Analysis of Bidirectional Transmission WDM-EPON System with Optical Wireless Channel

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Abstract - **As communication systems advance, high bandwidth is required to send more data at higher speeds. Wavelength Division Multiplexing (WDM): Ethernet Passive Optical Network (EPON) is important because of its efficiency, higher bandwidth, low-cost passive connection, and reduced complexity of deployment and network maintenance. The implementation of radio over optical fiber in wireless communications has achieved high data rate and high capacity through the use of high-capacity optical fiber and the flexibility of the wireless network. Optical Wireless Channel (OWC) is the most popular free-space optical communication technology, which is a kind of high-speed and high-performance communication system. It uses infrared light to transmit the message from the sender to the receiver. OWC is the solution to the last mile problem, mainly in crowded urban areas. This article demonstrated the integration of OWC and WDM-EPON technology, making the system more advanced, low-cost, high-bandwidth, high-data-rate. The performance of the proposed embedded system was evaluated in different multi-parameter scenarios using OptiSystem 14 software. The analysis of the simulation results is based on the bit error rate (BER), the quality factor (Q-factor) and the obtained eye model for different scenarios. The system was tested with different power source values and analysed with different lengths and operating wavelengths.**

Keywords: BER, Eye patter, OWC, Q Factor, WDM-EPON.

I. INTRODUCTION

In the communication system there are multiple number of ways to communicate. Wireless communication requires flexible designhigh data rate, low cost and high bandwidth due to the gradual increase in the number of subscribers. With wireless communication, information can be transmitted over long distances without cables or wires. Subscribers need very high definition video on demand and the Internet with guaranteed high quality data delivery [1]. Therefore, a new technology is introduced to meet these needs. Optical communication is shifting from long optical fibers to high-performance wireless communication. Laser communications can carry information at data rates up to several Gbit/s and can span thousands of kilometers (Tiwari, Pushplata and Jaiswal, AK and Agrawal, Neelesh and Nitin, Navendu, July 2015). OWC communication is high-speed, high-capacity communication. It uses free space as a channel and laser light in the IR range as a carrier. Laser light can travel a long distance because it has a very narrow beam width. The RF wavelength is much longer than the optical wavelength, another reason to use OWC. Therefore, the beam width achievable with lasers is narrower than that of HF systems and can move without large losses (Tiwari, Pushplata & Jaiswal, AK & Agrawal, Neelesh & Nitin, Navendu, 2015) [2].

The advantages of OWC are that it uses a very small antenna size on the transmitter and receiver side and also can minimize the power used for the communication system and provide high data throughput. The most attractive advantage of OWC is its ability to use a large amount of free, unregulated licensed bandwidth and solve the "last mile" problem, mainly in congested urban areas. (Tiwari, Pushplata and Jaiswal, AK and Agrawal, Neelesh and Nitin, Navendu, July 2015) [1].

II. LITERATURE REVIEW

EPON is an emerging local subscriber access architecture that combines low-cost point-to-multipoint fiber optic infrastructure with Ethernet. EPONs are designed to transport Ethernet frames at standard Ethernet speeds. The WDM multiple access technique was introduced in (Kramer, Glen and Pesavento, Gerry, February 2002) [3]. (M. Maier, 2007) He explained the advantages of WDM-EPON and its development to support future applications and services efficiently and cost-effectively. EPON was introduced and is the most popular among the various PON technologies. The disadvantage of EPON is that it is not scalable in terms of bandwidth or the number of clients. To overcome the bandwidth and scalability problems of the EPON system, the WDM-EPON system is introduced (A.P. Singh, January 4-6, 2008) [4]. The need for higher bandwidth and faster network access has risen over the recent development in new applications and services mainly of multimedia applications. These what so ever won't be fully realized with conventional

single-channel EPON. Under these conditions, the implementation of WDM-EPON is the best solution for building convergent triple-play networks. (M.R. Radivojević and P.S. Matavulj, 2013) [5].

For future high-performance in-vehicle networks, distributed broadband access networks and to meet the growing demand for multimedia services with guaranteed quality of service (QoS), Wireless over fiber is emerging as one of the most promising technology that can combine the capacity of optical networks together with the mobility and flexibility of wireless networks. The advantages of fiber optics as a transmission medium, such as low loss, low weight, high bandwidth, small size and low cost, make it the most flexible solution to efficiently transmit radio signals to remote locations. It refers to a fiber optic link where the optical signal is modulated with radio frequency (RF) and transmitted through the fiber to the receiving end. At the receiving end, the RF signal is demodulated and transmitted to the appropriate wireless user (N.M.Nawawi, S.M. Idrus and A.Marwanto, 2008) [6]. An article (Mohammad Shaifur Rahman and Jung Hyun Lee, 2009) provides an overview of RoF technology. This documentation provides the guideline procedure for network design selection related to distance, reliability, and availability of network fibers. The authors proposed a comparative analysis of network topologies for radio-over-fiber networks. They provided results using different topologies in terms of network availability, reliability and fiber distance [7]. The combination of wireless and optical networks can provide a solution to increase capacity and mobility, reduce power consumption and reduce network access costs. Therefore, future broadband access networks based on radio-over-fiber technologies have emerged as a reasonable alternative solution in environments such as conference centers, airports, hotels, shopping malls and possibly shopping malls, homes and small offices. (J. Yu, G.K. Chang , A.M.J. Koonen and Georgios Ellinas, 2009) [8].

Mobile data traffic is growing rapidly to access a variety of services. And also its access methods are diversified into different types of antenna radio interface, 3.5G, 3.9G and 4G, commercial or residential WiFi. This trend requires more efficient use of radio spectrum and a reduction in cell size for heterogeneous wireless access. Then it becomes necessary to deploy a large number of base stations (BS) and deploy more efficient and flexible mobile backhaul networks over a wide area (T. Tashiro, February 2012) [9]. As a broadband and flexible ingress network, it was proposed on the WDM-EPON architecture. Wireless over Fiber and WDM-EPON have recently attracted a lot of attention because of their enormous bandwidth and scalability.

The integration of OWC technology and optical fiber makes the system more advanced, cost-effective, high-bandwidth and also with a high-baud rate. The integration of proposed system is to be simulated using Optisystem software and also an analysis is to be performed based on BER, the Q-factor and the received power from 4 users.

III. PROPOSED SYSTEM DESIGN

Fig. 1 shows the schematic bidirectional transmission of WDM-EPON system based on bidirectional optical fiber and OWC. One OLT distributed to 8 ONUs via 1x8 bidirectional passive optical splitter. To add more than one OLT; WDM MUX is used after transmitter and at receiver side WDM DEMUX is used. Downstream and upstream signals were separated using Optical circulator and optical delay was used to ensure the correct timing of circulation. To analyze the output 3R regenerators and BER analyzers are used at measurement blocks.
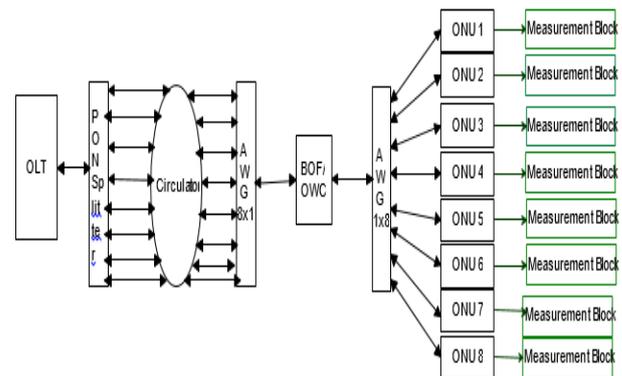

Figure 1: Network set up for WDM-EPON link based on BOF and OWC

This section briefly describes the simulation setup in OptiSystem, where all necessary parameters are based on EPON standardized properties. Figure 2 shows the schematic bidirectional transmission of WDM-EPON based on the OWC system. The data signal is constructed using a Pseudo-Random Binary Sequence Generator (PRBS) which generates a sequence of numbers to analyze the forward and reverse power of the signal. A train of non-return-to-zero pulses are generated by a non-return-to-zero (NRZ) pulse generator then data are encoded by a digital input signal. The laser is continuously pumped and emits light. The output of the NRZ pulse generator and the CW laser goes into the Mach-Zehnder Modulator (MZM) to convert an electrical signal into an optical signal. The optical signal is converted into an electrical signal using an avalanche photodiode (APD). The signal is then filtered using a Bessel low pass filter to regenerate the desired signal [3]. BER analyzer to analyze the data. In order to analyze the WDM-EPON system, three parameters (Q factor, BER, and eye height) were used.
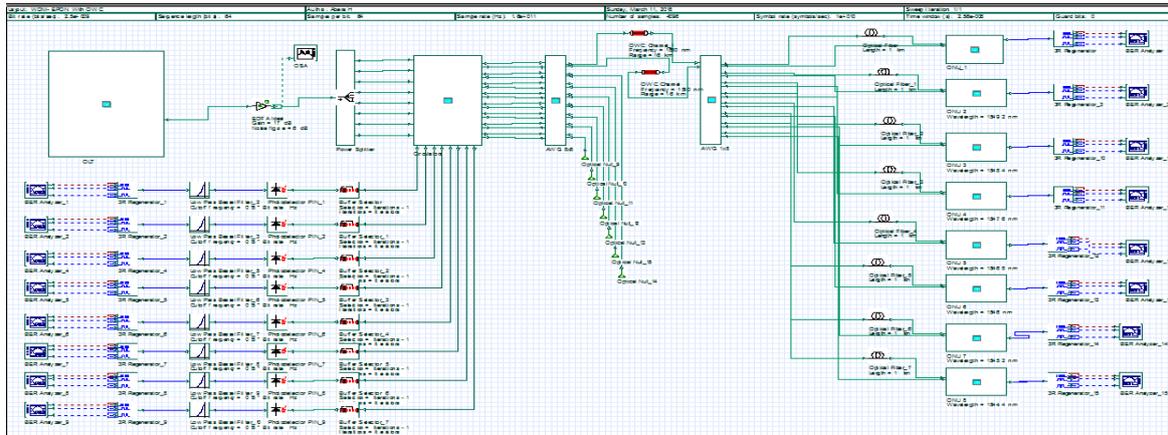
Figure 2: Simulation design of WDM-EPON with OWC

The parameters and their corresponding values adjusted the simulation purpose. All the design parameters were taken according to the IEEE 802.3 a standard.

IV. RESULT ANALYSIS AND DISCUSSION

4.1 Eye Diagrams

An appropriate way to measure the performance of the system is by using an eye diagram as shown in**Error! Reference source not found.** to figure 3. The eye opening clearly indicates that the system performance is good. The Q factor and BER performances of OWC for the different data rates are shown. The eye diagram output is taken by consider the bit rates of 2.5Gbps, 5Gbps and 10Gbps.In certain optical systems, the maximum value of Q factor for 2.5Gbps is higher than 5Gbps and 10Gbps and the minimum value of BER for 2.5Gbps is lower than 5Gbps and 10Gbps in case of both BOF and OWC. These, because of aye opening of 2.5 Gbps its performance are better than others.

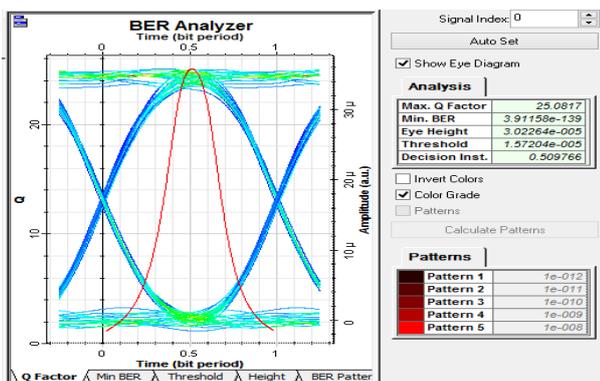### 4.2 Eye diagram of WDM-EPON with OWC

A) Data rate of 2.5Gbps

Figure 3: Eye diagram of Max Q Factor at 2.5Gbps 5 dBm, 50 km and 1550 nm OWC

B) Data rate of 5Gbps

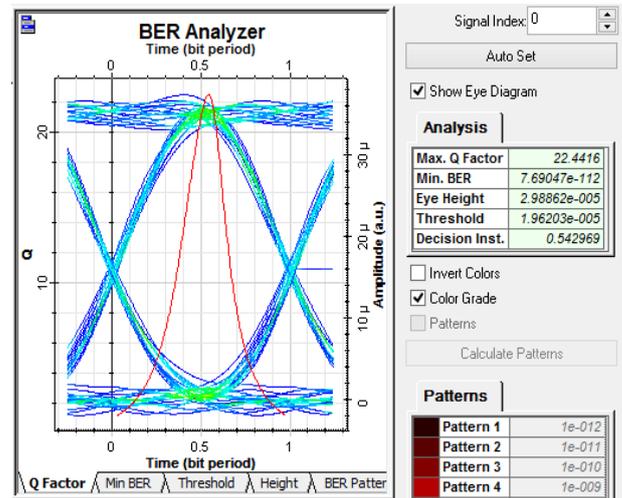**Figure 4: Eye diagram of Max Q Factor at 5Gbps, 5 dBm, 50 km and 1550 nm OWC**
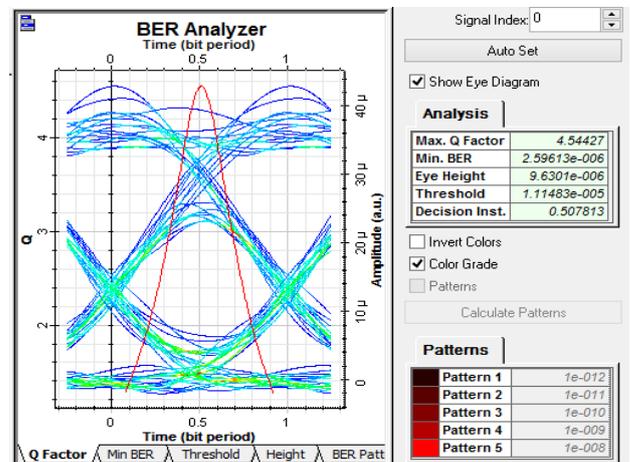
C) Data rate of 10Gbps

Figure 5: Eye diagram of Max Q Factor at 10Gbps, 5 dBm, 50 km and 1550 nm OWC

4.3 Q-Factor

In this section, a comparison is made between three different sets of bit rates which are 2.5Gbps, 5Gbps, and 10Gbps bit rates with the use of power and length. This comparison is made according to maximum Q factor.

4.4 Q-Factor of WDM-EPON with OWC

A) Variable Power

Table 2: Q Factor at 50 km OWC and variable power

Power (dBm)	Q-Factor (2.5Gbps)	Q-Factor (5Gbps)	Q-Factor (10Gbps)
0	11.0172	6.67948	3.21346
5	25.0817	18.2761	4.79369
10	71.798	48.9848	5.25715
15	120.949	63.4371	5.37226
20	131.472	72.0433	5.30778

Table 2 shows the power affects the performance of the system by taking random samples of OLT power. It has been observed that Q factor begin with 11.02 at 0dBm. By increasing the power t0 20dBm we get 131.47. This indicates that the power of fiber increased the Q factor values increased.
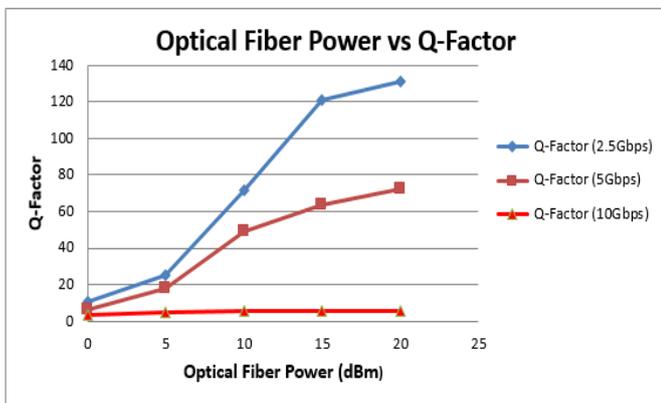

Figure 6: Max Q Factor at 50km, 1550nm with variable power for OWC

Figure 6 shows Q factor variable power range for 2.5Gbps, 5Gbps and 10Gbps bit rates. It has been observed that by increasing OLT power, Q Factor increased for all bit rates. We observed from the Q factor of 2.5Gbps is the best compared to 5Gbps and 10Gbps. Because of this 2.5Gbps bit rate has the best performance.

4.4 BER

The BER results are not clear in the graphs since the values obtained are very small. Therefore, the obtained results for the BER for both bidirectional optical fiber and OWC. In, both bidirectional optical fiber and OWC as the OLT power

increased the bite error rate decreased and the length increased the BER increases. That is because the dispersion increases as the optical fiber length increases. As can be seen in tables, which is the bit rates increases the BER increases. Therefore, as the bit rates increase, the performance of the system decreases.

4.5 BER of WDM-EPON with OWC

A) Variable Power

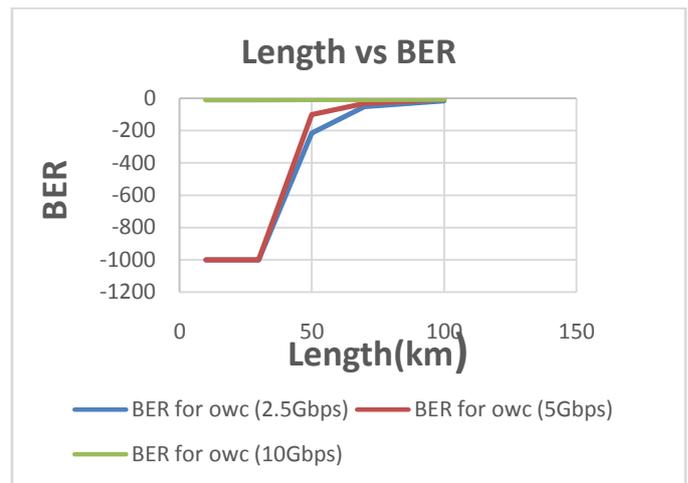**Figure 7: BER of OWC at 5dBm, 1550nm for Varied Power Values**

Figure 8: BER of OWC at 5dBm, 1550nm for Varied Length Values

V. CONCLUSION AND FUTURE WORK

WDM-EPON delivers greater distance capabilities, end-to-end transparency and ease of scalability. A totally separate downstream wavelength is given for each of the subscribers is the key advantage of WDM-EPON. To provide subscribers a

more bandwidth, better security and enhanced operational control, a separate wavelength is used.

WDM-EPON is very good choice for wireless internet user due to very high operating frequency, high data rate, and large bandwidth. From the above analysis the BER and Q-Factor depend upon data rate, power OLT, distance of OWC and operating frequency of ONU's. The system was analyzed using different power source values, length of fiber and operating wavelength for both downstream and upstream directions.

It has been found that, the more effective parameter in the performance was by increasing the power source of OLT in both downstream and upstream scenarios. It has also been found that OLT power source controls the upstream. In upstream changing length of fiber and operating wavelength situations, the results of BER and Q factor does not represent the correct behavior. As the distance between transmitters and receiver and data rate are increases the BER increases and Q-factor decreases.

The performance of received signal is very good up to 75km of OWC length. As the power increases BER decrease and Q Factor increase. It has been observed from simulation results that the use of OWC 2.5Gbps data rate gives a very high eye opening, maximum Q Factor and minimum BER, so, it is suggested to use OWC and 2.5Gbps data rate.

Further work may be initiated to increase the number of users, achieve longer distances and simultaneously improving the performance of the network.

- It is proposed to investigate the upstream problem in the future research.
- The design in this work can be upgraded to give better performance; data rate can be increased to increase the system efficiency.
- The number of ONUs can also be increased to 16 and 32 users.

Additional consideration to study the performance such as distortion, scattering and using different types of modulation can be taken.

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