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E-PON 기반 TDM 신호 전송 시스템

(Transmission System of TDM signal based on E-PON)

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요 약

본 논문은 기존의 E-PON 시스템에 TDM 의사회선 기능을 부가함으로써 데이터와 TDM 신호를 동시에 전달할 수 있는 시스템 개발에 관한 것이다. E-PON 기술은 FTTH를 구현할 수 여러 기술 중 하나이며, 저가의 이더넷 기술과 광 인프라를 결합한 차세대 액세스 네트워크 솔루션으로 대두되고 있다. TDM 의사회선 서비스는 패킷교환 네트워크를 통하여 기존의 TDM 회선교환 음성 및 데이터 트래픽을 전송할 수 있도록 해주는 새로운 음성/데이터 변환기술이다. 본 논문에서는 E-PON 시스템에 TDM 의사회선 서비스 모듈을 부가하고, QoS 제어 기능을 구현함으로써 QoS 손실 없이 데이터 및 TDM 서비스를 효율적으로 제공할 수 있다. 따라서 데이터와 TDM 신호가 동시에 전달될 수 있는 경쟁력 있는 시스템에 구축될 수 있다.

Abstract

This paper addresses the system development that can transfer data and TDM signals simultaneously by adding TDM pseudowires functions to E-PON system. E-PON technology is one of many technologies which can realize FTTH, has raised as next generation access network solution having both low-cost Ethernet technology and optical infrastructure. TDM pseudowires service is the new voice/data conversion technology which can transfer the existing TDM circuit switched voice and data over packet switching network. In this paper, this system can provide both data and TDM service without deteriorating QoS by adding TDM pseudowires service module to E-PON, and then implementing QoS control function. Therefore, the competitive system, which can transfer both data and TDM signal, can be installed.

Keywords : E-PON, FTTH, pseudowires, QoS, TDM

I. Introduction

A future information and communication era is ubiquitous one, which exchanges high-speed and large-capacity multimedia, such as convergence of voice and data, convergence of communication and broadcasting, home network, and so on.

It is FTTH that come into the spotlight as infrastructure to transfer high-speed and large-capacity multimedia data efficiently in ubiquitous era. Especially, as a part of installing next generation network, many countries in the world are willing to install FTTH competitively. A installation of FTTH remains in early stage, but distinguishes itself from the existing high-speed Internet line, such as ISDN, xDSL, and cable modem, and is rising rapidly[1, 7~8].

In these days, telecommunication service operator and corporate customers are interested in installing the system facilities which can supply voice and

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leased line through Ethernet, IP, and MPLS. VoIP technology has been completed, but it requires the additional investments because new network infrastructure and customer premises equipment are needed to install the system for VoIP. But TDM over IP/Ethernet (TDMoIP) technology uses the packet switched network as the information carrier, and also provides the path which can move the existing services to the new network without installing the additional devices for customers[14~15, 20].

As service providers who had introduced the network based on TDM in the late 1980s, have migrated their networks to IP network, they want to transfer both data and TDM signals through the system based on IP/Ethernet technology. If the legacy TDM network is connected to the system, such as E-PON, the dedicated line for TDM is needed[18~19]. But if both E-PON technology for transmitting Ethernet frame and TDMoIP technology will be applied to, it is possible to install the more competitive system that can transfer both data and TDM signal. Therefore, this system increases the penetration of domestic equipment to FTTH market which fully has been formed from 2006, and also can meet user's and ISP's need by developing the competitive FTTB/FTTC system using FTTH. This paper addresses the system that can data and TDM signals simultaneously by adding TDM pseudowires functions to E-PON system. This system can provide both data and TDM service without deteriorating QoS by adding TDMoIP module to E-PON, and then implementing QoS control function.

II. E-PON System Operation

Figure 1 shows the access network configuration consisting of E-PON system. E-PON consists of OLT(Optical Line Terminal), Passive Optical Splitter/ Coupler, and many ONUs/ONTs(Optical Networking Unit/Optical Networking Terminals). Because of its simple architecture, the access network can be configured efficiently. As E-PON uses the optic fiber that provides high bandwidth, it is efficient in

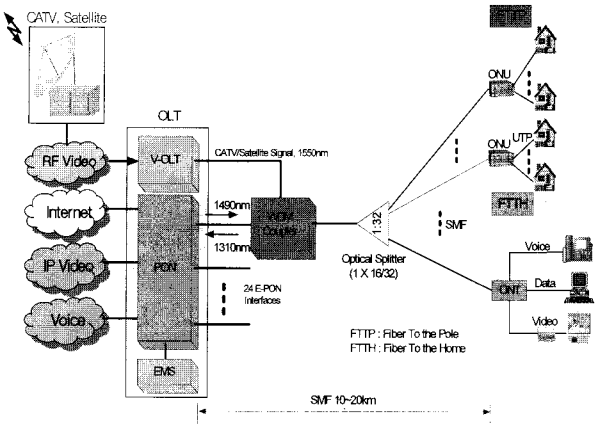

그림 1. E-PON 망 구성도
Fig. 1. E-PON network configuration.

transmitting data, video, and voice traffic. One optic fiber connected to OLT is branched to many optic fibers (16~64 branches) by passive optical splitter/coupler, and ONU/ONT are connected to the end of branched optic fiber. OLT and ONU/ONT are located at both end points of optical splitter, and they both are connected to optical splitter through optic fiber. E-PON system concentrates many signals into one signal or distributes one signal to many signals through optical splitter based on the transmission direction of optical signal. As OLT and ONUs/ONTs are connected in point-to-multipoint type, the installation cost of optic fiber is chapter than one of point-to-point type[1~2, 9~10].

IEEE802.3 standard defines two basic configurations of Ethernet network. One is the method that be configured on shared medium using CSMA/CD protocol, another is the one that stations can be connected to through switch using full duplex point-to-point link. E-PON is the combination of above two methods[4~5, 16~17].

Figure 2 show the traffic flow in E-PON network. In this figure, all ONTs synchronize themselves with the common standard time, and then the time slot is assigned to each ONT. In each time slot, many Ethernet frames can be delivered. ONT will buffer the frames received from subscribers until its own time slot is arrived at. When its own frame is arrived at, ONT bursts all buffered frames at full channel speed. if there are no frames in buffer to fill

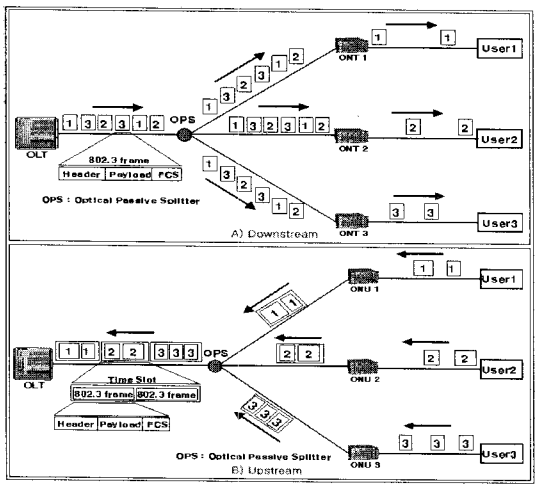

그림 2. E-PON 망에서 트래픽 흐름
Fig. 2. Traffic flow in E-PON network.

its own time slot, the ONT transmits 10-bits idle character. In time slot assignment methods, there are two methods, such as static assignment method (TDMA) for all ONTs, dynamic adaptive one based on the instantaneous queue length of all ONTs (statistics multiplexing)[8, 11~12]. In downstream, OLT broadcasts a packet to multiple ONTs, and then the destination ONT extracts the packet based on MAC address. In upstream, because of the direction in splitter, a data frame from any ONT is arrived at OLT and not ONT. Therefore, The operation of E-PON is similar to point-to-point architecture. But contrary to strict point-to-point, the data frames from different ONTs in E-PON can be conflicted. So in upstream, ONTs must have the arbitration mechanism to avert the collision and share the optic channel capacity fairly[3, 6, 16~17].

III. The System Architecture

In these days, the communication era based on TDM which has leaded the communication market during past 100 years is ended, and then IP convergence era has been started. Traditionally, voice and legacy data traffics are transferred over connection-oriented synchronous or asynchronous network, such as TDM network. As the packet switched network has been spreaded rapidly and has enough availability, it is required to integrate TDM

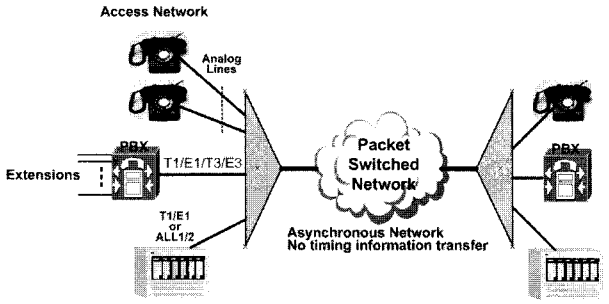

그림 3. 패킷교환망을 통한 회선교환 에뮬레이션
Fig. 3. Circuit Emulation over Packet Switched Network.

services into PSN network infrastructure. This (TDMoPSN) is implemented through the diverse technologies, such as TDMoIP, TDMoMPLS, and TDMoEthernet, and needs TDM circuit emulation in PSN. TDM Pseudowire is the technology that emulates TDM services in packet switched network, such as Ethernet, IP, and MPLS[13~15].

Figure 3 shows TDM pseudowire service network. In computer network and communication system, TDM over IP(TDMoIP) technology emulates TDM over packet switch. In general, TDM, which is the digital interleaving method to transfer many 64kbps circuit switched voice or data streams, presents T1, E1, T3, and E3 signals. And the packet switched networks are MPLS, IP, and Ethernet. the circuit emulation is a new voice/data conversion technology which can transfer both TDM circuit switched voice and data traffics without deteriorating QoS[19~20].

TDMoIP is a technology which TDM traffic be transferred through the packet switched network. Unlike other traffics, TDM traffics have the characteristic sensitive to time. Also, the commercializing TDM network has many kind of special characteristics, and the characteristics is required when transferring the phone channel lines of voice level.

To transfer the legacy traffic in the backbone network based on IP, TDMoIP, T1 or E1 circuits must be converted into IP/MPLS packet, and then are transferred to the packet switched network. As the original traffic and clock are recovered from the receiver data in receiving side and the connection is maintained throughout the packet switched network

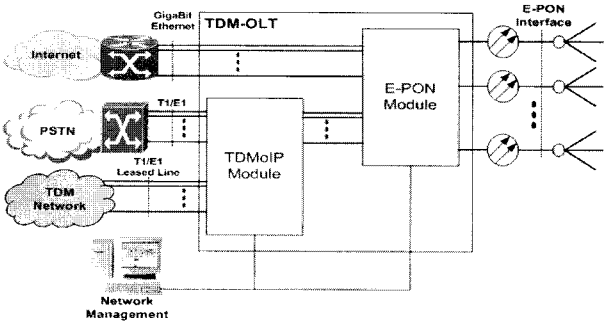

그림 4. TDM_OLT 시스템 구성도
Fig. 4. TDM_OLT system configuration.

transparently, the existing network characteristics and functions remains as it is[18~19].

Figure 4 shows TDM_OLT system configuration for transferring both data and TDM traffics based on E-PON system. To provide both data and TDM services through E-PON, TDMoIP module must be added to the existing E-PON. E-PON module must support E-PON interfaces based on IEEE 802.3ah and Gigabit uplink interfaces. TDMoIP module converts T1/E1 TDM traffics to IP packets or reverse. This system has the maximum 8Gbps bandwidth (expandable up to 12Gbps) for data and TDM traffics. Maximum 6Gbps bandwidth can be used for data traffic and up to 2Gbps bandwidth can be used for TDM traffic. And this can support many T1/E1 links for the transparent connection to multiple ONUs and the voice service.

This system can provide multimedia services, such as voice, data, and video based on E-PON and has the characteristics using the packet switched network instead of the existing TDM network. This system can support data transmission based on Ethernet by using the most economic E-PON one of many PON technologies, and can also support voice, E1/fraction E1 leased line through the packet switched network by using TDMoIP technology.

This system can support the legacy TDM service through E-PON system by adding TDMoIP technology to E-PON system as shown in figure 4. In this figure, TDMoIP module accommodates many T1/E1 lines of PSTN and T1/E1 leased line of TDM network. Therefore, this system based on the packet switched network has the characteristics, such as cost-effective and easy adaptability as next generation network technology. Main characteristics are following:

- ☐ Multimedia service network can be designed through the packet switched network
- ☐ TDMoIP technology can be used for TDM transmission, such as voice, E1/fractional E1
- ☐ Cost-effective E-PON technology is applied to
- ☐ Enough bandwidth of E-PON link can accommodate the coming service requirements

Figure 5 shows TDM_OLT architecture in E-PON system. TDM_OLT system performs OLT operation in E-PON system, and the terminating function for ONU or ONU. Gigabit Ethernet switching module performs uplink and control function. It has 1000Base-Tx and 1000Base-Fx interfaces for uplink. And it supports link aggregation function to supply the increasing function of bandwidth. This module includes Gigabit Ethernet switch that supports L2/L3 switching function. It has a few Gigabit Ethernet ports for uplink port, and these ports can be used for 1000Base-Tx.

E-PON line card supports E-PON interfaces, and is connected to Gigabit Ethernet Switching Module using 1000Base-Tx signal in backplane. Built-in processor of E-PON chip in E-PON line card is assigned to the private IP address for the appropriate slot location, and communicates with main processor in UDP message. And the processor is connected to main processor

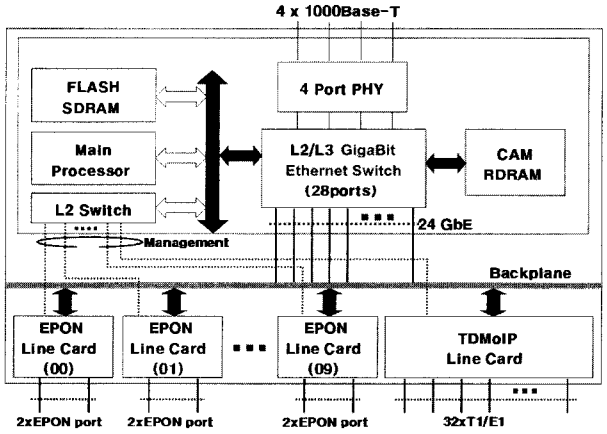

그림 5. E-PON 시스템의 TDM_OLT 구조
Fig. 5. TDM_OLT architecture in E-PON system.

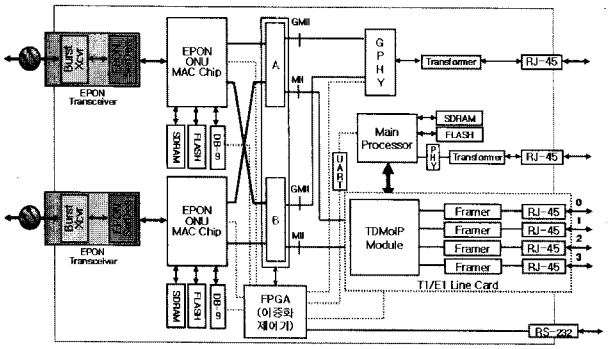

그림 6. NE-ONU1001-TDM 보드 블록도
Fig. 6. NE-ONU1001-TDM board block diagram.

through 100Mbps Ethernet interface for management, and then exchanges the control message with main processor. And E-PON line card supports the control path for control and statue/statistics information monitoring of all NE-ONU1001-TDMs connected to link. Each E-PON chip provides RS-232C interface for parameter setting and status monitoring. And this card supports 100Mbps Ethernet port for local management to test card itself.

TDMoIP line card accommodates many T1/E1 interfaces. This card converts T1/E1 signal into Ethernet frame, and then sends the frames to Gigabit Ethernet switching module. In reverse operation, this card receives Ethernet frame from the module, and then converts that frame to T1/E1 signals.

Figure 6 shows NE-ONU1001-TDM board to support both data and TDM services. This board has the functions defined in IEEE802.3ah through E-PON MAC chip and transmits/receives TDM signals through TDMoIP module. This board has two IEEE802.3ah E-PON ONU MAC chips for subscriber duplication, one gigabit Ethernet port for subscriber, one T1/E1 module for four T1/E1 lines, and one 100Base-T port for management. IEEE802.3ah E-PON ONU MAC chip has both GMII and MII interfaces. GMII interface supports 1Gbps for subscriber, and MII interface is connected to TDMoIP module accommodating four T1/E1 lines. This board operates as multi-port bridge between IEEE802.3ah E-PON MAC and two 10/100Base-T MACs. Each 1000Base-T MAC has unique LLID (Logical Link IDentifier) based on its own MAC address. Each NE-ONU1001-TDM port appears as individual point-to-point link through E-PON emulation layer in E-PON line card (TDM_OLT). NE-ONU1001-TDM is CPE (Customer Premises Equipment) of PON network, and converts the optical PON traffics into TDM signals to provide end-user with voice, T1/E1, and 1000Mbps Ethernet services.

IV. System Function

1. Protol and Frame format

After TDMoIP module performs segment, adaption and encapsulation function for TDM traffics at ingress edge of packet switched network, it sends the encapsulated TDM traffic to packet switched network. In egress edge of packet switched network, TDMoIP module performs the opposite operation to ingress edge, and then sends the original TDM signals to destination. TDM signal is mapped to IP network signals through this operation. This is the mechanism that the adaption function of ingress edge converts payloads to recovery TDM signals properly at egress edge. TDMoIP function can recover TDM signal and clock and tolerate packet losses to some degree through proper adaption function at egress edge.

Figure 7 shows the protocol stack that performs such a function at ingress edge of packet switched network. Capsulation function inserts the header having control information into the data received from upper layer. In this time, the data received from upper layer is preserved intactly. Therefore, TDM signals in transmitting side can be sent to receiving

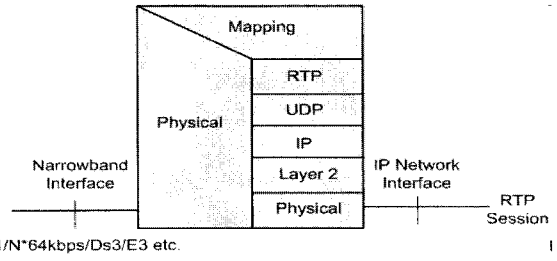

그림 7. TDM과 IP 네트워크간 연동 프로토콜 스택
Fig. 7. Interworking Protocol Stack between TDM and IP network.

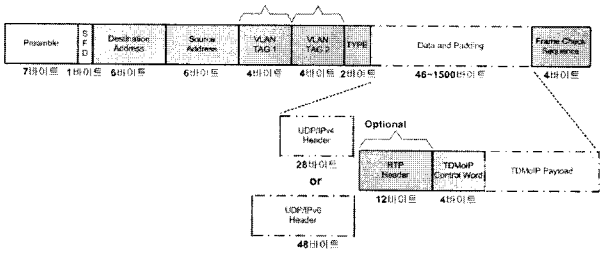

그림 8. TDMoIP 프레임 포멧
Fig. 8. TDMoIP frame format.

side transparently.

TDMoIP packet begins with header in packet switched network. This architecture is standard header in packet switched network technology. And in the case of not having option, there is 20 bytes header for UDP/IP. Figure 8 shows TDMoIP header format. This figure also shows IP packet format within Ethernet frame. There are UDP/IPv4 header or UDP/IPv6 header, and then TDMoIP fields in data field of Ethernet frame. In this architecture, TDMoIP control word of 4 bytes consists of sequence number, payload length, and statue flags. RTP(Real-Time Transport Protocol) is the protocol to transmit/receive voice or moving video in real time, and used with RTCP(RTP Control Protocol). RTCP is the protocol performed between terminals without relying on communication network equipments, such as router. RTP is used as the upper communication protocol of UDP. The transmitting side takes the recovery synchronization based on the time stamp, and then can drop the large packets with delay time. The receiving side checks transmission delay and bandwidth, and then can implement QoS control function by regulating the coding speed through the notification to the application layer in transmitting side using RTCP[15, 20].

2. Link configuration for QoS

To support TDM transmission based on IP, voice transmission based VoIP, and Internet service simultaneously through E-PON system, the suitable technologies are applied to TDM_OLT and NE-ONU1001-TDM. NE-ONU1001-TDM has the dedicated 100BASE-T port for packetized TDM

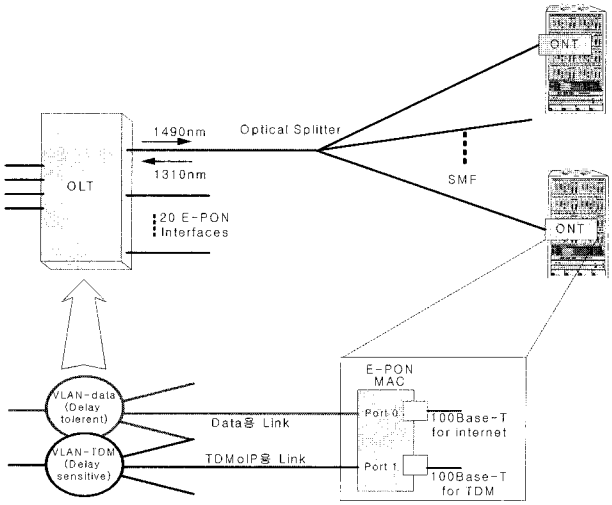

그림 9. TDM 서비스를 위한 링크 할당
Fig. 9. Link assignment for TDM service.

traffic and the data port for VoIP/Internet traffics. By assigning the individual virtual link to TDMoIP and data port respectively as figure 9, TDMoIP traffic transmission is not influenced by the congestion of data traffic. And to guarantee QoS of streaming video and VoIP traffics over data link, classification and scheduling functions are supported by ToS/IEEE802.1p.

To support QoS, TDM_OLT system sets up VLAN (Virtual LAN) accommodating the virtual link for data and TDMoIP traffic respectively, and then decides VLAN attributes suitable to the traffic characteristics. Through this configuration, The highest priority is assigned to VLAN accommodating the link for TDMoIP traffic having the characteristics sensitive to time, and then TDMoIP traffics are transmitted first. And this function classifies the traffics as VLAN accommodating the data traffics, and then performs the scheduling function of four step priorities to transmit VoIP traffic preferentially. But to support TDMoIP service, the more sophisticated traffic control technologies are needed. if there are the shaping function for each virtual link in TDM_OLT MAC, the probability of congestion will be decreased. And if the individual virtual link is applied to packetized TDM traffic, the congestion by Internet traffics can be prevented easily.

To support QoS for packetized TDM and real-time

data traffics, the diverse technologies are applied to TDM_OLT and NE-ONU1001-TDM. So VLANs are assigned to data and TDM traffic individually. And By treating the traffics according to the quality requirements, the enhanced QoS control function can be performed. Therefore, it is possible to perform the differentiated QoS control function according to the traffic characteristics. By using RED function in the case of congestion, it is possible to increase the jitter characteristics of traffic and the utilization of network resources. By using E-PON MAC chip having bandwidth allocation and shaping function for the virtual link of downstream traffic, the traffic interference over same link can be minimized. By separating the virtual link for TDM traffic from one of data traffic, QoS control characteristics can be improved in NE-ONU1001-TDM. And by using queueing/scheduling functions through ToS/CoS, QoS for real-time traffic can be guaranteed.

V. Test and Results

Figure 10 shows the system configuration to test the performance of TDMoIP traffic. This system consists of one NE_OUN1001_TDM, three ONUs, one TLIA, one ELIA, and one GESM. Only 4 of 32 T1/E1 ports in TLIA are used. Port 0 and 3 of T1/E1 ports in TLIA are connected to the test equipment (AX4000). The connection between NE_OUN1001_TDM and test equipment (AX4000) is configured in loop. ONU 1, 2 and 3 are regulated to test performance and jitter characteristics. NE_OUN1001_TDM sends upstream TDM traffics in full speed. ONU1 is regulated to give the variation load to system.

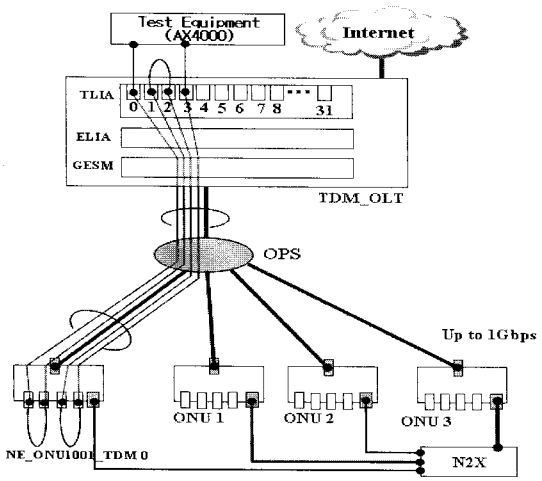

그림 10. 시험구성도
Fig. 10. The configuration for test.

Jitter is the important performance variable in communication system as the measure of delay variation. Jitter test is to measure the maximum allowable jitter value with satisfying QoS. Jitter buffer make delay variation constant, but generates additional delay. So the allowable value must be measured with satisfying QoS. To test jitter characteristics, ONU1 load has the burst mode characteristics as shown in figure. In figure 11, B value is constant, 100msec, and A value is variable, such as 1msec, 5msec, 10msec, 20msec, 30msec, 40msec, and 50msec. Jitter buffer must be set up according to these values, and then jitter characteristics is measured. In test, during A value is varied, Jitter characteristics of upstream TDMoIP traffic sent form T1/E1 port 0 to T1/E1 port 3 in TLIA are measured.

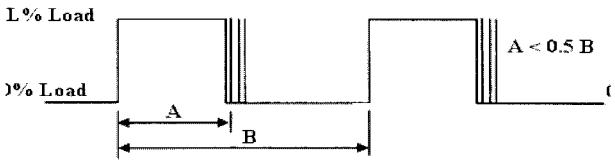

그림 11. TDM 패킷 지터 시험 환경 (ONU1)
Fig. 11. Test environment for TDM packet jitter. (ONU1)

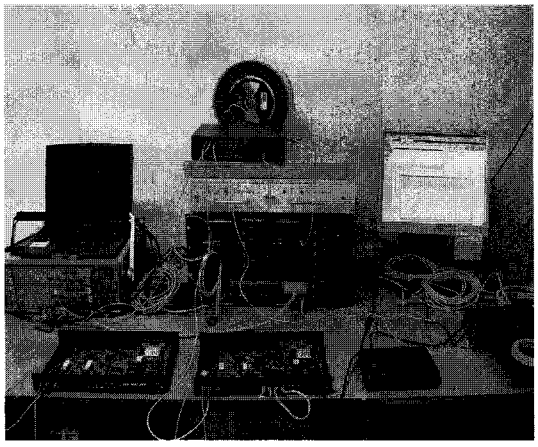

그림 12. 시스템 시험을 위한 구성도
Fig. 12. The configuration for system test.

표 1. 지터 버퍼 특성 시험을 위한 조건
Table 1. The condition for testing jitter buffer characteristics.

ONU NO.	LLID NO.	SLA (Min/Max)	Use	Remark
NE_OUN1001-TDM0	3702	50/1000	No use	
	3703	0/1000	TDM Port	
ONU1	3704	0/1000	Gb Ethernet Port	

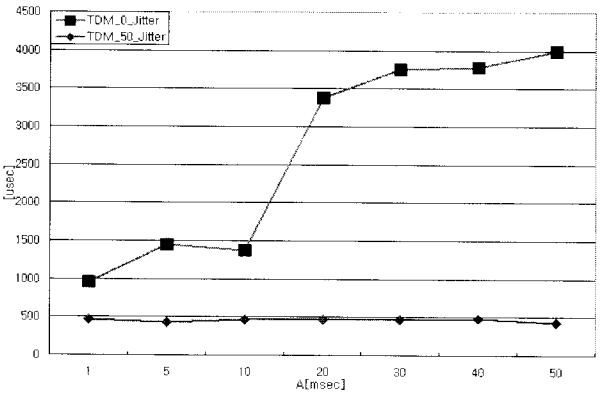

그림 13. SLA 값에 따른 TDM 트래픽의 지터 특성
Fig. 13. Jitter characteristics of TDM traffic for SLA values.

Figure 12 shows E-PON system and analysis equipment for test. the test is to measure jitter characteristics of TDM traffic. In test, we use OLT_TDM system, NE_OUN1001_TDM, and ONU.

NE_ONU1001_TDM and three ONUs are used for test, and the number of LLIDs is three. Test is performed for the varying minimum values of SLA (Service Level Agreement). ONU2 and ONU3 does not generate the stream, but only ONU 1 regulates the stream. In burst mode test, maximum load is 90%. packet length is 94 bytes (58bytes : header, 32 x n bytes : TDM data, 4 bytes : error check). And SLA value is assigned for TDM traffic. The packet length of N2X equipment is 512bytes, and TDM traffic is 32 x n bytes (n=1, 2, ...). Table 1 shows the condition for testing jitter buffer characteristics.

Figure 13 shows jitter characteristics of TDM traffic for SLA values, In this figure, TDM_0_jitter indicates the jitter characteristics when SLA of TDM traffic does not guarantee minimum value. TDM_50_jitter indicates the jitter characteristics when SLA of TDM traffic is 50. In this test, Queue size are 90 bytes for TDM and 40bytes for ONU 1

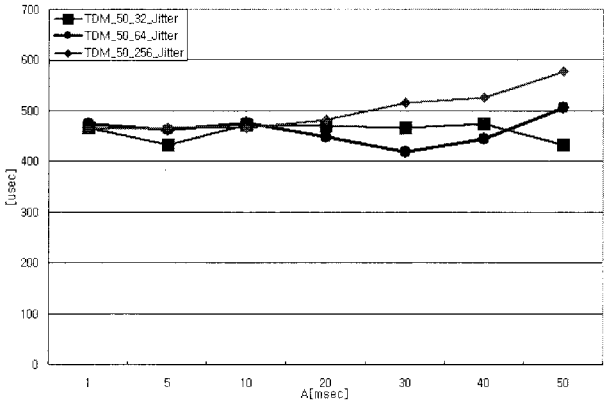

그림 14. Jitter Buffer에 따른 TDM 트래픽의 지터 특성
Fig. 14. Jitter characteristics of TDM traffic for Jitter buffers.

respectively. This test shows that if minimum value of SLA is not guaranteed, it has an effect on jitter characteristics of TDM traffic.

Figure 14 shows jitter characteristics of TDM traffic when SLA values for TDM and OMU1 are 50 and 900 respectively, queue size for both traffics is same as previous test, and jitter buffer size is variable. This figure indicates that if SLA minimum value for TDM traffic is guaranteed, TDM traffics are nearly not affected by jitter. And jitter buffer size has not nearly an effect on jitter characteristics of TDM traffic. Therefore, to transfer both data and TDM signal through E-PON technology, QoS for TDM signal, which is sensitive to time delay, must be guaranteed.

It is possible to use this system as FTTB/FTTC by adding TDM(T1/E1) transmission technology to E-PON for FTTH. As the communication capacity is assigned to user during silent period in TDM network, it brings about the waste of network resources. But in TDM over Ethernet technology, as the capacity is not assigned to continuously, and then the system can be used according to the specification, it can use the network resources efficiently. By connecting TDM switch to Ethernet switch directly through TDMoIP technology, it is possible to transmit all features and elements of existing solutions to Ethernet network transparently. And QoS control technology can be applied to E-PON as well as IP network.

VI. Conclusion

In this paper, we develop the system to transfer both Ethernet frame and T1/E1 TDM signals by adding TDMoIP technology to E-PON. The existing TDM signals can be transferred through TDM transmission equipment and leased-line, but if TDMoIP technology is added to E-PON one, this system can transfer both data and TDM signals. For this, we design and develop the interface boards to convert T1/E1 signal to Ethernet frame in OLT and ONU. This system can provide both data service and T1/E1 leased line service based on E-PON, and then can save the cost of network installation. And if the new access network must be installed, it is possible to save the cost and transit it to NGN (Nest Generation Network) based on IP by using E-PON system having TDM transmission function. Also by accommodating TDM technology through E-PON system, all features of existing solutions can be transferred to IP network. And if IP QoS technology is applied to, TDMoIP packets are classified by DiffServ or IP QoS, and then can be transferred preferentially in IP network. In future, we will implement the call processing function for TDM signal.

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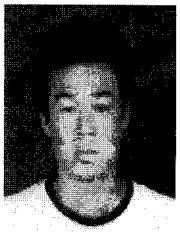

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