Performance analysis & Optimization of WDM-EPON for Metropolitan Area Networking

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Abstract- In this paper, we introduce Bidirectional WDM-EPON for metropolitan area network for simultaneous transfer of Data and Video for replacing copper pair cable, with high data rate communication between CO (Central Office) and Subscriber End/ ONU (Optical Network Unit). We analyses the network with different data rate to minimize the problem of high attenuation, power loss, and improve the efficiency.

Index Terms- Digital video, passiveoptical network (PON), video overlay, wavelength-division multiplexing (WDM).

I. INTRODUCTION

In the era of high data rate communication there are various ways to communicate either Using the traditional communication system by coaxial cable, twisted pair cable or wirelessly. In early 70's a new communication technique was evolved incorporating optical fiber cable communication. Fibers are Silica glass fiber cables used to transmit data in optical domain with high speed and enormous bandwidth. There are several ways to transmit data using fiber cables which may be divided on the basis of ways of transmission of fiber communication system;direct communication optical fiber system and shared communication optical fiber system.

The simplest optical distribution network is called direct fiber. In this architecture, each fiber leaving the central office goes to one customer, but technique is very expensive when we are talking in terms of several customers. So the shared fiber techniques have been evolved where in the fiber leaving the central office is shared by many customers. It is not until such a fiber gets relatively close to the customers that it is split into individual customer-specific fibers. There are two competing optical distribution network architectures which achieve this split; active optical networks (AONs) and passive optical networks (PONs).

Passive optical networks (PONs) have been considered attractive due to their longevity, low operational costs, and huge bandwidth and are widely deployed in the first/last mile of today's operational access networks. PONs come in a number of flavours. The so-called asynchronous transfer mode (ATM) PON (APON) and broadband PON (BPON) are ATM-based systems. Gigabit PON (GPON), the successor of BPON, is able to support traffic other than ATM (e.g., telephony and Ethernet) in its native format by using time-division multiplexing (TDM) partitions and generic framing procedure (GFP) which are similar formats. Recently, Ethernet PONs (EPONs), standardized by the IEEE 802.3ah Ethernet in the First Mile (EFM) Task Force, have been attracting and considerable attention from both industry and academia has been given. EPONs aim at converging the low-cost equipment and simplicity of Ether-net and the low-cost fiber infrastructure of PONs. EPONs are evolved to be a promising solution to provide sufficient bandwidth for emerging services such as video conferencing, distributed gaming, IP telephony, and video on demand.

Current EPONs are single-channel systems; that is, the fiber infrastructure carries a single downstream wavelength channel and a single upstream wavelength channel, which are typically separated by means of coarse wavelength-division multiplexing (CWDM). In the upstream direction (from sub-scriber to network), the wavelength channel bandwidth is shared by the EPON nodes by means of TDM. In doing so, only one common type of single-channel transceiver is used network-wide, resulting in simplified network operation and maintenance. At present, single-channel TDM EPONs appear to be an attractive solution to provide more bandwidth in a cost-effective manner.
Given the steadily increasing number of users and band-width-hungry applications, current single-channel TDM EPONs are likely to be upgraded in order to satisfy the growing traffic demands in the future. Clearly, one approach is to increase the line rate of TDM EPONs. Note, however, that such an approach implies that all EPON nodes need to be upgraded by replacing the installed transceivers with higher-speed transceivers, resulting in a rather costly upgrade. Alter-natively, single-channel TDM EPONs may be upgraded by deploying multiple wavelength channels in the installed fiber infrastructure in the upstream and/or downstream directions, resulting in WDM EPONs. As opposed to the higher-speed TDM approach, WDM EPONs provide a cautious upgrade path in that wavelength channels can be added one at a time, each possibly operating at a different line rate. More important, only EPON nodes with higher traffic demands may be WDM upgraded by deploying multiple fixed-tuned and/or tuneable transceivers, while EPON nodes with lower traffic demands remain unaffected. Thus, using WDM enables network operators to upgrade single-channel TDM EPONs in a pay-as-you-grow manner where only a subset of EPON nodes may be upgraded gradually.

In this paper ourfocus is on how to communicate up to the nearest part of subscriber's home or work place, in a Metropolitan Area Network (MAN). Sharing of one fiber in optical communication system can be done by using WDM-PONs (Wavelength Division Multiplexing Passive Optical Networks).

II. WDM EPON ARCHITECTURE

2.1 Proposed Bidirectional WDM PON

Diverse services like Video-on-demand and multimedia broadcasting using minimum number of wavelengths have been incorporated in WDM PON increasing its utility to offer broadcasting services.The system proposed is developed and simulated for full duplex VoIP, data and digital broadcast Video signals over single mode fiber based on WDM PON as shown in figure 2.1.

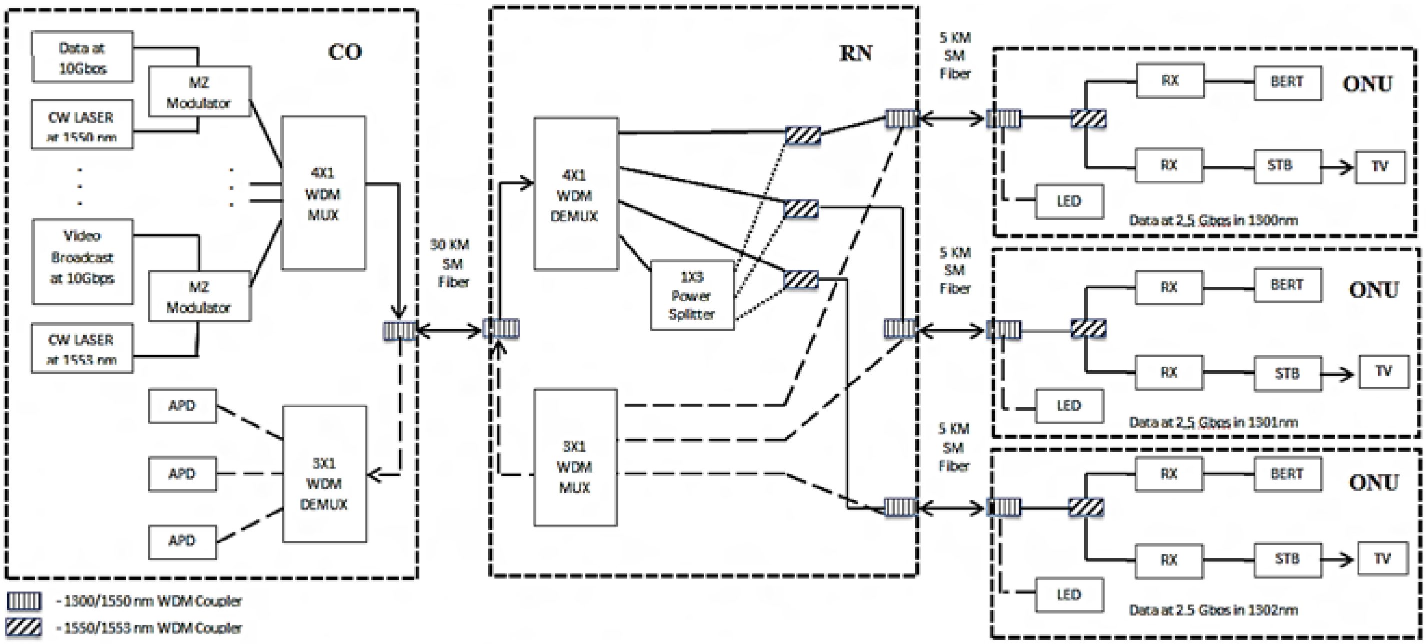

Figure 2.1: Proposed Bidirectional WDM PON Network. STB: Set Top Box

2.2Down Streaming of Data, VoIP and Video Signals

2.2.1 Operation at Central Office (CO)

For the downstream data transmission, four Continuous Wave (CW) lasers operating in the range of 1550 ~ 1553 nm at the central office (CO) are being used. The output power of threelasers(1550, 1551 and 1552 nm) was set to be 0 dBm and laser at 1553 nm was set to be 1 dBm. Three laser sources operating at 1550, 1551 & 1552 nm have been modulated at 10gbps, 5 gbps& 9gbps for data and laser source at 1553 nm is modulated at 10gbps for video signal. These are MZ Modulated in NRZ Format and then were multiplexed by using a 4X1 WDM Multiplexer. The modulated WDM channels passed through the 1.3/1.5 µm WDM couplers, which were used for the separation of upstream and downstream channels. For the digital broadcast video signal, a CW laser operating at 1553 nm (output power: 1dBm) have been used. This signal consisted of digital HD video channels from a bit sequence generator (operating in the range of 10 GHz). The root-mean-square (rms) optical modulation index (OMI) per channel was set to be 2.6%. The video signal was multiplexed with the 3 downstream data channels at the WGR and amplified by using an erbium-doped fiber amplifier (EDFA) (output power: 17 dBm). These multiplexed channels were transmitted to the remote node (RN) through 30 km of single-mode fiber (SMF).

2.2.2 Operation at Remote Node (RN)

At the RN, the downstream channels were separated into baseband data and video signal using a 1:4 WDM DEMUX. The video signal operating at 1553 nm was then split by using a 1X3 splitter and sent to three 2:1 WDM MUX input ports, so that it could be broadcasted to the 4 ONUs via 5 km of SMF. The baseband signals, delivered by three WDM channels operating in the range of 1550~1552 nm, were de-multiplexed by the WDM DEMUX and sent to each corresponding ONU. In order to minimise the work load of the central office we shifted the distribution system to the remote node for simplification of simulated optical network.

2.2.3 Operation at Optical Network Unit (ONU)

At the ONU, the video and baseband signals were directed to 1:2 WDM DEMUX and sent to corresponding p-i-n photo-diode (PIN-PD) receiver by the 1.3/1.5- µm WDM couplers. We used dedicated receiver to detect both the video and baseband signals when the data rate of the downstream data was 10Gb/s.

The output signal of the receiver was split, and sent to an error detector and a TV for the BER and video quality measurements, respectively. When the downstream data rate was 10 Gb/s, we separated the baseband and video signals using an additional 1550~1552/1553- nm WDM DEMUX and sent to two independent receivers.

2.3 Up Streaming of Data, Voice and Video Signals

For the upstream channels, a directly modulated LED operating at 1300~1302 nm at each ONU to transmit 2.5-Gb/s data has been used. The output power and 3-dB bandwidth of the LED were about 3 dBm, respectively. In this simulation, we operated the upstream channels only at 2.5 Gb/s due to the limited power budget. However, if necessary, it could be possible to increase the upstream data rate up to about 7.5 Gbps by using the high-power LEDs capable of operating at high speed. The upstream data were first coupled into the same fiber used for the downstream channels by using 1.3/1.5 µm WDM couplers, and then sent to the corresponding ports of the WDM MUX at the RN. Thus, the upstream channels were automatically spectrum-sliced and multiplexed by the WDM MUX at the RN. After transmission over 5 km of SMF, the multiplexed upstream channels were de-multiplexed by the WDM DEMUX at the CO. The de-multiplexed upstream channel was then detected by using the PIN photo-diode receiver via a 1.3/1.5 µm WDM coupler. In this network, identical transmitters were used at the entire ONUs since we used LEDs for the upstream transmission.

III. RESULT AND DISCUSSION

For this channel, the fiber length is set to be between 10 Km to 50 Km from CO to RN and 5Km will be added from RN to ONU. Value of Q-factors and signal power is taken and compared within the range of fiber length as shown in figure 3.1 and figure 3.2 respectively. The value of the Q-factor are decreasing when the length of the fiber is increasing same as the transmission signal power, it be will decrease as the length is increasing. The variation of OSNR with distance coverage as shown in figure 3.3 indicates that when the fiber reach 30 Km the quality of transmission is still good and gets deteriorated as the length is increased beyond 30 Km, but when it reaches40 Km to 50 Km, the performance of transmission is getting worst. It is further observed that when the length reaches 40 Km to 50 Km, its performance is worst and therefore an amplifier needs to be incorporated. The value of parameters e.g. Q-factor, signal power, noise power and OSNR for the specified length(0+5, 10+5, 20+5, 30+5, 40+5 and 50+5 Km), at different data rates are shown in Table No. 3.1, Table No. 3.2, Table No. 3.3 & Table No. 3.4.

Table 3.1: System Measurement at 10 Gb/s at 1550 nm for Data.

Length (Km)	Q-Factor	Signal Power (dBm)	Noise Power (dBm)	OSNR (dB)
0+5	4.21518	10.2810	-51.2647	51.5457
10+5	4.10117	8.19247	-49.2647	51.4572
20+5	4.33012	6.18614	-47.2647	51.4509
30+5	4.37036	4.16775	-45.2647	51.4325
40+5	4.38897	2.1423	-43.2647	51.4070
50+5	4.45080	0.13474	-41.2647	51.3995

Table 3.2: System Measurement at 5 Gb/s at 1551 nm for Data.

Length (Km)	Q-Factor	Signal Power (dBm)	Noise Power (dBm)	OSNR (dB)
0+5	5.54020	8.50604	-50.9485	49.4546
10+5	4.76874	6.37868	-48.9485	49.3272
20+5	5.1722	4.36422	-46.9485	49.3128
30+5	5.35873	2.34143	-44.9485	49.2900
40+5	5.51902	0.321221	-42.9485	49.2698
50+5	5.59244	-1.71130	-40.9485	49.2372

Table 3.3: System Measurement at 9 Gb/s at 1552 nm for Data.

Length (Km)	Q-Factor	Signal Power (dBm)	Noise Power (dBm)	OSNR (dB)
0+5	4.40331	7.76382	-50.7254	48.4892
10+5	4.14752	5.57348	-48.7254	48.2989
20+5	4.30115	3.54628	-46.7254	48.2717
30+5	4.13236	1.51757	-44.7254	48.2429
40+5	4.07893	-0.527713	-42.7254	48.1977
50+5	3.99816	-2.548160	-40.7254	48.1772

Table 3.4: System Measurement at 10 Gb/s at 1553 nm for Video.

Length (Km)	Q-Factor	Signal Power (dBm)	Noise Power (dBm)	OSNR (dB)
0+5	5.61559	6.91018	-55.2344	52.1446
10+5	5.56571	4.58242	-53.2344	51.8168
20+5	5.33704	1.92976	-51.2344	51.1642
30+5	4.96501	-0.934781	-49.2344	50.2996
40+5	5.03402	-3.74776	-47.2344	49.4866
50+5	5.78113	-6.14907	-45.2324	49.0853

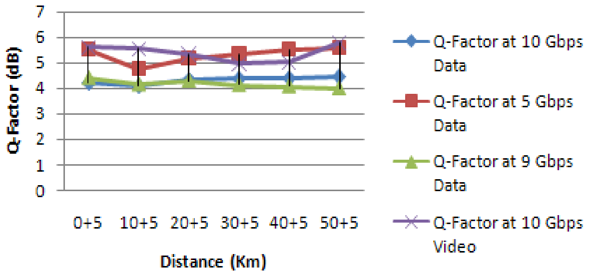

Figure3.1: GraphQ-Factor (dB) with Distance Variation

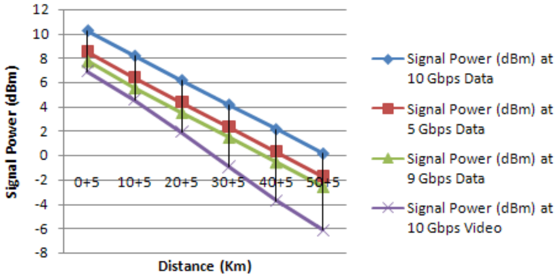

Figure 3.2: Graph Noise Power (dBm) with Distance Variation

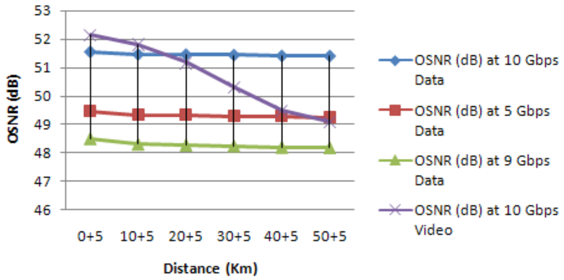

Figure 3.3: Graph OSNR (dB) with Distance Variation

IV. CONCLUSION

We have proposed and demonstrated a bidirectional PON for the simultaneous transmission of 4 WDM signals and HD digital broadcast video channels, up to35 km. This network could be implemented cost-effectively using a single strand of SM fiber for bidirectional transmission, LEDs for upstream WDM channels and one receiver for the detection of basebandsignals at 2.5 Gb/s. In addition, the capacity of the proposed network could be upgraded easily by incorporating an additional WDM coupler and a receiver at the ONU.

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