Optical Networks for Optimized and cost effective Performance

Ankur Singhal, Vinay Bhatia, Abhishek Sharma

Abstract: ***Recently there is rapid increase of multimedia applications in the access networks. The focus of this paper is to suggest a novel system architecture that can provide efficient and cost effective solutions for the access networks. To offer economical solutions with higher bandwidth optical networks are designed with passive components. In the presented system, 512 subscribers can access information for aggregated system line rate of 80Gbps. Proposed frameworks are subjected to intensive investigation in terms of Modulation Format, External Modulator, Photo Detector so that system architectures perform at an optimized level. Also, the access network is designed without the use of reach extender devices like optical amplifier or repeater so that installation and the recurring cost are minimized.***

Index Terms: Access networks, Central office, Cost, Modulation formats, Optical networks,

1. INTRODUCTION

The rapid augmentation of broadband services offered on the Internet has resulted in increased bandwidth requirement from customers affecting both backbone networks as well as access networks.

Access networks also termed as last mile systems because they comprise the last section of a communication network with the connection from service provider Central office (CO) to residential and commercial customers. Transmission capacity requirements of residential subscribers have increased sharply for accessing multimedia services. Access networks are more sensitive to operational and infrastructural expenditure because it connects few customers in comparison with the backbone network. Backbone network has shown tremendous growth in system capacity but access network have not scaled up commensurately due to revenue dynamics. It has created bandwidth bottleneck between end users and service provider central office over the access network. The major factor contributing to recent research initiatives in the access networks is to upgrade existing network infrastructure at decreased investment and operating expenses. Along with increasing requirements of customers for higher transmission bandwidth with communication at wider network spans so as to connect subscribers located at far off places without any major additional infrastructure [1].Using passive components in the optical access networks minimizes the energy requirements and so operational expenditure is reduced [2]. Still, the capital expenditure of Passive Optical Access Networks (PONs) is a huge concern with vital facilities costing several thousand dollars. Infrastructural costs are a major challenge in meeting the huge end-user expectations for cheaper access to broadband multimedia streams [3]. It was observed that by distributing the system infrastructure among a large number of subscribers, the operative cost can be shared in a cost-effective fashion. By allocating the access system between more numbers of clients, it becomes easier and economical for service operators to repay the expenses incurred in installing the access systems. Most of the optical access architectures defined in the literature use optical amplifiers in diverse forms [4]. An optical amplifier alters the revenue dynamics of the access network by adding to the infrastructure and operational cost. Removing the use of reach extender devices without affecting the quality also helps in making the system cost-effective. For accomplishing the obligations of higher transmission capacity access networks hybrid WDM/TDM technology is believed as the best solution for cost-efficient subscriber shared infrastructure in optical passive access networks. Requirements of next generation access systems defined by various competent bodies worldwide include aggregated capacity of 128 Gbps to 500 Gbps with the support of up to 1024 ONUs, 40 Km or more extended reach using hybrid WDM/TDM technology [5].With these considerations for access networks in mind, literature is surveyed.

In literature, hybrid WDM/TDM access network by utilizing cost-effective components like reflective semiconductor optical amplifier (RSOA) and an Optical add-drop multiplexer (OADM) to communicate over two channels with a line rate of 1.25 Gbps and length of 25 Km were investigated in [6]. In [4], an optical access system for diverse modulation formats like NRZ, RZ and Manchester encoding were evaluated and observed that NRZ mechanism gives

Revised Manuscript Received on June 15, 2019.

Ankur Singhal, **Vinay Bhatia, Abhishek Sharma**, Electronics and Communication Engineering Department, Chandigarh Engineering College, Landran, Mohali

better results in comparison of other modulation formats. The designed network gives optimum results up to a span of 20 Km. Researchers in [7] analyzed RZ and NRZ modulation formats for next-generation passive optical systems with a line rate of 10 Gbps. Performance of WDM-PON architecture by employing Mach-Zehnder modulator (MZM) for transmission of bit streams with a data rate of 10 Gbps over 16 channels was examined in [8]. In [9], Optical signal is generated using Electro-Absorption Modulated (EAM) laser with a power of 0 dBm. Performance of Hybrid TDM/WDM 40 Gbps optical access system to fulfill higher capacity demands of next-generation subscribers was evaluated in [10]. Optical receivers are an important component in an access system, its performance was investigated in [11-12] and a comparative analysis of the system performance when PIN & APD photodiodes are employed at the optical receiver was done.

Various system parameters impact the performance of optical passive networks like the design of OLT and ONU along with a choice of components used and their design parameters. Most of the models were optimized in terms of any one of the parameters but a comprehensive investigation on each and every component and parameter is still not carried out. It is also observed that presented system architectures are limited in terms of users connected, aggregate transmission rate and network length. In the proposed novel system architecture, the work given in literature is pushed by testing the system in diverse configurations so that it can support 512 users with aggregated system rate of 120Gbps and enhanced coverage area of 80 Km without the help of any reach extender devices.

2. SYSTEM MODEL

The system model of hybrid WDM/TDM optical access system in 08×512 configuration is depicted in figure 1.

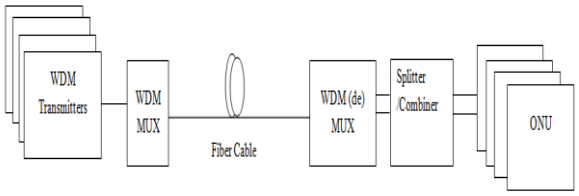


Figure 1: System Model of Hybrid WDM/TDM optical access network

In the presented system architecture, sixteen WDM transmitters are located at service provider Central Office (CO) to communicate with 512 users at varying data rate. Information generated is combined by WDM Multiplexer and transferred to subscriber Optical Network Units(ONUs) through optical fiber cable with a varying length of 50-130 Km. At receiver terminal, data signals are separated by WDM (de)multiplexer and sent to 512 ONUs using power splitters. Information is transmitted in the frequency range of 192.4 THz to 193.9 THz which are separated by 100 GHz frequency (0.8 nm). WDM Transmitter consists of an information source, electrical signal generator, Continuous Wave (CW) laser and the external modulator. At ONU, information signal received from optical splitter is fed to the photo-detector which is the primary component of receiver that converts the incoming optical signal to an electrical output which is further passed through a filter circuit before the signal being analyzed by various test equipment's. In the proposed framework, clients access information without utilizing any reach extender device like amplifier or repeater, thereby making the system economical.

The proposed system is examined using the common performance metrics such as Q Factor (Q.F.), Bit Error Rate (BER) and Eye Diagram. Q.F. can be determined from the mean values η_0 and η_1 and the standard deviations σ_0 and $\sigma_1$of the received information signal voltage levels 0 and 1respectively, as expressed in equation 4.1.

$$Q.F. = \frac{\eta 1 - \eta 0}{\sigma 1 + \sigma 0} \quad (4.1)$$

The BER can be expressed in terms of Q factor as per equation-II by using the decision-circuit method introduced in [47][133],

$$BER = \frac{1}{2} erfc\left(\frac{Q.F}{\sqrt{2}}\right) \quad (4.2)$$

3. RESULTS AND DISCUSSION

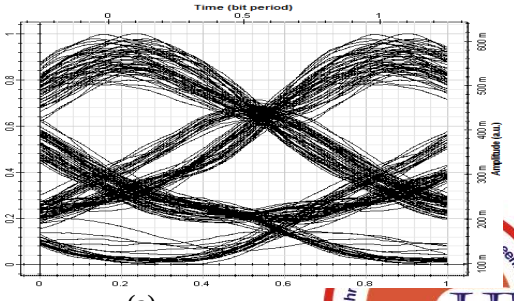
The optical access networks, is comprehensively investigated for various system configurations to find the optimum one that can satisfy the needs of Next Generation Access Networks (NGAN). The system architecture is tested with various possible components and parameters for comparative analysis and selecting an optimized configuration.

The system is analyzed for encoding format, NRZ and RZ data format is used. MZM and EAM modulator are examined to find the better external modulator. The system is evaluated for a variable transfer rate of 05Gbps and 10Gbps and network length from 50 Km to 120 Km. Hybrid access architecture is examined to find the better photo-detector. In the proposed system, a comparative evaluation is carried out to figure out a suitable detector for the system. The results of the analysis are presented so that an optimum configuration can be used for the access networks. Encoding scheme has a significant effect on the system performance. Initially, the system is evaluated in terms of encoding format for a line rate of 10Gbps at a distance of 50 Km as tabulated in table 1.

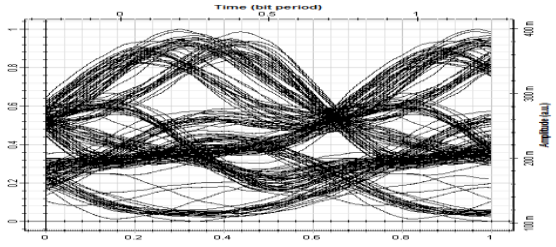
Table 1: Comparison of various encoding formats

Modulation Technique	Q.F. (dB)
NRZ	5.7266
RZ	4.789

It is evident from the table NRZ data format gives better Q.F. than RZ scheme. The results are verified by eye diagram analysis as shown below in figure 2.



(a)



(b)

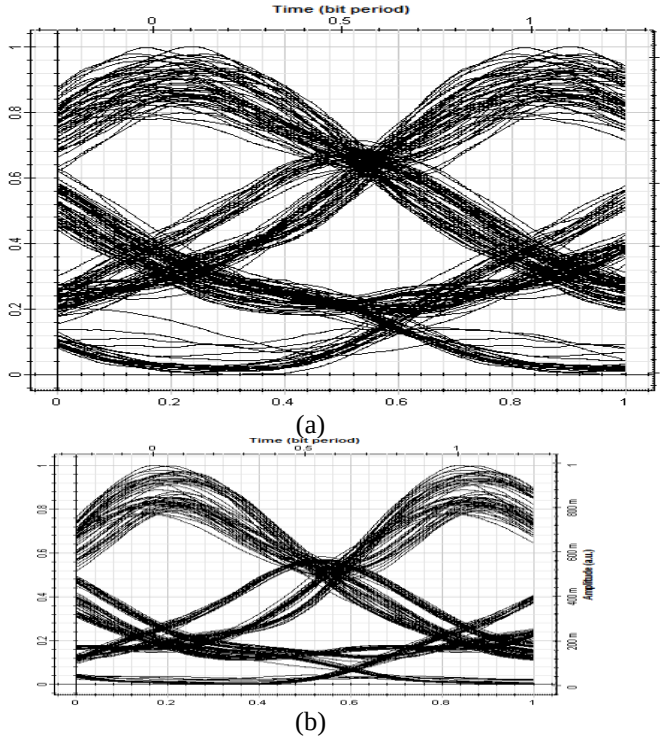
Figure 2: Eye Diagram of a system for (a) NRZ, (b) RZ encoding scheme

From the eye diagram examination done using figure 2, it is clear that eye-opening reduces when RZ encoding scheme is used and validates our observation that NRZ encoding scheme gives better results. The system is investigated for an external modulator, the two modulators possible as per literature are considered. Table 2 given below, depicts the values of Q.F. for diverse external modulators for transmission at a rate of 10Gbps for a network range of 50 Km. It is deduced from the table that the MZM modulator works better than the EAM as it gives a better quality factor for Mach-Zehnder Modulator.

Table 2: Comparison of various external modulators

Modulator	Q.F. (dB)
Mach Zehnder Modulator	5.7266
Electro Absorption	3.984

The observation is further verified using eye diagram analysis as shown below in figure 3. It is construed from the figure eye-opening is better for MZM modulator than EAM and validates our result.



(a)

(b)

Figure 3: Eye Diagram of a system (a) MZM, (b) EAM External Modulator

Further, the introduced framework for various optical-detectors is examined, and Q. F. is measured for a transmission rate of 15 Gbps. At receiver terminal, when the information signal is detected using APD photo-detector, the system gives a Q.F. of 5.7266. For the same distance of 50 Km, PIN photo-detector gives a Q.F. value of 5.0324 as depicted in table 3. It shows that the proposed architecture works better when the signal is detected with APD photo-detector.

Table 3: Q factor (dB) for various photo-detectors

Photo Diode	Q.F. (dB)
APD	5.7266
PIN	5.0324

The proposed system architecture performs well with NRZ encoding scheme when modulated through MZM modulator transmitted. Further, receiver terminal ONU designed with APD photo-detector gives optimum configuration. From the above analysis, it is clear that the system with a line rate of 10Gbps/channel and aggregate rate of 80Gbps can transmit for a maximum distance of around 50 Km with acceptable quality.

4. CONCLUSION

The presented system serves 512 users with full system rate of 80Gbps and transmits information signal over a distance of 50 Km without the use of the active device. By sharing the system infrastructure among 512 subscribers which may be remotely placed at a high rate without the use of additional resources, the installation and operational expenses are amortized in a cost-effective way. The system architecture performance is achieved without the use of reach extender devices like an amplifier and so the recurring cost is also reduced. The investigated hybrid system is an ideal choice for future access networks in comparison with the other system frameworks defined in the literature.

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Authors Profile

Prof.(Dr.) Ankur Singhal received his Ph.D in Electronics and Communication Engineering. Currently he is serving as Professor in Department of Electronics and Communication Engineering at CGC landran. He has authored about 55 research papers in various national/international conferences/journals. Currently he is working on access networks and network security.

Prof.(Dr.) Vinay Bhatia is a B.Tech, M.Tech, Ph.D in Electronics and Communication Engineering. Currently he is serving as Professor and Head, Department of Electronics and Communication Engineering at CGC landran. He has authored about 90 research papers in various national/international conferences/journals. Currently he is working on routing and security issues pertaining to wireless networks. His main research interests include mobile and ad hoc wireless networks, wireless mesh networks and wireless securities.

Prof.(Dr.) Abhishek Sharma received his Ph.D in Electronics and Communication Engineering. Currently he is serving as Associate Professor in Department of Electronics and Communication Engineering at CGC landran. He has authored about 23 research papers in various national/international conferences/journals. Currently he is working change detection algorithms in image processing.

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