A Reconfigurable All-Optical VPN Based on XGM Effect of SOA in WDM PON

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Abstract: We propose and experimentally demonstrate a reconfigurable all-optical VPN scheme enabling intercommunications among different ONUs in a WDM PON. Reconfiguration is realized by dynamically setting wavelength conversion of optical VPN signal using a SOA in the OLT.

1. Introduction

In recent years, wavelength division multiplexed passive optical network (WDM PON) has gained much attention as a promising next-generation optical access network to increase the bandwidth [1]. Meantime, in order to provide dedicated optical channels for end users, optical virtual private network (VPN) in PON has been investigated with great interest [2]. Typically, optical VPNs need to be reconfigured to allow new users to inter-communicate and maintain secured connections in dynamic networks. A reconfigurable optical VPN scheme [3] in a WDM PON was proposed, which can only deliver optical VPN service between two optical network units (ONUs) with complex transmitters. However, it is desirable to achieve a more flexible optical VPN among a large number of ONUs in WDM PON.

To deliver efficient access service in a large area and realize dynamic network functions, we propose a novel scheme to support a reconfigurable optical VPN among multiple ONUs in WDM PON. In our scheme, a commercial semiconductor optical amplifier (SOA) is used to convert the optical VPN signal to the desired wavelengths. By selectively feeding different wavelengths into the SOA, one can simply reconfigure the all-optical VPN among different ONUs. To the best of our knowledge, this is the first demonstration of reconfigurable all-optical VPN among multiple ONUs in a WDM PON.

2. **Principles**

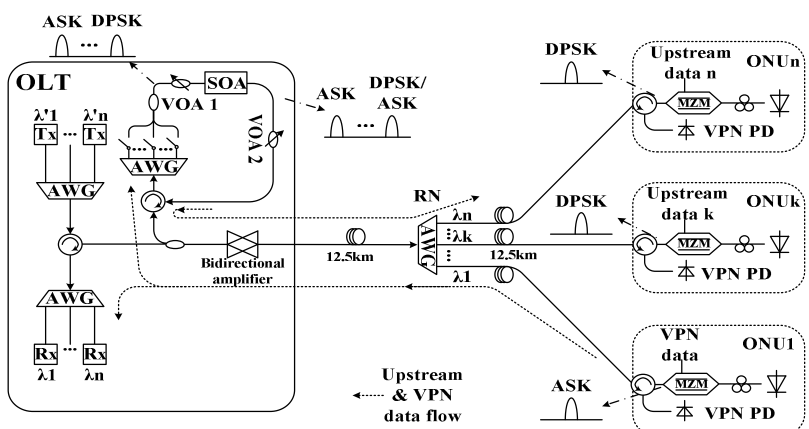

Fig. 1. The reconfigurable optical VPN in WDM PON.

The schematic diagram of the proposed all-optical VPN structure in a WDM PON system is depicted in Fig. 1. In our scheme, a single MZM in each ONU is employed to transmit the upstream and all-optical VPN signals in differential phase shifting keying/amplitude shifting keying (DPSK/ASK) modulation format in different time intervals respectively. After transmitting through the distribution fiber, all the wavelengths are multiplexed by an arrayed waveguide grating-router (AWG) at remote node (RN) and then launched into a feeder fiber. At the OLT, a bidirectional amplifier is used to compensate the transmission loss. The amplified signals are split into two parts by a 1×2 optical coupler. One part is directly detected by DPSK receivers to recover the upstream data carried in the DPSK format. The other part goes though a loop consisting of a circulator, another AWG, a set of optical switches, an N×1 optical coupler, two variable optical attenuators (VOAs) and a SOA. By turning on/off the switches, m wavelengths are selected and injected into the SOA to form a switchable all-optical VPN. In the SOA, the VPN signal with the ASK format in one wavelength is copied onto the other $m-1$ wavelengths using the cross-gain modulation (XGM) effect. Through the VOA, the circulator, the optical coupler and the bidirectional amplifier, the m amplified VPN signals are launched into the feeder fiber. Here, the VOAs are used to control the input power of the signals injected into the SOA and the bidirectional amplifier. At the RN, the signals are demultiplexed by the

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AWG and delivered to the individual ONUs. Thus, an all-optical VPN in *m* different wavelengths is realized. It should be noted that the all-optical VPN data in *m* wavelengths have to be well scheduled in time to avoid interference with each other.

3. Experiment and results

Fig. 2 depicts the experimental setup for providing optical VPN service in three different wavelengths. At the ONUs side, three continue-wave (CW) light sources with wavelengths at λ_1 (1551.32nm), λ_2 (1554.08nm) and λ_3 (1555.68nm) are used as upstream carriers. An ASK signal at 1551.32nm is generated by driving a MZM with a 1.25-Gbps pseudorandom bit sequence (PRBS) optical VPN data. The other two CW lights are DPSK-modulated by 10-Gbps PRBS upstream data1 and upstream data2. The output powers of the three signals are 3 dBm, -3 dBm and -3 dBm respectively. After 25-km transmission, in the OLT, the amplified optical signals are split into two parts. One passes through a circulator and an AWG, and is detected by upstream DPSK receivers. The other part goes through a second circulator, another AWG, two VOAs and a SOA. By adjusting the VOA1, the DPSK signals at λ_2 and λ_3 with a power of -3 dBm are coupled with the ASK signal at λ_1 of 3 dBm, and then they are launched into a commercial SOA (SOA-NL-OEC-1550 from CIP). The spectra before and after the SOA are shown in insets (i) and (ii) of Fig. 2 (a). There are certain out-of-band four-wave mixing components in inset (ii), which are about 25 dB lower than the signals. At the output of the SOA, two signals at wavelength λ_2 and λ_3 carrying the inversed optical VPN data are obtained due to the XGM effect.

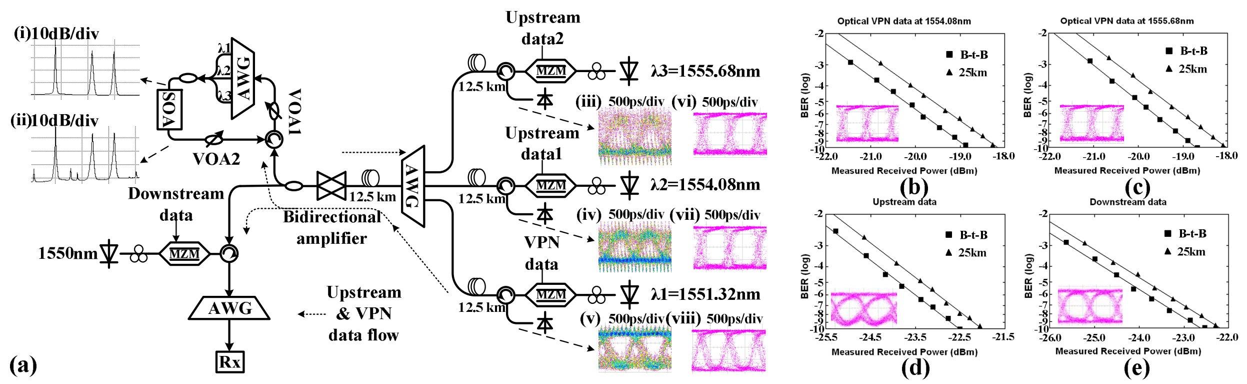

Fig. 2. (a) Experimental setup and results; (b) BER curves for OVPN data at λ_2; (c) BER curves for OVPN data at λ_3; (d) BER curves for upstream data; (e) BER curves for downstream data.

After 25-km transmission, the signals are demultiplexed by the AWG and delivered to the individual optical VPN receivers. The insets (iii), (iv) and (v) in Fig. 2 (a) show the optical eye diagrams after the transmission. Due to the insufficient suppression of the 10-Gbps DPSK signals, the eye diagrams of the signals at λ_2 and λ_3 exhibit 10-GHz ripples. After detected by a 2.5-GHz PD, the ripples can be effectively removed and the electrical eye diagrams with wide opening are provided in the insets (vi), (vii) and (viii). Fig. 2 (b), (c), (d) and (e) show the BER curves for the two optical VPN signals, upstream signal and downstream signal. Error-free performances are achieved for all the data.

In the experiment, we switch off the wavelength λ_2 before the signals are fed into the SOA and an optical VPN between the other two wavelengths is achieved. Similarly, when we change the wavelengths of the three CW light sources or inject more than three wavelengths into the SOA, another optical VPN can be realized. In practice, one can employ a set of switches to select the wavelengths and thus realize a reconfigurable optical VPN within multiple ONUs using different wavelengths.

4. Conclusion

We have proposed a reconfigurable all-optical VPN architecture in 10-Gbps WDM PON, and experimentally demonstrated the optical VPN data transmission in three different wavelengths with a data rate of 1.25 Gbps. This work was supported by the 863 High-Tech program (2009AA01Z257).

References:

[1] A. Banerjee et al., "Wavelength-division-multiplexed passive optical network (WDM-PON) technologies for broadband access: a review," J. Opt. Netw. 4, 737-758, 2005.

[2] Y. Su et al., "All-optical virtual private network in passive optical networks," Laser & Photonics Reviews. 2, 460-479 (2008).

[3] T. Jayasinghe et al., "Wavelength switchable ONU transmitter using a self-seeded RSOA for reconfigurable optical VPN over WDM PON," In Proc. OECC'08, ThL2 (2008).