drop function) from an incoming high bit rate data stream. Simultaneously the remaining data channels should be left undisturbed (through function), and in the remaining vacant time slot a new channel can be added (add function). Recently, all-optical add-drop multiplexers operating at 40 Gbit/s based on cross phase modulation [2], a monolithic Mach-Zehnder interferometer [3], and an electroabsorption modulator [4] have been demonstrated. This Letter presents OTDM add-drop multiplexing in a GT-UNI switch operating at 80 Gbit/s, to the best of our knowledge the highest bit rate in OTDM networking so far. Several OTDM demultiplexing experiments with the GT-UNI switch have been reported e.g. [5], however complete add-drop multiplexing was not investigated. In our experiments we achieved error free operation without significant penalties of all add-drop node functionalities: drop, through, and add.

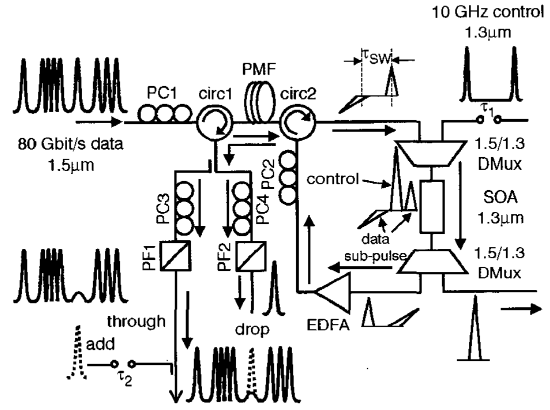

Fig. 1 *Experimental setup*

Experimental setup: Fig. 1 presents the experimental setup. A 8 × 10 Gbit/s OTDM data signal at 1.55 μm, enters the GT-UNI switch by an optical circulator (circ1). The polarisation state at the input of a highly birefringent polarisation maintaining fibre (PMF), is set by a polarisation controller (PC1) such that the data pulses have equal components in the main axes of the PMF and after leaving the PMF they are separated in time by a delay $\tau_{SW} = 5$ ps. Next, two sub-pulses are coupled via circ2 into a fold-back loop containing a 1.3 μm semiconductor optical amplifier (SOA). After passing the SOA, the sub-pulses are amplified by an erbium-doped fibre amplifier (EDFA) and are re-launched into the same highly birefringent PMF by circ2. Here, the polarisation states of the data sub-pulses are adjusted by the PC2 in such a way that the delay between two sub-pulses is reversed and a single pulse appears at the PMF end. There are two output ports, which are formed by a power splitter, polarisation controllers (PC3 and PC4), and polarisation filters (PF1 and PF2). In the absence of 1.31 μm control pulse both data sub-pulses experience the same condition in the loop. As a result, the recombined pulse leaves the GT-UNI switch via the through port (PF1). For switching, a high-intensity control pulse of 4 ps pulse width is inserted between the two data sub-pulses using a 1.5/1.3 μm multiplexer. A variable delay line controls the insertion timing. When a single control pulse is launched between data sub-pulses, the leading sub-pulse will preserve its original phase but the trailing sub-pulse will experience a nonlinear phase shift. The polarisation state of the switched recombined data pulse will therefore be rotated with respect to the polarisation state of the un-switched pulse. By this way, the data pulse will leave the drop port (PF2). In the case of the phase shift less than π rad, a fraction of drop pulses will appear in the through port, causing optical crosstalk for a channel eventually added in this time slot. A 10 Gbit/s add channel, controlled by another delay line, is inserted into the through port by a passive fibre combiner. The 10 Gbit/s drop channels can be directly evaluated using a bit error rate (BER) tester. The 7 × 10 Gbit/s remaining through channels and the inserted 10 Gbit/s Gbit/s add channel are first demultiplexed to 10 Gbit/s by a cascade of two electro-absorption modulators (10 ps gating time) and then evaluated by the 10 Gbit/s receiver and the BER tester.

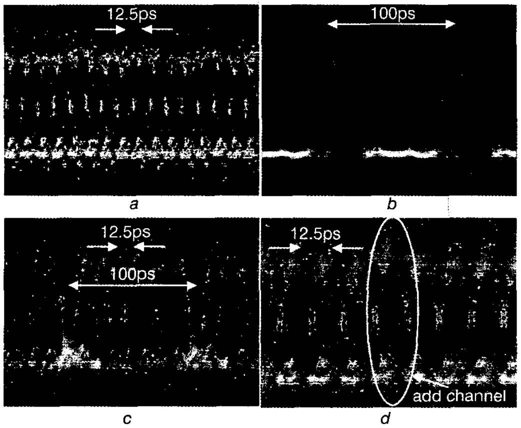

Fig. 2 *Measured eye diagrams*
a Input 80 Gbit/s OTDM signal
b 10 Gbit/s drop channel
c 7 × 10 Gbit/s through channels
d 7 × 10 Gbit/s through channels with inserted 10 Gbit/s add channel

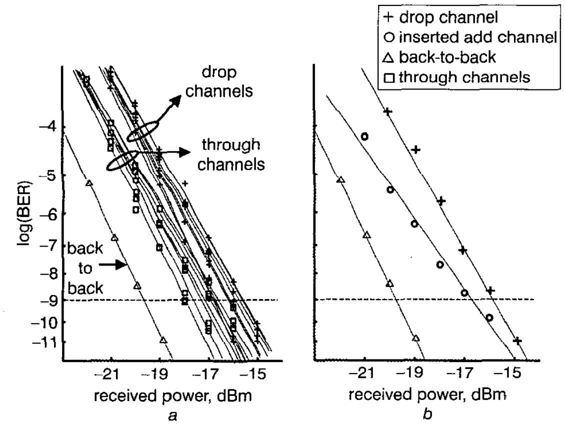

Fig. 3 *BER performance*
a Drop and through channels
b Drop and inserted add channel

Results and discussion: Fig. 2 presents eye diagrams of the outputs of the GT-UNI switch. Fig. 2*a* shows the 80 Gbit/s data input stream, Fig. 2*b* a 10 Gbit/s drop channel, Fig. 2*c* seven remaining 10 Gbit/s channels in the through port. The perfect emptying of the drop time slot is visible. After dropping one channel we inserted a 10 Gbit/s data channel at the same wavelength in the empty time slot to form again the 80 Gbit/s data stream, Fig. 2*d*. All eye diagrams in Fig. 2 indicate clear open eyes and excellent operation of the GT-UNI switch. For the BER measurements we used a pseudorandom bit sequence of length $2^7 - 1$. As a reference we measured an optimised 10 Gbit/s signal in a back-to-back configuration. Fig. 3*a* shows the BER measurements for eight drop channels and for seven 10 Gbit/s through channels. The average sensitivity penalties at $\text{BER} = 10^{-9}$ for the drop channels are 3.7 dB and for the through channels 2.7 dB. The difference between the worst and best channel in both cases is about 1.4 dB, proving proper operation of the GT-UNI switch. Fig. 3*b* presents the BER performance of one of the drop channels and the channel inserted in the empty time slot add, demonstrating OTDM networking. The sensitivity penalty at $\text{BER} = 10^{-9}$ for the drop channel is 4.0 dB and for the inserted add channel 3.0 dB. The sensitivity penalties are a combination of the reduction of optical-signal-to-noise ratio, polarisation misalignment, and in the case of the inserted add channel the interferometric crosstalk with the residual optical signal of the dropped channel. However these interferometric effects are so small, that they are barely observed in Fig. 2*c* and *d* and in the BER measurements.

Conclusions: We have demonstrated the excellent performance of an all-optical 80 Gbit/s OTDM add-drop node based on a GT-UNI switch. We achieved error free operation for all add-drop functionalities. Insignificant penalties for all operations were observed. These remarkable results indicate the great potential of GT-UNI switches for OTDM networking.

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References

1 SPÄLTER, S., HEID, M., JANSEN, S.L., LEHMANN, G., MEISSNER, E., and LANKI, B.: 'Ultra fast switching in OTDM networks'. 28th European Conf. on Optical Comm., Copenhagen, Denmark, 2002, Paper 11.4.1(Invited)
2 RAU, L., RANGARAJAN, S., WANG, W., and BLUMENTHAL, D.J.: 'All-optical add-drop of OTDM channel using an ultra-fast fiber based wavelength converter'. Proc. Opt. Fiber Comm. Conf., Anaheim, CA, 2002, Paper WM1
3 FISCHER, S., DÜLK, M., GAMPER, E., VOGT, W., HUNZIKER, W., GINI MELCHIOR, H., BUXENS, A., POULSEN, H.N., and CLAUSEN, A.T.: 'All-optical regenerative OTDM add-drop multiplexing at 40 Gb/s using monolithic InP Mach-Zehnder interferometer', *IEEE Photonics Technol. Lett.*, 2000, **12**, (3), pp. 335–337
4 PHILLIPS, I.D., GLOAG, A., MOODIE, D.G., DORAN, N.J., BENNION, I., and ELLIS, A.D.: 'Drop and insert multiplexing with simultaneous clock recovery using an electroabsorption modulator', *IEEE Photonics Technol. Lett.*, 1998, **10**, (2), pp. 291–293
5 SCHUBERT, C., DIEZ, S., BERGER, J., LUDWIG, R., FEISTE, U., WEBERH, G., TOPTCHIYSKI, G., PETERMANN, K., and KRAJINOVIC, V.: '160-Gb/s all-optical demultiplexing using a gain-transparent ultrafast nonlinear interferometer (GT-UNI)', *IEEE Photonics Technol. Lett.*, 2001, **13**, (5), pp. 475–477

Transmission over 5.6 km large effective area and low-loss (1.7 dB/km) photonic crystal fibre

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A 10 Gbit/s non-return-to-zero signal at 1550 nm over 5.6 km photonic crystal fibre (PCF) with 1.7 dB/km loss has been successfully transmitted, demonstrating the potential of PCF as transmission fibre.

Introduction: Photonic crystal fibres (PCF) are strong candidates to serve as basic building components for future optical communication systems. Their optical properties such as chromatic dispersion,