

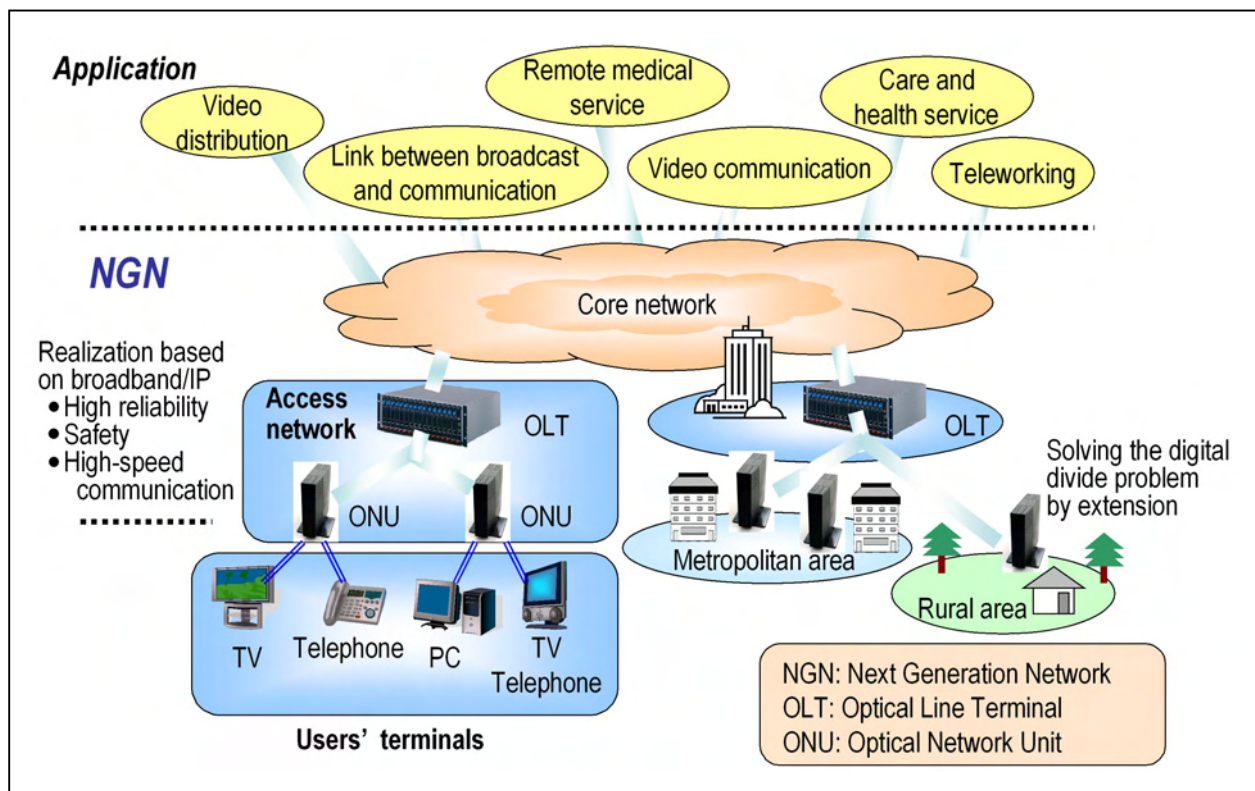
Technologies for Next Generation Optical Access Network

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Abstract

Introduction of the GE-PON system has accelerated the use of FTTH in Japan, changing the access network from simply an Internet connection to a social infrastructure that provides services directly related to daily life, such as IP telephone service. Mitsubishi Electric has the largest share of the GE-PON market in Japan and is now working on the next generation GE-PON. The role of the NGN is becoming increasingly important as the communication network is expected to provide rich content such as real-time applications including video communications. Along with this trend,

the next generation optical access system requires new features including (1) Links to service-related functions such as QoS for smooth use of different applications and bandwidth control function; (2) Link function for full IP communication and broadcasting that are highly compatible with the NGN; and (3) Measures to prevent the digital divide in local areas. This paper discusses these technological challenges, their solutions, and the technologies required for realizing coexistence with GE-PON for standardization toward second-generation FTTH currently under way.



Development efforts for Next Generation optical access system

As the GE-PON system is now widely used, the number of FTTH users in Japan is steadily increasing. In the near future, a high-grade QoS function will have to be installed in the access network with an eye toward the NGN. The optical network, which is already part of the social infrastructure, will have to incorporate measures against the digital divide by extending the service range.

1. Evolution of Access Network

The Internet access environment has changed from dial-up connection (up to 128 kbps) to asymmetric digital subscriber line (ADSL, up to 50 Mbps), and further to fiber-to-the-home (FTTH, up to 1 Gbps), with transmission speed increasing in that order. First, the change from dial-up to ADSL increased the transmission speed by two orders of magnitude. At the same time, a flat-rate system was introduced for data communications. These improvements expanded the number of Internet users. However, the transmission speed was limited in proportion to the distance between the users and the central office (CO); different bandwidths were allocated even though all users paid the same charge. Meanwhile, since its introduction in 2004, FTTH via the Gigabit Ethernet Passive Optical Network (GE-PON) has steadily grown in Japan. The initial user interface speed was 100 Mbps, which is larger than that of ADSL by one order of magnitude, and service was provided equally regardless of the distance from the CO. In addition, the quality of IP telephone service reached almost the same level as that of conventional fixed-line telephone service, and video distribution service became available with the utilization of optical fiber broadband characteristics. Video distribution using a combination of communication and broadcasting is expected in the future.

In this way, the Internet connection environment has improved dramatically and the access network has advanced from a mere Internet connection to a communication network that can provide various applications such as telephone service and video contents distribution. Technological challenges in enhancing the functions of the access system include the following.

- (1) Priority control compatible with real-time applications
- (2) High-grade functions for IP broadcasting
- (3) Extension of transmission distance

As the video distribution service improves and numerous services such as remote medical service, video-type communication, teleworking, and nursing and health care services are expected in the future, the access network will require better priority control over real-time applications and IP broadcasting service. The optical access network, which is now a key social infrastructure that is replacing the conventional telephone network, must be equipped with measures against the digital divide, such as the technology for extending the transmission distance.

2. High-Grade Functions for Optical Access Network

First, improvement of priority control is described below. As services diversify, the network will gradually conform to the next generation network (NGN) concept,

and the system will require significantly enhanced QoS (quality of service). For example, simple two-class communication (i.e., IP telephone + data communication) will have to be upgraded to allow users to more fully enjoy the services by mapping versatile real-time applications to multiple delay classes or priority classes provided by the network.

On the other hand, as shown in Fig. 1, the GE-PON system uses time-division access control for upstream and broadcast access control for downstream, for which the logical link identifier (LLID) allocated to the optical network unit (ONU) is used as an identifier for access control. The optical line terminal (OLT) controls bandwidth allocation for each LLID to prevent the collision of upstream signals transmitted from the ONUs. The dynamic bandwidth allocation (DBA) algorithm, which determines the policy of bandwidth allocation for each ONU, is the heart of the system.

One of the most important technological challenges with the NGN is associating the transport technologies of Layer 2 such as GE-PON with the service stratum (service-related technologies), which is represented by a session initiation protocol (SIP) server. To apply GE-PON to NGN, as shown in Fig. 2, the grouping function for the resource assignment control protocol, a DBA function to allocate bandwidth in accordance with resource allocation instructions from the service stratum, and a mapping function that can flexibly map users' sessions to the LLID, are promising.

Next, the functions required for linking communication and broadcasting in an IP-based environment are discussed. There are two methods for video distribution: (1) Wavelength division multiplexing in which the modulated video signal wavelength is multiplexed to the communication wavelength; and (2) Distribution of video signal at the same wavelength as the communication wavelength, using IP multicasting technology.

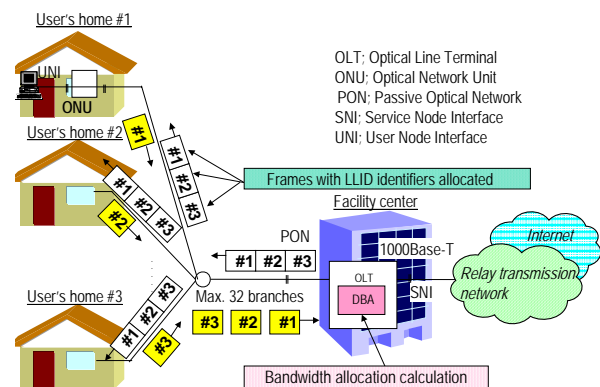


Fig. 1 GE-PON system

The former distributes broadcast waves by optical fiber and can efficiently provide a number of broadcast programs to the users' homes. The latter distributes IP-compatible video and is expected to provide diverse content in the future; it is considered a promising solution having high compatibility with the NGN, although related regulations are yet to be established.

When delivering broadcast programs via the communication network, it is necessary to distribute only those programs being viewed by the subscribers, using the minimum network resources so that the bandwidth in the downstream direction is not wasted. Furthermore, in consideration of the diversity of broadcasts and services in each region, the system should limit the distribution addresses to specific areas.

The challenges described above are resolved by the GE-PON system's applied Source-Specific Multicast (SSM) defined in Internet Group Management Protocol, Version 3 (IGMPv3) and Multicast Listener Discover, Version 2 (MLDv2). The system is highly broadcast-compatible since the PON has a star-shaped topology and uses the data broadcasting mode in the downstream direction, as shown in Fig. 1.

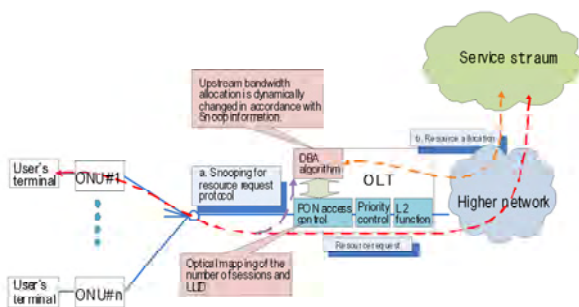


Fig. 2 Improved QoS function in GE-PON system

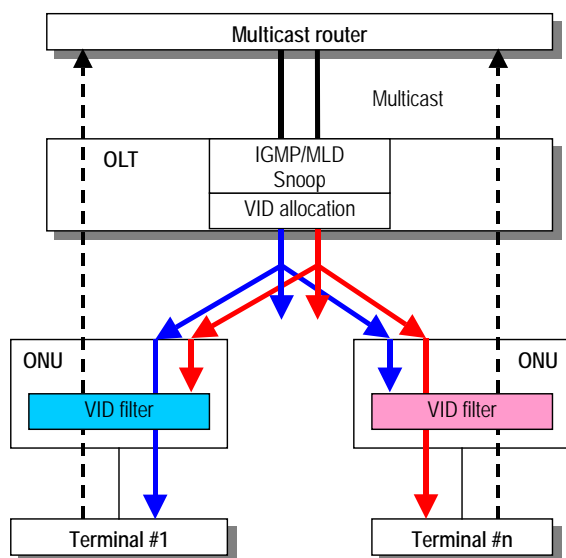


Fig. 3 GE-PON system to realize link between communication and broadcast

In practice, as shown in Fig. 3, IGMP/MLD Snooping is mounted in the OLT of the GE-PON, the Layer 3 parameters allocated for each program such as source and group IP address and the Layer 2 parameter Virtual LAN Identifier (VID) are linked, then VID filter configuration is made to forward the requested multicast from the OLT to the ONU. Furthermore, multicast is transmitted by broadcasting LLID in the optical distribution network for reception by all ONUs, so that a system can be established in which only ONUs permitted to forward can view the broadcast programs⁽¹⁾. This method achieves efficient multicast distribution. The main advantage is that since not only the destination IP address but also the source IP address is referenced for setting the identifier, the method can be applied to limited distribution-area services.

As the importance of ICT in daily life increases, measures against the digital divide are urgently required, meaning that identical services must be provided in both rural and metropolitan areas. There are three main methods of extending the transmission distance between OLT and ONU for the expansion of GE-PON service areas: (1) reducing the number of branches in PON; (2) using 3R repeaters; and (3) using optical amplifiers.

Table 1 and Fig. 4 compare the respective methods. Branch-number reduction allocates most of the GE-PON power budget to transmission loss by reducing the number of branches. If the number is reduced to around 4 branches, the transmission distance can be extended up to approximately 40 km. On the other hand, if the number of branches is required, extension of the transmission path by means of 3R repeaters or optical amplifiers is necessary, although the characteristic passivity of the PON transmission path will be lost. The 3R repeater method provides regenerative repeating signals along the extended transmission path. The optical amplifier method also extends the transmission distance by amplifying attenuated signals along the transmission path.

Table 1 Comparison between extension methods

	Branch number reduction method	3R repeater method	Optical amplifier method
Passivity of transmission path	Good	Not good	Not good
Transmission distance	~40km	~50km	~50km
Impact to existing equipment	Very high	Medium	Medium

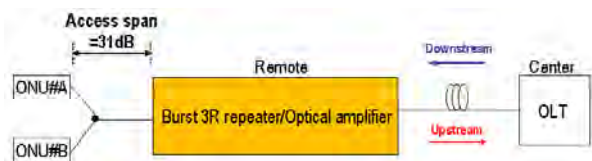


Fig. 4 Extension of transmission path

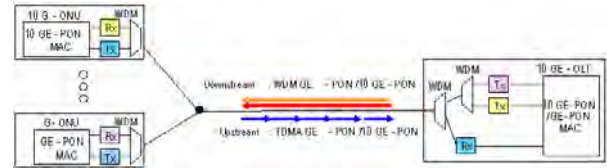


Fig. 5 Coexistence of 10G-EPON and GE-PON

3. Optical Access System in Future

Along with the increased popularity of FTTH, traffic levels have also been rapidly increasing. The speed of FTTH as an access network supporting various services must be increased. Studies on 10-gigabit-class access system have also been conducted⁽²⁾. The 10G-EPON standardized by the IEEE 802.3av Task Force is a promising candidate for the next generation optical access system. The scope of standardization is focused on the physical layer. For higher layers, existing standards will be applied, such as the 10 Gigabit Ethernet (10GbE) standardized in IEEE 802.3ae and the Multipoint Control Protocol (MPCP) standardized in IEEE 802.3. Taking into consideration the recent FTTH circumstances in Japan, coexistence with the GE-PON will be examined. The solution may employ time-division multiplexing for upstream and wavelength multiplexing for downstream, as shown in Fig. 5.

Other issues must be resolved before constructing the final system. In particular, continuous development is required for the encryption method between OLT and ONU, bandwidth allocation control for the upstream direction, and QoS control, which are key technologies for realizing the 10G-EPON system.

References:

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