Optical Switching and Networking 5 (2008) 244–252

Contents lists available at ScienceDirect

Optical Switching and Networking

journal homepage: www.elsevier.com/locate/osn

A 40 Gb/s IM payload/2.5 Gb/s header AOLS technique based on an all fiber realization

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ARTICLE INFO

Article history:
Received 15 November 2006
Received in revised form 29 November 2007
Accepted 14 March 2008
Available online 30 March 2008

Keywords:
AOLS
MPLS
Optical FSK
FWM
DSF
NOLM
Interferometer wavelength converter
Kerr effect
Raman effect

ABSTRACT

An all fiber IM/FSK coding technique for the realization of the 2.5 Gb/s NRZ label swapping onto a 40 Gb/s NRZ payload signal has been numerically studied in this work. Four wave mixing (FWM) and cross phase modulation (XPM) on a dispersion shifted fiber (DSF) are used, for the combination of the Intensity modulated (IM) payload with Frequency Shift Keying (FSK) modulated header *synchronously on the same optical carrier*, and for the header removal and payload wavelength conversion respectively. Simulations have proven the feasibility of this DSF fiber based method, and shown the potential for high bit rate AOLS applications.

1. Introduction

MULTIPROTOCOL label switching (MPLS) technology is a promising solution to the problem of the imposing need for ultrahigh link capacities and packet switching speeds at network nodes. Instead of reading huge route lookups, a single label is read on each packet [1]. The MPLS protocol is supported by Generalized MPLS (GMPLS), when IP packets are bypassed directly over the WDM layer, avoiding the two intermediate layers, ATM and SDH respectively. In this case, the label switched paths of the MPLS protocol have been replaced by the wavelength switched paths of the GMPLS protocol [2]. Apart from the wavelength labeling, additional label information can be encoded and attached to the IP packet, via various label encoding methods, at the edge nodes before entering the WDM core network layer. All optical label swapping (AOLS) is the method of coding the optical label onto the packet, after having removed the old one, for all optical packet routing and forwarding. Many label encoding techniques for label swapping have been proposed so far [3], such as subcarrier modulated header (SCM) [4], bit serial header and orthogonal modulation schemes [5]. In this paper we thoroughly investigate an AOLS method using a 40 Gb/s NRZ payload and a 2.5 Gb/s NRZ header. This method relies on the combination of the two orthogonally modulated signals via FWM in a Highly Nonlinear (HNL) DSF fiber [6]. The Four Wave Mixing (FWM) in Dispersion Shifted Fiber (DSF) is used to combine these two data streams on the same optical carrier. In this way bitrates of 40 Gb/s are easily achievable in contrast to the Semiconductor Optical Amplifier (SOA) based approach, where up to 10 Gb/s payload can be achieved [7].

Key points in this work are the 40 Gb/s NRZ payload modulation and the simulation and performance evaluation of a cascade of nodes taking into consideration typical

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doi:10.1016/j.osn.2008.03.001

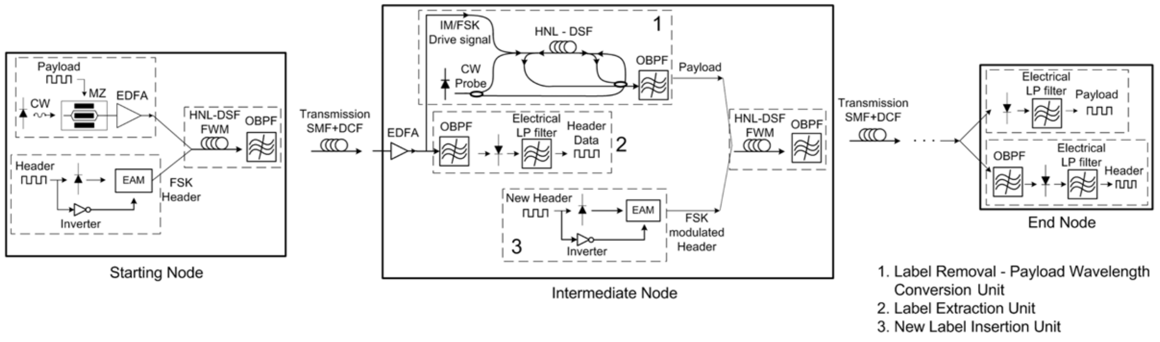

Fig. 1. Detailed block diagram of the proposed scheme.

fiber transmission links between the nodes. The paper is structured as follows: In Section 2, there is a description of the system architecture and its parameters. In Section 3, there is a description of the unidirectional and bidirectional DSF fiber modules, used in our simulations along with a component investigation. Simulation results for the 40 Gb/s NRZ IM payload with the 2.5 Gb/s NRZ, FSK header is included in Section 4. Finally, Section 5 concludes the paper.

2. System description

A block diagram of the proposed architecture is shown in Fig. 1 where the main functional blocks of the starting node, the end node and the intermediate node are shown. Between successive nodes there is also the transmission module, consisting of standard single mode fiber (SSMF) dispersion compensated. Dispersion compensation is required for proper propagation of the IM modulated payload signal along the fiber, as well as for proper FSK label demodulation, due to the walk off effect, when the tone spacing is sufficiently large.

The starting node includes the transmitter modules for payload and header and a unit where the two signals are *combined together, synchronously, onto a common optical carrier*, which is the FWM based DSF fiber module. IM 40 Gb/s modulated packet payload is generated by externally modulating a Mach–Zehnder (MZ) amplitude modulator at a low extinction ratio. Header information, at 2.5 Gb/s, is generated by chirping through direct modulation the laser transmitter at a low modulation index, according to a typical FSK scheme. An already proposed FSK compensation scheme [8] has been applied on the FSK transmitter. According to this scheme, the optical FSK data are fed to an external electroabsorption (EA) modulator, which accepts the optical FSK data, while at the same time it is driven with the inverse electrical data, thus removing the label intensity variations at the output of this transmitter (see Fig. 2 where an example of the transmitted signal with and without header compensation is considered) and minimizing the residual intensity modulation effect on the payload signal when they are coupled together. Both signals enter the DSF fiber after being amplified (using an EDFA) in such a way that payload is the pump and label is the signal according to a FWM scheme. This ensures us, at the output of the FWM fiber, higher extinction ratio for the payload, while at the same time transfer of the FSK information to the conjugate signal. *Exactly due to this specific conditions under which the FWM operates (strongly intensity modulated pump with FSK modulated signal) the use of a SOA as the nonlinear medium is prohibitive due to the carrier lifetime limitations resulting in a maximum* 10 Gb/s *operation bitrate.* In Fig. 3 examples of individual header spectra and total spectra at the FWM output are shown. Although this node can be implemented more easily, using an external modulator in order to combine the IM payload information and the FSK modulated header on the same optical carrier, FWM effect was selected so as to have the same setup for starting and intermediate nodes concerning IM and FSK combination. The signal after its propagation over a multispan route, according to a label swapping mechanism, removes its final label information at the end node, so that the pure IP packet remains. The end node simply consists of individual receivers for header and payload demodulation respectively.

The intermediate node, according to Fig. 1, consists of three units: the label extraction unit, the label removal and payload wavelength conversion unit and the label insertion unit. The label extraction unit is a typical optical FSK receiver and is composed by a Gaussian optical bandpass filter, a PIN photodiode and the appropriate electrical lowpass filter. The same module also applies to the end node, for the final label extraction.

The dominant element of the label removal and payload wavelength conversion is a bidirectional interferometric HNL DSF fiber [9]. The CW probe signal is fed into the interferometer via an input coupler and split into two portions. The combined IM modulated 40 Gb/s NRZ payload signal with the 2.5 Gb/s FSK modulated NRZ header (drive signal), after being amplified by an EDFA is coupled into the DSF with the CW probe. Part of the probe co-propagates with the drive signal experiencing a nonlinear phase modulation proportional to the power of the drive signal, due to the nonlinear Kerr effect. The remaining part of the probe enters the fiber from the opposite side and counter-propagates with respect to the drive beam. The nonlinear phase shift imposed on the counter-propagating CW probe by the drive signal is considered negligible compared to the one imposed by the co-propagating one, due to the short interaction time