G-PON System

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The Gigabit Ethernet Passive Optical Network, IEEE802.3h (GE-PON) is being rapidly spread in Japan according to NTT's mid-term plan that targets 30 million fiber to the home (FTTH) subscribers by 2010. Conversely, in the U.S., such carriers as Verizon are aggressively promoting the introduction of FTTX, but Broadband PON (B-PON) specified by ITU-T is currently dominant. However, regarding the requirements from Triple Play, especially for High Definition TV (HDTV), B-PON capacity is insufficient in terms of bandwidth, and thus Gigabit PON (G-PON) with four times the capacity is now being standardized by ITU and will soon be recognized globally as being mainstream. This paper describes the G-PON system jointly developed by Fujitsu, Fujitsu Access, and Fujitsu Network Communications, Inc.

1. Introduction

The need for high-capacity access lines continues to increase. For example, because of the high demand for Triple Play, the bandwidth of Broadband Passive Optical Networks (B-PONs) is already insufficient.

Fujitsu has recently released its flagship access product, the FLASHWAVE 6100 system. This system is initially intended for the U.S. based Gigabit PON (G-PON) market. However, it has a versatile architecture that will allow it to address many other technologies. It can serve high-density Ethernet drops, Gigabit Ethernet Passive Optical Network (GE-PON) drops, ADSL2+, VDSL2, DS1, DS3, and many other access technologies.

This paper gives an overview of the G-PON system.

2. Access network configuration

The access network in the U.S. consists of several different media. Twisted pair has been deployed for about 130 years for the telephony-based carriers; it currently carries voice services and also packet data with DSL technology. The cable TV companies have installed a coax network, which primarily provides RF-based TV channels and can also carry voice and data with Data Over Cable Service Interface Specifications (DOCSIS) technology. Wireless access networks are also available to carry video, data, and voice services. Terrestrial video typically carries local channels in both standard-definition and high-definition formats, while satellite-based TV carries national channels and a wide range of other channels. WiMAX and local WiFi hotspots are available for wireless data services, and cellular technologies carry voice and low-speed data services.

Fiber in the access plant is a relatively new phenomenon in the U.S. Verizon's FiOS service is the first nationally deployed Fiber To The Premises (FTTP) service. It is on track to connect a total of 6 million homes this year and will provide voice, data, and RF video services. Fiber is also being deployed in access plants, for example, by new homebuilders, municipalities, cable companies, and smaller telephone companies. By 2010, it is expected that more than 12 million U.S. subscribers will be served by FTTP. However, this will be difficult to achieve in the U.S. because the majority of lines are buried instead of carried by telephone poles. **Figure 1** shows the configuration of the access network.

3. Comparison between G-PON and GE-PON

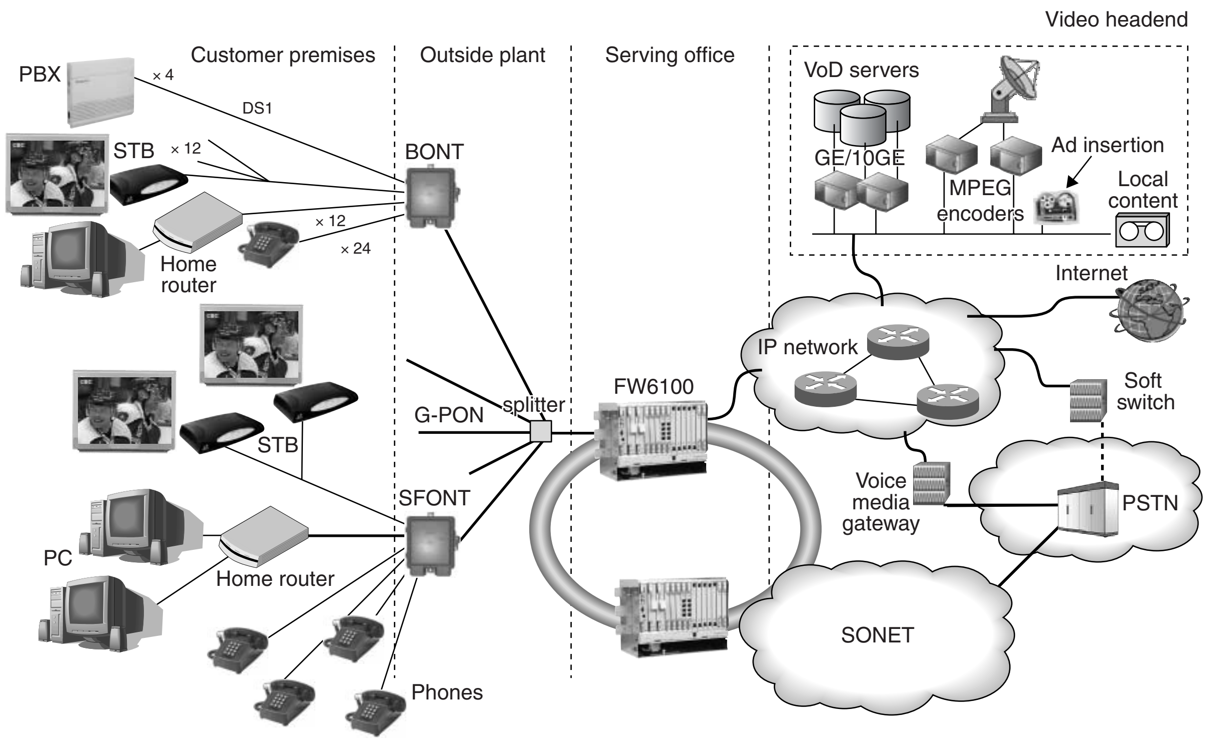
The U.S. carriers have primarily chosen the Full Service Access Network (FSAN)-based ITU standard G.983 (B-PON) and G.984 (G-PON) for their FTTP deployments. **Table 1** shows a comparison of G-PON and GE-PON specifications. The reasons for this choice are as follows:

1) Data rates
- G-PON: 2.4 Gb/s downstream (from the central office [CO] to the subscriber premises), 1.2 Gb/s upstream (from the subscriber to the CO).
- GE-PON: 1.2 Gb/s symmetrical bit rates (downstream and upstream).

2) Security
- G-PON: Uses Advanced Encryption Standard (AES) for security.
- GE-PON: Relies on external end devices to provide their own security.

3) Operations, administration and maintenance (OAM) features
- G-PON: Uses a secure and private channel for management of the optical network terminals (ONTs) (OMCI: ONT management and control interface).
- GE-PON: Uses Simple Network Management Protocol (SNMP) for network element management of the ONTs.

4) Generic framing and Class of Service (CoS)
- G-PON: Allows for traffic type separation through the use of generic framing and explicitly supports IP, TDM, and ATM traffic types.



FW6100: FLASHWAVE 6100

Figure1
Configuration of access network.

Table 1
Comparison of G-PON and GE-PON.

		G-PON	GE-PON
Standard		ITU G.984	IEEE802.3h
MAC layer	Service	Full service (POTS, Ether, TDM)	Ethernet data
	Frame	GEM frame	Ethernet frame
	Reach	10 km/20 km (logical: 60 km)	10 km/20 km
Physical layer	Maximum branch	64 (logical: 128)	>16
	Transmission (b/s)	Upstream: 155 M/622 M/1.25 G/2.4 G Downstream: 1.25 G/2.4 G	Upstream: 1.25 G Downstream: 1.25 G
	Transmission capacity	Same as above (NRZ coding)	1 G (8B10B coding)
	Fiber loss	15/20/25 dB	15/20 dB
	Wavelength	Upstream: 1260 to 1360 nm Downstream: 1480 to 1500 nm	Upstream: 1260 to 1360 nm Downstream: 1480 to 1500 nm
	PON header for upstream	12 bytes for 1.25 Gb/s Guard time: typical guaranteed 32 bits Preamble: 44 bits Delimiter: 20 bits	Laser on/off: 512 ns max. Receiver set: 400 ns max. Clock recovery: 400 ns max. Delimiter: 4 bytes

GEM: G-PON Encapsulation Model

- GE-PON: Traffic type separation and CoS requires Ethernet-based mechanisms and is not explicitly built into the protocol.

5) Timing

- G-PON: Requires that timing be based on an 8 kHz reference clock that can be directly tied to the public switched telephone network (PSTN) for Stratum 1 traceability for TDM services.
- GE-PON: Based on loose Ethernet timing and requires other mechanisms for tight timing control to support TDM services.

4. Optical Line Terminal (OLT)

The OLT resides in the central office (**Figure 2**). This device provides the northbound WAN-based interfaces to the network. It also typically provides Ethernet aggregation capability and link aggregation on the WAN ports for additional capacity and protection.

The OLT sends all downstream information to all ONTs. The data is addressed to specific ONTs, and the unaddressed ONTs ignore the data. The OLT also acts as the traffic cop for upstream data. Because the topology of the network is point-to-multipoint, without a collision avoidance mechanism, the ONTs could interfere with each other if they are not instructed when to transmit upstream data. The OLT takes on this role and informs the ONTs when they can and cannot transmit upstream data.

The first release of the FLASHWAVE 6100 system provides 20 G-PON ports in a 9-rack unit (9RU) form factor and 8 × Gigabit Ethernet ports for its WAN interface. The second release will provide 40 G-PON ports in a 9RU form factor and 4 × 10 Gigabit Ethernet ports for its WAN interface. The system supports SONET/SONET-based interfaces to carry TDM services such as DS1 and E1.

5. Optical Network Terminal (ONT)

The ONT is installed at the customer premises (**Figure 3**). Typically, it is located outside the customer's house for easy access by the carrier's craft personnel. The ONT requires local power, so it comes with a power supply and typically a battery to protect against power losses. Due to the shortened life of the battery under extreme temperature variations, the battery and the power supply are typically placed

Figure 2
G-PON OLT (FW6100).

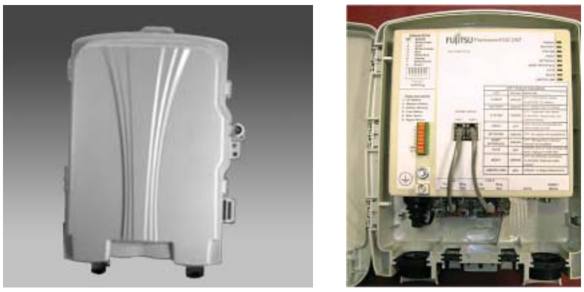


Figure 3
G-PON ONT.

Table 2
ONT options.

	POTS	10/100/1000BT	VDSL2	DS1	RF video	MoCA
SFU	2	2			1	1
MDU	24	12	12		1	
MTU	24	8		4	1	

inside the residence, for example, in a garage or basement.

The ONT directly provides all of the services for the customer. It provides an equivalent twisted-pair for telephony service, an RJ45 jack for Ethernet services, and an F-connector (coax) for RF-based TV services.

The FLASHWAVE 6102 ONT provides two telephony-based lines, can support 10/100/1000BaseT from its Ethernet port, and can provide a –14 dBm CATV signal for RF channels. Further, it can support a MoCA channel (Multi-Media over Coax Alliance — which is Ethernet over RF over coax). The MoCA capability enables carriers to install Ethernet in a subscriber's house without needing to re-wire the house with category5 cable or install a wireless LAN. It fits into a 10-inch × 13-inch housing, which is currently one of the smallest housings in the industry for an outside plant (OSP)-based ONT.

Fujitsu's FLASHWAVE 6100 system will also support business ONTs. These ONTs are designed specifically for business applications and provide high reliability, protection on the fiber feeds (as an option), and TDM-based services. In the U.S., TDM services such as T1s are very common in small businesses. Therefore, the business ONT must support these services and be able to transfer them without degradation through the network.

Fujitsu's ONTs support two methods of DS1 encapsulation that allow them to deliver the DS1s to the network more efficiently. If the network interface includes a SONET, the business ONT can VT map the DS1s for direct delivery to the SONET. If the network interface is WAN based, the business ONT will map the DS1 into an MEF8 circuit emulation format for transport over WAN.

Fujitsu will also support a multi-dwelling-unit ONT to serve apartment complexes. These ONTs will support VDSL2 technologies for delivering large amounts of bandwidth over very short copper runs. **Table 2** shows the ONT options.

6. NETSMART

NETSMART 1500 is a carrier class element/network management system that provides a rich set of features, a variety of external interfaces for Operation Support System (OSS) interoperability, and unprecedented scalability. NETSMART 1500 currently manages over 140 000 SONET and DWDM network elements in North America, and Fujitsu Network Communications has spent several years fine-tuning an architecture that was designed specifically for our largest customers. NETSMART 1500 will support the G-PON deployment forecast with a single-server platform, providing a unified view of the G-PON. This scalability is achieved by adding processors, memory, and storage to one large server, thus providing vertical or flat scalability rather than a clustered or hierarchical network of servers. Aside from providing a single view of the G-PON, the advantage of a single-server approach is that it minimizes the administration work required to support the G-PON element/network management system. **Figure 4** shows an example of a NETSMART 1500 screen.

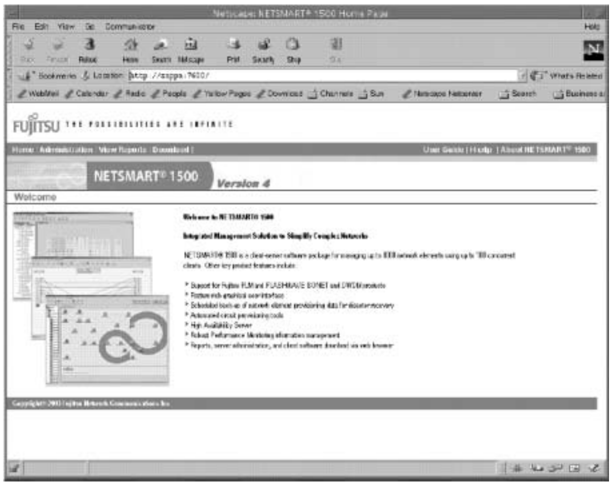


Figure 4
NETSMART 1500 screen.

Developing a management system to support very large networks requires that performance be a key consideration in all aspects of software design. The fundamental system platform must address scalability and performance, and the selection of third-party software must similarly be capable of high degrees of scalability.

7. Hybrid G-PON (HG-PON)

Once G-PON becomes widely deployed, it will provide sufficient bandwidth for the carriers to provide enhanced services in the immediate future. With G-PON's bit-rate capacities of 2.5 Gb/s downstream and 1.2 Gb/s upstream, Internet browsing, voice services, and even HDTV video services will be handled with relative ease. However, tomorrow's network demands are unknown and it is highly unlikely that customer appetite for bandwidth will be satisfied for a long

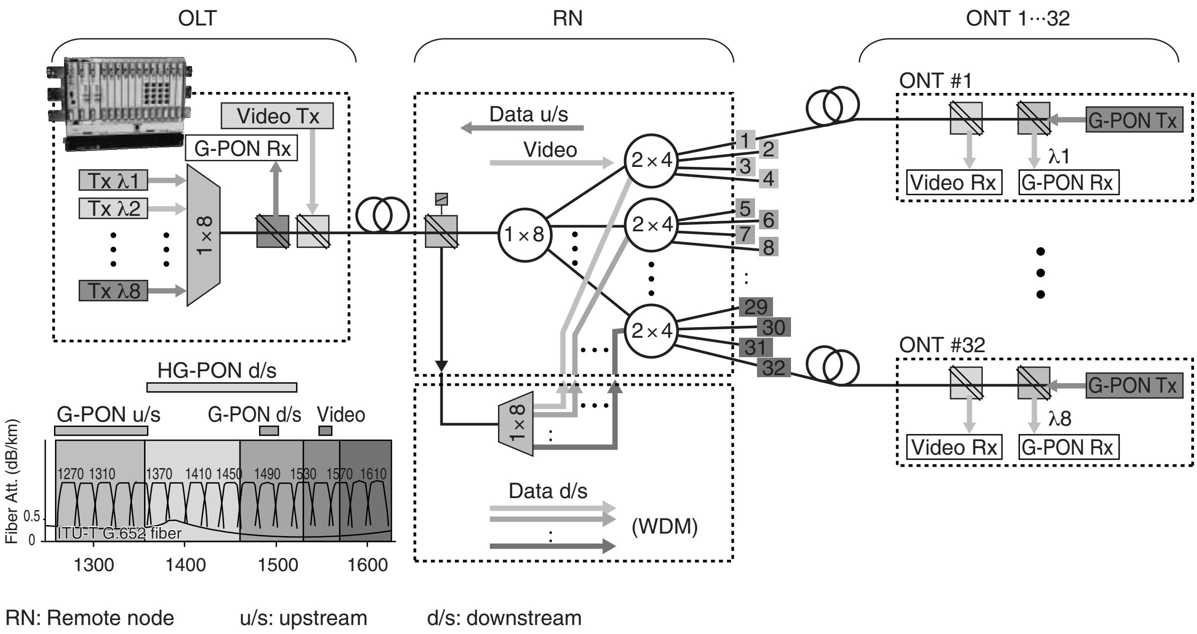


Figure 5
HG-PON system configuration.

time. New services are likely to appear that will require even higher speeds and additional network capacity.

Over the past 30 years, Moore's Law has fairly accurately predicted the growth in the number of transistors in a CPU (CPU horsepower), which essentially doubles every two years. This growth was based only on technology advances and consumer demand for ever-increasing CPU performance. In the communication world, bandwidth growth has been somewhat hindered due to the constraints of access network capacity. With the introduction of the dramatically higher speeds of FTTP PON architectures, the access bottleneck is beginning to open up. It follows that if consumers could have all the bandwidth they wanted, then new, richer, multimedia services would evolve and bandwidth growth would more closely follow a Moore's Law type of curve.

Fujitsu has recently submitted multiple patents pertaining to a Hybrid G-PON (HG-PON) architecture.

HG-PON allows the OLT system or service unit to be upgraded to WDM PON without needing to replace or upgrade the ONTs (**Figure 5**). This allows an ONT or a group of ONTs to be segmented from the rest of the ONTs on a splitter, thus effectively reducing the split ratio. It also maintains today's current upstream structure so all of the ONTs on the splitter share the same upstream wavelength. This is a hybrid architecture because it supports WDM PON downstream with the same single wavelength and a layer 2 G-PON structure upstream.

The essential value of HG-PON is that bandwidth capacity can be added to the system in the downstream direction without incurring the high cost of upgrading the ONTs.

8. Conclusion

Deployment of fiber deep within access plants is inevitable. The U.S. carriers realize this and are making the huge investment to upgrade their copper plants to fiber. Verizon is the first carrier to make this leap in a broad and bold way, but others will soon follow. This upgrade will take place over the next 20 years and over many generations of fiber-based equipment.

Fujitsu's FLASHWAVE 6100 system is the first product in Fujitsu's U.S. lineup to address this market. It is a very capable and forward-looking packet-based system. However, for FLASHWAVE 6100 to also support transitional technologies such as ADSL, VDSL, and EoCU, other access service technologies will also need to be supported.

Fujitsu intends to be a dominant player in this market. Success in this market will require careful planning, big investments, shortened development cycles, aggressive sales, and — above all — solid teamwork.

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Mr. Murase received the B.S. degree in Electronics Engineering from the University of Tokyo, Tokyo, Japan in 1977. He joined Fujitsu Ltd., Kawasaki, Japan in 1977 and was engaged in the development of digital transmission systems, fiber optic systems, digital loop systems, and broadband access systems. From 1998 to 2004 he was assigned to Fujitsu Telecommunications Europe Limited (UK). Mr. Murase is a member of the Institute of Electronics, Information and Communication Engineers (IEICE) of Japan.

Stephen Smith, *Fujitsu Network Communications Inc.*
Mr. Smith is a distinguished product planner for Fujitsu Network Communications. He spent the first 15 years of his career in engineering, designing NGDLCs, DSL, FTTC, and other access-based equipment. He has spent the last 10 years working in the product planning and product marketing aspects of the industry. His industry experience entails employment at Reltec, Bellcore (as a visiting researcher), AFC, and Fujitsu. He is now providing direction for Fujitsu's access strategy, serving as lead planner for the FLASHWAVE 6100 G-PON product line.

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Mr. Ohtsuka received the B.S. and M.S. degrees in Communication Engineering from Osaka University, Osaka, Japan in 1988 and 1990, respectively. He joined Fujitsu Ltd., Kawasaki, Japan in 1990, where he has been engaged in the development of ISDN systems and optical access systems. He was assigned to Fujitsu Access Ltd. in 2001.