A Novel Physical Security in Wavelength Division Multiplexing Passive Optical Network (WDM-PON) Using Broadband Light Source

Naveen Gupta, Divya Dhawan, Piyush Jain

Abstract— In this paper we proposed the physical layer security scheme in WDM-PON. Simulated result of eavesdropping attempt in WDM-PON is presented. This physical security enhancement is accomplished through inclusion of Broadband Light Source in OLT to create a TDM signal in which each data frame is transmitted at unique wavelength. Simulation tools verify that implementation of enhance security technique can be successfully employed in PON.

Index Terms — Broadband Light Source (BLS), Optical Circulator, Passive Optical Network (PON), Time Division Multiplexing (TDM), Wavelength Division Multiplexing (WDM).

1. INTRODUCTION

Wavelength division multiplexed passive optical network has been consider as promising solution for future Broadband access networks. With the rapid increase of transmission capacity of WDM-PONs, survivability become significant since any fiber failure may disrupt large amount of transmission data. PONs are the right choice to satisfy increasing demand for the bandwidth by residential and business alike, and because of their cost factor as compare to network with active component they are potential candidate for realization of Fiber To The Home (FTTH) connectivity [1]-[3]. These PON networks consist of Optical Line Terminal (OLT), multiple Optical Network Unit (ONU) and Optical Distribution Network (ODN) with passive optical components [4]. It is basically a tree topology connecting an OLT with multiple ONU via optical link. In downstream direction PON is point to multipoint and in upstream direction PON is multipoint to point.

1.1 Eavesdropping in PON

Due to point to multi point downstream nature of PON eavesdropping occurs [4]-[8]. A conventional PON network use a filter and encryption scheme to prevent uses from accessing frames not intended for them, through the disabling of filtering system and access to the encryption key all the downstream security feature can effectively be countered as shown in Fig. 1.

In this TDM-PON network shown in Fig. 1 data is transmitted between OLT and user through passive elements in which individual time slots are allocated to different user. The OLT assigned a unique time slot to the generated data and transmitted it on single optical fiber on common wavelength. The fiber is then passes through an optical splitter and the same TDM data stream is transmitted to each ONU. Inside the ONU data is filtered in order to transmit only correct data to each ONU. Eavesdropping can occur when one of the filter is disabled and Fig. 1 shows how eavesdropping occur in TDM PON.

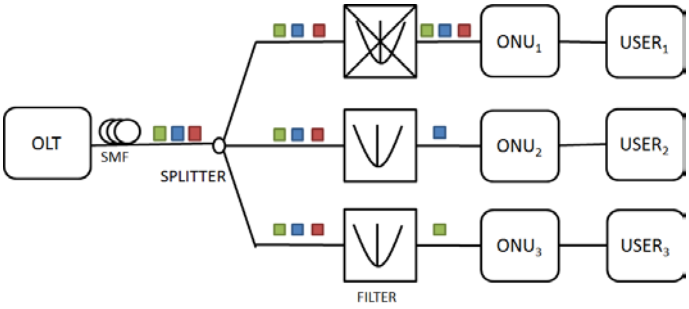

Fig.1 Eavesdropping in TDM-PON

2. SIMULATION SETUP FOR ENHANCE SECURITY

A preferable approach to security implementation in PON has been accomplished through the use of WDM-PON. A WDM-PON scheme allow for creation of point to point link at

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unique wavelength between OLT and ONU [9]. A schematic view of the WDM-PON is shown in Fig. 2. Data from the different Transmitters are multiplexed and then circulated with the help of Broadband Light Source (BLS). The Broadband Light Source injects the signal to lock the OLT and allow the single wavelength to move from input port to the output port.

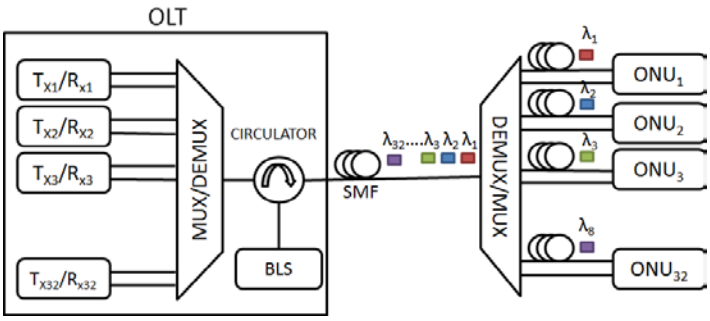


Fig. 2 Physical Security in WDM-PON

In order to verify the physical operation of WDM PON, a 10 Gbps data source was configure in the Optical Line Terminal using optisystem [11]. Data from the OLT is then circulated with help of the Broadband Light Source (BLS) and transmitted onto a 20 km length of single mode fiber (SMF), at that point data was de-multiplexed and then transmitted to each destination ONU through 5 km single mode fiber (SMF).

To reduce the cost of WDM-PONs, injection-locking scheme has been developed. This technology eliminates the wavelength-specific sources and replaces them with low-cost identical FP-LDs. A broadband light sources (BLSs) at different bands is located at the CO for injection of broadband light into FP-LDs located at the CO and the ONUs. L-band (1581.3–1585.8 nm) is used for the downstream data transmissions [12]-[15].

3. Simulation And Results

To verify our model to implement the physical layer security on WDM-PON, a 10 Gbps signal data source was configure in OLT using optisystem. The data is passed through Optical Circulator and a 20 km length of single mode fiber (SMF) and then data is demultiplexed and then transmitted 5 km length of single mode fiber (SMF) to each destination ONU.

The transmission spectrum of 32 channels WDM-PON before demultiplexer is shown in Fig. 3.

The 100 GHz spacing is sufficient to avoid disturbances to an acceptable level from adjacent frequencies.

The variations in optical power are observed and this is due to various losses within the circulator and 20 km fiber, as well as variable noise levels simulated in different channels. The multi-wavelength signal by the output of optical coupler is then separated by demultiplexer into its essential frequencies accepted by each ONU. Each frequency is routed to its corresponding ONU.

Fig. 4 shows the transmission spectrum for first four out of the 32 channels at their respective ONUs and it is clearly visible that output at each ONU is for its specific frequency and all other frequencies are filtered out at the demultiplexer.

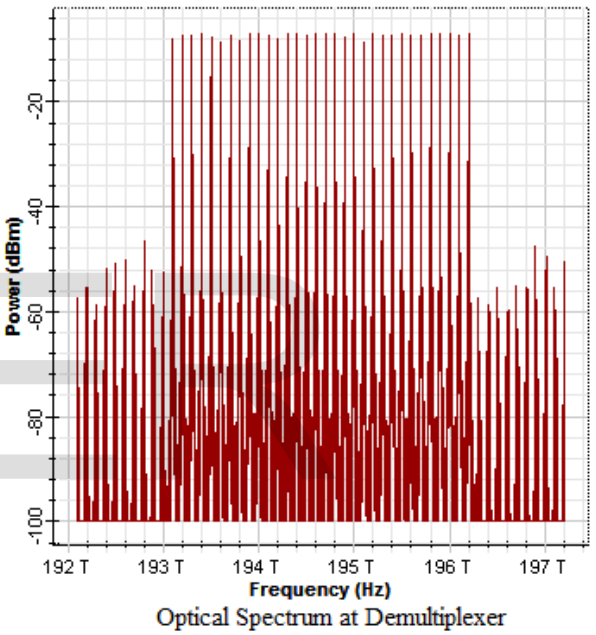
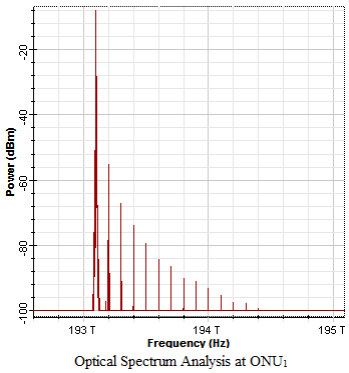
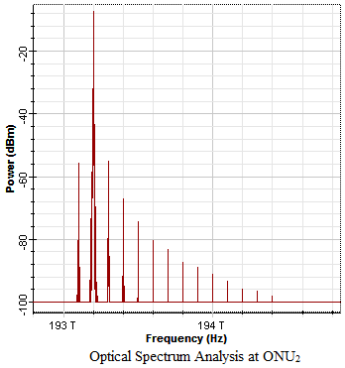


Fig. 3 Transmission Spectrum at Demultiplexer

A small amount of signal power from the adjacent channels that is at a level well below the receiver threshold is still observed at each ONU in the WDM-PON.





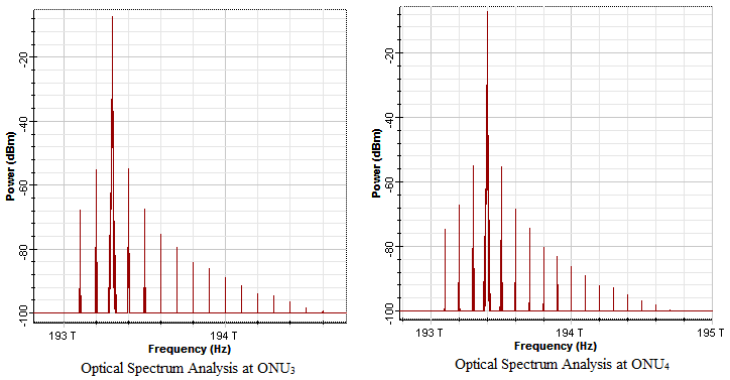


Fig. 4 Optical Spectrums of First four ONUs

Now eye diagram is used to verify the quality of the signal received at each ONU, eye diagrams for first four of the 32 WDM-PON channels were selected at their respective ONUs, and they are shown in Fig 5. The eye diagram for 4 of the channels shows that the WDM-PON scheme results in a high level of signal reception at each ONU.

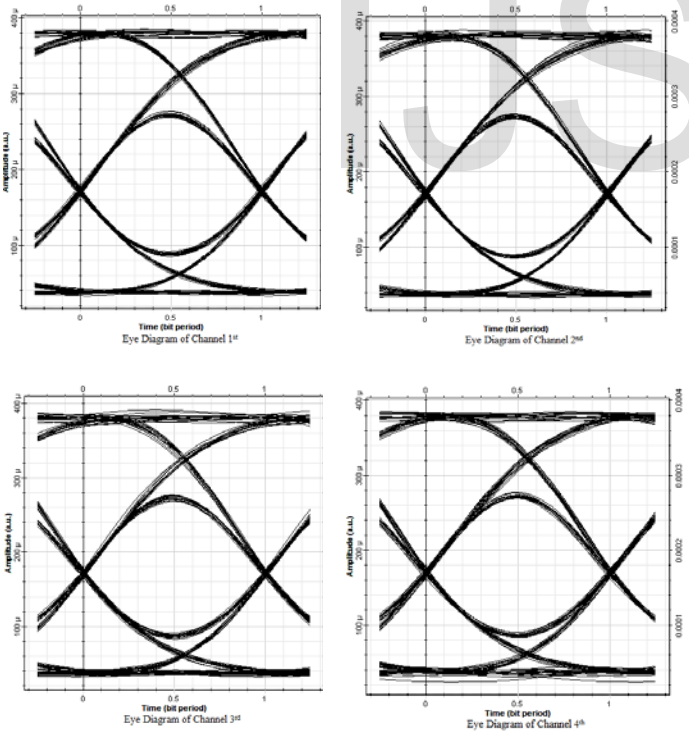


Fig. 5 Eye Diagram of First four ONUs

Now the secure nature of the WDM-PON design is verified by attempting the eavesdrop information intended for ONU_1. In this eavesdropping attempt the optical filter used after demultiplexer to filter out the λ_1 wavelength of first ONU then low power frequency is pass through the filter and further amplified by a Erbium Doped Fiber Amplifier (EDFA) to increase the power level of the signal that is intercepted. A schematic of the eavesdropping configuration is shown in Fig. 6.

A plot of the optical spectrum of the amplified filtered signal that is intended to be eavesdropped is shown in Fig. 7. This plot shows that amplification of an adjacent signal power is possible.

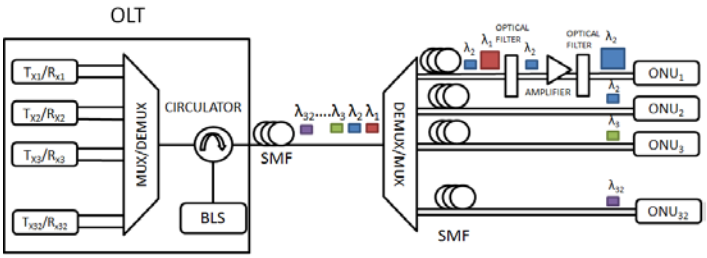


Fig. 6 shows eavesdropping attempt at First ONU.

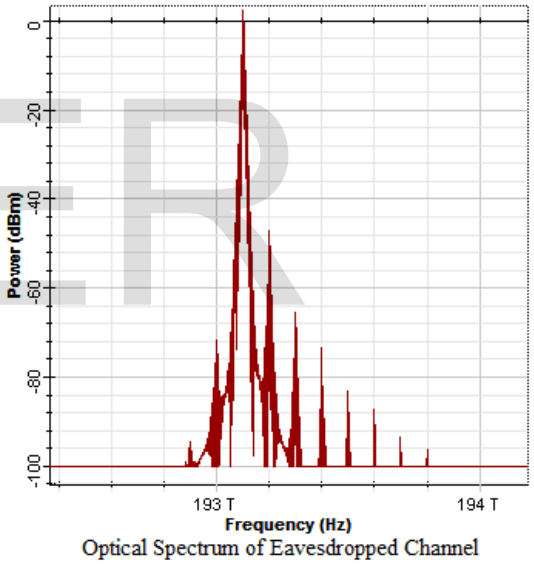


Fig. 7 Optical Spectrum of Eavesdropped Channel

The Eye diagram clearly shows in Fig. 8 that the original information of the particular ONU cannot be reconstructed from the adjacent ONU. Due to the low optical power adjacent channel is insufficient to contain any usable data.

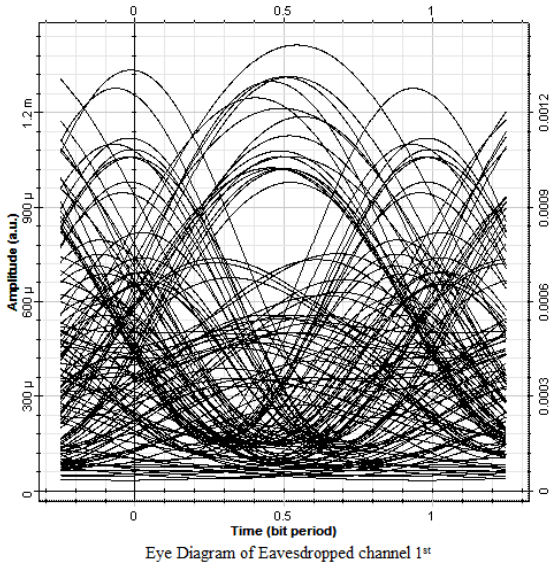


Fig. 8 Eye Diagram of Eavesdropped Channel

4. CONCLUSION

A WDM-PON design operating at a data rate of 10 Gbps in the downstream direction for physical security enhancement has been presented. Through a modification to the OLT by using Broadband Light Source, a multi-wavelength TDM data stream is generated in order to create a secure P2P connection between the OLT and each of 32 ONUs. Simulation results have been presented in order to verify the enhanced physical security mechanism.

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