A NOVEL SCALABLE OPTICAL PACKET COMPRESSION/DECOMPRESSION SCHEME

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Abstract: A novel optical packet compression/decompression scheme is proposed allowing for high compression rates and large packet sizes thereby reducing the rate conversion latency. Extensive simulations are performed in order to investigate the feasibility of the proposed scheme. An OSNR of more than 22 dB is estimated for very large packets.

Introduction

Ultra-fast access to the optical medium can be particularly obtained by using optical packet compression/decompression technique. Recently, several methods for optical compression and decompression have been proposed. Most of these optical rate conversion schemes are based on an optical recirculating loop and a sampling technique /1//2/. However, this method leads to some restrictions concerning bit-rate and packet size. A further technique for optical packet rate conversion is a feed-forward delay-line structure consisting of $q = log_2(N)$ stages reported in /3/. This technique allows simultaneous compression and decompression of N-bit large optical packets using the same device. Since only passive components are required it is easy to implement, but for larger packet lengths the splitting losses (3 dB per stage) must be compensated by an optical amplifier. However, the maximum packet size is here limited by the compression rate K as: $L_{p,max} = K - 1$, where $K = T_0/\tau_0$. Consequently, for an 100:1 compression ($K = 100$) $L_{p,max}$ is limited to 99 bits. Such short packets are usually impractical in many applications. Therefore, we propose a scalable optical packet compression/decompression scheme using a parallel arrangement of Optical Delay Line Lattices (ODLLs). This scheme allows simultaneous compression and decompression of optical packets not limited in size and compression rate.

Packet Compression/Decompression Units

The proposed scheme depicted in Fig. 1 consists of M parallel compression/decompression units, each of them responsible for the rate-conversion of a part of the optical packet. The principle operation of the device can be described as follows /5/: N–bit large high-speed input packets (at H-S In) are divided into M separate n-bit sequences using a splitter and M bi-directional optical gates. Those sequences are then copied n times in an n-bit ODLL ($n = N/M$). Each copy is delayed by $(T_0 - \tau_0)$ with respect to the next copy of the packet. A fast OTDM demultiplexer selects bits separated by the bit period T_0 within very narrow switching window, thereby down-converting the high-speed sequence. Finally, all M sequences are delayed by an appropriate optical delay line $DL_{2,m}$ and combined by a $M \times 1$ combiner. Thus, the whole high-speed input packet is down-converted. Moreover, by using the same device in the reverse direction, a low-speed packet (with bit period T_0) can be compressed. The low-speed optical packet (at L-S In) is first divided into M sequences by a $1 \times M$ distributor. Each sequence is then delayed by an appropriate delay line $DL_{2,m}$ and compressed by an n-bit ODLL. The fully compressed sequences are finally selected by the gates and combined by a M x 1 combiner. The result is a high-speed output signal (with bit period τ_0) that has the same bit pattern sequence as the low-speed packet. Note that both compression and decompression can occur simultaneously within the same device.

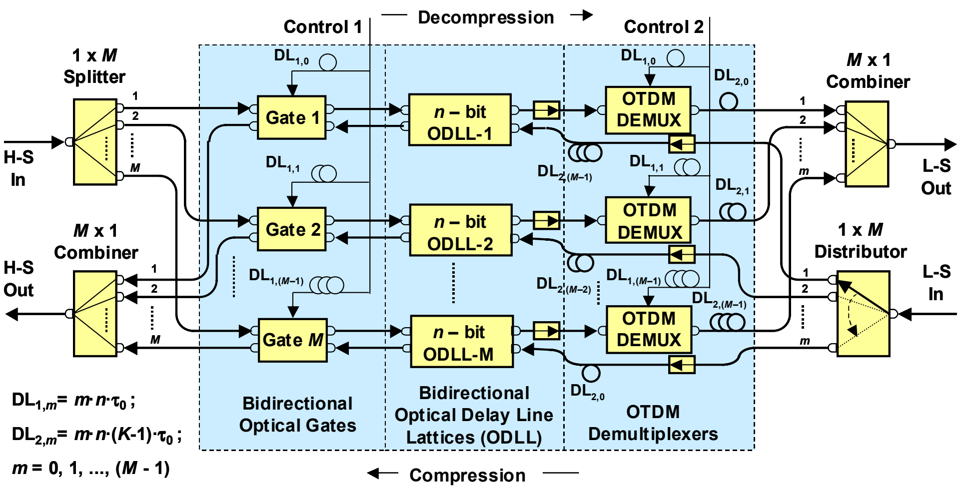

Figure 1: Optical packet compression/decompression unit

Simulation Results

Simulations were carried out in order to investigate the feasibility of the proposed compression/decompression scheme. 8-bit large packets at 10 Gbit/s (4 ps FWHM pulses at 1.55 µm) were generated and compressed by a compressor composed of two parallel 4-bit ODLLs. The compressed packets were then transmitted over 300 m of standard single mode fiber (SSMF) and finally decompressed by the receiver using the proposed scheme, also consisting of two 4-bits ODLLs. In the transmission path, an EDFA (Erbium Doped Fiber Amplifier) and an OBPF (Optical Band Pass Filter) were deployed for fiber loss compensation and for suppressing amplifier ASE (Amplified Spontaneous Emission), respectively. A symmetric Mach-Zehnder Interferometer (MZI) with SOAs in its arms was used as an OTDM demultiplexer. A 168 to 10.5 Gbit/s demultiplexing experiment has already been reported using a similar structure /4/. We used a $LiNbO_3$ modulator for implementing the gating functionality. A fast all-optical switch (e.g. MZI) can be also deployed if ultra-fast gates are required. In our case, an extinction ratio better than 13 dB was measured at the low-speed output. Note that an important advantage of this scheme is its scalability. It is possible to choose an optimal configuration (optimal M and n values) for achieving a lower packet conversion time along with large packet sizes and compression rates.

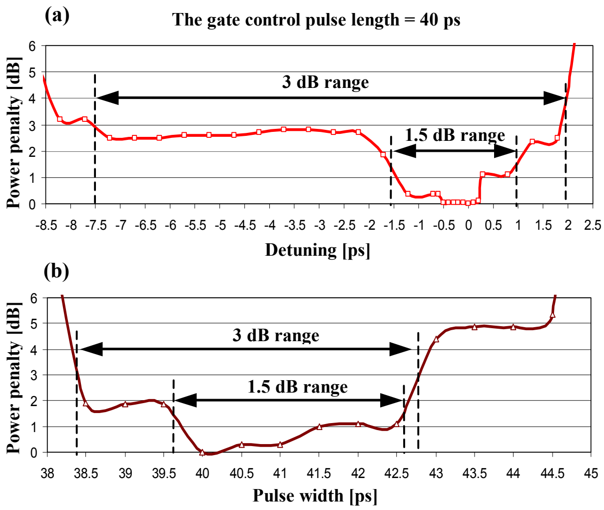

Figure 2: Impact of the gate control signal (a) adjustment and (b) broadening

However, the gate control signal (Control 1) has to be synchronized with the incoming/outgoing high-speed optical packets. In order to investigate the impact of the gate control signal detuning and broadening, the simulation setup was extended to four parallel 4-bit ODLLs enabling BER measurements with $2^{23} - 1$ PRBS. For the optimal gate control signal adjustment (0 ps) the measured receiver sensitivity was –24.6 dBm (BER = 10^{-9}). The obtained power penalty is shown in Fig. 2. From Fig. 2(a) it can be seen that a gate control signal detuning from –7.5 ps to +1.9 ps (interval of 9.4 ps) as well as a pulse broadening (Fig. 2.b) from –1.65 ps to +2.8 ps (in total 4.45 ps) results in a power penalty of up to 3 dB.

ASE Noise Estimation

To compensate power losses in the compression/decompression unit, optical signal amplification can be applied after each i-th ODLL stage. The gain of the amplifiers (G) has to be selected such that the losses are completely compensated. Moreover, we assume the presence of an OBPF to limit the noise bandwidth. The ASE noise produced at the output of the amplifiers can impair the optical signal-to-noise ratio (OSNR). Therefore, in this subsection we estimate the ASE noise accumulation for the proposed scheme. The OSNR for the ideal loss compensation case and assuming an ideal OTDM-Demux is given by:

$$OSNR_{ODLL} = \frac{P_{in} g}{P_n \lceil q_M / i \rceil M} \quad , \qquad (1)$$

where P_{in} denotes the pulsed power at the low-speed input, g is the optical loss of the gate, P_n is the spectral density of the ASE noise, i.e. $P_n = n_{sp} h \nu (G-1) B_0$ and q is the number of stages in an ODLL given by $q_M = log_2(N/M)$.

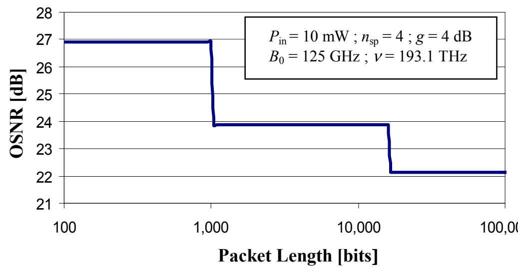

Figure 3: OSNR vs. *N* for *i* = 4 and *M* = 4

Fig. 3 plots the calculated OSNR versus packet size N assuming ideal loss compensation. From the curve it can be seen that an OSNR of more than 22 dB can be obtained for very large packets (more than 100 kbits).

Conclusions

In conclusion, a new optical packet compression/decompression scheme using a parallel arrangement of optical delay line structures is proposed and investigated in this paper. The proposed scheme allows high compression rates and large packet sizes. We estimated an OSNR of more than 22 dB for a compression of very large packets (more than 100 kbits). Our simulations show general feasibility of the proposed scheme. A gate-control signal detuning in an interval of 9.4 ps induces power penalties up to 3 dB for a 100 Gbit/s signal. This results show that the synchronization of the gate-control signal with the incoming/outgoing high-speed optical packets is accomplishable.

Acknowledgements

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