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Hybrid OCDMA/WDM System using Spectral Direct Detection Technique for Gigabit Passive Optical Network Application

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Abstract: This study a hybrid Optical Code Division Multiple Access (OCDMA) over Wavelength Division Multiplexing (WDM) network is proposed to supporting large numbers of subscribers for Gigabit Passive Optical Network (GPON). Gigabit Passive Optical Network (GPON) is a developing innovation for satisfying high transfer speed interest of clients with long separation scope. In this study, the Modified Double Weight (MDW) code is used as signature address to designing the system regarding this code can accommodate huge number of simultaneously active users. The simulation model of GPON systems is derived by Spectral Direct Detection (SDD) technique which has been developed for the analysis of feasibility and implementation issues of the application. The aim was to analyse the impact of the most important parameters of the components that are needed for new network elements. On the basis of the results achieved (e.g., $\leq 10^{-10}$) the optimal of the GPON system for 20 km fibre length. Hence, this system can be considered as a promising solution for gigabit passive optical network application.

Key words: Modified Double Weight (MDW) code, gigabit passive optical network, spectral direct detection, Spectral Direct Detection (SDD), Gigabit Passive Optical Network (GPON), application

INTRODUCTION

Over the last two decades, communication systems have developed rapidly to meet the increasing broadcast capacity requirement. Applications like video call, Wi-Fi connection, bluetooth connections are few examples of the technologies being improved in this era. The rapid expansion of optical communication networks mostly depends on a high speed transmitter, a high-capacity optical fiber and a high speed receiver. OS-CDMA code family in which the weight is equal to zero and in pair arrangement and cross-correlation of this code is 1. Modified Double-Weight (MDW) code is another variation of a DW code family that can has a variable weight >2. And EDW is the enhanced version of DW code. The EDW code can be any odd number that is greater than one. MDW code, performance is better than compared to the existing codes such as Hadamard and Modified Frequency-Hopping (MFH) codes (Aljunid *et al*., 2004). Direct detection technique is used only one pair of decoder and detector to its implementation whereas in complementary subtraction technique two pairs are required. Additionally, no subtraction process is needed in SDD. In this technique, desired only those component of the optical spectrum which are retain. Rest of the components is removed by filtering. Direct detection technique adequately recoverable from any of the chips that do not overlap with any other chips from other code sequences. Advantage of this technique has successfully eliminated the MAI (Abdullah *et al*., 2008).

Flexible design allows a variety of high bandwidth applications Up to 2 gigabits accessible to each user that permits for convergence of voice, data and video. Gigabit Passive Optical Network (GPON) design allows Voice over Internet Protocol (VoIP) and pots services to run concurrently (Shea and Mitchell, 2007). GPON architecture allocates building by building deployment while existing networks are operational. Active transmission equipment in GPON network consists only of Optical Line Termination (OLT) and Optical Network Unit (ONU). Not only does GPON offer twice the bandwidth of EPON/GEPON at its downstream speed of 2.5 Gbps but it also supports twice the split ratio (Bakarman *et al*., 2010). This means that with a 64-way split, each GPON subscriber still receives an impressive connection

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bandwidth of about 35 Mbps. If a service provider chooses to implement lower split ratios such as 16 or 32, then even more bandwidth can be delivered to subscribers (Quzwini, 2014).

This greater bandwidth delivered by GPON is fully available to subscribers due to the improved bandwidth efficiency of the GPON standard. GPON is designed to provide triple-play services (data, video and voice) not just high-speed Internet access and higher line speed, greater split ratios and support for triple-play services combine to offer maximum flexibility and cost advantages for service provider deployments. GPON networks, up to 64 ONTs can share one fiber connection to the OLT. This makes GPON an attractive option for service providers wanting to replace copper networks with fiber, particularly in high-density urban areas (Wei *et al*., 2001).

MATERIALS AND METHODS

Network simulation setup: OptiSystem is a comprehensive software design suite that enables users to plan, test and simulate optical links in the transmission layer of modern optical networks. This study analyzes the GPON hybrid OCDMA/WDM system (Fig. 1).

Direct detection: The implementation of spectral direct detection technique is completely different from and subtraction detection technique. Figure 2 shows the implementation of spectral direct detection technique. For this detection scheme, only wanted spectral chip in the optical domain is filtered.

This detection scheme doesn't need subtraction detection technique at electric side. Therefore, MAI and Phase Induced Intensity Noise (PIIN) will not exist in this detection scheme. However, this technique is only applicable to codes which the spectral chips are not overlapped with other spectral chips of the other channel. MDW and Modified Frequency Hopping (MFH) are the examples (Zhaoqing, 2011).

Gigabit passive optical network: Gigabit capable passive optical network is a kind of network that features one to multipoint architecture. It consists of Optical Line Terminal (OLT), Optical Network Unit (ONU) and an optical splitter. It supports triple play a long reach up to 20 km of service coverage. The upstream of GPON uses the wavelength reference at 1310 nm whereas, the downstream of GPON uses the wavelength reference of 1490 nm. Each house is served by a single lighted fiber with downstream and upstream data being transmitted on different wavelength on the same fiber.

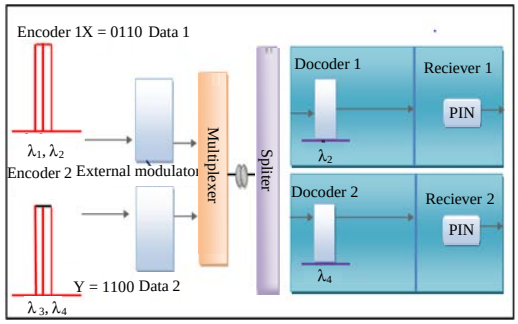

Fig. 1: Implementation of spectral direct detection technique

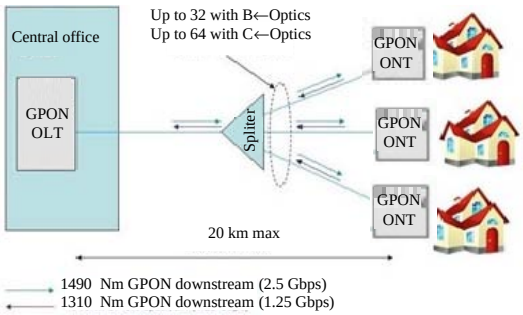

Fig. 2: GPON network

Table 1: GPON system parameter

Components	Parameters	Values
PRBS generator	Bit rate	2.5 Gbps
	Sequence length	32
	Sample per bit	2048
LED	Wavelength	1490 nm
	Bandwidth	10 nm
Optical fiber	Zero dispersion slop	0.075 ps/(nm^{2}km)
	Attenuation	0.2 dB/km
ADP photodiode	Dark current	10 nA

The GPON system parameter: Table 1 shows PRBS generator is used for generation of randomly defined data where the value for bit rate 2.5 Gbps and sequence length 32. GPON system handled LED 1490 nm for wavelength and 10 nm bandwidth. For optical fibre is zero dispersion slop where attenuation is 0.2 dB/km. Dark current APD photodiode is 10 nA.

In Fig. 3, the important criteria in a successful GPON transmission are the BER and also the propagation loss between the Optical Line Terminal (OLT) through the Optical Distribution Network (ODN) and the Optical Network Terminal (ONT). In the simulation, the transmission can carry up to maximum of 20 km as specify in ITU-T G.984 having a range of 1.5-5 dBm of transmitter output power and have a BER $<10^{-10}$. The signal attenuation must be <28 dB to meet the requirements for

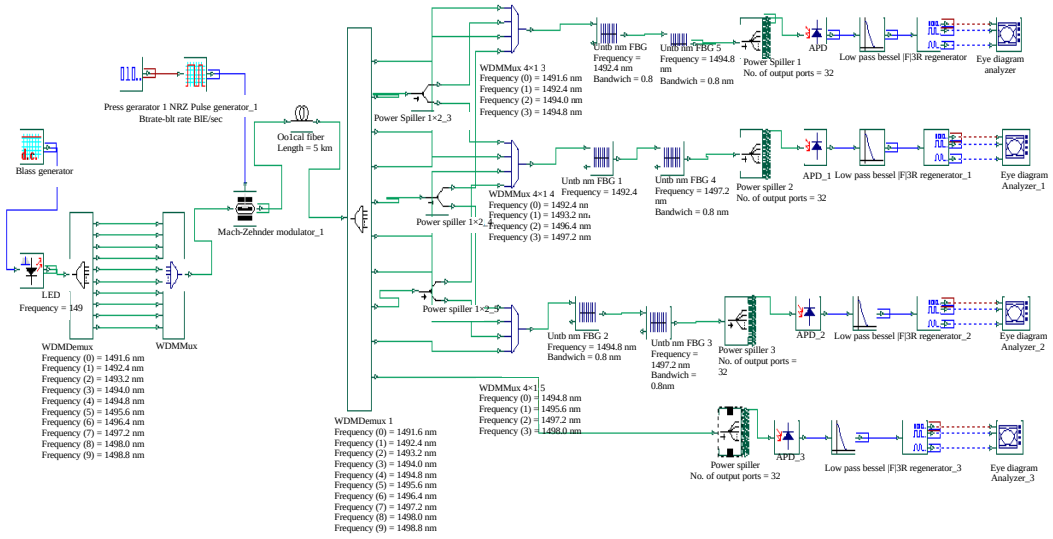

Fig. 3: GPON system downstream transmission

a class B+path loss. The GPON system attenuation is calculated by subtracting the power leaving the OLT and the power receive at the ONT.

RESULTS AND DISCUSSION

The simulation model that was developed for the analysis represents a class B+GPON system which utilizes centralized splitter architecture and uses one splitter with 1:32 split ratio. Downstream transmission direction of the 2.5 Gbps data stream was considered. According to the ITU-T G.984 in such a network, a physical reach of 20 km must be achieved. The simulation model can be presented through three sections, representing the OLT transmitter and ONT (Optical Network Terminal) receiver (Table 2-4). By measuring the power leaving the OLT and power received at the ONT, the total loss through ODN was calculated to be 23.248 dBm which is in the allowable range for B+attenuation class.

The BER for the system are recorded to be 5.19524E-17 for WDM and 2.30264E-16 for the OCDMA part. The criteria specification for a GPON Network is achieved for both total loss and the BER. Comparisons are done by in comparing the BER together with the fiber length. Table 3 BER for the system are recorded to be 5.19524E-17 for WDM and 2.30264E-16 for the OCDMA part. The criteria specification for a GPON Network is achieved for both total loss and the BER. Comparisons are done by in comparing the BER together with the fiber length (Fig. 4).

Figure 5, the GPON system can be seen to be working well below the length of 5 km. the longer the fiber length,

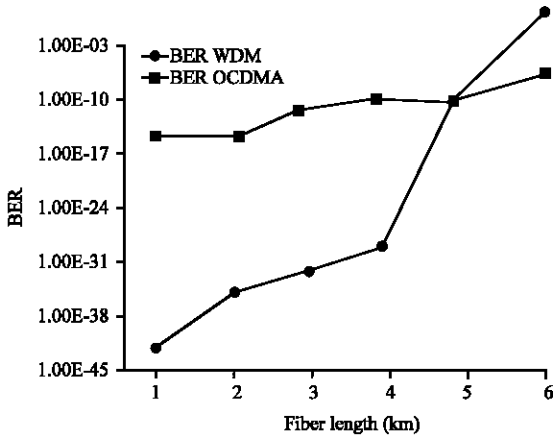

Fig. 4: BER against fiber length for GPON network

Table 2: GPON total loss

Parameters	Values (dBm)
Power leaving OLT	4.540
Power receive at ONT	-18.708
Total loss	23.248

Table 3: Distance of fiber and BER for GPON network

Distance (km)	BER OCDMA	BER WDM
1	1.10E-42	8.79E-21
2	1.68E-37	5.42E-20
3	7.65E-35	3.41E-17
4	1.01E-32	2.03E-16
5	2.30E-16	5.20E-17
6	1.99E-07	7.29E-15

Table 4: Input power and BER for OCDMA and WDM GPON

Input power (dBm)	BER OCDMA	BER WDM
1	2.76E-16	6.31E-13
2	1.97E-16	2.40E-14
3	1.38E-16	1.96E-15
4	1.11E-16	1.53E-16
5	1.05E-16	2.13E-17

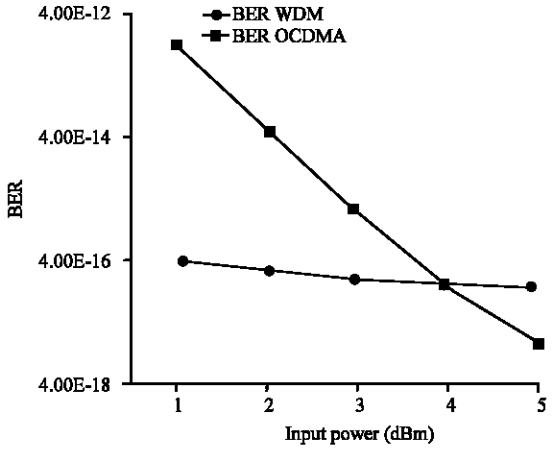

Fig. 5: BER vs. input power for GPON system

the lower the BER. The system only uses one source of LED. LED cannot support for a long range transmission distance. Figure 6, the GPON system is analysed to work better when the input power or in this case the power leaving the OLT increase. When the power leaving the OLT increases, the signal performance becomes better. In the simulation of GPON network, theoretically the maximum range can be achieved is 20 km and the signal is proven to increase when the power leaving the OLT increase.

Nevertheless, due to attenuation and losses throughout the transmission, added with a limited LED power supply, the transmission range can only reach 5 km before the signal BER reach $>10^{-10}$. Modification such as changing from LED source to laser source can be done in the future to study the effect in term of signal

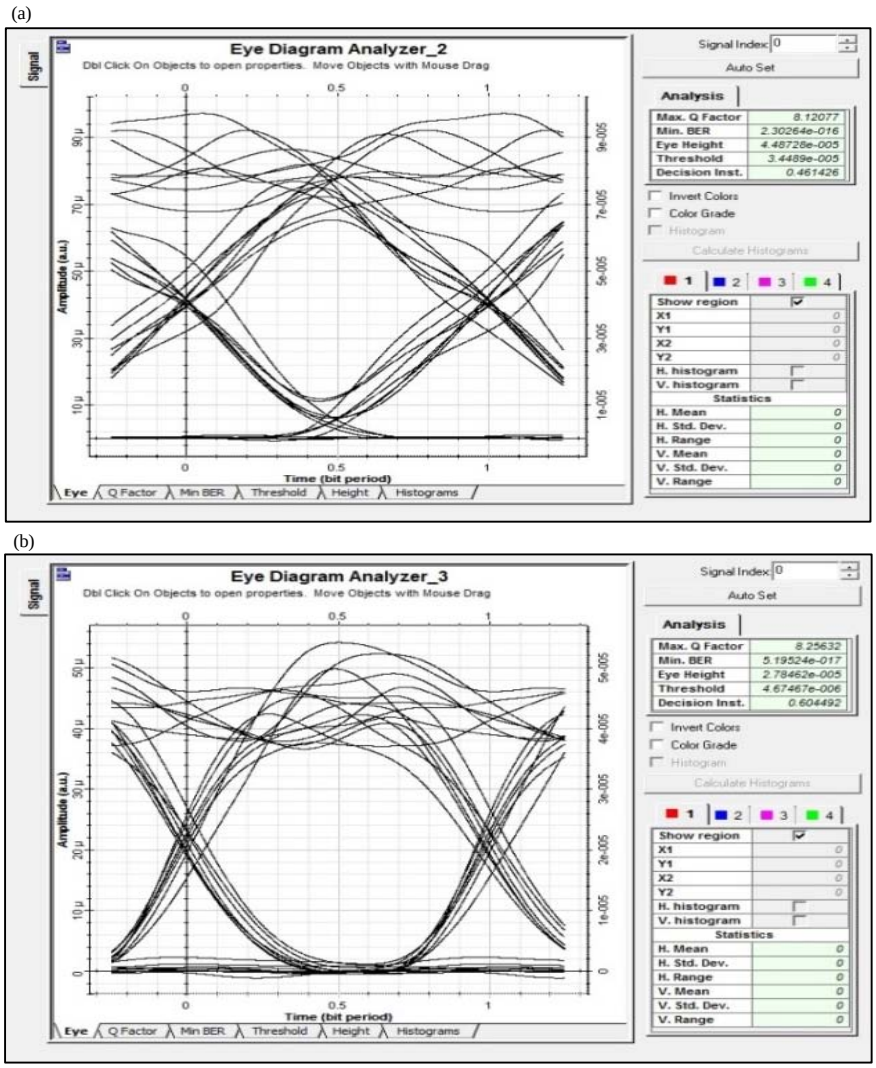

Fig. 6: Eye diagram for GPON Network: a) OCDMA and b)WDM

performance. Overall, for the downstream transmission presented for GPON system has met all the basic criteria set by the ITU-T G.984.

CONCLUSION

This study has simulated the Gigabit Passive Optical Network (GPON) access manner which provides a reliable long reach connection with high bandwidth. GPON is the superlative technology for large applications where various end-users require an emergent bandwidth. In this study, the application of Gigabit Passive optical network has been evaluated. By observing the tables and analyzing the eye diagrams it is found that at the fiber length of 20 km the system performs better by taking parameters as BER, quality factor, dispersion and optical power into accounts. The GPON Network is observe using a fixed fiber length of 5km and the performance is observed. From the simulation eye diagram, a bit error rate $<10^{-10}$ is achieved.

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