Simulative Analysis for the Integration of STARGATE Network to Passive Optical Networks

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Abstract—The emergence of new bandwidth hungry applications and services impose the network upgrades of current time-division multiplexing passive optical network (TDM PONs) to their upgraded successor wavelength division multiplexing (WDM) PONs. Access network has to overcome the first/last mile bandwidth bottleneck between the high bandwidth demand at user end and high speed backbone network. Single hop WDM network based on central passive star coupler (PSC) have received a great deal of attention as promising solutions for metropolitan and local area networks which face increasing amount of traffic. This work explores the performance of a stargate network, a relatively new class of single hop network based on an Arrayed Waveguide Grating (AWG), which provide all-optical integration of Ethernet based wavelength division multiplexing passive optical networks (WDM EPONs) with metropolitan area networks. The simulation analysis revealed that the STARGATE network architecture is cost effective with minimum hop count between transmitting and receiving ends and wavelength reuses by exploiting multiple free spectral ranges (FSRs) of arrayed waveguide grating (AWG).The simulation has been performed using Optisystem V.12 software and results have been shown as eye diagrams and BER plots obtained at the receiver end.

Keywords— WDM, AWG, Optical Bypassing, Free Spectral Range, Passive Optical Networking

I. INTRODUCTION

STARGATE is a proposed network architecture which integrates to hybrid ring-star based metro network. The emergence of new bandwidth hungry applications and services impose the network upgrades of current time division multiplexing passive optical networks (TDM PONs) to their upgraded successor wavelength division multiplexing passive optical networks (WDM PONs).Access network has to overcome the first/last mile bandwidth bottleneck between the high bandwidth demand at user end and high speed backbone network. In current access networks like fiber to the home (FTTH) and fiber to the premises (FTTP),asynchronous transfer mode (ATM) and Ethernet based PONs are widely deployed because of their access length, smaller attenuation and high bandwidth. Current access network mainly consist of time division multiplexing (TDM) PONs with single upstream and downstream wavelength and the channel is shared by PON nodes by means of time division multiplexing. Due to increase in number of end users and the bandwidth demand, the current single channel TDM PONs need to be upgraded. WDM EPON provides a cautious upgrade with addition of different wavelength channels [1]. A WDM STARGATE network with optical by-passing for all optical communication through arrayed waveguide grating (AWG) and integration with WDM EPON access network is proposed as a current solution to the current first/last mile bandwidth bottleneck problem [2]. The STARGATE network provides a single hop communication between all optical network units (ONU) through star topology with AWG and passive star coupler (PSC) working parallel as central routers. So packet latency is reduced with a considerable amount while the throughput is increased.

II. STARGATE NETWORK

Resilent Packet Ring (RPR) is an optical dual-fiber bidirectional ring network where each fiber ring carries a single wavelength channel. Destination stripping in conjunction with shortest path routing is deployed to improve the spatial reuse of bandwidth. Each node is equipped with two fixed tuned transmitters and two fixed-tuned receivers, one for each fiber ring. Each node has separate (electrical) transit and station queues for either ring. Furthermore, RPR provides resilience against any single link or node failure. The proposed WDM upgrade approach, only a subset of RPR nodes need to be WDM upgraded and interconnected by a dark fiber star WDM sub network in a pay-as-you-grow manner according to given traffic demands and cost constraints, as opposed to conventional WDM-upgraded rings that require all RPR nodes to be WDM upgraded at the same time. Unlike WDM rings, the resultant hybrid ring-star network improves the resilience, spatial reuse, and bandwidth efficiency of RPR dramatically.

RPR can easily bridge to Ethernet networks such as EPON and may also span into metropolitan area networks (MANs) and wide area networks (WANs). This makes it possible to perform layer 2 switching from access networks far into backbone networks [3]. From an all-optical integration point of view, however, end-to-end optical islands of transparency are not feasible, and are expected to be of limited geographical coverage due to physical transmission impairments as well as other issues such as management, jurisdiction, and billing issues. As a matter of fact, islands of transparency with optical bypassing capability are key in MANs in order to support not only various legacy but also future services in an easy and cost-effective manner.

STARGATE network is proposed to all optically integrate Ethernet based access networks like EPONs to metro networks. STARGATE is based on three fundamental principles:

1) *Evolutionary downstream SDM upgrades :*

As the bandwidth demand from end users is increasing due to many new emerging multimedia applications and services, so it need to upgrade the existing access networks to provide enough bandwidth to each end user. Installation of long run multifiber cables cost almost same as cables containing single or few cables [4]. The standard IEEE 802.3ah supports not only point-to- multipoint (P2MP) topology but also a hybrid EPON topology consisting of point-to-point (P2P) links in conjunction with P2MP links. In STARGATE, a separate P2P or P2MP fiber link to connect OLT with subset of one or more ONUs for downstream direction is being deployed. Thus, STARGATE makes use of evolutionary downstream space-division multiplexing (SDM) upgrades of WDM/TDM EPONs.

2) Optical Bypassing :

The problem with using SDM in EPONs is the increased electro-optic port count at the OLT. To avoid this, STARGATE makes use of optical bypassing. Specifically, all wavelengths on the aforementioned additional P2P or P2MP downstream fiber link coming from the metro edge ring are not terminated at the OLT, thus avoiding the need for optical-electronic-optical (OEO) conversion and additional transceivers at the OLT. Note that OEO conversion usually represents the major part of today's optical networking infrastructure costs. Due to the small to moderate distances of STARGATE's access-metro networks, optical bypassing and the resultant transparency can easily be implemented, thereby avoiding OEO conversion and resulting in major cost savings.

In STARGATE network architecture, optical bypassing shown in Fig.1. is used to avoid optical-electronic-optical (OEO) conversion done in OLTs. The wavelength channels which are meant for all optical communication are directly routed to AWG after bypassing the OLT through a WDM coupler. This WDM coupler separates channels on the basis of wavelengths selection. Thus by avoiding the OEO conversion that are able to cut the cost and have achieved the passive all optical end to end communication. Through this optical bypassing we also achieve the single-hop communication between ONUs, so the packet latency is reduced by considerable amount.

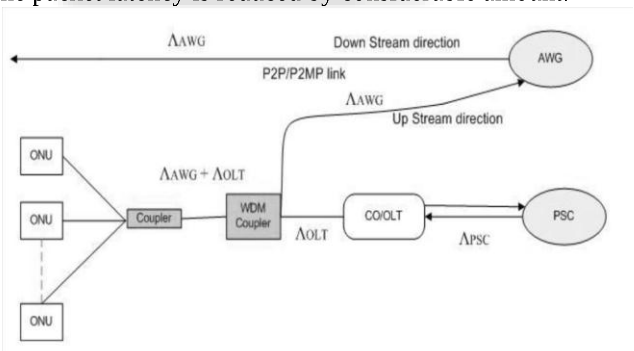

Fig. 1: Optical by-passing of OLT and central office.

3) Passive Optical Networking:

STARGATE uses AWG and PSC as wavelength channel routers to ensure the passivity of network. STARGATE is based on the idea of letting low-cost passive optical networking technologies follow low-cost Ethernet technologies from access networks into metro networks. STARGATE makes use of an a thermal (temperature-insensitive) arrayed waveguide grating wavelength router, which eliminates the need for temperature control and monitoring the wavelength shift of the AWG, and thus leads to simplified network management and reduced costs.

A. Architecture

STARGATE is a proposed network architecture which integrates to hybrid ring-star based metro network. The network architecture of STARGATE is shown in Fig 2. STARGATE consists of an RPR metro edge ring that interconnects multiple WDM EPON tree networks among each other as well as to the Internet and server farms.

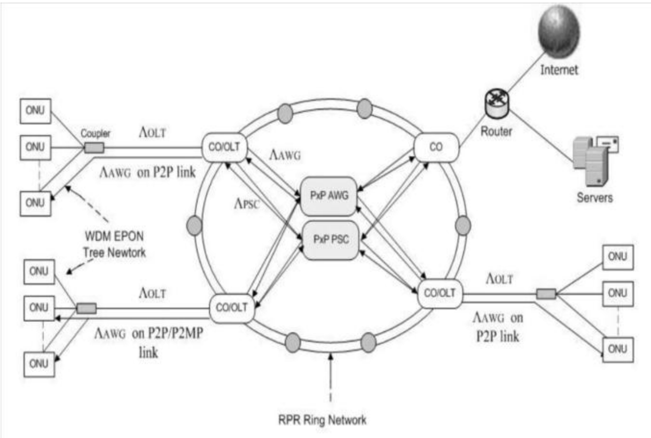

Fig. 2: STARGATE architecture

All The P (P is an arbitrary number) Central Offices (COs) are connected through single-hop WDM star sub network whose hub is based on wavelength-broadcasting P x P PSC in parallel with an a thermal wavelength-routing P x P AWG. Λ OLT denotes the number of wavelengths in upstream and downstream direction in WDM EPON. Λ AWG are wavelengths passing through the AWG router, while ΛPSC are wavelengths passing through the PSC router. Λ AWG wavelengths are bypassed from OLT and CO with WDM coupler and directly routed to AWG in upstream direction. In this way, optical bypassing to avoid O-E-O conversion has been achieved successfully. While in downstream direction Λ AWG wavelengths are carried through P2P or P2MP link from AWG to the subset of attached ONUs. The CO in the upper right corner of Fig.2. is assumed to be attached to the Internet and a number of servers through a common router. This CO is called hot-spot CO. This hot-spot CO communicate on any of the Λ AWG wavelengths, hence able to send and receive data all-optically through single-hop AWG based star network. In other words, the star forms a gate for all-optically interconnecting multiple WDM EPONs. Accordingly, the network is call STARGATE.

B. Significance of AWG

A conventional WDM metro star network is usually based on N x N PSC, which can be connected to only N nodes. This is due to the limitation of available ports and wavelengths. Since N x N coupler has splitting loss of 1/N so the number of ports cannot be increased beyond a specific number. Also in PSC based networks, one wavelength can be used for only one node [5]. AWG can be used as optical router to route a large number of wavelength channels with routing function performed on individual wavelengths [6]. The AWG allow us to reuse the wavelengths so that it can apply same wavelengths at different ports of AWG [7]. An AWG, a wavelength routing device that allows for spatial wavelength reuse. The AWG allows for spatial wavelength reuse at all ports. Fig.3. illustrates that all four wavelengths and an additional broadband signal can be applied at both combiners simultaneously without resulting in collisions at the splitter output ports.

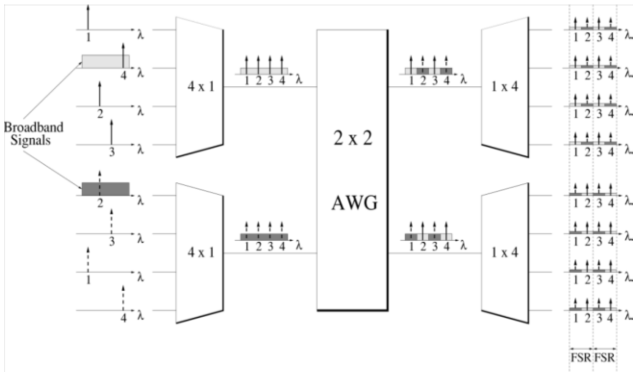

Fig. 3: Multicasting with spatial wavelength reuse.

Generally, with a AWG each wavelength can be spatially reused D x D times. Each FSR contains two wavelengths since AWG routes every second wavelength to same output port. Generally FSR of an AWG is the period of wavelength response and have D wavelengths in each FSR of a D x D AWG. In other words the degree of wavelengths is same as the number of wavelengths in each FSR [8]. Wavelength reusability is achieved by exploiting these FSRs. The AWG routes wavelengths such that no channel collision occurs at the AWG output ports. On one hand, for a given transceiver tuning range of R . D wavelengths, a small D implies that more FSRs R are used but also that a given multicast packet is received by more nodes attached to the corresponding splitter. On the other hand, a large increases spatial wavelength reuse, reduces the number of used FSRs R, and partitions a multicast into smaller subgroups [9].

III. SIMULATION DESIGN.

A. AWG-BASED STARGATE NETWORK

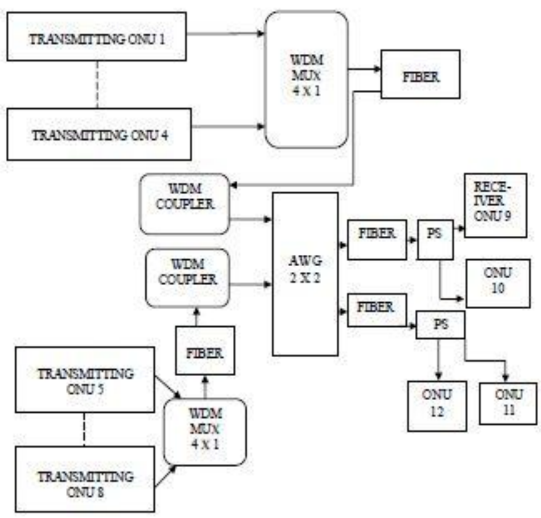

Fig. 4: Block diagram of AWG based STARGATE network.

The system consists of 8 transmitting ONUs. In transmitting ONUs of WDM EPON network, the 10 Gbps logical data signal is generated by using a Pseudo Random Bit Sequence (PRBS) generator. This logical data signal is converted into a NRZ electrical signal. The continuous wave laser with a peak optical power of 10 mW is externally modulated in accordance with this generated data signal by a Mach Zehnder modulator. Six wavelength channels have been used for 8 transmitting ONUs. The first four transmitting ONUs are multiplexed by a 4 x 1 WDM MUX and another four transmitting ONUs are multiplexed by a second 4 x 1 WDM MUX. Out of these 6 wavelengths 2 are ∧ AWG (1549.2 and 1550 nm) i.e. those pass through the AWG router. The wavelength channels which are meant for all optical communication are directly routed to AWG after bypassing the OLT through a WDM coupler. By using AWG, one can specially reuse the 2 wavelengths for 4 ONUs working on ∧ AWG. The simulation layout of AWG based STARGATE network is shown in Fig. 5.

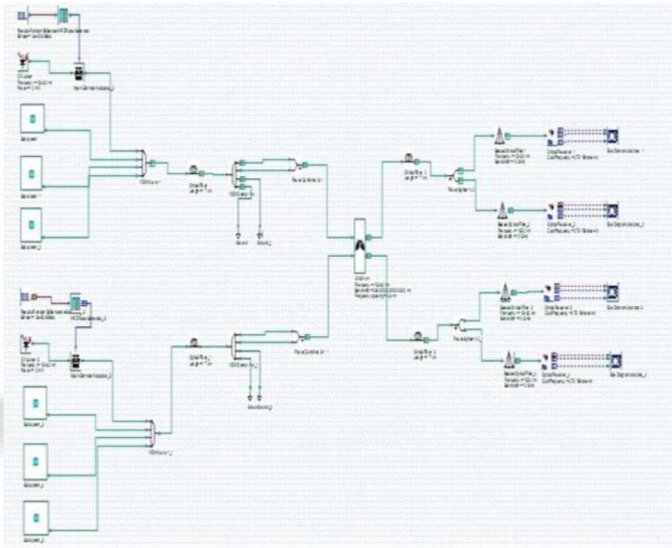

Fig. 5: Simulation layout of AWG based STARGATE network

B. PSC- BASED STARGATE NETWORK

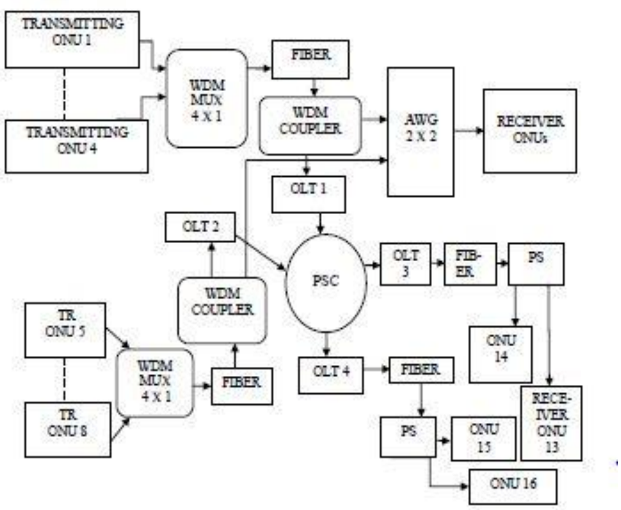

Fig. 6: Block diagram of PSC based STARGATE network

The system consists of 8 transmitting ONUs. Six wavelength channels have been used for 8 transmitting ONUs. The first four transmitting ONUs are multiplexed by a 4 x 1 WDM MUX and another four transmitting ONUs are multiplexed by a second 4 x 1 WDM MUX. Out of these 6 wavelengths 4 wavelengths are used by the 4 ONUs which are working on ∧ PSC (1551.6.1552.4, 1553.2,1554 nm). In this network architecture, the 4 OLTs which connects 8 ONUs both at transmitting and receiving ends. In Optical Line Terminal (OLT) of WDM EPON network, there is an array of fixed tuned transceiver operating on the wavelength channel in use. Each of these fixed- tuned transceiver is dedicated for single wavelength channel.

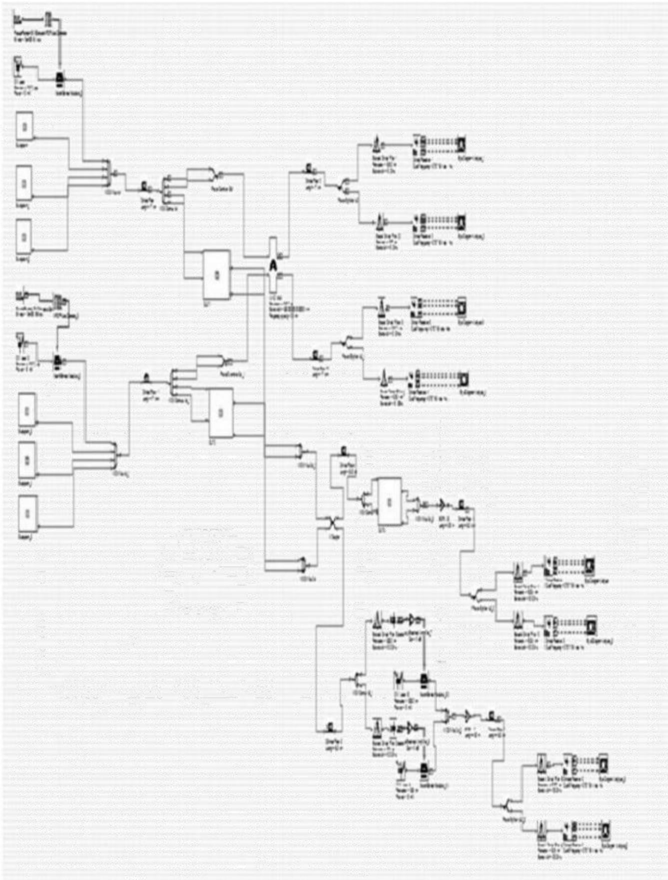

Fig. 7:Simulation layout of PSC based STARGATE network

IV. SIMULATION RESULTS AND ANALYSIS.

The AWG and PSC based STARGATE network architecture has been simulated in optical communication systems software Optisystem V.12. The results of the simulation are obtained with the help of visualization tools such as eye diagram analyzer or BER analyzer etc

A. *AWG-BASED STARGATE NETWORK*

The AWG based STARGATE network architecture has been simulated in optical communication systems software Optisystem V.12.The eye diagram of received signal at receiver ONU-9 is shown in Fig. 8.

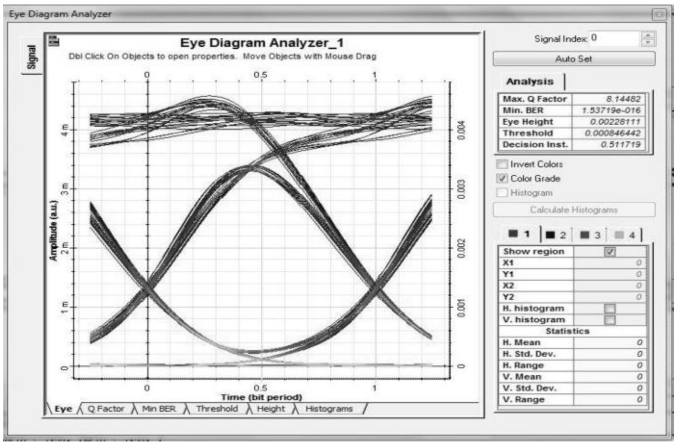

Fig. 8: Eye diagram at receiver ONU-9

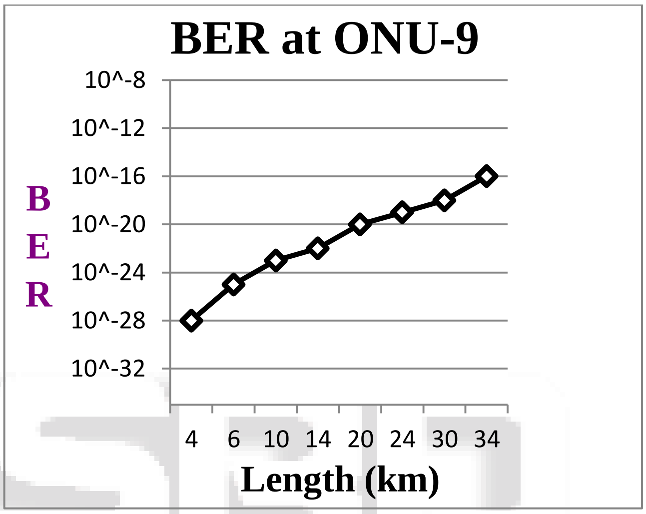

Fig. 9: BER plot t Receiver ONU-9

The BER plots shows the variation of BER function with transmission distance.L1 is distance from transmitter to AWG and L2 is the distance from AWG to receiver. The value of both L1 and L2 is 17 km each. So total transmission distance for network is 34 km. After this 34 km, a BER of 10^{-16} at ONU-9 have been attained, which is very much acceptable for communication systems. ONU-9 is one of the ONUs which are working on the ∧ AWG wavelengths, i.e., it is communicating all-optically to other ONUs in the network through AWG router. Note that there is no OEO conversion in the communication path of these ONUs and signal needs no amplification for at least 34 km. In Fig.8, the eye diagram obtained at ONU-9, the received peak-to-peak signal amplitude is 4 mV, which is low but acceptable one in communication system.

B. *PSC- BASED STARGATE NETWORK*

The PSC based STARGATE network architecture has been simulated in optical communication systems software Optisystem V.12.The eye diagram of received signal at receiver ONU-16 and BER plot of ONU-16 are shown in Fig. 10 and Fig.11 respectively.

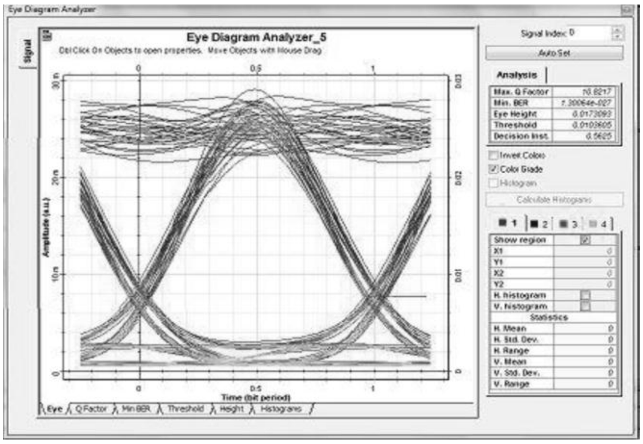

Fig. 10: Eye diagram at receiver ONU-16

Fig. 11: BER plot at receiver ONU-16

The BER plots shows the variation of BER function with transmission distance.L1 is distance from transmitter to PSC and L2 is the distance from PSC to receiver. The value of both L1 and L2 is 17 km each. So total transmission distance for network is 34 km. After this 34 km, a BER of 10^{-28} at ONU-16 have been attained. The ONU-16 is one of the ONUs which are working on the ^ PSC, i.e., signal coming to this ONU through PSC router has experienced OEO conversion and amplification through the post-amplifier installed in each Optical Line Terminal (OLT).So a BER value of 10^{-28} has been obtained, as shown in Fig.11, which is smaller as compared to one obtained at ONU-9 against same distance of 34 km. However, installation of optical amplifier in each OLT is required otherwise the received signal would have much higher BER value, which may not be suitable for any communication system. Similarly the high peak-to-peak signal amplitude of 23 mV at ONU-16 is because of signal amplification in the communication path.

V. CONCLUSION

The STARGATE is a proposed network architecture which allows all-optical integration of Ethernet based PON access networks to metro network. It provides low cost and pay as grow upgrades to existent WDM networks. The AWG and PSC based STARGATE network architecture has been thoroughly simulated. The performance of this system is then analysed. The BER for different distance based on AWG and PSC STARGATE network is analysed. A BER of 10^{-16} have been attained in AWG based STARGATE network and there is no O-E-O conversion in the communication path and also no needs of amplification for at least 34 km. However due to the installation of optical amplifier in each OLT, a BER of 10^{-28} have been obtained in PSC based STARGATE network and experienced OEO conversion and amplification through the post-amplifier installed in each Optical Line Terminal (OLT). It is observed that as the distance increases the BER also increases. The simulational analysis revealed that the STARGATE architecture is a simple and cost effective architecture with minimum hop count between transmitting and receiving ends.

REFERENCES

[1] Shahazad, A. Fayyaz, S.F. Shaukat, “Feasibility analyses of stargate network with integration to Ethernet based passive optical network”, Journal of faculty of engineering & technology, 2012.
[2] M. Maier, M. Herzog and M. Reisslein, “STARGATE: The next evolutionary step towards unleashing the potential of WDM EPONs”, IEEE Commun. Mag. vol. 45, no.5, May 2007, pp. 50-56.
[3] F. Davik et al., “IEEE 802.17 Resilient Packet Ring Tutorial,” IEEE Commun. Mag., vol. 42, no. 3, Mar. 2004, pp. 112–18. S25.
[4] H.-S.Yang, S. A. M. Kirmani, S. Shin, “A Metro WDM Star Network with a Hybrid MAC Protocol Based on an Arrayed Waveguide Grating”,JOSK,vol.11,no 2,june 2007,pp 59-62.
[5] G. Chaqin, S. Xiaohan and Z. Mingde, “WDM star single-hop network reusing wavelengths” Science in China (series F), June 2002,vol.45,no.3,pp 196-202.K.A McGreer, “Arrayed Waveguide Gratings for Wavelength Routing” IEEE Commun. Mag. December 1998,pp 62-68.
[6] P.E Green, “Fiber to the Home-The New Empowerment”, Wiley, 2006.
[7] W.-R. Chang, H.-T .Lin,S.-J .Hong, and C.-L .Lai, “A Novel WDM EPON Architecture with Wavelength Spatial Reuse in High-Speed Access Networks”, IEEE ICON 2007, pp 155-160.
[8] W.-R. Chang, H.-T .Lin,S.-J .Hong, and C.-L .Lai, “A Novel WDM EPON Architecture with Wavelength Spatial Reuse in High-Speed Access Networks”, IEEE ICON 2007, pp 155-160.
[9] M. Reisslein, M. Scheutzow and M. Maier, “The Arrayed-Waveguide Grating-Based Single-Hop WDM Nework: An Architecture for Efficient Multicasting,” IEEE Journal of selected areas in communications, vol. 21, no. 9, pp. 1414-1431, Nov. 2003.
[10] Lehan Meng, Chadi M. Assi, Martin Maier, and Ahmad R. Dhaini, “Resource Management in STARGATE – Based Ethernet Passive Optical Networks(SG-EPONs)”, Journal of optical communication network, Vol. 1, No. 4,SEP 2009.