Optik 124 (2013) 6363–6366

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Performance analysis of novel optical label technologies

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ARTICLE INFO

Article history:
Received 12 December 2012
Accepted 10 May 2013

Keywords:
OLS
Dedicated wavelength
Manchester-SCM
Hybrid modulation

ABSTRACT

The generation, extraction, identification and regeneration of optical label are the key problems in optical label switching technology. This paper proposes two methods to generate optical packets in OLS system and compares their performance. Results show that when other conditions are equal, the scheme using dedicated wavelength technology has obviously better performance than that of the scheme without this technology.

1. Introduction

At present, the switching in optical cross-connect (OXC) and optical add-drop multiplexer (OADM) devices is based on wavelength switching. OXC completes cross-connection from one wavelength to another through nodes, while OADM implements up and down telephone channels between master-slave networks by way of adding and dropping a wavelength. The switching in services is completed by core routers. Current core routers adopt switching mode based on electrical technology and will increase equipment costs. A large number of DWDM and OTDM high-speed optical signals are changed into low-speed optical signals and then into electrical signals in order to implement packet forwarding. There is electronic bottleneck in this method and switching rate is restricted by backplane rate and number of core routers.

In order to solve the problem of electronic bottlenecks and implement all-optical switching, recently optical label switching (OLS) [1] technology is introduced and a lot of new ideas are proposed. OLS is the combination of IP addressing, control, optical cross connection and wavelength switching. Unlike SDM, TDM and WDM to exchange the sub-channel carrying user data, it implements routing or switching of user optical information through extracting and updating the optical label.

The generation, extraction, identification and regeneration of optical label are the key problems in optical label switching technology. This paper mainly studies the generation of the label and proposes two schemes. The rest of this paper is organized as follows. In Section 2, we mainly introduce some typical OLS systems and describe their respective characteristics. Two optical label schemes are described in Section 3. In Section 4, we analyze and compare simulation results. We summarize the paper in Section 5.

2. Typical OLS systems

Generally, the optical label is generated by way of optical modulation (ASK, FSK and PSK), while processed by optical or electrical methods. So far, a variety of optical label technology solutions have been studied, such as subcarrier multiplexing (SCM) [2,3], time division multiplexing (TDM), dedicated wavelength label, multi-wavelength optical label [4], hybrid modulation label and high-intensity optical pulse label, etc.

The major advantage of the sub-carrier multiplexing (SCM) technique is its simple configuration. Also, the coupling of the label and payload signals in the same wavelength channel helps to ease the bookkeeping in the routing node. Moreover, the label data can be completely asynchronous to the payload data and no strict synchronization is required [1].

Hybrid modulation optical label technology is similar to the SCM label scheme. For the labeling schemes using modulation format diversity, the label and payload signals are encoded using different formats and they are multiplexed on one wavelength for transmitting. In OLS system, this technique is sometimes known as orthogonal labeling and it allows the label and payload to be processed asynchronously. With this technique, it is easier for core nodes to separate the label from payload and identify or update the label information.

In dedicated wavelength label scheme, the label information of different optical headers uses the same wavelength as carrier and is combined in TDM mode for transmitting. However, the homologous payload information uses another wavelength as carrier and

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0030-4026/$ – see front matter
http://dx.doi.org/10.1016/j.ijleo.2013.05.041

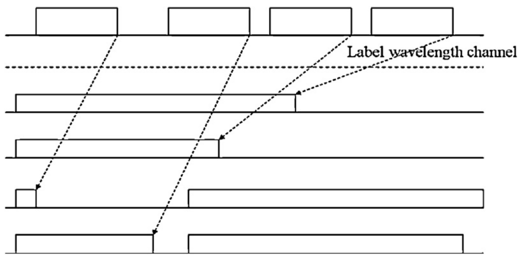

Fig. 1. Channels of dedicated wavelength optical label and multi-wavelength payload.

is transmitted in its own wavelength channel, as is shown in Fig. 1. Optical label and payload information transmits asynchronously. Optical label contains payload-corresponding offset delay and carrier wavelength information and it can be easily extracted and identified. It is relatively easy to control payload-corresponding route switching through above information and regenerate or insert new optical label information. The switching mode corresponding to this label technique is similar to the optical burst switch (OBS) [5] and it adapts to optical switching networks with larger granularity. The advantage of dedicated wavelength label is that the technology in label generation, extraction, identifying and insertion is mature and it is easy to implement because of its no need for complexity optical synchronization. However, this technique will occupy more wavelength resources.

Experiments have proved that Manchester coding can get better transmission performance compared to general OOK signal and CSRZ-DPSK coding has an optimization in dispersion and nonlinear tolerance. We propose two methods to generate optical packets in OLS system. For the first one, we combine SCM and hybrid modulation label techniques, in which we modulate the payload with high-speed and the label with in-band low-speed SCM after Manchester encoding. For the second one, we combine SCM, hybrid modulation and dedicated wavelength label techniques, in which we also modulate the payload with high-speed CSRZ-DPSK and the label with in-band low-speed SCM after Manchester encoding. But what is different from the first one is that the label and payload signals are modulated on optical carriers with different wavelengths.

3. The optical packet generating schemes

Fig. 2 shows the sending and receiving schematic of the first method. A CSRZ-DPSK transmitter consisting of a CW laser is followed by two external $LiNbO_3$ Mach–Zehnder Modulators. The first modulator is used to generate 40 GHz NRZ-DPSK signal driven by the payload data which has been differentially encoded. The second modulator is used to generate CSRZ-DPSK signal driven by a half-bit rate clock and biased at the null point of its transmission curve. The label data is modulated onto a subcarrier with amplitude modulation after Manchester encoded. Obtained two signals enter into the electro-absorption modulator (EAM) and the EAM

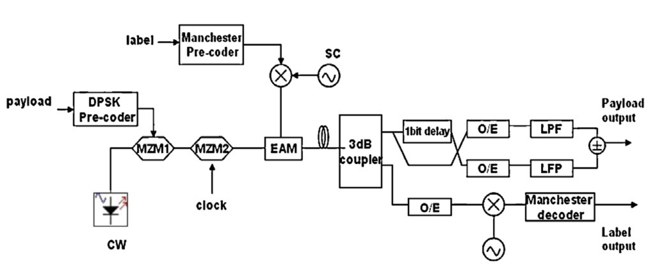

Fig. 2. Sending and receiving schematic of the first method.

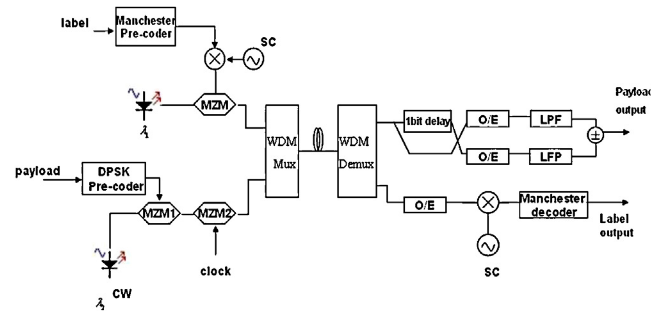

Fig. 3. Sending and receiving schematic of the second method.

modulates the amplitude of CSRZ-DPSK signal using electrical modulation signal. The label receiver contains an optical detector and the detected signal is coherently demodulated before Manchester decoded. The payload receiver is composed of a balanced differential delay detector. Customarily, we use signal intensity to express the transmission features:

$$E_o^2 = E_i^2 \cos^2\left(\frac{\pi}{2}\frac{V(t)}{V_\pi}\right) \tag{1}$$

where E_o and E_i, respectively, represents output and input electric field of light waves, $V(t)$ is driving voltage, and $V\pi$ is half-wave voltage used to generate π phase shift.

For the EAM, assuming that the optical input signal is E_{in}, the following equation describes the behavior of the model:

$$E_{out}(t) = E_{in}(t) \cdot \sqrt{\mathrm{Mod}(t)} \cdot \exp\left[j\frac{\alpha}{2} \cdot \ln(\mathrm{Mod}(t))\right] \tag{2}$$

where $E_{out}(t)$ represents the output optical signal, α is the chirp factor, and Mod(t) is defined as Mod(t) = (1 − MI) + MI · modulation(t), where MI represents the modulation index and modulation(t) is the electrical input signal. The electrical input signal is normalized between 0 and 1.

Fig. 3 shows the sending and receiving schematic of the second method. The label data is modulated onto a subcarrier with amplitude modulation after Manchester encoded and then an optical carrier with λ_1. A CSRZ-DPSK transmitter consisting of a CW laser with λ_1 is followed by two external $LiNbO_3$ Mach–Zehnder Modulators [6]. The two modulators have the same functions as that in the first method. Obtained two signals enter into a WDM Mux and are combined to one signal. The label receiver contains an optical detector and the detected signal is coherently demodulated before Manchester decoding. The payload receiver is composed of a balanced differential delay detector.

4. Performance analysis

In the two simulation systems, we set the payload rate to 40 Gb/s, label 620 Mb/s, SC frequency 20 GHz and the optical power 4 mW. In the second scheme, λ_1 is 1554.1 nm, λ_2 is 1552.5 nm.

According to schematics shown in Figs. 2 and 3, we set up two simulation systems and obtain certain intuitive results. Fig. 4 shows the eye diagrams observed at the payload receiver (a) and label receiver (b) in Scheme 1 and Fig. 5 shows that in Scheme 2. In Scheme 1, the max-Q-factor of label and payload is, respectively, about 62.98 and 22.43 after transmitting 60 km, while that in Scheme 2 is 89.88 and 85.91. The max-eye opening factor of them is, respectively, 0.9841 and 0.9554 in Scheme 1, while that in Scheme 2 is 0.9887 and 0.9884. These results mean that Scheme 2 can improve transmission performance of signals and the interaction between label and payload signals is smaller than that in Scheme 1.