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# E-PON 기반 Triple Play Service를 위한 QoS 제어 기능

## ( QoS control function for Triple Play Service based on E-PON )

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요 약

본 논문에서는 E-PON 기반 TPS (Triple Play Service)에 대한 연구와 더불어 E-PON의 단점인 양방향 QoS 기능 개발에 관한 것이다. E-PON 시스템은 TPS에 적합한 구성을 가지고 있으나, upstream 지연이 상대적으로 큰 특성을 가지고 있으므로, 양방향 실시간 트래픽 전달을 위한 QoS 제어 기능이 지원되어야만 실제 환경에서 TPS를 효과적으로 지원할 수 있다. 따라서 본 논문에서는 TPS를 위한 다양한 품질 요구사항을 제시하고 이를 기반으로 실제 환경에서 종단간 각 요소들의 QoS 특성에 따른 품질 특성을 검증할 수 있는 TPS 플랫폼을 개발하였다. 이 결과는 향후 일반화될 TPS에 품질 개선을 위한 기반으로 활용될 것이며, 서비스 사업자 입장에서는 품질 기준을 수립하는데 기준으로 활용될 수 있으며, 신규 시스템 개발 시 개발 방향에 지침으로 활용될 수 있을 것이다.

Abstract

In this paper, we address TPS (Triple Play Service) based on E-PON and also develop QoS control function for both directions, which is disadvantage of E-PON. E-PON technology has the configuration suitable for TPS, but relatively the large delay characteristics in upstream, so if QoS control function must be supported to transfer the real time traffic for both directions, E-PON technology can support TPS efficiently. Therefore, in this paper, we address the diverse requirements of quality for TPS, and then develop TPS platform to verify the quality characteristics according to QoS characteristics of each element in real environment based on this. This result will be used to improve the quality of TPS that become conventional in near future. ISP will use this result as the basis in establishing quality reference and as the guidance in developing new system.

**Keywords :** E-PON, QoS, OLT, TPS, FTTH

## Ⅰ. Introduction

In these days, as network applications sensitive to delay, such as VoIP, VoD, continue to be used, the requirement for bandwidth and network performance are being increased. But as the bandwidth and performance of existing infrastructure can not be expended infinitely, ISPs want to transfer TPS or MPS (Multi Play Service) through the existing infrastructure without extra investment. Therefore, they concentrate on QoS mechanisms; logical means that can guarantee the optimum use of their available resources. While many ISPs have already provided voice, IP-TV, and Internet access service simultaneously, these solutions can be only made possible by combining the diverse dedicated infrastructures, such as wire, wireless, and mobile/satellite networks. To preoccupy TPS market, many ISPs consider the convergence of video, voice, and data as key business strategy.

As the wire network proceeds to improve the speed of the existing network (xDSL, HFC, Ethernet) with aiming at FTTH (Fiber To The Home), it is being evolved to PON (Passive Optical Network) considered as the effective method in implementing FTTH. As E-PON (Ethernet-PON) is a tree type of

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network that connects one OLT (Optical Line Terminal) to multiple ONTs (Optical Network Terminal), its penetration and spreading into public network depends on the proper security. The core service using QoS function are VoIP and Internet broadcasting. In general, VoIP, Internet broadcasting, and data service are called triple play service. As VoIP and Internet broadcasting of these services have characteristics sensitive to transmission speed as well as latency, it is not easy to guarantee the service quality without using QoS functions in router. Therefore, as QoS function is the basic and important one to provide a new type of service based on network in Internet service, such as the existing best-effort service, the use of it will continue to be increased. In general, as the traffic congestion is generated from user to router at the router connecting the user, QoS function must be operated effectively in its router.

People can use high-speed Internet service conveniently through FTTH. For example, they can exchange the motion video of big size with others at once. The current dwelling space can be expended to economy and social space, culture space, and educational space by providing the diverse new services, such as the convergence service of broadcasting and communication, so our life will be changed. As FTTH services based on E-PON is activated, TPS technology, which can transmit voice, video, and data simultaneously, must be applied to. E-PON system has the configuration suitable for TPS, but it has relatively longer upstream delay. So the system can support TPS efficiently in real environment through QoS control function, and then it can transmit the real time traffics in both directions. Therefore, it is necessary to address the diverse quality requirements for TPS, and then develop the platform of it according to the QoS characteristics of each element between end users in real environment based on these requirements. And it is necessary to apply this platform to real services.

In this paper, we address the diverse requirements of quality for TPS, and then develop TPS platform to verify the quality characteristics according to QoS characteristics of each element in real environment based on this. This result will be used to improve the quality of TPS that become conventional in near future. ISP will use this result as the basis in establishing quality reference and as the guidance in developing new system.

## II. Network requirements for triple play service

When network resources are shared with others services, most services also need a certain type of QoS to guarantee the service quality that the end-user expects. To support QoS, The requirements of network can vary with services. For example, the telephone service has more strict QoS than other general Internet services. There are a few parameters indicating which quality is applied to a certain type of service, and then how the quality will be supported for the service.

First parameter is delay/delay variation. The services that must be transmitted in real-time, such as VoIP, have more strict requirements than non real-time one, such as file download service, for delay and delay variation. VoD is less sensitive to delay because the video streams are often buffered in player for a few seconds. Second parameter is packet loss. When the errors are occurred, the lower packet loss is very important for services that can not retransmit the information. These are applicable to the most real-time services that have no enough time to retransmit. To guarantee that the requirements for delay/delay variation and packet loss can be performed for the specific traffic flow in network congestion, most networks have a certain type of QoS mechanisms. These mechanisms perform the marking function, and then use this marking part when servicing. For example, the voice traffic is assigned to higher priority then Internet traffics, and then voice traffic is serviced preferentially.

The method for TPS provides the model based-on call admission for video and VoIP. Once the service

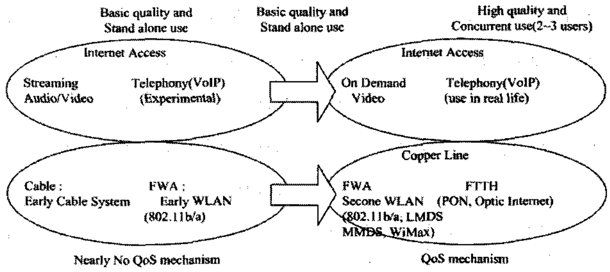


그림 1. QoS 요구사항
Fig. 1. Requirement of QoS.

connection is accepted, it is necessary to guarantee the characteristics for delay, jitter, and loss. As this architecture also includes shaping and policing function having no values for video and VoIP, it satisfies the bandwidth control per user, the necessity of different QoS for high speed Internet. With supports for differentiated contents, it is possible to differentiate the service prices in high-sped Internet using this architecture. ISP can control the service levels according to user through differentiated QoS policy and enforcement. Figure 1 shows the requirement of QoS. In early days, almost no QoS mechanisms were in existence. But as the traffic characteristics are varied and the network is getting complicated, the requirements of QoS are being increased.

## III. E-PON architecture

E-PON consists of OLT, optic splitter, and multiple OLTs, and can configure the network in efficient method because of its simple architecture. As E-PON uses the optical fiber providing the high bandwidth, it can transfer data, video, and voice traffic efficiently, and then has the characteristics suitable to transfer TPS. Data flow in E-PON system can be classified into upstream and downstream shown in figure 2. In downstream, the frame transmitted by OLT is delivered to ONT through OPS (Optic Passive Splitter). OLT broadcasts a packet to multiple ONTs, and then the destination ONT extracts the packet using MAC address. In upstream, because of the direction in OPS, a frame from any ONT is received only at OLT. Therefore, the operation of E-PON is

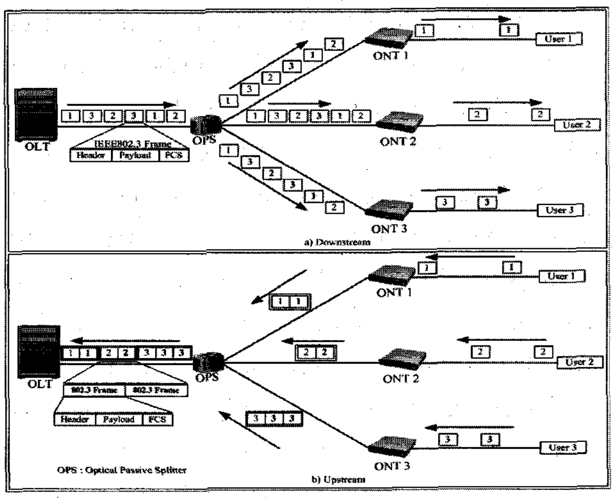


그림 2. E-PON에서 데이터 흐름
Fig. 2. Traffic flow in E-PON.

similar to point-to-point configuration. Contrary to strict point-to-point, there can be collisions between data frames from different ONTs in E-PON. So in upstream, ONTs must have an arbitration mechanism to avert the collisions and share the optic channel capacity fairly.

In upstream, all ONTs must synchronize the common standard time, and then the time slot is assigned to each ONT. Each time slot can delivery many Ethernet frames. ONT will buffer the frames received from users until its own time slot is arrived at. When the frame is arrived at, the ONT bursts all frames at full channel speed. If there are no frames in buffer to fill the entire time slots, ONT transmits the idle bit pattern of 10bits. There is a static one (TDMA : Time Division Multiple Access) using the instantaneous queue length on all ONTs (statistics multiplexing) in time slot assigning methods. As E-PON system has a configuration suitable for TPS, but relatively the large delay characteristics in upstream, it must support QoS control function to transfer the real time traffic for both directions. Therefore, E-PON system can support TPS efficiently.

In Figure 2, upstream data is transmitted from ONT to OLT via splitter, and downstream data is transmitted to all ONTs through splitter. Upstream data is transmitted using TDM method; downstream data is transmitted using broadcasting method. So, in downstream, all ONTs receive data from OLT, but only the addressed ONT can receive the data, and other ONTs discard the data.

As all ONTs is not located at same distance, E-PON uses MPCP (Multi-Point Control Protocol) control message. MPCP consists of REPORT (control from ONT to OLT) and GATE (control from OLT to ONT) messages which request or assign the transmission opportunity. It is the basic mechanism to control the traffics on PON, and uses the high-level function for bandwidth assignment, ONT synchronization, and ranging. An entity, which receives GATE message and then replies REPORT message, is logical link, and distinguished by LLID (Logical Link Identifier). The number of LLID per ONT is based on design method, and each LLID can have more then one queues for user data. The number of LLID on ONT has a major impact on performance and is one of the most important elements in designing E-PON system.

To maintain the compatibility with IEEE802 architecture, E-PON uses the point-to-point mechanism. This has E-PON medium operate as a group of point-to-point links. Simulation mechanism is to tag Ethernet frame using the unique value called LLID. For point-to-point emulation, OLT must have many MAC ports (one per logical link). In downstream (from OLT to ONT), the emulation function in OLT asserts the LLID related to the specified MAC port that the frame arrives at. Even if frame dose not arrive at each ONT, only one ONT matches LLID of that frame with its own value, and then receives the frame, passes the frame to MAC layer for verification. MAC layer on remaining ONTs can not look the frame. Therefore, frame looks like being transmitted to only one ONT through point-to-point link. In upstream, ONT inserts its own LLID in the preamble of each frame. Emulation function in OLT demultiplexs the frame into the proper MAC port based on unique LLID. Figure 3 shows point-to-point emulation function in E-PON system.

ONT meets the standard and can support multiple

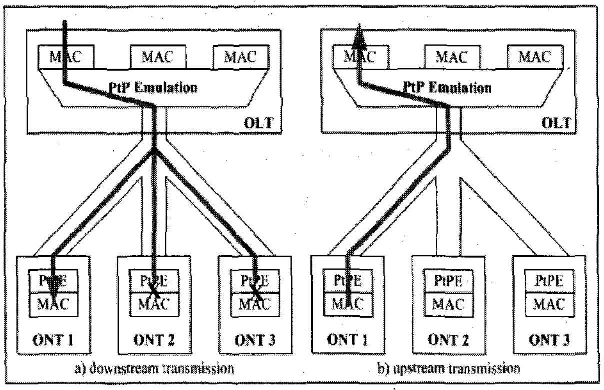


그림 3. E-PON 시스템에서 점대점 에뮬레이션
Fig. 3. Point-to-Point Emulation in E-PON system.

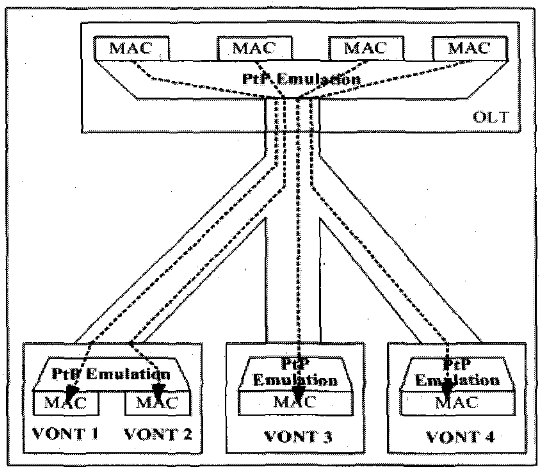


그림 4. E-PON 시스템에서 가상 ONT
Fig. 4. Virtual ONT in E-PON system.

MAC ports. In the view point of OLT, this ONT is similar to a set of ONTs having its own LLID. This is called virtual ONT because multiple virtual ONTs can be implemented through one physical device shown in figure 4. OLT must consider each virtual ONT as individual physical ONT. This means that the scheduling decision can be performed by OLT. LLID can be used to indicate one service class, but LLIDs can be scheduled differently according to its own service class. For example, one LLID can be assigned to the time sensitive traffic, and then the traffic can receive the service preferentially. Another one is assigned to the loss sensitive traffic, and then the traffic can receive the service according to this. OLT has the individual virtual port for each LLID. Bridge can be connected to this virtual port, and then ONT can communicate with each other and OLT.

## Ⅳ. Implementation of QoS control functions for triple play service in E-PON

Figure 5 shows the link assignment for TPS in E-PON system. We adopt the most suitable configuration through OLT and ONT to support IP-TV service, voice service based on VoIP, and Internet service simultaneously in home. ONT have the dedicated port for IP-TV and the data ports for VoIP/Internet. By setting up the individual virtual link for IP-TV port and data one between OLT and ONT, the quality of IP-TV traffic can be protected originally from data traffic. For traffics going through data port, four priority queues are assigned to transfer VoIP traffic and streaming one based-on data preferentially, and then the queues are handled by ToS/IEEE802.1p.

To support QoS in OLT, There are two VLANs in OLT. One is assigned to the virtual link for data; another is assigned to one for IP-TV. And VLAN attributes are set suitable to the traffic characteristics. By assigning the highest priority to VLAN accommodating the virtual link for IP-TV, video traffic can be transferred preferentially. And by classifying the traffics in VLAN accommodating data traffic, the priority scheduling can be performed in four levels to transfer VoIP traffic preferentially.

Figure 6 shows the problems in the existing E-PON system. The problem is that if the traffics received from multiple uplinks concentrate on specific E-PON port in OLT, the transmission quality can be deteriorated by the instantaneous congestion. But as the congestion can not be prevented originally, the technologies are required to transfer the traffic sensitive to delay and loss preferentially. When the drop phenomenon is occurred by congestion, RED function must be applied to.

In the case of having the user port of 100Mbps, the transmission quality can be deteriorated by the concentration of downstream traffic in ONT. In the case of not supporting the shaping function per the virtual link in OLT MAC, the transmission quality can be deteriorated by the instantaneous congestion in ONT. Therefore, ONT must have the function to transfer the traffic sensitive to delay and loss preferentially using the priority queuing/scheduling.

The flow control function must be used for QoS in downstream of ONT. This is to guarantee the service of high priority. But the flow control per service or per user is not supported because it is based on port. If the priority service of medium is not protected from the flow control, the high priority service will experience the very large delay. If the flow control is used, one user will block the service of another user. Large-scale buffer in downstream is needed for copy

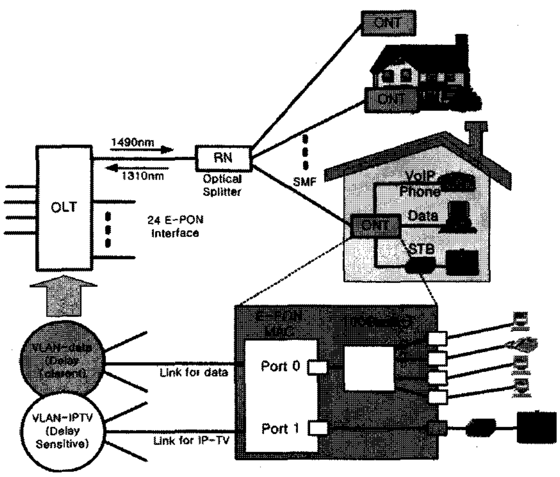


그림 5. TPS를 위한 링크 할당

Fig. 5. Link assignment for TPS.

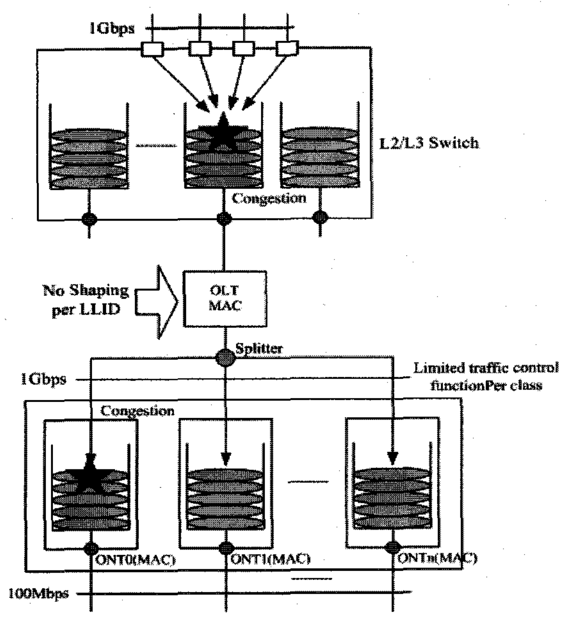


그림 6. E-PON에서 폭주 발생 위치

Fig. 6. The location of congestion in E-PON.

in each ONT.

Figure 7 shows QoS control function used to decrease the congestion at points shown in figure 6. A more sophisticated traffic control technologies are required to support new TPS. In the case of supporting the shaping function per the virtual link in OLT MAC, the probability of the congestion in ONT is decreased, and if the separate virtual link is used for the video service, it favors the guarantee of traffic quality and the charging per usage. In this figure, link 1 is assigned to IP-TV dedicatedly, and link 2 classifies packets to assign the packet to the priority queue. In this case, ToS/CoS field is used to classify the packet. And priority queues assigned to link 2 are treated by strict priority scheduling.

ONT board has all functions defined in IEEE802.3ah standard using E-PON MAC chip. This board operates as multi Port Bridge between IEEE802.3ah E-PON MAC and two 10/100Base-T MACs. Each 10/100Base-T MAC has unique LLID based-on its own MAC. Through E-PON emulation layer in OLT, each ONT port is individual point-to-point link. E-PON MAC chip in OLT board also supports DBA (Dynamic Bandwidth Allocation), traffic shaping, QoS, VLAN tagging, and encapsulation. The unified IEEE802.1d Bridge blocks the traffic from

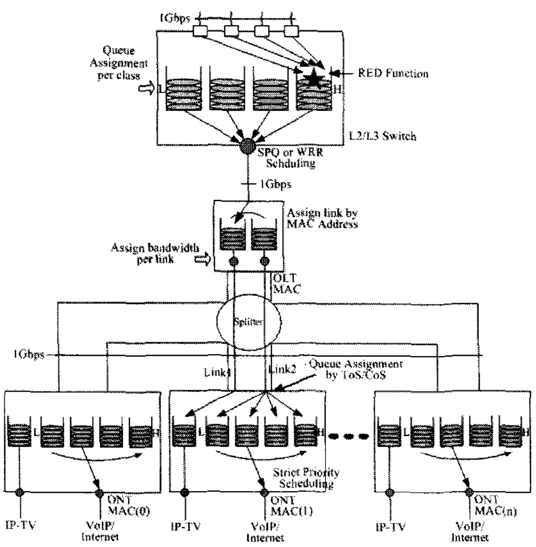


그림 7. OLT와 ONT에서 지원하는 QoS 제어 기능 (하향)

Fig. 7. QoS control function in OLT and ONT. (Downstream)

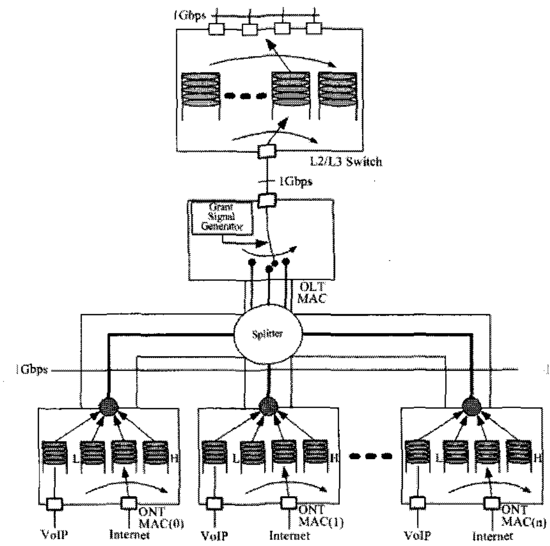


그림 8. OLT와 ONT에서 지원하는 QoS 제어 기능(상향)

Fig. 8. QoS control function in OLT and ONT. (Upstream)

E-PON port.

Figure 8 shows QoS control function in upstream from ONT to OLT. In fact, the traffic level in upstream is lower than one in downstream because IP-TV service is simplex only from OLT to ONT. Queuing based-on priority in ONT is used to transfer the signal with minimum delay and guarantee that the priority data and the high-speed Internet service are treated better than best-effort service in upstream service traffics. By having FIFO queue for each LLID in OLT, data can be classified as FIFO queue based-on LLID. Grant signal generation of OLT always monitors FIFO queue. If FIFO queues get empty, Grant signal is transferred to the link with corresponding LLID.

## V. The measurement of performance

Figure 9 shows E-PON system for test, the test is performed for QoS function and system performance. We measure QoS control characteristics per traffic in ONT by using the separated virtual link for TPS. To support QoS in OLT, VLANs accommodating the virtual link for data and IP-TV are set up individually, and then the attribute of VLAN is set up to suit the traffic characteristics. And the high-priority is assigned to VLAN accommodating

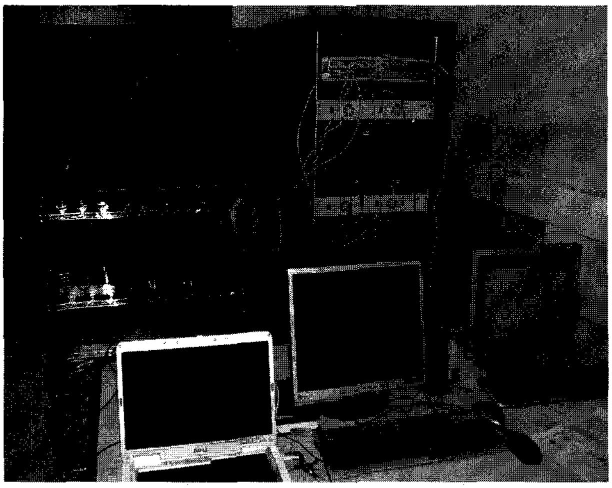

그림 9. 테스트를 위한 시스템 구성도
Fig. 9. System configuration for test.

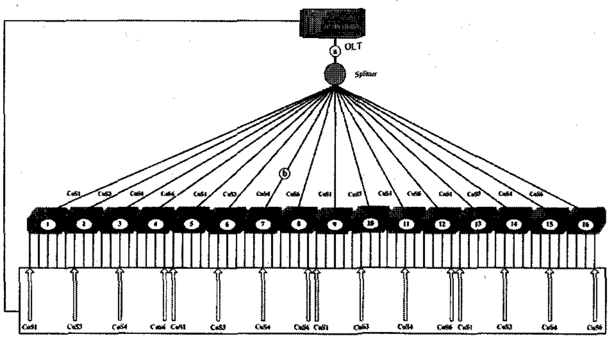


그림 10. 상향/하향에 대한 시험 구성도
Fig. 10. Test Configuration for upstream/ downstream.

the link for IP-TV sensitive to delay time, and then the video traffic can be transferred over the link preferentially. In VLAN accommodating the data traffic, the traffic is classified according to its characteristics, and then the schedule function of four levels can be performed. It guarantees to transfer VoIP traffic preferentially.

Figure 10 shows the network configuration that the different priority is assigned to each ONT in the system having above QoS control function. We measure the transmission characteristics for upstream and downstream through this configuration. In upstream, 13 ONTs are used. For this environment, there are no packet losses up to 3,000s delay time under maximum 53.4Mbps transmission speed. In downstream, 16 ONTs are used. For this environment, there are no packet losses up to 270s delay time under maximum 51.6Mbps transmission speed in 15 ONTs and 19.9Mbps in another one

표 1. SBA/DBA 값에 따른 지연 및 대역폭 특성
Table 1. Delay and bandwidth for SBA/DBA values.

| | ACT BW [Mbps] | DBA(No Unit) | -> | ACT BW [Mbps] | SBA(No Unit) | -> | ACT BW [Mbps] | SBA(No Unit) | -> | ACT BW [Mbps] | SBA(No Unit) | -> | ACT BW [Mbps] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ONT1 | 43.0 | 10000 | -> | 3.00 | ADD 1000 | -> | 4.00 | Del 1000 | -> | 3.00 | - | - | - |
| ONT2 | 43.0 | 20000 | -> | 6.18 | ADD 1000 | -> | 6.18 | Del 1000 | -> | 6.18 | - | - | - |
| ONT3 | 43.0 | 30000 | -> | 10.18 | ADD 1000 | -> | 11.18 | Add 2000 | -> | 13.18 | - | - | - |
| ONT4 | 43.0 | 40000 | -> | 13.19 | ADD 3000 | -> | 16.19 | Reset 2000 | -> | 15.19 | - | - | - |
| ONT5 | 43.0 | 50000 | -> | 17.36 | ADD 1000 | -> | 18.36 | Del 1000 | -> | 17.36 | - | - | - |
| ONT6 | 43.0 | 100000 | -> | 34.55 | ADD 3000 | -> | 37.55 | Del 5000 | -> | 34.55 | - | - | - |
| ONT7 | 43.0 | 200000 | -> | 69.20 | ADD 1000 | -> | 70.20 | Del 1000 | -> | 69.20 | Del 1000 | -> | 69.20 |

ONT. If the transmission speed is increased above that, the packet loss is occurred irrespective of priority.

Table1 shows delay and bandwidth characteristics for SBA (Static Bandwidth Allocation)/DBA (Dynamic Bandwidth Allocation) values. The bandwidth is varied only for upstream (direction from ONT to OLT). We use 16 ONTs for the test, and then set up about 43Mbps transmission speed for each ONT in upstream and about 40Mbs for ONT in downstream. In this environment, we assign much active bandwidths (74.0Mbps) to ONT 7 to confirm the big DBA value and then perform the test. If SBA is applied to first, we can not confirm the variable bandwidth. This is because this test environment is not as competitive as real one, but one that the measuring instrument transfers the traffics unilaterally. In the case of DBA, there is no unit in the setting value. This table shows that 1000 DBA values are equal to about 3Mbps and the test result has the linear bandwidth limitation characteristics to some extent. After setting up DBA value, SBA operation considers the DBA value as base ground, and then operates as add (add bandwidth), del (delete bandwidth), and reset bandwidth. And SBA operation is not decreased below the base bandwidth. If SBA/DBA is not applied to ONT, the delay time is

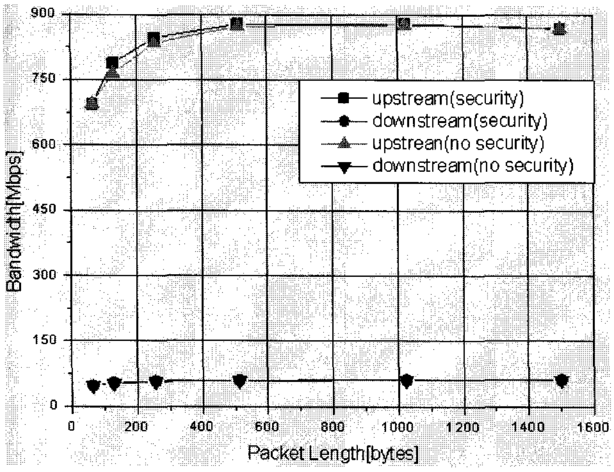


그림 11. 패킷길이별 최대성능

Fig. 11. Maximum performance per packet length.

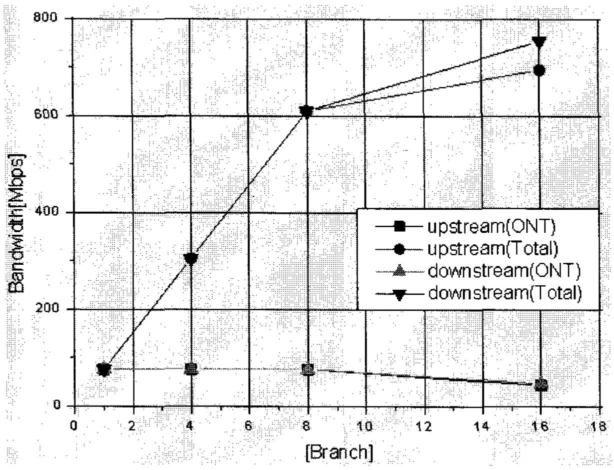


그림 12. 분기수에 따른 성능변화

Fig. 12. Performance for each branch.

1,565s. if only DBA is applied to ONT, the time is 5,400s. if both SBA/DBA is applied to ONT, that is 34,300s.

Figure 11 shows the maximum performance per packet length. We perform the test for security in both directions. As downstream transmission in E-PON is from one to multiple points, the security communication becomes a critical issue. But as upstream transmission is point-to-point, the security communication is not as critical. We measure the bandwidth per the packet length whether the security function is added to bi-direction traffic or not. Less is the packet length; the more is the ratio of security function in total packet length, and then the more is the influence on the bandwidth. This figure shows also that the longer is the packet length, the less is

표 2. 하향 4개 등급별 대역폭

Table 2. Bandwidth for 4 classes in downstream.

| size(bytes) / Class | 64 | 128 | 256 | 512 | 1024 | 1500 |
|---|---|---|---|---|---|---|
| CoS6(Mbps) | 19.5 | 21.62 | 23.19 | 24.06 | 24.52 | 24.67 |
| CoS4(Mbps) | 19.5 | 21.62 | 23.19 | 24.06 | 24.52 | 24.67 |
| CoS3(Mbps) | 19.5 | 21.62 | 23.19 | 24.06 | 24.52 | 24.67 |
| CoS1(Mbps) | 19.5 | 21.62 | 23.19 | 24.06 | 24.52 | 24.67 |

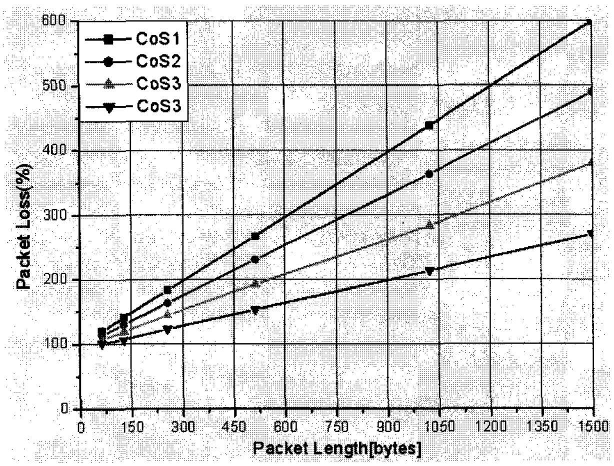


그림 13. 하향 4개 등급별 트래픽 전달 특성

Fig. 13. Traffic transmission characteristics for 4 classes in downstream.

the influence on the bandwidth.

Figure 12 shows the performance variation according to the number of branch. We perform the test for 1, 4, 8, and 16 branches. We perform the test in both directions. E-PON system uses optical splitter architecture, multiplexing signals with different wavelength for downstream (1490nm) and upstream (1310nm). Downstream signals are split at optical splitter into a number of drop sections and delivered to individual ONTs. Upstream signals from individual ONTs are combined at optical splitter into a single data stream directed at the OLT. This figure shows that the bandwidth of downstream is more than one of upstream. This is that ONTs have an arbitration mechanism to avert the collisions and share the optic channel capacity fairly for upstream.

Table 2 shows the traffic characteristics according to four levels in downstream. In this case, 8 ONTs are used. In downstream, there are one class for IP-TV service, and three ones for other services. For delay time of traffic according to each priority, figure 13 shows that the high-priority traffic has low delay

표 3. 상향 3개 등급별 대역폭
Table 3. Bandwidth for 3 classes in upstream.

| size(bytes) / Class | 64 | 128 | 256 | 512 | 1024 | 1500 |
|---|---|---|---|---|---|---|
| CoS6(Mbps) | 14.48 | 16.0 | 17.3 | 17.5 | 17.6 | 18.3 |
| CoS3(Mbps) | 14.48 | 16.0 | 17.3 | 17.5 | 17.6 | 18.3 |
| CoS1(Mbps) | 14.48 | 16.0 | 17.3 | 17.5 | 17.6 | 18.3 |

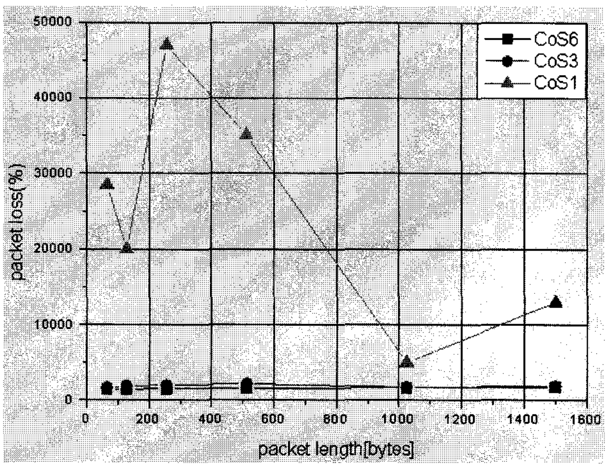


그림 14. 상향 3개 등급별 트래픽 전달 특성
Fig. 14. Traffic transmission characteristics for 3 classes in upstream.

time, but if we adjust the bandwidth on the measuring instrument, the delay time between priority traffics often is reversed.

Table 3 shows the traffic characteristics according to three priorities in upstream. In table, 16 ONTs are used. In upstream, there are three classes because IP-TV is service only for downstream. Figure 13 shows traffic transmission characteristics for 3 classes in upstream. If the measuring instrument connected to ONT transfers the traffic in full speed (100Mbps), about 25Mbps is assigned to CoS 6 traffic for all ONTs. Any bandwidth is not assigned to CoS 1 traffic of lowest priority (called starvation). About 18Mbps is assigned to CoS 3 traffic, but the variation is large because there are no fairness between ONTs.

## V. Conclusion

In this paper, we address TPS based on E-PON and also develop QoS control function for both directions, which is disadvantage of E-PON. As the greatest advantage of E-PON is cheap installation cost, simple network architecture, and efficient operation, the investment cost is relatively low. But the disadvantage is that the complex protocol deteriorates the efficiency of upstream traffic, so scalability and bi-direction is fragile. If E-PON overcomes these disadvantages, it can support TPS efficiently.

Therefore, we address the diverse requirements of quality for TPS, and then develop TPS platform to verify the quality characteristics according to QoS characteristics of each element in real environment based-on this. This result will be used to improve the quality of TPS that become conventional in near future. ISP will use this result as basis in establishing the quality reference and as the guidance in developing new system.

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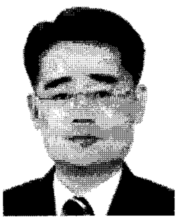

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