Broadband Home Network Modeling based on Plastic Optical Fiber

Jung wook Lee*, Yong ohk Chin *Regular Members*

ABSTRACT

Rapid growth of digitalization in telecommunication and broadcasting and remarkable enhancement in broadband and high speed transmission capability of media raised a problem of integrating communication and broadcasting. In order to implement this, the government has selected construction of Broadband Convergence Network (BcN) as a main new growth engine of the country. The BcN will be realized based on FTTH and Broadband Home Network (BHN) will be implemented through this solution. Transfer rate and bandwidth required for the BcN to be constructed aiming at integration of communication and broadcasting will be specified and the performance of basic transmission media, the plastic optical fiber, will be discussed in order to present its appropriateness.

Key Words : BcN, FTTH, broadband home network, POF, Bandwidth Requirement

Ⅰ. Introduction

The BcN for integrated accommodation of communication and broadcasting is a next generation network which basically integrates communication network, broadcasting network and internet network. In other words, the concept of BcN is integrating the communication network which interconnects wired phones and mobile phones, the broadcasting network which interconnects terrestrial broadcasting, satellite broadcasting and CATV, and the Internet network using xDSL, FTTH and HFC into one broadband network by multiplexing technology.

The BcN under discussion includes backbone network and subscriber network. Subscriber network usually consists of subscriber access network, local area network and home network, and this paper focuses on the study of home network. Integrated accommodation of communication and broadcasting should be based on FTTH network with broadband transmission characteristics. The FTTH technology which was developed first for information communication such as voice telephone, data communication, image transmission and others has been enhanced in order to implement integrated accommodation of broadcasting.

When communication and broadcasting are accommodated based on this FTTH technology, Plastic Optical Fiber (POF) is proved to be the most appropriate as the basic transmission media for home network from the analysis of transfer rate required for BcN type home network.

Ⅱ. Bandwidth Requirement of BHN

A representative value is set for each communication and broadcasting service which is likely to be serviced through FTTH and home network installed aiming at integration of communication and broadcasting. In addition, it is necessary to determine bandwidth requirements for these services to be converged into the broadband home network.

2.1 Internet and Video Transmission

The core service in communication is internet. Internet is serviced for many users through ADSL and VDSL. ADSL provides downstream 8 Mbps (max.) and upstream 1 Mbps. Enhanced ADSL-2 provides 12 Mbps and ADSL-2+ can provide up

* 일진전기(주) (leewook@paran.com)
논문번호 : KICS2004-11-295, 접수일자 : 2004년 11월 30일

to 16 Mbps. Now, ADSL is replaced with VDSL, which provides theoretical transmission rate of 12.96 Mbps through 55.2 Mbps symmetrically [1]. Assuming 5 Mbps for web surfing, 2 Mbps for games and 4 Mbps for image information searching [2], 10 Mbps bandwidth is regarded sufficient for Internet service.

When provided through TV-based high definition customized video service, VoD is transmitted at 4~6 Mbps by the MPEG-2 compression technology and Web-based bi-directional VoD is transmitted at 5 Mbps by MPEG-4 [3]. Besides, 20Mbps bandwidth should be ensured for HDTV-based IP VoD service or IP STB-based real-time bi-directional VoD [4].

Video conference service is typically provided with transmission rate of 1~20 Mbps and high definition image transmission requires 30 Mbps bandwidth [5]. IP Streaming Video Service, which is also called IP-Multicasting or IP-Broadcasting service, is provided with 20 Mbps for the current high definition DTV level and up to 60 Mbps for HD level video transmission. Here, the practical transmission bandwidth for high definition video transmission is set to 20 Mbps [6].

2.2 Wired LAN and Wired Home Link

For IP data transmission in wired LAN and home network, IEEE 802.3 specifies transmission rates and MAC to 10 Mbps, 100 Mbps and 1 Gbps [7][8]. The most common LAN type is CSMA/ CD of IEEE 802.3/ISO 8802.3, which is called Ethernet. Ethernet is a multi-access network in which several nodes receive and send data through shared links.

IEEE 802.12 standard specifies interconnection of various LAN types which construct a large network without bridge and allow varieties of frame lengths. IEEE 802.12 covers 100(Base) VG-Any LAN. VG indicates voice grade and AnyLAN means connection with any type of LAN.

In particular, IEEE 1394 defines bandwidth of 100~400 Mbps considering use of PC peripherals such as large memory devices like hard disk or CD-ROM, scanner, printer and household multimedia devices such as imaging device with the video capturing function. However, this bandwidth has been improved up to 800~3200 Mbps recently.

2.3 Wireless LAN and Wireless Home Network

IEEE 802.11b covers wireless LAN standard which supports 11 Mbps(max.) up to 100m using 2.4GHz frequency and CCK modulation. IEEE 802.11a supports transmission rate of 54 Mbps max. through OFDM using 5GHz frequency [7]. Basic units of the 802.11 structure are cells, which are configured into a BSS(Basic Service Set). BSS typically consists of one or more wireless stations and one base station, that is, Access Point (AP). IEEE 802.11 uses the carrier detecting multi access CSMA/CA protocol to avoid collision.

Bluetooth is specified in IEEE 802.15 and can transmit 1 Mbps data with 10m radius using GFSK scheme with 2.4GHz bandwidth [7].

Like wired home network, wireless 1394 is specified to transmit audio, video and IP data at transmission rate 70 Mbps. For broadband transmission in the future, IEEE 1394 + UWB(ultra wide band) is specified with improved bandwidth of 100~400 Mbps. Bandwidth for automatic control of various household products, remote metering of the used amount of electricity, water and gas supply and home security is set to 1 Mbps [4].

2.4 Terrestrial Broadcasting and Digital TV

Bandwidth per terrestrial analog TV (ex: NTSC) channel is 6 MHz and bandwidth per repeater of satellite DTV is 27 MHz. World-wide TV modes include NTSC, PAL and SECAM.

NTSC mode is cost-efficient as many broadcasting channels are available on account of narrow frequency bandwidth. PAL mode is featured by clear quality of image and SECAM mode is featured by stabilized phase and clear image. In the case of NTSC, modulation is accomplished by NTSC RF AM-VSB scheme. The bandwidths required for uncompressed PAL and NTSC and compressed MPEG-2 are given in Table 1 [8].

As shown in Table 2, bandwidth required for digital TV as determined according to the SDI(Serial Digital Interface) standard is about 270 Mbps in the case of SDTV and about 1.485 Gbps in the case of HDTV[9].

Table 1. Terrestrial analog TV bandwidth

Transaction Type	Format	Uncompressed bit rate	Compressed bit rate
Broadcast Television	MPEG-2(PAL) MPEG-2(NTSC)	124.4 Mbps 124.3 Mbps	15 Mbps(max) 15 Mbps(max)

In general, analog TV signals are compressed and transmitted at about 4Mbps. SDTV signals is compressed according to MP@ML specified in the MPEG-2 standard and transmitted at 15Mbps(max.) and HDTV signal is compressed according to MP@HL specified in the MPEG-2 standard and transmitted at 80Mbps(max.) [9]. In this paper, practical transmission bandwidth is set to 5 Mbps in the case of SDTV and 20 Mbps in the case of HDTV [4].

Table 2. Bandwidth requirement per digital TV channel

	SDTV	HDTV
Active Pixels / Line	720 x 486	1920 x 1080i
Interlaced sampling frequency	858 x 525 x 29.97 = 13.5 MHz	2200 x 1125 x 30 = 74.25 MHz
Fields / Frame	2	2
Bits / Channel	10	10
Total bit rates	13.5 x 2 x 10 = 270 Mbps	74.25 x 2 x 10 = 1.485 Gbps

2.5 CATV

Like general TV, bandwidth of one downstream CATV channel is 6MHz and that of upstream channel is 1.6MHz. As shown in Table 3, 54~750MHz is allocated to downstream frequency bandwidth of the CATV system. 54~552MHz of it is used for analog TV, 552~750MHz for digital TV and Internet services and 5~42MHz is used for upstream transmission. CATV is compressed and transmitted at 15Mbps according to SP@ML specified in the MPEG-2 standard [9]. There are three digital broadcasting standards for CATV transmission- Open Cable(USA), DVB-C(EU), ISDB-C(Japan). Korea adopted open cable technology as a broadcasting standard of CATV system.

Table 3. Bi-directional CATV frequency band(Mhz)

Bandwidth	5~42	54~552	552~750
Usage	Data Control Upstream Signal	Analog broadcasting	Digital broadcasting Internet

According to this standard, one downstream channel transmits 27Mbps by 64QAM modulation and 39Mbps by 256QAM modulation. For upstream channel, one channel transmits 256 Kbps, 1.544 Mbps and 3.048 Mbps by QPSK modulation. In the DOCSIS 2.0, we can use 30Mbps for upstream [10]. DOSCIS (Data Over Cable Service Interface Specifications) is the standard interface of the cable modem that handles data input and output between cable TV company and computer or TV set.

This technical specification defines modulation and protocol for bi-directional signal exchange over the cable and supports downstream 27 Mbps for users. However, as this data rate is shared by many users and most CATV companies are connected with Internet at T1, actual downstream rate experienced by an individual user is no more than 1.5-3 Mbps. As the data sent from users to the server is much less than this, total upstream rate is designed at about 10 Mbps and the upstream rate experienced by each user is about 500 Mbps ~2.5 Mbps. In the U.S, high data rate cable mode is set to 38.58 Mbps [11].

2.6 Determining BHN Throughput

Bandwidth requirements for services based on the transmission rates presented for LAN and home network are listed in Table 4. For the BHN which assumes convergence of communication and broadcasting, it is reasonable to determine bandwidth requirement by FTTH configuration by specifying home network limits and area in terms of technical aspect. Multi-unit home network consists of building intra network (BIN) and home intra network (HIN), and bandwidth for single-unit home is defined for home access network (HAN) and home intra network (HIN).

Home network bandwidth requires about 1.3 Gbps or more for BIN and about 150 Mbps or more for HAN. Broadcasting interface for HIN requires a considerably high transfer rate. In other words, AON scheme requires about 1.2 Gbps or more and PON requires about 20 Mbps or more. About 20 Mbps is appropriate for connection with PC and peripheral devices.

However, HIN configured in home LAN defined by IEEE 1394 standard may require 800 Mbps~3.2 Gbps to prepare for using multimedia devices in the future.

Table 4. Bandwidth requirement by home network service

BcN Service	Bandwidth (Mbps)	Terminal
· High speed Internet	10	PC
· VoD / EoD	20	TV/PC
· Web Surfing	5	PC
· Game	2	PC
· Video conference	20	PC/TV
· CATV/ Satellite TV		TV
· HDTV/Channel	20	
· SDTV/Channel	5	
· ATV/Channel	4	
· IP-broadcasting/Channel	20	PC/TV
· Remote metering, Home appliances control	1	PC/Mobile

Ⅲ. Analysis of Optical Cable Characteristics for Broadband Home Networking

3.1 Glass Optical Fiber(GOF)

Glass optical fiber includes two types of step-index profile fiber and graded-index profile fiber, depending on refractive index profile. Step-index profile fiber consists of the core of refractive index n_1 at the center and cladding of refractive index n_2 surrounding the core.

Step-index profile fiber has three types of GOF(Glass Optical Fiber) cladded with glass with a little low refractive index, PCF(Polymer Cladded Fiber) cladded with plastic and POF(Plastic Optical Fiber) cladded with a different type of plastic. In general, GOF has the smallest refractive index difference, PCF has a little larger refractive index difference and POF has the largest refractive index difference [12].

The graded-index (GRIN)fiber has a core material whose refractive index decreases continuously with distance from the fiber axis. Light rays travel through the fiber in the oscillatory fashion. The changing refractive index causes the rays to be continually redirected toward the fiber axis and cause them to be periodically refocused.

Glass fiber types are also classified into single mode fiber and multi mode fiber depending on propagation of light within the optical fiber. MMF includes step-index profile fiber and graded-index profile fiber described above and lights incident in various angles are transmitted in multi mode. However, as the core diameter of SMF is too small, the incident light is transmitted in single mode. Therefore, there is no problem induced by difference in arrival times resulting from different incident angles. MMF and SMF are usually used for local access network, and SMF is used for super-broadband transmission and long distance communication network.

Table 5 shows the characteristics of the cable. As the existing MMF or SMF cable is inflexible on account of its core made of glass optical fiber and SMF is difficult to connect with because of extremely thin core, there are problems such that it is difficult to install it in buildings.

Bending a fiber causes attenuation. Two types of bends are macroscopic and microscopic. Macroscopic refers to large-scale bending, such as that which occurs intentionally when wrapping the fiber on a spool or pulling it around a corner.

Loss is not the only adverse affect of bending. In addition, bending reduces the fiber's tensile strength. A fiber's strength depends on the microscopic flaws located on its surface. These flaws will grow over time if the fiber is subjected to stress or moisture, weakening the fiber. Thus, the

Table 5. Comparison of characteristics between MMF and SMF

Classification	MMF	SMF
Core Material	Silica	Silica
Clad	Silica	Silica
Core Diameter	62.5,50㎛	< 10㎛
Clad Diameter	125㎛	125㎛
Transmission Loss	< 3.5dB/km	< 0.5dB/km
Transmission Frequency	850,1310nm	1310,1550nm
Optical Module Cost	Expensive	Expensive
Connectivity	Difficult	Very difficult

stress owing to bending may cause the early failure of a fiber [12].

The bending criteria of optical cable comply with residential telecommunications cabling standard defined by TIA. Minimum bending radius of GOF is 1 inch under unloaded condition and 2 inches under minimum tension load of 222N. Static fatigue failure probability in bending is 6.7×10^{-5} at bending radius of 1.5 inches and increases to 22×10^{-5} in the case of 0.5 inches [13].

3.2 Plastic Optical Fiber (POF)

POF was developed to clear these problems. This cable has excellent flexibility, so it is not damaged even at a small bending curvature of about 2mm [14]. It has superior ductility and can be cut easily. Therefore, it provides simple cable coupling or splicing and fast fiber termination and connector attachment. Eventually, it provides fast and cost-effective installation as the networking cost using GI-POF is just a half of the cost using GOF [15].

POF is theoretically classified into SI-POF (Step-Index POF) and GI-POF (Graded-Index POF). First, as refractive index of the core of SI-POF is higher than that of clad, light propagates along the optical cable while totally reflecting at the discontinuous boundary surface. This type is mostly applied to short-distance transmission, lighting and image guide of low speed and low throughput.

Second, refractive index of core of GI-POF is decreasing outward from the central axis with Gaussian distribution and all incident lights propagate while crossing the optical axis. It is appropriate for wide transmission bandwidth and large-scale high speed transmission and has many applications.

Table 6. Comparison of characteristics between PMMA- POF and PF-POF

Classification	PMMA-POF	PF-POF
Core Material	PMMA	Perfluorinate
Clad	PMMA	PMMA
Core Diameter	980㎛	120㎛
Clad Diameter	1,000㎛	500㎛
Transmission Loss	< 220dB/km	< 40dB/km
Transmission Frequency	650nm	850nm
Connectivity	Very easy	Easy
Optical Module Cost	Very low	A little high

On the other hand, POF can be classified into PMMA-POF and PF-POF in terms of core material. Table 6 shows the characteristics of them [16][17]. PMMA-POF was developed by Mitsubishi Rayon, Asahi Chemical, Toray and Fuji Film using PMMA(Polymethyl Methacrylate) as core material. PF-POF was developed by the professor Koike of Keio University in Japan using Perfluorinated as core material and is under production by Asahi Glass Co., Ltd.

Ⅳ. POF for transmission media of BcN

4.1 Properties of POF

Material dispersion of a PF Polymer is smaller than that of glass fiber particularly in the short wavelength range (~850nm). This means that the potential bandwidth of PF GI POF having quadratic refractive index profile is higher than that of MM-GOF. For realizing higher than 10 Gbps transmission by the PF GI POF, the refractive index profile should be controlled to be the power-law form described by formula (1)[18][19].

$$n(r)n_1\left[1-2\triangle\left(\frac{r}{a}\right)^g\right]^{1/2} 0\le r\le a \quad (1)$$

$$\triangle = \frac{n_1^2-n_2^2}{2n_1^2}$$

where, n_1 is the refractive index of the core center, n_2 is the refractive index of cladding, r is the distance from the core center, a denotes the core radius, Δ indicates relative refractive index difference, and g indicates index exponent.

PF GI POF has index exponent 2.1 at 850nm and takes broadband characteristics compared with MM-GOF because it has a small material dispersion value on account of the optimum g value. In a demonstration, PF GI POF showed a narrower pulse width than silica based MMF at 650nm wavelength and succeeded in 10 Gbps data transmission at the distance 100m [19]. Figure 1 compares the attenuation values theoretically possible for Fluorinated Polymers with those achieved for SM GOF. However, practical experience shows that these impressive theoretical values are in fact difficult to achieve [20]. In general, PF-POF shows 10~50dB/Km attenuation characteristics at the frequency range 800~1300nm and bandwidth-length products are known to be 5GHz·Km.

Recently demonstrated performances-11 Gbps over 100m, 2.5 Gbps over 550m and 1.23 Gbps over 990m-are likely to arouse the interest of broadband home network medium [21]. The highest data rate of yet for a POF system with 11 Gbps over 100m PF GI POF was demonstrated by Lucent Technologies [20]. According to another test results, attenuation is below 40dB/Km at 850nm using pigtailed LED as a light source and bandwidth is measured as high as 5 GHz at 850nm over 100m [22].

In Korea, LG Cable has been produced PF GI-POF since 2003 and is being supplied with the raw material (CYTOP) from Asahi Glass, Japan. The attenuation of CYTOP product, POF of low attenuation characteristics, was reduced from 50dB/km to 30dB/km first and reduced to 15dB/km at 1300nm presently [20].

Therefore, it has advantage in horizontal wiring of LAN and is an exact media at short-distance range of 200m and less. It is also suitable for BIN as well as HIN for broadband home networking.

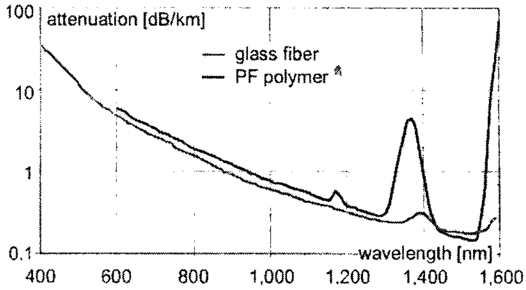


Fig. 1. Comparison of theoretical attenuation between GOF and PF POF

On the other hand, Figure 2 shows the wavelength-dependent attenuation curve of a PMMA SI-POF. It has three attenuation minima with wavelengths of 520nm, 570nm and 650nm. LED or LD may be used for the transmitter at these wavelengths.

PMMA-POF has limited application distance on account of high attenuation. Theoretical attenuation of this fiber was announced to be 108dB/Km at 650nm [21], but practical attenuation shows 180~220 dB/Km [23]. From these attenuation characteristics, PMMA-POF gives sufficient transmission rate for HIN rather than BIN. In Korea, several companies including SKC and Optimedia are producing this fiber.

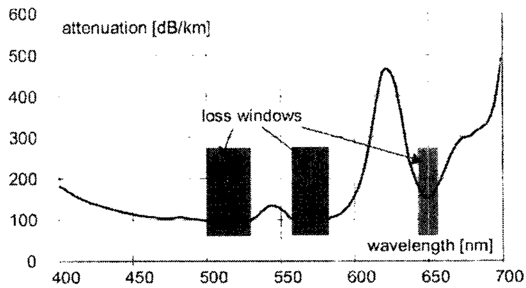


Fig. 2. Attenuation characteristics of PMMA SI POF

4.2 Bending Radius of POF

Bending radius of POF is very excellent so that it is possible to bend optical fiber of 0.125mm in diameter up to 2mm without attenuation. The results obtained from actual installation proved convenience of handling equal to UTP cable, which is strong against bending [15]. The tensile performance of Simplex PF GI-POF cable recently produced by Nexans is 300N maximum[22]. A fiber bending with the radius as small as 10nm caused little change in the bandwidth of the GI POF. Furthermore, the smaller core diameter caused the smaller bending loss. The bending loss was strongly influenced by both NA (Numerical Aperture) and core diameter [18].

4.3 Coupling Efficiency of POF

The optical performance of a fiber is characterized by its attenuation, pulse spreading and numerical aperture. Coupling efficiency and the choices of a suitable fiber is reviewed here.
First, MM GI fibers can transmit at higher information rates than MM SI fibers. SI source coupling is normally more efficient, while losses for the two fiber types are the same. MM GI fibers are designed for low pulse distortion, making them appropriate for long-distance, high-rate applications. Second, MM fibers are larger and easier to handle than SM fibers. The advantage of a SM fibers is their large information capacity, resulting from the absence of modal pulse spreading. It is suitable for long-distance and large-information capacity systems.

Third, in terms of fiber materials, GOF has the lowest attenuation, making it the choice for long paths. Although PCS fibers have higher losses, their larger numerical apertures makes coupling more efficient. PCS fibers are used for moderate path lengths. POF have large losses. However their large cores and high numerical apertures make them convenient and efficient for short runs such as a home network.

An important characteristic of an optic system is its ability to collect light incident over a wide range of angles. In general, the optic receiver consists of a lens and a photodetector. The lens is much larger than the detector surface. So, it is possible to collect more beams of light than those directly collected by the detector. NA is defined to be the formula (2) [12].

$$NA = n_o \sin\theta \qquad (2)$$

where, n_0 is the refractive index of the material between the lens and photodetector, and θ is maximum acceptance angle. Typically optical fiber for long-distance are designed to have NA from about 0.1 to 0.3. The low NA does make coupling efficiency tend to be poor but improves bandwidth of the optical fiber. POFs are designed to have high NA of 0.4~0.5, which is higher than that of GOF, to improve coupling efficiency in order to partially offsetting the high propagation losses [12].

V. POF-based BcN Type Home Networking

5.1 Data and video transmission using POF

A problem in high speed data transmission using POF is the size of the receiver. PD with a 1GHz or higher 3-dB-frequency have a diameter below 0.4mm. Coupled to a 1 mm fiber this results in a loss of approximately 10 dB if no optic is used [24].

According to the recent records of high-speed data transmission using PMMA-POF, IEEE 1394b s800 was successfully implemented by using SI-POF, 650nm DVD Laser for transmitter and 1GHz silicon PIN Photodiode(0.33mm PD) for receiver [24]. Also, data transmission was carried out with 250 Mbps data rate at 100m using PMMA-POF cable with 0.09 dB/m attenuation at frequency 520nm and GaN green LED of SQW structure [25].

On the other hand, the recent trials in high speed data transmission using PF GI-POF, successful data transmission was accomplished with Gbps data rate at 850nm wavelength using the passive optical coupling technique developed by Nexans and the most cost-efficient optical source VCSEL[22]. Also, in Japan, 10 Gbps data transmission at 100m was accomplished successfully [19].

Home networking infrastructure based on IEEE 1394b requires multimedia devices and high-performance backbone network for telecommunication and computer, and it was proved that POF may be used for this purpose [26]. In particular, CATV transmission is an important application in triple play service which integrates TV, data and voice. However, commercial O/E products which enable CATV transmission using POF are not available at present. As analog and digital CATV may co-exist for a considerable period, the optical transmission system should be able to process both signals.

In order to transmit a multichannel CATV signal with a good resulting picture quality, several requirements have to be met: high bandwidth, high Signal-to-Noise Ratio(SNR) and high linearity. In the CATV transmission system, SNR is defined as Carrier-to-Noise Ratio (CNR) and should be 40dB or better for good picture quality. Second order signal distortions due to nonlinearities are quantified by the definition of the Composite Second Order(CSO) which should be 50dB below the carrier signal [27]. Possibility of video transmission using POF is discussed below. In order to transmit analog CATV signal, high linearity is required for transmitter LD, driver and receiver parts. Unlike APD PDs, most PIN PDs have high linearity and LDs with linear optical electric curve should be selected.

Recently, in Germany, an experiment was carried out to transmit analog CATV signal using GI-POF and SI-POF. It contains 41 analog channels, most of them are in the frequency range below 470 MHz, and some channels are in the frequency range of the expanded CATV specification up to 862 MHz. The CATV signal is amplified and transmitted over 100m GI POF and 30m SI POF respectively. From the results of the experiment, CNR was decreased by 3 dB compared to input spectrum and still higher than 40dB for all channels. CSO showed no increase [28]. As GI POF has broadband characteristics and low modal noise, it is appropriate for transmitting analog CATV signal. SI POF may be applicable to short distance.

5.2 BcN type Home Network System using POF

POF cable is selected as a transmission media for the broadband home network from the analysis of transmission capacity and mechanical characteristics discussed above. The configuration shown in Figure 3 is obtained by introducing POF into BIN and HIN and by developing Central Transmission System(CTS) for integration of communication and broadcasting and the distribution device Home Gateway(HGW).

In Figure 3, A indicates CTS and B indicates HGW . CTS and HGW basically consist of Optical Multiplexer and Demultiplexer and adopt Wavelength Division Multiplexing (WDM) technology. WDM will be feasible for optical short distance communication only if low-cost WDM devices are available.

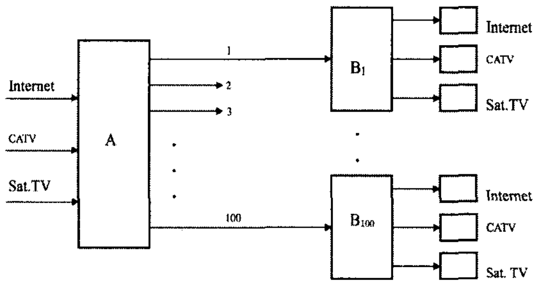
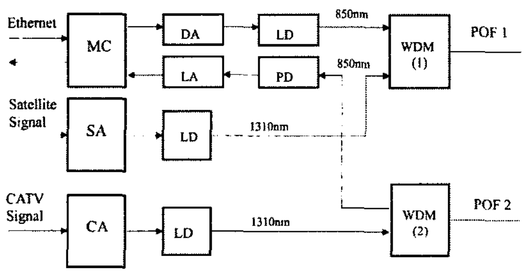


Fig. 3. Configuration of POF-based FTTH system

Commercial WDM components-especially those of Dence WDM(DWDM) - are extremely expensive. So, We need to design cost effective devices for Coarse WDM(CWDM) based on polymer components for low cost home network with POF. ITU G.694.2 recommends a CWDM wavelength grid that covers 18 wavelengths over the entire optical spectrum between 1270nm and 1610nm with 20nm channel spacing. When we use PF GI POF for BIN and HIN, a particularly attractive combination for WDM operates with one channel at 850nm and one at 1,310nm. Wavelength division can be used to produce a fully duplexed network, as shown in Fig.4 and Fig.5. So, CWDM is used to transmit video, audio and data signals because it allows low cost access network configuration compared with DWDM. In this system, CTS performs converged transmission for very high speed Internet, CATV and satellite DTV, and HGW distributes the converged signals.

Fig.4 shows the basic model of CTS including amplifiers, optical transmitters, optical receivers and WDM modules. In the CTS, 1310nm DFB Laser was chosen for video transmission of CATV and satellite DTV. Depending on the FTTH link requirements, light source such as Fabry-Perot or DFB lasers dominate so far as the technology of choice. DFB lasers have a number of unique properties arising from the grating structure. In addition to their narrow linewidths, which make them attractive for long high-bandwidth transmission paths, they are less temperature dependent than most conventional laser diodes.



MC : Media Converter   SA : Satellite Amplifier
CA : CATV Amplifier   DA : Driver Amplifier
LA : Limiting Amplifier   LD : Laser Diode
PD : Photo Diode
WDM : Wavelength Division Multiplexer

Fig. 4. Basic model of CTS

DFB lasers are also more linear in their response than conventional laser diodes. This allows their use in analog systems where a high degree of linearity is required to reduce distortion. Linearity also minimizes intermodulation when several channels are multiplexed for simultaneous transmission. For this reason, DFB lasers have been used successfully for analog modulation of multiplexed CATV Signals.

For Ethernet data signal, 850nm VCSEL is used for transmission and 850nm PIN PD for reception. VCSELs are widely used as light sources of optical data communication such as Gigabit Ethernet. Typical wavelength of the VCSELs is 850nm. Besides the emission in a single longitudinal mode, the VCSEL stands out for low power consumption, easy fiber coupling due to a rotation symmetric far field, and small linewidth even under direct modulation. The largest advantage of PF-POF is the compatibility with 850nm VCSEL. Due to the commercialization of PF POF, 850nm VCSEL becomes a major candidate for light source of high-speed home network and consumer electronics. Regarding the cost of 850nm VCSELs, market demand from datacom application has continuously been pushing the price lower. The use of VCSEL enables much easier and low cost system design. Fig.5 is the basic model of HGW that are composed of WDM modules for POF, optical transmitter and receivers, amplifiers for terminal sets.

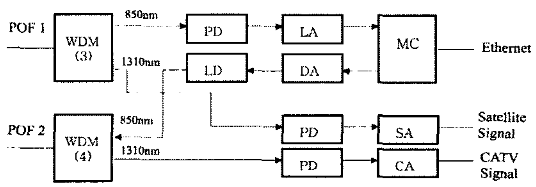


Fig. 5. Basic model of HGW

In the case of HGW, 1310nm PIN PD is set for video signals, 850nm VCSEL for data signal transmission and 850nm PIN PD for data signal reception. The detector in a fiber communications system will be either an APD or a PIN PD. The PIN device is cheaper, less sensitive to temperature, and requires lower reverse bias voltage than the APD. The speeds of the two devices are comparable, so the PIN diode is preferable in most systems.

Ⅵ. Conclusion

At present, copper cable and coaxial cable are commonly used as the transmission media for home network. However, they have limitation in transmission capacity as loss significantly increases depending on frequency. GOF has no limitation in transmission capacity but is not suitable for home network infrastructure due to poor flexibility and difficulties in cable connection and installation because its core is made of glass fiber and core diameter is extremely small. On the other hand, POF has advantages of simple connection owing to large core diameter and fast cable installation by high flexibility.

In the future, home network for integration of communication and broadcasting will require broadband of 1Gbps or more for BIN and HIN respectively. PF GI POF showed broadband performance of 10 Gbps up to 100m and is appropriate for BIN as well as HIN. PMMA POF showed Gbps broadband performance at a short distance with 250 Mbps transmission characteristics up to 100m and is particularly suitable for HIN. So, I suggest a basic model based on Plastic Optical Fiber for Broadband Home Network. The future project will be design and development of cost-efficient commercial optic/electric and electric/optic products to complete BHN based on POF.

REFERENCES

[1] Larry L. Peterson, Bruce S. Davie, Computer Networks, Korean Ed.(Scitech Media Inc., Seoul, Korea, 2001), pp.79-86

[2] Nam-Hwan Yeom, "KT's home network solution," 2004 Home Network Solutions Seminar, KHNIA, Proc. pp.3-8, 2004

[3] Sang-Taek Park, "E-PON trial project in Gwang-Ju," Report on FTTH trial project, NCA, Proc. pp.41-53, 2004

[4] Hyung-Jin Park, "FTTx technology issues and trend", Broadband World Forum Seoul 2004, IEC, Program disk, 2004

[5] Ho-Young Song, "FTTH technology trends in Korea and advanced country," Report on FTTH trial project, NCA, pp.77-106, July 2004

[6] Byung-Soo Chang, "Home Network : KT's vision and strategy," Broadband World Forum Seoul 2004, IEC, Program disk, 2004

[7] James F. Kurose, Keith W. Ross, Computer Networking, Second Ed.(Addison Wesley, Boston, USA, 2002), pp. 456-488

[8] Fred Halsall, Data Communications, Computer Networks and Open Systems, Fourth Ed.(Addison Wesley, USA, 1998), pp. 271-316, 560-562

[9] G. P. Chung, J. W. Moon, S. Y. Ahn, Digital Broadcasting Technology(Cha-song, Seoul, Korea, 2002), pp.133-149, 215-219

[10] Ho-In Jeon, "Home networking system: Architecture for ubiquitous networking," Broadband Home Networking and Experts training Seminar, KICEA & KPCF, Proc.pp.135-181, 2004

[11] Arch Luther, Andrew Inglis, Video Engineering, Third Ed.(McGraw-Hill, USA, 2003), pp.185-191, 2003

[12] Jeseph C. Palais, Fiber Optic Communications, Fourth Ed.(Prentice hall, New Jersey, USA, 1998), pp.112, 146, 168-169, 178-186, 251-252

[13] P.D. Patel, H. C. Chandan, D. Kalish, "Failure Probability of Optical Fiber in bending," The 30th International Wire and Cable Symposium, Proc. pp.37-44, 1981

[14] N. Ohtsu, T. Tsutu, Y. Koike, "What is application of Gigabit Network by GI-POF," The 11th International POF Conference 2002, ICPOF, Proc. pp.77 -78, 2002

[15] Experimental Report for high speed POF(Japan Telework Association, Tokyo, Japan, 2003), pp. 63-72

[16] Atrushi Kondo, Yasuhiro Koike, Takahashi Ishigure, "Perdeuterated Graded Index POF," The 11th International POF Conference 2002, ICPOF, proc. pp.123, 2002

[17] Andreas Weinert, Plastic Optical Fibers(Publicis MCD Verlag, Munich, Germany, 1999), pp.22-29

[18] K. Makino, T. Ishigure, Y. Koike, "Analysis of GI POF link performance under fiber bending based on link power penalty," The 13th International POF Conference 2004, ICPOF, Proc. pp.187-194, 2004

[19] T. Ishigure, H. Endo, K. Takahashi, Y. Ebihara, Y. Koike, "Total dispersion compensation design of POF," The 13th International POF Conference 2004, ICPOF, Proc. pp.179-185, 2004

[20] Werner Daum, Jurgen Krauser, Peter E. Zamzou, Olaf Ziemann, Polymer Optical Fibers for Data Communication(Springer, Berlin, Germany, 2002), pp.14, 83, 113, 197

[21] G. Widawski, J. Fournir, J. Goudeau, B. Bareel, P. Zamzow, "Cable design for Plastic Optical Fiber application," The 11th International POF Conference 2002, ICPOF, Proc. pp.45-48, 2002

[22] J. Goudeau, G. Widawski, B. Bareel, M. Rossbach, R. Helvenstein, L. Huff, "GI POF for Gigabit Ethernet Links," The 13th International POF Conference 2004, ICPOF, Proc. pp.76-81, 2004

[23] A. Appajaiah, V. Wachtendorf, "Aging behavior of Polymer Optical Fibers," The 13th Inter- national POF Conference 2004, ICPOF, Proc. pp.167, 2004

[24] B. Offenbeck, S. Junger, W. Tschekalinskij, N. Weber, "IEEE 1394 transmission with SI-POF at 800 Mbps," The 13th International POF Conference 2004, ICPOF, Proc. pp.225-231, 2004

[25] S. Kato, O. Fujishima, T. Kozawa, T. Kachi, "Transmission characteristics of a 250 Mbps POF data link employing GaN green LED," The 13th International POF Conference 2004, ICPOF, Proc. pp.232-236, 2004

[26] Uwe Schelinsk, Klaus Frommhagen, Michael Schollis, "A home networking infrastructure using POF based on IEEE 1394," The 13th International POF Conference 2004, ICPOF, Proc. pp.59-65, 2004

[27] S. Junger, W. Tschekalinskij, N. Weber, "Cable TV transmission over POF," The 13th International POF Conference 2004, ICPOF, Proc. pp.35-39, 2004

[28] S. Junger, M. Schradar, A. Plotz, W. Tschekalinskij, N. Weber, "High linearity CATV transmission with GI-POF and SI-POF," The 13th International POF Conference 2004, ICPOF, Proc. pp.106-111, 2004

Acronyms

AM	Amplitude Modulation
ADSL	Asymmetrical Digital Subscriber Line
AON	Active Optical Network
AP	Access Point
APD	Avalanche Photo Diode
BcN	Broadband Convergence Network
BHN	Broadband Home Network
BIN	Building Infra Network
CA	CATV Amplifier
CATV	Cable Television
CCK	Complementary Code Keying
CD-ROM	Compact Disk-Read Only Memory
CNR	Carrier to Noise Ratio
CSMA/CD	Carrier Sense Multiple Access with Collision Detection
CSO	Composite Second Order
CTS	Central Transmission System
CYTOP	Cyclic Transparent Optical Polymer
CWDM	Coarse WDM
DA	Driver Amplifier
DOCSIS	Data Over Cable Service Interface Specifications
DTV	Digital Television
DVD	Digital Video Disk
DWDM	Dense WDM
FTTH	Fiber To The Home
GFSK	Gaussian Frequency Shift Keying
GI-POF	Graded Index POF
GOF	Glass Optical Fiber
GRIN	Graded Index
HAN	Home Access Network
HDTV	High Definition Television
HFCN	Hybrid Fiber Coaxial Network
HGW	Home Gateway
HIN	Home Intra Network
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
ISO	International Standards Organization
LA	Limiting Amplifier
LAN	Local Area Network
LD	Laser Diode
LED	Light Emitting Diode

MAC	Medium Access Control
MC	Media Converter
MMF	Multi Mode Fiber
MM-GI	Multi Mode Graded Index
MM-SI	Multi Mode Stepped Index
MP@HL	Main Profile at High Level
MP@ML	Main Profile at Main Level
MPEG	Moving Pictures Experts Group
NA	Numerical Aperture
NTSC	National Television System Committee
O/E	Optical/Electrical
OFDM	Orthogonal Frequency Division Multiplexing
PAL	Phase Alternation by Lines
PCF	Polymer Cladded Fiber
PCS	Plastic Cladded silica
PD	Photo Diode
PF GI-POF	Perfluorinated Graded Index-POF
PIN-PD	Photo Diode with P-I-N semiconductor structure
PMMA	Polymethylmeth acrylate
POF	Plastic (Polymer) Optical Fiber
PON	Passive Optical Network
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RF	Radio Frequency
SA	Satellite Amplifier
SDI	Serial Digital Interface
SDTV	Standard Definition Television
SECAM	Sequential Couleur Avec Memoire
SI-POF	Step Index POF
SMF	Single Mode Fiber
SNR	Signal to Noise Ratio
SP@ML	Spatial Profile at Main Level
SQW	Single Quantum Well
STB	Set Top Box
TIA	Telecommunication Industry Association
UTP	Unshielded Twisted pair
UWB	Ultra Wide Band
VCSEL	Vertical cavity surface Emitting Laser
VDSL	Very high speed Digital Subscriber Loop
VoD	Video on Demand
VSB	Vestigial Side Band
WDM	Wavelength Division Multiplex

이 정 욱(Jung wook Lee) 종신회원

1968년 2월 연세대학교 전기공학과 졸업(학사)
1973년 2월 서울대학교 행정대학원 졸업(석사)
2005년 2월 경희대학교 정보통신대학원 졸업(공학박사)
1970년 5월 제5회 기술고등고시 합격
1993년 7월 한국전기통신공사 기술기획실장
1995년 7월 한국전기통신공사 연구개발원장
1996년 6월 한국전기통신공사 네트워크본부장
1997년 7월 한국전기통신공사 부사장, 사장대행
1999년 7월 한국정보인증㈜ 대표이사 사장
2003년 9월 일진전기㈜ 부회장(현)
2004년 2월 한국POF통신포럼 의장(현)
2004년 9월 국제플라스틱광섬유협력기구(ICPOF) 집행위원(현)
2005년 2월 한국정보통신기술인협회 회장(현)
<관심분야> FTTH, BcN, POF, 홈 네트워크

진 용 옥(Yong ohk Chin) 종신회원

1968년 2월 연세대학교 전기공학과 졸업(학사)
1975년 2월 연세대학교 대학원 졸업(석사)
1981년 2월 연세대학교 대학원 졸업(공학박사)
1980년 7월 통신기술사(전기통신부문)자격취득
1979년 2월 경희대학교 전자공학과/전파공학과 교수(현)
1991년 3월 경희대학교 정보시스템공학연구소장(현)
1994년 1월 한국음향학회 회장
2000년 6월 경희대학교 정보통신대학원 원장
<관심분야> FTTH, BcN, 홈 네트워크, 인지통신