Multiple Optical Private Networks Over EPON Using Optical CDMA Technique

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Abstract: A novel architecture of multiple optical private networks (PNs) on EPON independent of OLT is experimentally demonstrated. Two active PNs are established using OCDMA, which ONUs within a PN are interconnected sharing the same codeword.

OCIS codes: (060.2330) Fiber optics communications; (060.4250) Networks

1. Introduction

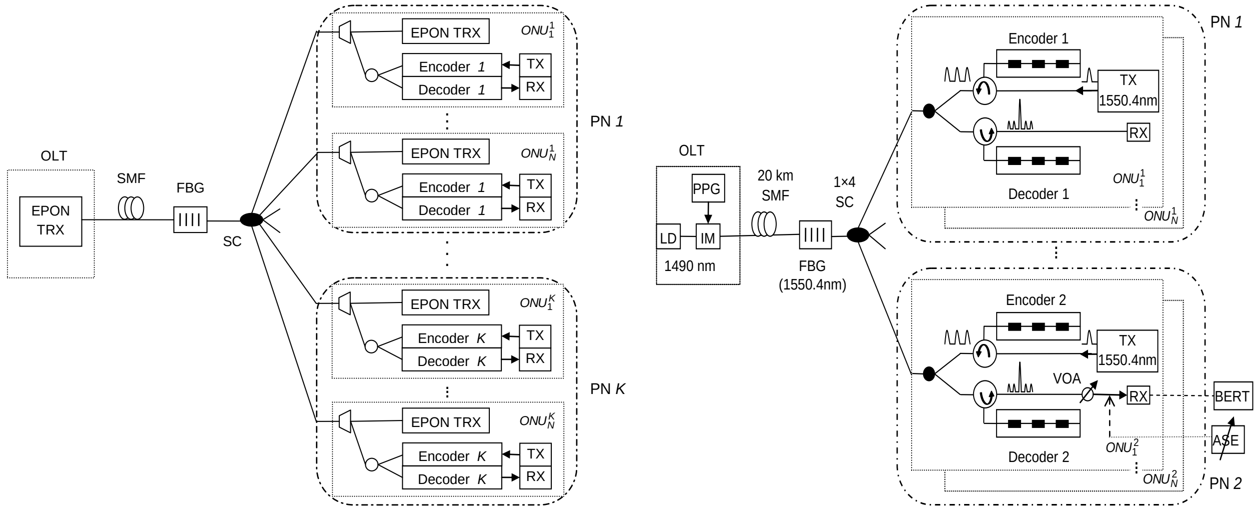
Ethernet Passive Optical Network (EPON) is an emerging low-cost technology which is an attractive solution for broadband access network [1]. EPON architecture is consisted of optical line terminal (OLT), star coupler (SC) and optical network units (ONUs) using tree topology. The downstream traffic is broadcasted from OLT to ONUs at 1490 nm wavelength, while the upstream traffic is sent to OLT at 1310 nm wavelength. Based on conventional PON architecture, all data communication among ONUs such as peer to peer application either video and data sharing should be passed by OLT. The electronic processing of gigantic number of packets such as buffering and scheduling is performed by inserting a router in OLT, which degrades the throughput performance of the network. In order to reduce packet traffic load on the OLT electronic bottleneck, inter-ONU communication independent of OLT seems to be a good solution. Therefore, Private Networks (PNs) are established between different enterprise sites, different university campuses and even inter-buildings without installing extra network infrastructure.

Different network architectures have been proposed to build optical PNs independent of OLT. One solution is consisted of reflecting private network data with Fiber Bragg Grating (FBG), located before the PON star coupler, towards the entire ONUs of the network [2]. However, just one PN is supported in this proposition. Another solution suggests using a dynamic waveband reflector to re-direct one ONU packets to other ONUs in the same group [3]. However, simultaneous data transfer of up/downstream PON and PN is not possible since they use the same wavelength [4].

Recently, we have experimentally demonstrated the installation of private networks on EPON using a ring topology [5]. Although, using the power budget to prevent the circulation of data in the ring based architecture results in limited number of PNs. In this paper, we propose and demonstrate a novel architecture of multiple optical private networks over EPON using optical code-division multiple access (OCDMA) as a multiplexing technique to achieve multiple secure PNs communications. By inserting a FBG before PON star coupler, PNs communications become independent of OLT which does not add any extra traffic management to OLT. As a result, different ONUs belonging to the same PN, communicate with each other sharing the same codeword. Furthermore, simultaneous transmission of up/downstream PON and PN are available since they are at different wavelengths. In the following, we present the network architecture and demonstrate experimentally the feasibility of two PNs over EPON using OCDMA technique operating at 1.25 Gbps data bit rate.

2. Network architecture

Fig. 1a shows multiple optical private networking over PON architecture. Each ONU is provided with standard equipments for the up/downstream standard EPON communication and an appropriate codeword is assigned for PNs communication. The role of FBG reflector between feeder fiber and SC is to pass up/downstream EPON data and to reflect PNs data towards ONUs. As a conventional EPON transmission, the OLT and ONUs exchange their data on the specific wavelengths which passes freely through the grating based on time division multiplexing (TDM) protocol. To achieve multiple secure PNs, OCDMA technique is used in which each user data bit is encoded with a given sequence of pulses. Private networking data at 1550 nm wavelength is reflected by FBG towards ONUs and is welcome to ONUs with the matched code. It means that data from *j*-th ONU which belongs to *i*-th PN (ONU_j^i), is only detectable by the ONUs in the same PN (*i*-th PN) since they possess the same codeword and it is not decoded



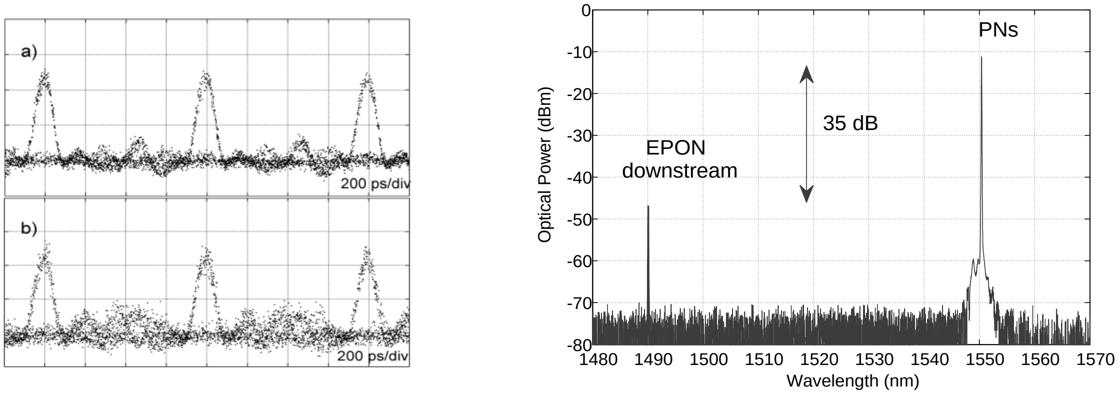
(a) (b)

Fig. 1. a) Architecture of multiple optical private networks over EPON, b) Experimental setup (PPG=Pulse Pattern Generator, IM= Intensity Modulator, ASE=Amplified spontaneous emission)

by other PNs. Therefore, within the EPON infrastructure, multiple PNs are realized compatibly with EPON datastream transmission without affecting it.

3. Experiment and result

To demonstrate the feasibility of proposed architecture, the experimental setup was arranged as shown in Fig. 1b. A DFB laser at 1550.4 nm wavelength is used at ONUs as a PN light source. The modulation of pseudo random binary sequence (PRBS) data at 1.25 Gbps is performed using 1:8 duty cycle RZ format. In this experiment, we apply Direct-sequence OCDMA en/decoders using extended quadratic congruence (EQC) codes with non-periodic structure [6]. These codes have good correlation properties. DS-OCDMA en/decoders were implemented with superstructured-FBG to generate an on-off keying (OOK) codeword. The encoded sequences are generated at 1550.4 nm Bragg wavelength on which the reflection window of FBG is placed. Therefore, PN encoded data is reflected from 2 nm bandwidth FBG to all ONUs. At the detection stage, the encoded data is passed through the decoder to construct the autocorrelation function. The decoded signal of PN 2 includes the autocorrelation peak and multiple access interference (MAI) noise from code 1 which degrades the bit error rate (BER) performance. Fig. 2a and 2b show the electrical waveform of the received signal at PN 2 for one and two active PNs respectively.



(a, b) (c)

Fig. 2. a) One PN (without MAI), b) Two PNs (with MAI), c) Reflected spectra of EPON and PN datastream

To investigate the effect of EPON datastream on private networks transmission, we have used a DFB laser source in OLT at the wavelength of 1490 nm. This traffic passes freely through the grating with low insertion loss

(0.5dB). Fig. 2c shows the power difference of reflected optical spectra of PNs and EPON datastream. This observation demonstrates that EPON signal was suppressed below the PNs by 35 dB. Therefore, PNs can simultaneously establish the inter-ONU communication using OCDMA technique with no effect on EPON and vice versa.

Fig. 3 shows the measured BER performance for two configurations. BER is measured as a function of optical signal-to-noise ratio (OSNR) with resolution bandwidth of 0.1 nm. The noise here is the presence of the amplified spontaneous emission (ASE) that is generated and is relatively broadband. We have successfully achieved a BER$\leq 10^{-9}$ with an OSNR of 23.3 dB in the configuration with two active PNs. The degradation of BER performance by adding the second PN is due to MAI noise from code 1. When a high number of PNs are active, optical thresholder can be used to eliminate MAI and leads to better BER performance.

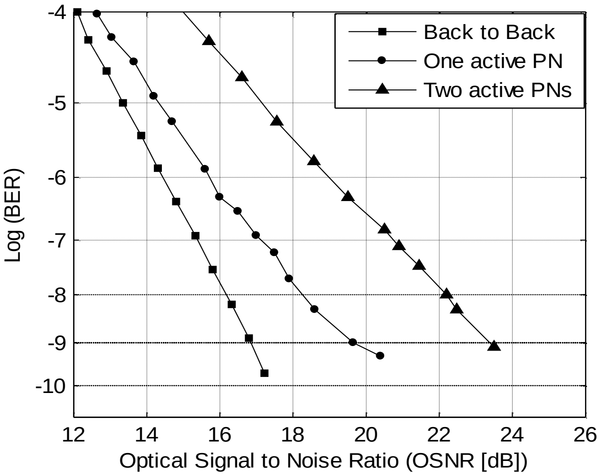


Fig. 3. Measured BER performance

4. Conclusion

To reduce the packets processing load of upstream transmission on OLT due and to improve private networking applications throughput, we have proposed and demonstrated a novel architecture supporting multiple optical private networks independent of OLT. PNs can simultaneously communicate with each other sharing the appropriate codeword according to OCDMA technique with no effect on EPON. In this paper, we have shown the feasibility of two active PNs using OCDMA technique over EPON. Furthermore, the number of users can be increased by bringing into play the higher capacity codes.

5. References

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