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Performance Evaluation of Bidirectional Hybrid PON using Common Carrier

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Abstract—*In this work, bidirectional hybrid Wavelength Division Multiplexing / Time Division Multiplexing Passive Optical Network (WDM / TDM PON) with the use of common carrier concept is proposed. With the use of a single Carrier for all the Optical Network Units (ONUs), the proposed designed system becomes simple and cost - effective. A continuous wave laser is used to generate the carrier signal at the central office (CO) and then this signal is remodulated for uplink transmission at the subscriber side. And hence, ONU becomes less complex and cheaper. Furthermore, the two different wavelengths are used for data transmission in both the directions. In this system, 1550 nm and 1310 nm are used for downstream and upstream data respectively. It is found that data is transmitted at 5Gbps and it is obtained up to 145 Km distance for 8 ONU' s with acceptable Q factor.*

Keywords: *Bit Error Rate, Common carrier, Data rate, Eye Height, Hybrid Passive optical networks, OLT, ONU.*

1. INTRODUCTION

The passive optical network (PON) is the mostly liked system to fulfil the ever-increasing bandwidth requirement from organizations or households. Till today, many PON architectures [1] have been offered. But hybrid PON' s are the hot areas of research in today's era. The PON's are the point to multipoint access networks in which no active elements are involved between source and destination. These PON' s contain Optical Line Terminal (OLT) which is to be connected to many Optical Networks Units (ONU' s). The OLT is in central office and the ONU' s are located at the user's locations which are some distance away from OLT. It basically involves two channels, one for the downstream data and another for the upstream data. In the downlink, the data is being transferred from the OLT through single fiber which are then received selectively by each ONU. In the uplink, the data is being transmitted from ONU' s to the OLT i.e. multiple ONU' s share a same medium of propagation for the transmission of information to OLT.

Since the number of users are increasing day by day so there is a need to deploy more and more number of ONUs. Therefore, it becomes necessary to upgrade the existing hybrid PON architecture.

1.1 Hybrid Passive Optical Networks (TWDM PON' s)

The PON's were accepted as the final system in the FTTH (Fiber - to - the - Home) market [5]. The Time - Division Multiplexing Passive Optical Network (TDM PON) for example ethernet PON (EPON) and Gigabit PON (GPON) are the most likely technologies for optical access networks. The WDM PON [6] supports several subscribers than TDM PON [7] and provides more security by using different wavelength channels for transmission of data. Therefore, it is known as the next generation option of FTTH, but components used in WDM system are costlier, which restricts the widely use of WDM PON [6] for practical uses. Therefore, a new network known as hybrid PON is inoculated which eliminates the disadvantages of both TDM PON as well as WDM PON. It combines the advantages of both WDM and TDM passive optical networks. Hence, the existing TDM PON [7] is upgraded to future WDM PON.

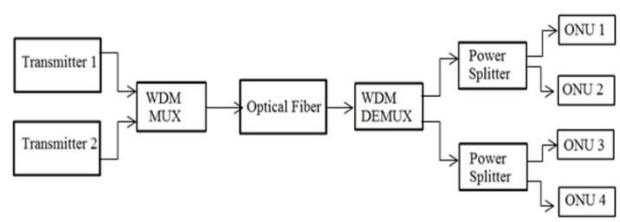

Figure 1: Block Diagram of Hybrid PON [2]

The hybrid PON architecture provides proper allocation of the bandwidth resources depending on the requirements of data traffic. This architecture not only employs the similar components in each ONU but it allows all ONU' s to share all of the wavelength resources.

The main objectives behind the hybrid PON [3] are:

(i) Fast transfer from the current TDM to future PON by incorporation of WDM technology
(ii) Proper utilization of bandwidth and
(iii) Supporting large number of ONU' s.

The components used for hybrid PON are shown in Fig. 1. It shows the downlink data transmission setup. In the proposed system, CO is occupied the OLT devices and an ONU device is being located at the user side. In Fig. 1, the OLT comprises two transmitters which are then multiplexed and sent over the optical fiber. Then with the use of demultiplexer and power splitter signal is sent to the users at ONU side.

2. SIMULATION SETUP

The simulation setup is designed and analyzed using Opti System version 14.2 software. Fig 4. shows the simulation setup designed in optisystem in which 2 sender systems at the OLT section are used with data rate of 5 x 10^9 and the data is sent over the separation of 145 km. In this proposed configuration, the 2 signals are sent over the fiber with different wavelengths as 1550nm and 1310nm. In each sender system contains Continuous Wave (CW) lasers and having power level of 0 dBm. The response of this system is modulated by using Mach Zehnder modulator. It involves Pseudo Random Bit Sequence (PRBS) with NRZ format.

The NRZ is that format which is the mostly liked data format for the transmission of data [2]. Then the two signals are combined with the use of WDM multiplexer and then the signal is launched through the optical fiber having a length of 145 km. The signal is then demultiplexed using WDM demux. The 1:8 power splitter is used to split the incoming signal to 8 several channels. Then these obtained signals of power splitter are reached to the subscribers at the ONU section. A PIN photo diode is used to change the optical signal into electrical signal. To view output signals like optical spectrums and eye diagrams etc., many output measuring equipments such as optical spectrum analyzer, BER analyzer and eye diagram analyzer have been used. Various eye diagrams are taken at different data rates and for different fiber lengths. The Q factor, BER values and eye height are then calculated so that we can verify the results.

Our study here is done for three cases.

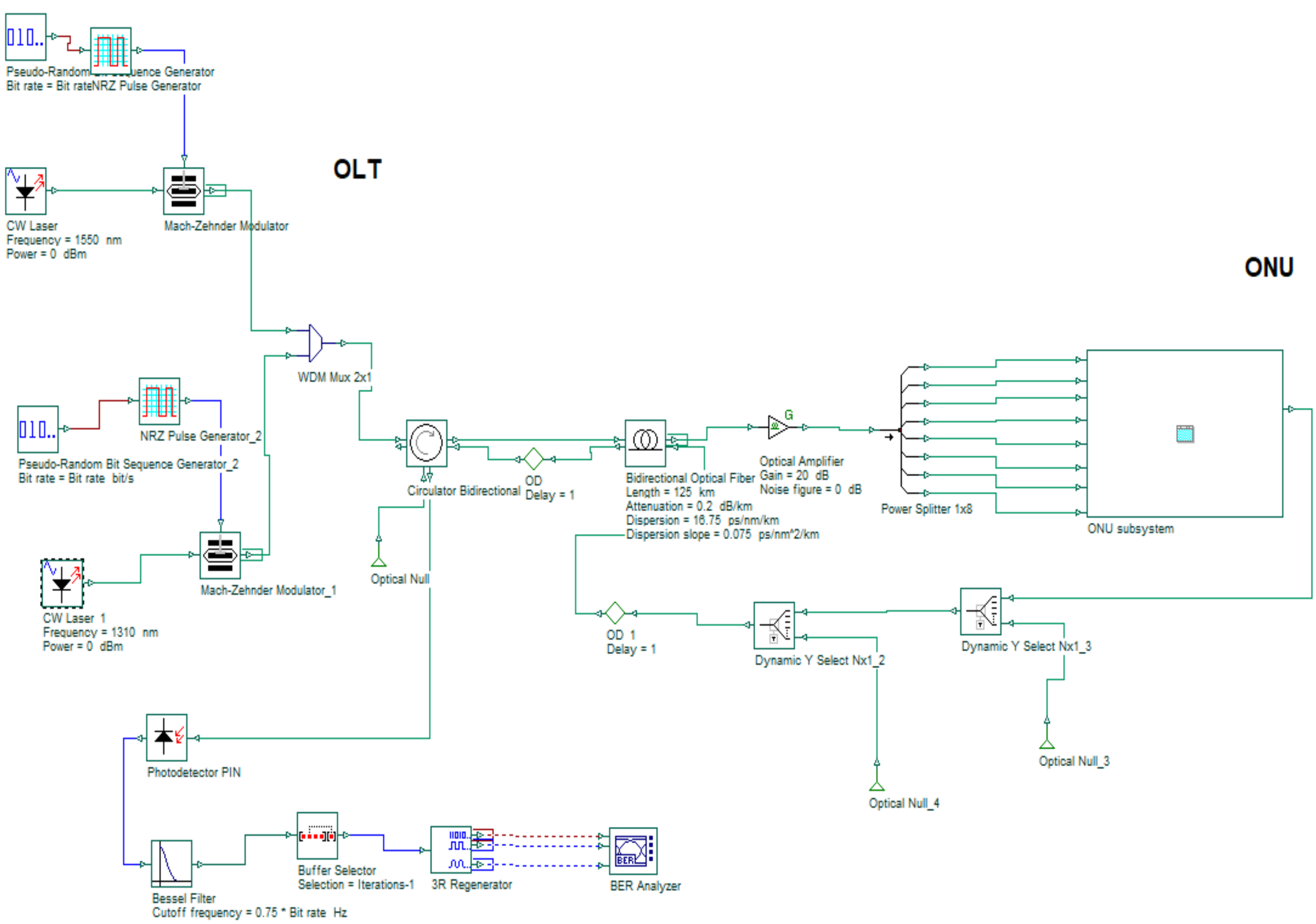

Figure 2: Simulation Setup for Hybrid WDM/TDM PON Architecture for 145 km Fiber Length in OptiSystem Software

Case (A), when the transmission distance is varied; the Q factor, Bit Error Rate values and eye height are calculated.

In case (B), the data rate is varied and then these parameters are compared.

In case (C), the input power levels of both the transmitters are increased at the OLT and then parameters are compared.

The Bit Error Rate, Q factor and eye height are the mostly employed output measuring terms in optical communication system.

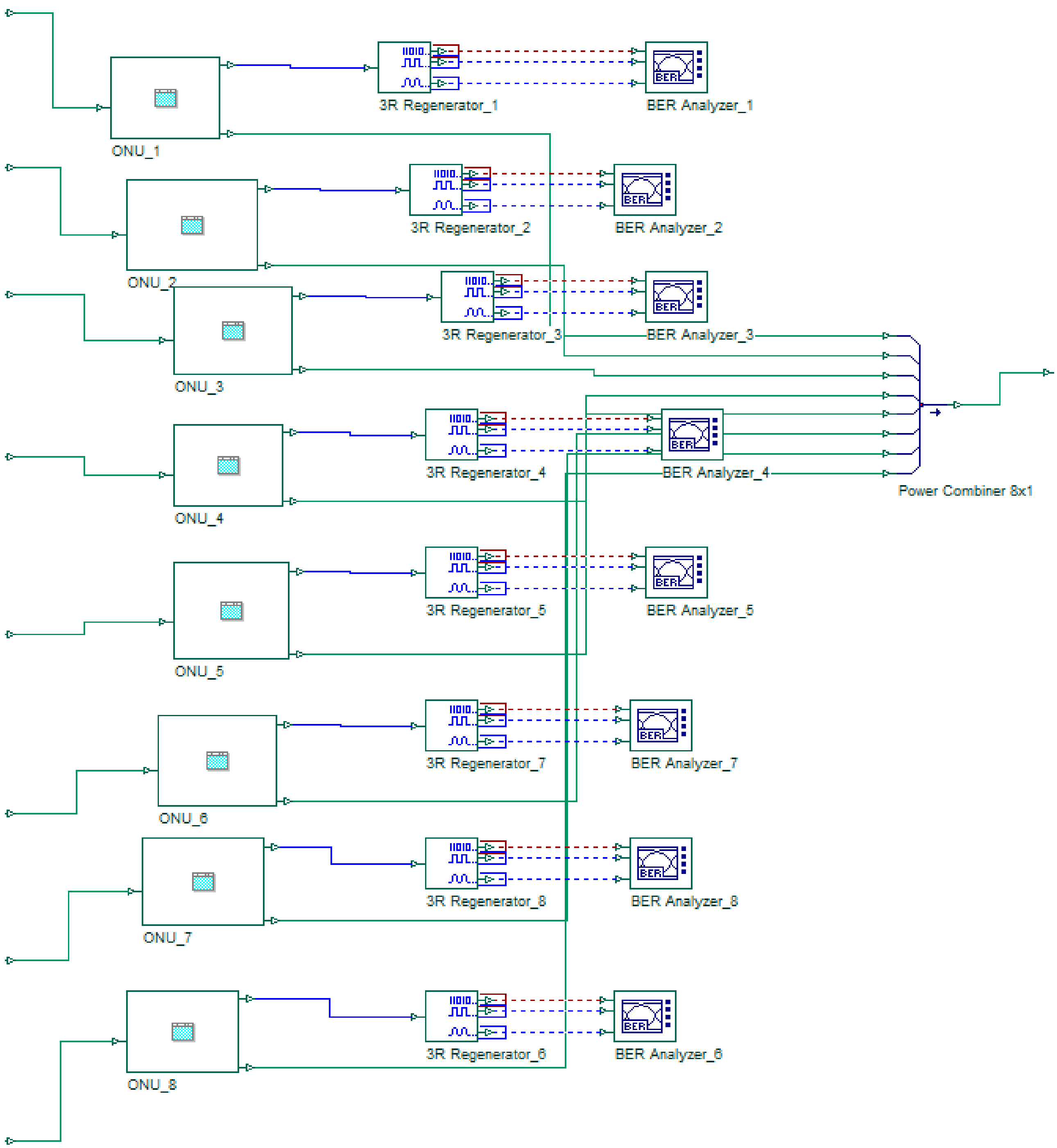

Figure 3: Simulation Setup of ONU subsystem

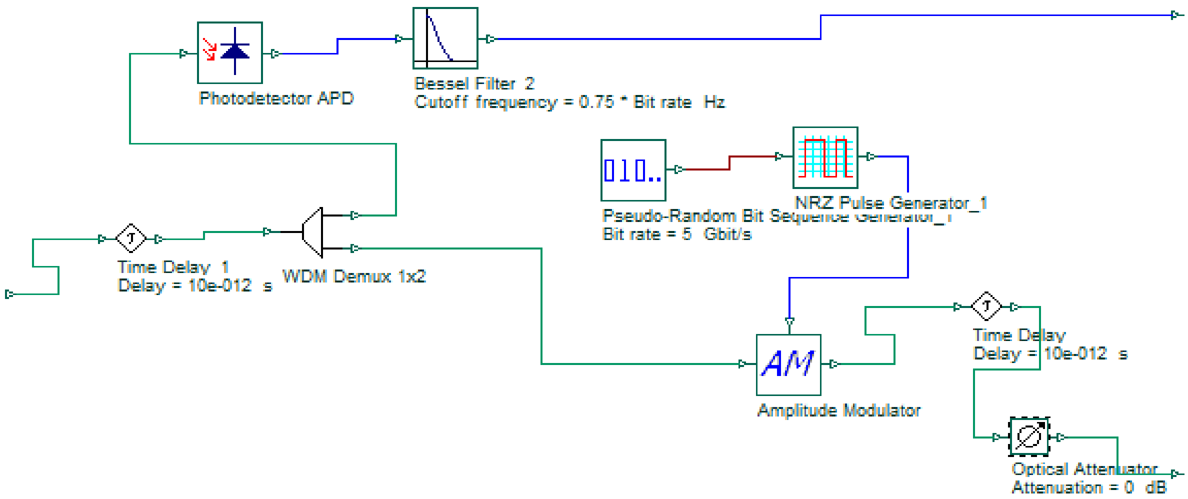

Figure 4: Internal Simulation Setup for ONU

(1) Q factor

The Q factor is defined as the term which is used to calculate the superiority of the input signal determine the BER. Usually, we use Q factor as a figure of merit.

The Q factor can be estimated from-

$$Q = \frac{m_1 - m_0}{\sigma_1 + \sigma_0} \qquad ...(1)$$

here m_1, m_0 are the mean values of output signal strength at different sampling intervals when a logical bit 1 or 0 is sent and σ_1, σ_0 are their respective values of standard deviations.

(2) Bit Error Rate

The Bit Error Rate can be pointed as the ratio of transmitted bits having error to the total count of bits accepted for data transmission. It is normally indicated by a power of ten in minus. The BER gives a warning to retransmit a data packet or other unit because of any error. By calculating the value of Q factor, the BER can be measured from following equation –

$$BER = \frac{1}{2}\text{erfc}\left(\frac{Q}{\sqrt{2}}\right) \qquad ...(2)$$

(3) Eye Height

If the eye highness is full – size, at that time it is advised as the best instant to make samples of output signal. Because of distortion in the amplitude of the signal, the height of eye becomes diminished. The amplitude of distortion can be pointed by the vertical separation among the opening of eye and the plenty of signal strength. This is much tedious to differentiate among 1's and 0's in the signal if the eye closure is more and more. The eye height can be calculated from

$$E_H = (m_1 - 3\sigma_1) - (m_0 + 3\sigma_0) \qquad ...(3)$$

3. RESULTS & DISCUSSION

The hybrid PON is analyzed using optisystem 14.2 software. The output obtained from analysis for the three cases are given below:

3.1 Distance is variable

It is observed from the figure 6 that when distance is increased from 80 km to 145 km for both uplink and downlink data, then Q – Factor decreased from 10 to 6 dB for downlink. However, for uplink data, Q – Factor decreases from 15.05 to 14.3 dB. For this, fiber length, data rate and power levels are fixed at 145 km, 5 Gbps and 0 dBm respectively for both uplink and downlink data transmission.

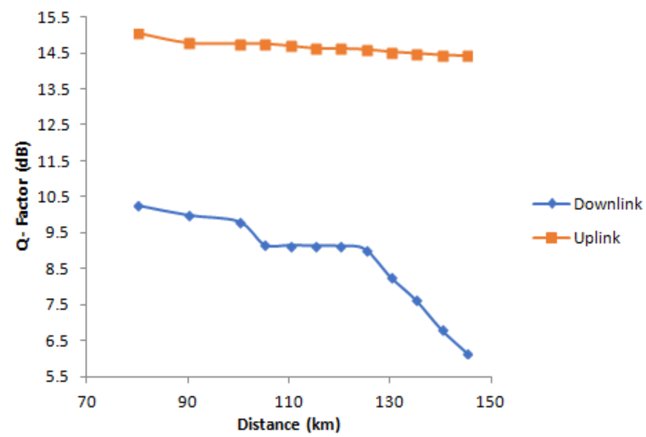

Figure 5: Q factor vs fiber length for uplink and downstream with 5Gbps data rate

3.2 Data rate is changed

It can be observed from the figure 7 that when data rate is raised, the Q factor drops. Due to which, the receiver is not able to detect the transmitted date correctly.

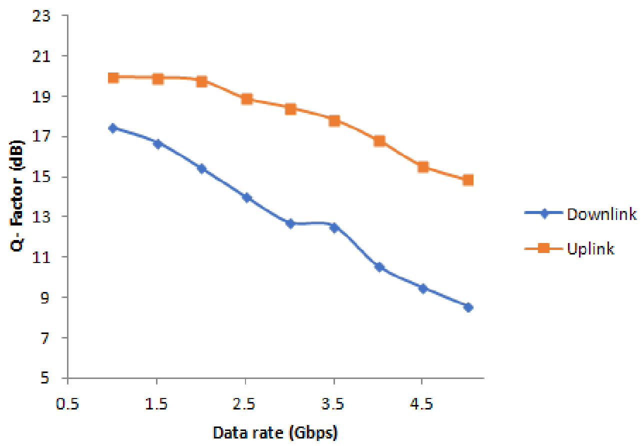

Figure 6: Q factor vs data rate for uplink and downlink at 125 km

3.3 Input power levels of both transmitters are increased

Figure 8 shows that when input power levels of both the transmitters are increased from 0 to 30 dBm, then Q – Factor for both uplink and downlink data is also increased. Q – factor for uplink is inclined from 19 to 34 dB and for downlink, it goes to 39 dB.

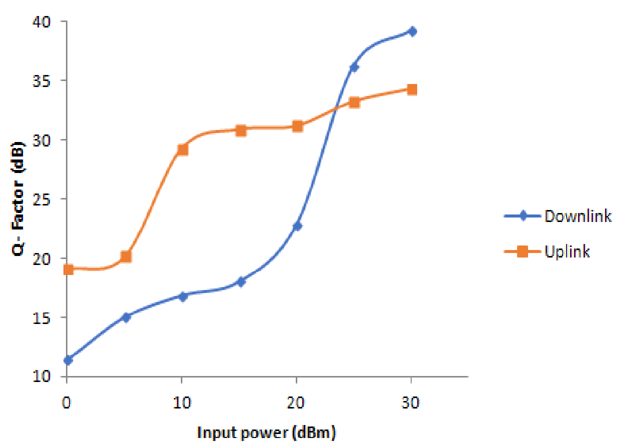

Figure 7: Q factor vs input power of 2 transmitters with 125 km

4. CONCLUSION

In this paper, bidirectional hybrid PON for 8 ONU' s using common carrier is investigated. In hybrid PON, the both of WDM and TDM techniques have been combined to optimize the bandwidth allocated to each user at ONU side. The users can also send the information signals of different wavelengths through the same fiber. We have investigated the performance of hybrid PON using common carrier concept and compared the various parameters for 3 different cases. With the use of common carrier technique, ONU becomes simple and cost – effective. The uplink and downlink data transmission with 5 Gbps rate is achieved for 8 ONU' s upto 145 km distance. It has been observed that with the increase of transmission distance, Q – Factor decreases. The same trend is followed for Q – Factor with the variation of data rate at 125 km. However, the Q – Factor rises when input power levels of both the transmitters are enhanced.

There is more reach for the further experimentation work to maximize the number of subscribers at ONU end, obtain longer transmission distances and simultaneously improving the performance of the PON architectures.

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