10G-EPON System Featuring High-Speed and High-Capacity Layer 3 Switching

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We have been providing advanced broadband technology and internet access equipment to the market. FSU7100 is our latest product that aims for the next generation high-speed transmission service. We offer 1G-EPON (Ethernet passive optical network) cards, 10G-EPON cards, and aggregation switch cards for FSU7100. This paper reports on the specification parameters of the common framework of sOFIA (Sumitomo Electric optical fiber access system integration architecture), line cards, and switch cards. In addition, as a software feature that enables operators to replace DOCSIS (Data over Cable Service Interface Specifications) systems with PON systems at low cost, DPoE (DOCSIS provisioning of EPON) is introduced.

Keywords: 10G-EPON, FTTH, DPoE, optical, Internet access

1. Introduction

With continuously growing communication traffic, Internet subscriber lines have shifted from telephone lines (copper wires) and coaxial cables to passive optical network (PON), which is capable of transmitting/receiving large amounts of data. Large-scale passive optical network systems have been in use since 2004, notably in the East Asian region including Japan, China, and South Korea. Sumitomo Electric Industries, Ltd. began commercializing PON technology in 2005 and started distributing 1G Ethernet passive optical network (EPON)-based communication systems to operators. This distribution inspired a new service capable of larger-scale data transmission. For example, IP video streaming is now pursuing a new service of 4K high-definition TV distribution, and video sharing services have significantly increased the upstream traffic. Mobile communications and their advancement from 3G-LTE to 4G and 5G also stimulate the need for faster distribution channels.

This paper reports on a fiber-to-the-home (FTTH) system equipped with high-speed and high-capacity switching. The system supports 10G-EPON as well as 1G-EPON for subscriber lines, offers aggregation switch cards for EPON lines, and is capable of high-speed and high-capacity switching for 10GE-PON lines. It is also compatible with DPoE*1 to mitigate the costs incurred by CATV operators when they replace their existing systems with PON systems.

2. System Overview

2-1 System architecture

The FSU7100 (Fig.1) is an optical access platform that supports up to 10,240 subscriber lines for 1 Gbit/s service, and up to 16,384 subscriber lines for 10 Gbit/s service. This platform is equipped with two aggregation switch cards in a redundant configuration, each of which has integrated control/monitoring and switching functions for the entire system. The FSU7100 can accommodate up

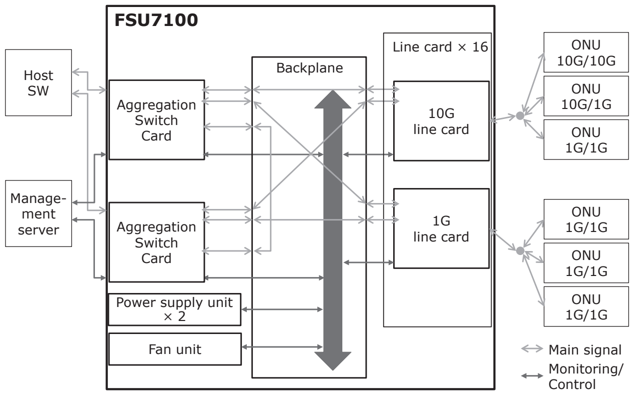

Fig. 1. Block Diagram

Table 1. FSU7100 Specifications

Item			Spec
Enclosure	Size	Dimensions (mm)	W434 × D334 × H444
	No. of slots		Power supply unit × 2 Fan unit × 1 Aggregation switch card × 2 Line card × 16
Aggregation switch card	Uplink interface	No. of ports	8 ports
		Physical interface	SFP+/SFP
		Compliant with	10GBASE-R 1000BASE-X
	Monitoring/ Control interface (Remote)	No. of ports	1
		Physical interface	RJ-45
		Compliant with	1000BASE-T 100BASE-TX 10BASE-T
	Monitoring/ Control interface (Serial)	No. of ports	1
		Physical interface	RJ-45
		Compliant with	RS232C
1G line card	PON I/F	No. of ports	10 ports
		Physical interface	SFP
		Compliant with	1000BASE-PX20
10G line card	PON I/F	No. of ports	8 ports
		Physical interface	XFP
		Compliant with	10GBASE-PR 10/1BASE-PRX 1000BASE-PX

to 16 line cards, with any combination of 1G-EPON and 10G-EPON line cards. PON cards, power source units, and a fan unit can be replaced without any interruption for power shutdown, thus advantageous in various occasions such as system faults and 1 Gbit/s to 10 Gbit/s upgrades. The communication bandwidth between aggregation switch cards and line cards is 80 Gbit/s. Each line card is connected to both aggregation switch cards. Consequently, the FSU7100 offers a switching capacity of 2.56 Tbit/s in total (a bandwidth of 80 Gbit/s between each aggregation switch card and a line card × 16 slots × 2 aggregation switch cards operating in active-active mode).

2-2 Common framework (sOFIA)

With diverse customers' requirements and newly developed technologies, enhancement in the efficiency of software development for access systems is now our major challenge.

To improve the productivity and quality of software, the authors have developed a common access platform called Sumitomo Electric optical fiber access system integration architecture (sOFIA) (Fig. 2). This section introduces sOFIA and its achievements.

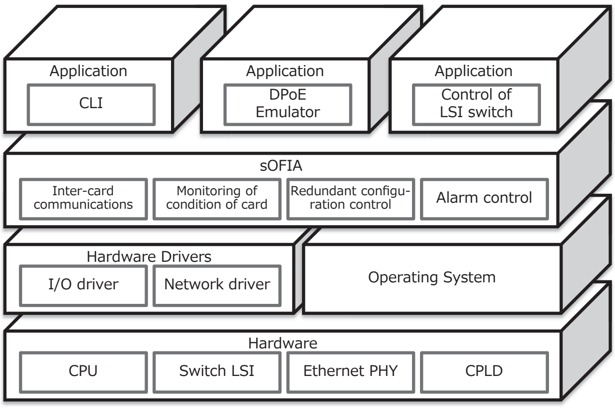

Fig. 2. Hierarchical structure of access equipment software

● Hierarchical software structure

The software is classified into the following hierarchical modules:

(1) Application: Software modules, including a command-line interface and DPoE functions, designed to meet customer requirements and enhance product value.
(2) sOFIA: Basic and auxiliary functions that can be used commonly in individual applications.
(3) Hardware driver: Interface for hardware control.
(4) Operating system (OS): Providing basic system control and management services
(5) Hardware: Physical components, such as electronic circuits and devices.

● sOFIA functionality overview

As shown in Table 2, sOFIA consists of a set of basic functions essential for system design and auxiliary functions to facilitate application development.

Table 2. Example sOFIA functions

Component	Description
Inter-card communications	Provides functions for application-to-application communications, either within a card or between cards.
Card status monitoring	Monitors card presence and its hardware/software operating status.
Redundant configuration control	Improves system reliability, by controlling card redundancy (operation/standby).
Alarm control	Collects and controls alarm status occurring in cards (keeps updated logs and issues maintenance notices).
Operating system abstraction	Operating system abstraction allows applications to disregard OS differences.

● Major achievements of sOFIA

(1) Improved efficiency in application software development
(a) sOFIA hides product-specific hardware, hardware drivers, and OS, and thus provides applications with a defined application programming interface (API). This feature enables the reuse of existing applications with new cards—potentially differing in hardware from the existing ones—without requiring changes in the application level.
(b) Highly complex functions are provided as a package, limiting the need for new development.
(c) The packaged functions allow the incorporation of flexible combinations of functions in each product, and thus improve application development efficiency.

(2) Quality improvement/standardization

Quality can be improved by utilizing proven software as standard components. By using standard components for various products, product quality is enhanced or improved quickly.

3. FSU7100 Features

3-1 Line cards

In the FSU7100 product line, there is a 1G-EPON card and a 10G-EPON card. Up to 16 line cards can be installed into a FSU7100. Each 1G line card has 10 ports, whereas each 10G line card has 8 ports. Both 1G and 10G line cards allow operators to replace faulty optical transceivers without interrupting service on other normal ports.

This section describes the features of 10G-EPON line cards.

(1) Increased number of ONUs

Each 10G line card supports 128 optical network units (ONUs; home PON units) per port, which represents an enhancement from 1G line cards, each of which is connected to 64 ONUs. The increased number of ONUs supported by each card, a reduced unit price per port, and a reduced number of installed fibers make it possible to reduce the initial investment cost.

(2) Support for multiple operating modes

The 10G-EPON line cards support the EPON mode—in which the card directly uses the monitoring/control the functions of the EPON equipment—along with the DPoE mode (to be described later), which sets up EPON equipment as if it were a cable modem termination system

(CMTS) or cable modem (CM) specified by DOCSIS.*[2] The DPoE mode is effective in reducing installation cost for CATV operators. In contrast, the EPON mode—intended for users other than CATV operators—is advantageous in that it ensures fast ONU connection, because service configuration is saved in the optical line terminal (OLT; station PON unit).

(3) Connection with multiple ONU types

The 10G-EPON line cards support three types of ONU: 1G-ONUs (specified by the 1G-EPON standard), 10G symmetric ONUs, and 10G asymmetric ONUs (these latter two specified by the 10G-EPON standard); the coexistence of these ONUs at the same PON port is permitted. Consequently, when a user desires to replace an existing 1G-EPON system with a 10G-EPON system, all that is required is to change the station unit. Furthermore, replacing 1G-ONUs with 10G-ONUs enables 10 Gbit/s high-speed communications.

(4) Long-distance transmission performance

Inserting a 10G repeater between a 10G line card and a 10G-EPON ONU enables long-distance transmission. The impact of the repeater on the performance of the 10G line card is described in terms of both throughput*[3] and latency.*[4]

Figure 3 shows the upstream throughputs between a 10G line card and a 10G ONU with a 10G repeater, measured at the total distances of 20, 40, and 60 km.

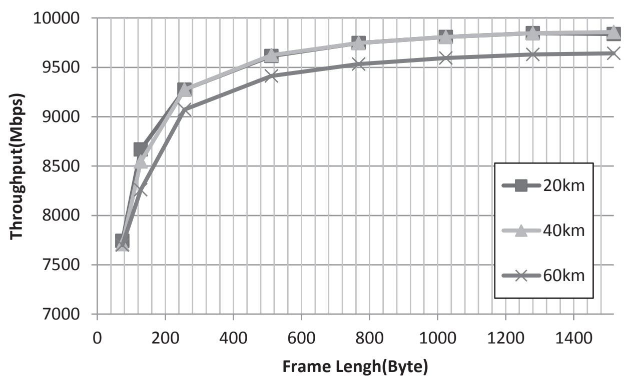

Fig. 3. L2 throughput with a connected 10G repeater

This measurement shows that the L2*[5] throughput is basically maintained, whether the connection distance is 20 or 60 km. In short, throughput degradation is mostly the same, irrespective of connection distance.

Downstream delay depends exclusively on the transmission path delay implied by the fiber length. PON technology controls upstream collision by means of dynamic bandwidth allocation. Hence, upstream delay can be calculated by Eq. (1), which contains the transmission path delay as a parameter.

$$\text{Upstream delay time} = 2 \times \text{Transmission path delay} + \alpha \quad \cdots\cdots \quad (1)$$

where α is the time delay within the repeater.

Figure 4 shows the upstream latency, measured at connection distances of 20, 40, and 60 km.

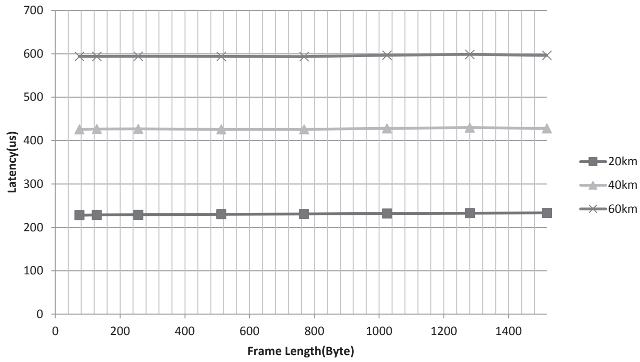

Fig. 4. Latency with a 10G repeater

As can be seen from the test results presented above, when α is 30 μs, Eq. (1) can hold any of the distances (20 km, 40 km, 60 km). This indicates no extra delays were caused by the 10G repeater connection.

3-2 Aggregation switch card

Aggregation switch cards offer traffic aggregation and fault tolerance in addition to control and management functions. The switching capacity of one card is 720 Gbit/s. The upstream communication bandwidth of the card is 80 Gbit/s (10 Gbit/s × 8 ports). The uplink ports support various standards by replaceable SFP+ optical module.

(1) Management functions

The aggregation switch card offers the management functions shown in Table 3. These functions allow changing and saving the FSU7100 operational configuration.

Table 3. Management functions of the aggregation switch card

Management function	Description
SNMPv1/v2c/v3	Remote management
CLI (enables communications via SSH/Telnet)	Command input
TFTP/SFTP client	File transfer
syslog client	Management information transfer
SNTP/NTP client	Time synchronization
RADIUS client	Accounting
TACACS+ AAA client	Authentication, Authorization and Accounting
Access control list	Security
Remote software upgrading	Remote upgrading

(2) Traffic aggregation functions

The aggregation switch card interconnects data channels between uplink ports and line cards. This function reduces the number of required physical ports on northbound routers. Additionally, the aggregation switch card offers both L2 and L3*[5] switching to enable high-speed data transfer and advanced control.

Using the L2 switching function of the FSU7100, the aggregation switch cards offer VPN services to handle data transmission between customer offices across wide area network like a dedicated line [U.S. Metro Ethernet Forum*[7] (MEF) 9 and MEF14 certified].

The L3 switching function of the FSU7100 allows provisioning of Internet access service. The L3 switch carries out data recipient control, while exchanging information with other routers within a network. The FSU7100 supports multiple routing functions to adapt to the size of the customer networks (Table 4).

Table 4. Routing protocols of the aggregation switch card

Routing protocol	Description
OSPFv2	For medium-sized networks
RIPv2	For small networks
M-ISIS	For medium-sized networks

(3) Fault tolerance

The aggregation switch card collects communication data from the individual line cards, and establishes an Internet connection. In light of this role, communication line faults and failures that may occur on the aggregation switch card have a major impact on the entire system. To solve this issue, the FSU7100 has multiple features for enhanced fault tolerance. Installing two switch cards into one chassis enables a high availability topology known as Active-Active topology. This configuration also improves the overall system performance via distributed processing, allowing two switch cards with identical configurations to operate simultaneously. Moreover, if a fault occurs in one switch card, the other switch card takes over the functions of the faulty card (known as a fail-over service). This is shown in Fig. 5, and ensures the desired fault tolerance.

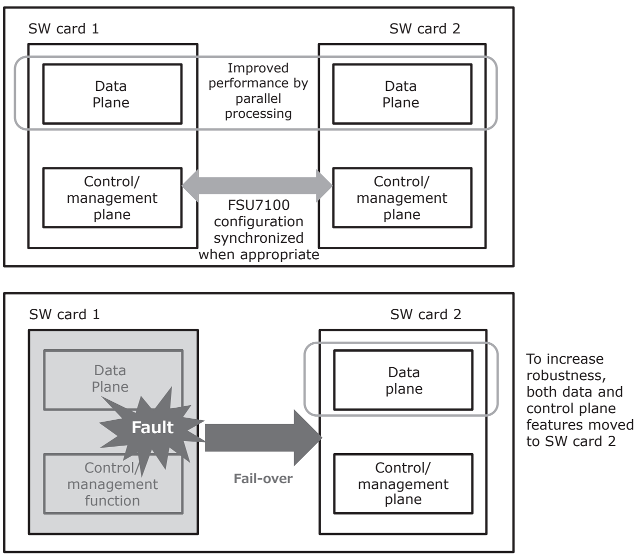

Fig. 5. Active-Active Topology

An additional degree of reliability and fault tolerance is also obtained via link aggregation (LAG) and equal cost multi-path modes (ECMP), which handle multiple communication lines as if they were constituted by a single line.

3-3 DPoE

CableLabs is a U.S.-based consortium of CATV operators. In 2011, this consortium released the DPoE 1.0 specifications. This is a set of specifications designed to implement wide-area Ethernet services for businesses, and broadband Internet access services for general subscribers. DPoE is also designed to operate and manage EPON without changing the CATV operators' existing operation support system, on which they have made a large development investment.

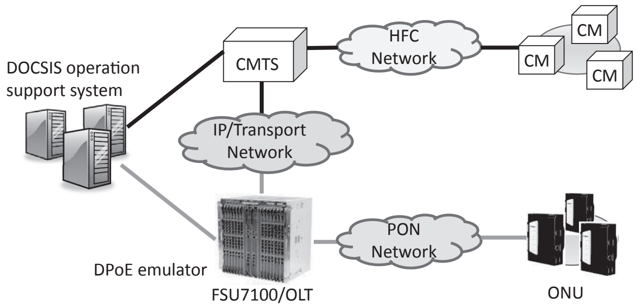

Fig. 6. DPoE network

In 2009, Sumitomo Electric began to develop the FSU7100 for CATV operators. Since then, the company has taken part in creating certification test plans led by CableLabs, as well as in DPoE 1.0 interoperability testing. In 2013, Sumitomo Electric became one of the first DPoE 1.0-certified device vendors for both OLTs and ONUs. At the same time, aiming to explore the EPON market in North America, Sumitomo Electric has participated in the standardization efforts to implement 10G-EPON for higher levels of broadband operations, such as the extension of wide-area Ethernet services for businesses, IPv6, and multicast. The company has also contributed to the establishment of the DPoE 2.0 specifications in 2012.

The FSU7100 has a built-in DPoE emulator, to provide part of the function set defined in DPoE 1.0 and DPoE 2.0.

The DPoE emulator virtualizes DOCSIS CMTS and CMs for an OLT and ONUs, respectively. It thus controls both of them, converting the commands sent to them from an operation support system. This enables users to use their existing operation support system equipped with DOCSIS management functions at reduced EPON installation cost. Moreover, by saving a CM configuration file on the operation support system, it becomes possible to define the quality of service for each ONU, and to achieve traffic control (Fig. 7).

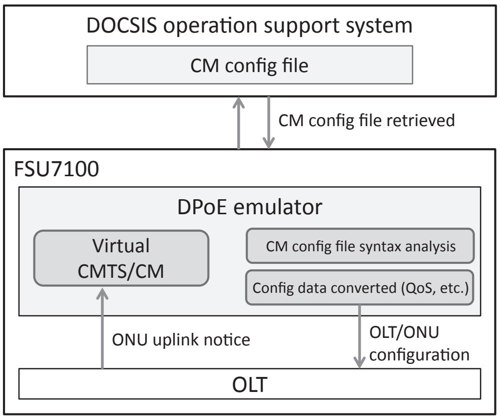

Fig. 7. DPoE emulator

4. Conclusion

This paper presented an overview of an optical access platform that supports 10G-EPON and incorporates high-speed and high-capacity switching. The authors believe that the newly developed PON system will help the growth of increasingly fast-operating access networks, both in Japan and abroad.

• sOFIA is a trademark of Sumitomo Electric Industries, Ltd.

Technical Terms

∗1 DOCSIS Provisioning of EPON (DPoE): A set of technical specifications designed to enable operators who have been using DOCSIS service to provide high-speed Internet access service by means of fiber-optic PON technology, utilizing the customer management systems already in use for the DOCSIS service.

∗2 Data Over Cable Service Interface Specification (DOCSIS): A technical specification established with the aim of providing internet access services by using the idle bandwidth of existing coaxial cables installed for cable TV applications.

∗3 Throughput: The amount of data that can be passed through a channel, process or system.

∗4 Latency: A delay in data transfer; it comprises the internal processing time of intervening equipment plus the transfer waiting time.

∗5 L2, L3: Data transfer modes MAC layer (L2) and IP layer (L3); L3 permits a more complex data transfer control than L2.

∗6 Frame length: The length of the data blocks sent over a transmission path.

∗7 Metro Ethernet Forum: A consortium working on the establishment of technical specifications for the public Ethernet service.

Reference

(1) T. Senou, "Commercialization of FTTH System for Cable-TV Operators," SEI Technical Review No.77 (2013)

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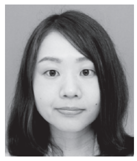

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