Enhancement of the Fiber Length and Subscribers in FTTH BPON Network using Optical Amplifier

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Abstract— In this paper, a transmission system for triple play (Voice, video and data) with centralized coarse wavelength division multiplexing fiber-to-the-home broadband passive optical network (CWDM-FTTH-BPON) based on an external modulator is demonstrated. At the one of arms of system, voice and internet data are transmitted using pseudo random binary sequence (PRBS) generator at bit rate of 1.25 Gbps and another arm of network, video is transmitted with the help of 16 QAM modulated CWDM signal. The 1.25 Gbps voice signal, 1.25 Gbps data signal and 0.8 Gbps video signal have been transmitted over 60 Km single mode fiber (SMF) successfully for 64 subscribers with the help of optical amplifier used before the optical fiber cable.

Key words: FTTH, BPON, CWDM, OLT, ONT, Optical Amplifier

I. INTRODUCTION

A. *Fiber-to-the-home (FTTH)*

The future generation technology needs to be compatible with today's bandwidth requirements and also offer bandwidth stretch to support future growth based on network expansion and new programs development. Since optical technology has proven to have large bandwidth competence, it appears to be the proper choice to solve the restricted access between backbone and access networks. Fiber-to-the-home refers to a broadband telecommunication system based on fiber optic cables and associated optical electronics for release of multiple advanced services such as telephone, broadband internet and television to houses and businesses [1]. This advance communication medium will be provided by optical fiber systems to residential communities and commercial developments by partnering with multiple service providers. It is an idea of bringing high speed networking i.e. high speed internet, digital TV and telephone service to residences using fiber optic cables. It is a broadband telecommunication system which is based on fiber optic cables and associated optical electronics for delivery of multiple advanced services to homes and businesses. FTTH is relatively new and fast growing method of providing very higher bandwidth to consumers and also for businesses and thereby enabling more robust any kind of services [2]. Figure 1 represents the simple optical distribution network in which many services are provided by FTTH network. Thus several fiber-to-the-home (FTTH) or fiber-to-the-premises (FTTP) networks have been proposed to provide broadband services to the end user. FTTH is simply the 100% deployment of optical fiber in the access network. Several architectures have been proposed of time division multiplexing PON (TDMPON) provides broadband PON (BPON) with downstream of 622 Mbps, Ethernet PON with 1.25 Gbps downstream [7,8].

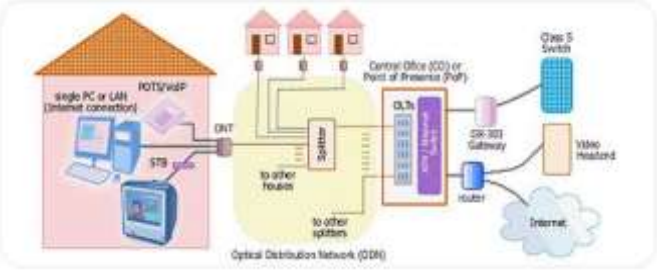

Fig. 1: Simple optical distribution network

Thus several fiber-to-the-home (FTTH) or fibers-to-the- premises (FTTP) networks have been proposed to provide broadband services to the end user. FTTH is simply the 100% deployment of optical fiber in the access network. Several architectures have been proposed of time division multiplexing PON (TDMPON) provides broadband PON (BPON) with downstream of 622 Mbps, Ethernet PON with 1.25 Gbps downstream. Gigabit-capable passive optical network (GPON) is the basic technology to support the structure of the next generation FTTH system. BPON is regarded as one of the best choices for broadband access network in the present. Kocher Dental, (2013) in her paper proposed network link design for 32 subscribers at 15 Km reach at 1.25 Gbps bit rate. But this simulation work reports BER of 1e-040 at 1.25 Gbps systems for the case of 64 subscribers at the 60 Km length of fiber.

B. *Broadband passive optical network (BPON)*

The basic principle of PON is to share the central optical line terminal (OLT) and the feeder fiber over as many optical network units (ONUs) as is practical given cost effective optics. Since each ONU represents in some sense a customer or group of customers, this sharing helps to diminish the amount of network capital expense supported by each customer. This enables broadband fiber access in scenarios that up to now were unprofitable for traditional point-to-point or ring-based fiber architectures. A passive optical network (PON) is a point-to-multipoint, fiber to the premises network architecture in which unpowered optical splitters are used to enable a single optical fiber to serve multiple premises, typically 32-64 [5]. A PON configuration reduces the amount of fiber and central office equipment required compared with point to point architectures. The physical infrastructure of the B-PON uses a single fiber PON in most implementations.

C. *Coarse Wavelength Division Multiplexing*

Wavelength division multiplexing is a technique, which uses a special property of optical fiber. This property allows the combination of multiple signals onto a single strand of optical fiber.

Each signal is assigned to a differ wavelength of light. Since one wavelength does not affect another wavelength, the signals do not interfere. CWDMs perform two functions. First, CWDMs filter the light, ensuring only

the desired wavelengths is used. Second, they multiplex or demultiplex several wavelengths, which are used on a single fiber link. The difference lies in the wavelengths, which are used. In CWDM space, the 1310-band and the 1550-band are divided into smaller bands, each only 20 nm wide. In the multiplex operation, the several wavelength bands are combined onto a single fiber. In a demultiplex operation, the several wavelength bands are separated from a single fiber.

II. COMPONENTS OF BPON FTTH ACCESS NETWORK

A passive optical network (PON) is a point-to-multipoint, shared optical fiber to the premises network architecture in which unpowered optical splitters are used to enable a single optical fiber to serve multiple premises, typically 32-64. Passive optical networks are typically passive, in the sense that they employ a simple passive optical splitter and combiner for data transport. A PON takes advantage of wavelength division multiplexing (WDM) using one wavelength for downstream traffic and another for upstream traffic on a single non-zero dispersion shifted fiber (ITU-T G.652).

A. Optical Line Terminal (OLT)

The optical line terminal (OLT) is the main element of the network and it is usually placed in the local exchange and it's the engine that drives FTTH system. The most important functions that OLT perform are traffic scheduling, buffer control and bandwidth allocation. OLTs typically operate using redundant DC power (-48 VDC) and have at least one line card for incoming internet, one system card for on-board configuration, and one to many BPON cards. Each BPON card consists of a number of BPON ports.

B. Optical Splitter

The optical splitter splits the power of the signal that is each link (Fiber) entering the splitter may be split into a given number of fibers leaving the splitter and there is usually three or more levels of fibers corresponding to two or more levels of splitters. This enables sharing of each fiber by many users. Due to power splitting the signal gets attenuated but its structure and properties remain the same. The passive optical splitter need to have the following characteristics:

- broad operating wavelength range
- low insertion loss and uniformity in any condition
- minimal dimensions
- high reliability
- support network survivability and protection policy

C. Optical Network Terminal (ONT)

Optical network terminals (ONTs) are deployed at customer's premises. ONTs are connected to the OLT by means of optical fiber and no active elements are present in the link.

In BPON the transceiver in the ONT is the physical connection between the customer premises and the central office OLT. WDM triplexer module separates the three wavelengths 1310 nm, 1490 nm and 1550 nm (For CATV service). ONT receives data at 1490 nm and sends burst traffic at 1310 nm. Analogue video at 1550 nm is received. Media access controller (MAC) controls the upstream burst mode traffic in an orderly manner and ensures that no collision occurs due to upstream data transmission from different homes. They are fiber to copper media converters that offer RJ11, RJ45, and F-Series connectors to any device. These devices are available in many configurations and port densities up to 24 ports. ONTs [3] are available for outdoor and indoor use provide POE or no POE, 10/100/1000, AES encryption, and can include batteries for survivability in the event of a power outage. BPON uses dynamic bandwidth allocation that is it dynamically allocates the bandwidth depending on the number of packets available in the T-CONT. Once the OLT reads the number of packets waiting in T-CONT it assigns the bandwidth. If there are no packets waiting in the T-CONT, then OLT assigns the bandwidth to other T-CONT which have packets waiting in T-CONT. If an ONT has a long queue OLT can assign multiple T-CONTS to that ONT.

D. Optical Amplifier

Optical amplifiers are used extensively in fiber optic data links. Optical amplifiers can be used to enhance the performance of optical data links. A booster amplifier is used to increase the optical output of an optical transmitter just before the signal enters an optical fiber. The optical signal is attenuated as it travels in the optical fiber. An inline amplifier is used to restore (Regenerate) the optical signal to its original power level. An optical pre-amplifier is used at the end of the optical fiber link in order to increase the sensitivity of an optical receiver.

III. OPTSIM SIMULATION

OptSim can be used to design optical communication systems and simulate them to determine their performance given various component parameters. OptSim is designed to combine the greatest accuracy and modeling power with ease of use on both Windows and UNIX platforms.

Design and deployment activities for FTTH (Fiber-to-the-home) and FTTP (Fiber-to-the-premises) access networks are on the rise in order to support the increasing demands and delivery of new multimedia services to the customer premises such as interactive video, voice and high-speed internet.

There are many types of FTTH technologies: the most popular one is based on the concept of using a passive fiber distribution network known as a passive optical network (PON) [5]. FTTH employing PON access architecture is the accepted choice of delivery channel for triple-play services (Voice, video and data) from service providers to the home and business users. Three major PON technologies are currently under consideration as the basis for FTTH deployments.

Broadband PON (BPON), Gigabit PON (GPON) and Ethernet PON (EPON). Broadband PON is the most mature and widely used among them to the date. BPON is a set of standards that specify the service capabilities and network protocols for broadband services over fiber access. In a PON the active optoelectronics are situated on either ends of the passive network. An optical line termination (OLT) device is installed in the central office (CO), and an optical network termination (ONT) device is installed on the other end, in or near each house or business site. Fiber distribution is completed using a tree and branch architecture. A single fiber connected to the OLT can be split up to 64 times and connected to multiple ONTs.

Current simulation models a typical BPON FTTH design with 64 subscribers and 60 Km reach as shown in figure 2. The Central Office is connected through a 60 Km standard single mode fiber to the first remote node with a 1:4 splitter. Each of the four outputs goes through another 4.5 Km fiber and then enters the remote node a with 1:8 splitter. Outputs from the 1:8 splitters are connected to eight end-users at the ONT though drop-off cables of length varying from 100 to 900 feet. An optical amplifier is inserted before the optical fiber to increases the length of the optical fiber cable from 15 Km to 60 Km. The triple-play service is realized as a combination of data, voice and video signals. To optimize the bandwidth in BPON the transmission through the optical fiber path employs the CWDM technique with data and voice component transmitted at wavelengths in the range of 1480-1500 nm and video within the 1550-1560 nm range. The high-speed internet component is represented by a data link with 1.25 Gbps downstream bandwidth. The voice component can be represented as VOIP service (Voice over IP, packet-switched protocol), which is gaining popularity as an alternative to traditional PSTN (Public switched telephone network) with POTS (Plain old telephone service) at the customer end. Figure 3 shows the signal spectrum output from OLT with data, voice signal at 1500 nm and video signal at 1550 nm. For video transmission, system is composed of three main blocks CWDM transmitter, optical path and CWDM receiver.

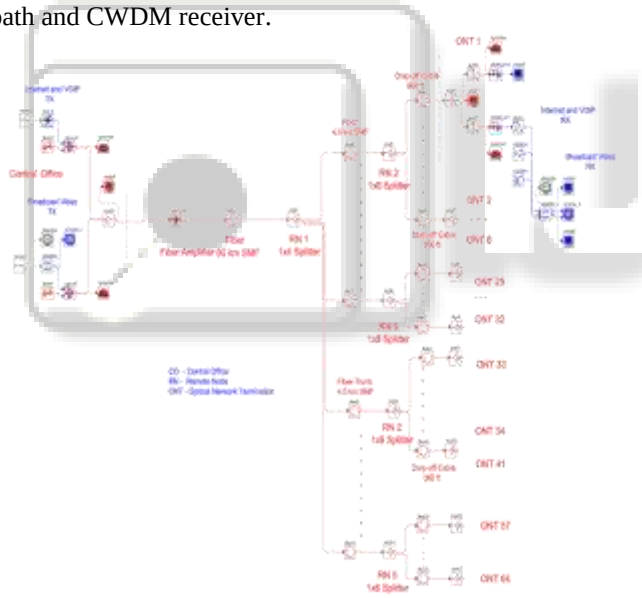

Fig. 2: Schematic of FTTH-BPON system

The signal from the central office travels though a 60 Km long fiber (1 dB loss per km) distribution network and arrives at optical network termination unit [4]. The optical spectrum at the input to ONT is shown at Figure 4. Here the optical signal first demultiplexed into data, voice and video components. The data component goes to the optical receiver, PIN. Optical power meters inserted after transmitters and before receivers show that total attenuation from fiber spans and splitters is about 29 dB and input power to the receiver is about 25 dBm. The signal from the central office travels through a 60 Km long fiber distribution network and arrives at optical network termination unit. Figure 2 depicts the system setup used to describe the distribution of voice, video and data in FTTH-BPON network. For transmission of voice and data signal, PRBS generator and an external modulator is used. CW laser is used in optical path as optical transmission.

IV. Results & Discussion

The optical spectrum at the input to ONT is shown at figure 3. Here the optical signal first demultiplexed into data, voice and video components. The data goes to the optical PIN type receiver. Optical power meters inserted after transmitters and before receivers show that total from fiber spans and splitters is about 29 dB and input power to the receiver is about-25 dBm in case of voice and data and 1.6 dBm in case of video. The receiver eye diagram for voice, data and video signals is given in figure 4 and in figure 5 respectively. The video component of the received signal enters at CWDM receiver. Electrical spectrum, frequency spectrum and scattering are analyzed at receiver.

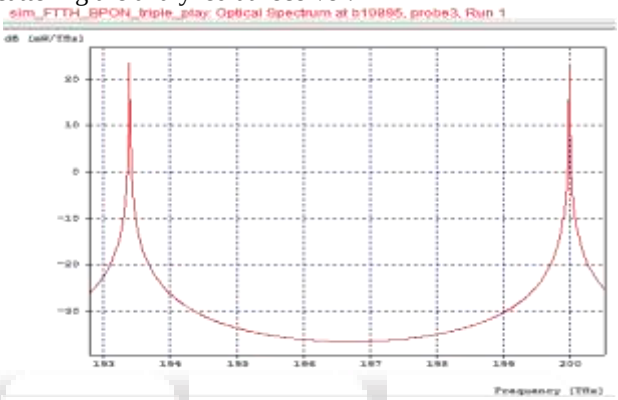

Fig. 3: Output spectrum from Central Office

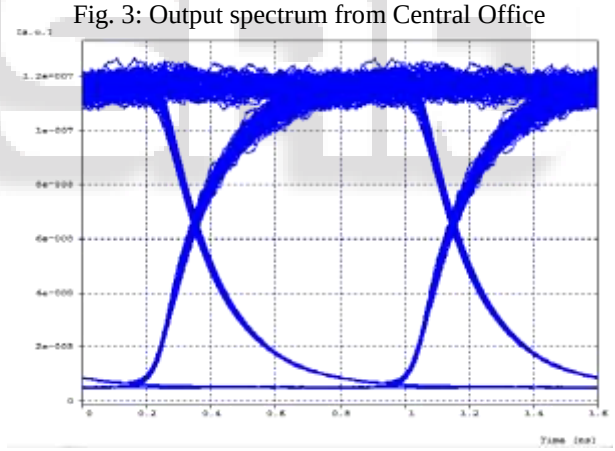

Fig. 4: Received eye diagram for voice and data signal

We have transmitted voice and internet data by using PRBS generator at the data rate of 1.25 Gbps at a Q-factor value of 31.7998 lin or 30.048476 dB.

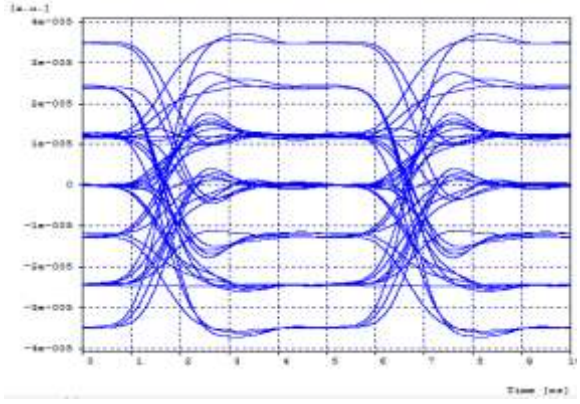

Fig. 5: Received eye diagram for video signal

Also transmit a video signal of 0.8 Gbps at the Q-factor value of 6.020600 dB.

V. CONCLUSION

A transmission system is established for triple play (Voice, video and data) with centralized CWDM-FTTH-BPON based on an external modulator. We have transmitted voice and internet data by using PRBS generator at the data rate of 1.25 Gbps at a BER of 1e-040 and Q-factor of 30.048476 dB. And video is transmitted with the help of 16 QAM [9, 10] modulated CWDM signal at the data rate of 0.8 Gbps at a BER of 0.0227501. The 1.25 Gbps voice signal, 1.25 Gbps data signal and 0.8 Gbps video signal have been transmitted over 60 Km single mode fiber (SMF) in a FTTH network with the help of optical amplifier for 64 subscribers successfully.

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