Simple Dynamic Bandwidth Allocation Algorithm for Loop-Back WPON

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Abstract — **This paper describes a WDM-PON architecture to provide diverse broadband services. We propose a Loop-Back WDM-PON(LPB-PON) architecture with adaptive frame structure and corresponding framing procedure. Also, we propose a novel simple polling with service level(SPSL) scheme that allows the upstream bandwidth to be shared among many subscribers. We modeled the proposed SPSL scheme using the OPNET simulator and the simulation results show that the proposed scheme is suitable for guaranteed bandwidth services for diverse applications.**

Keywords — **WDM-PON, LPB-PON, Dynamic Bandwidth Allocation, SPSL.**

1. Introduction

Fiber-To-The-Home (FTTH) has been considered as an ideal solution for access networks because of huge capacity, small size and lightness, and immunity to electromagnetic interference of optical fibers [1]. Because optical fibers are widely used in backbone networks, wide area networks (WANs), and metropolitan area networks (MANs), and are also being deployed in local area networks (LANs). With the introduction of new optical Ethernet standards, the implementation of the FTTH in access networks will complete all-optical-network revolution. Optical access networks draw much attention from the research and industrial communities because of their potential to solve the bandwidth bottleneck in the first mile. For the first generation optical access networks, the major thrust in research and industry has focused on passive optical network(PON) using a tree topology and a media access control (MAC) protocol based on time division multiple access (TDMA). Current TDM-PON standards specify the line rate up to 1Gbps and maximum link reach of 20 Km or more [2,3,4]. These capabilities support the high speed broadband access needs of current residential customers. As more broadband applications appear, however, demands from end-users will soon outgrow the capacity of the first generation optical access networks.

Therefore, upgrading TDM-based optical access networks will be a major challenge and WDM has been considered an idea solution to extend the capacity of optical networks without drastically changing the currently deployed fiber infrastructure. WDM can provide a virtual point -to -point link to each end-user over a PON without complicated MAC protocols [3~9], which simplifies tasks of network management, protection [10], and security to the level of traditional point-to-point networks. However, WDM devices are very expensive and we need low-cost and easy inventory architecture without WDM devices (see Figure 1).

Our discussions of FTTH focuses on the WDM-PON-based solutions. This thesis is organized as follows. First, Section 2 reviews existing WDM-PON solutions and propose a Loop-Back WDM-PON architecture and the corresponding frame structure. Section 3 propose SPSL scheme in proposed LPB-PON architecture after discussing existing bandwidth allocation algorithms in PON. Section 4 analysis performance of the proposed scheme. A conclusion is followed in Section 5.

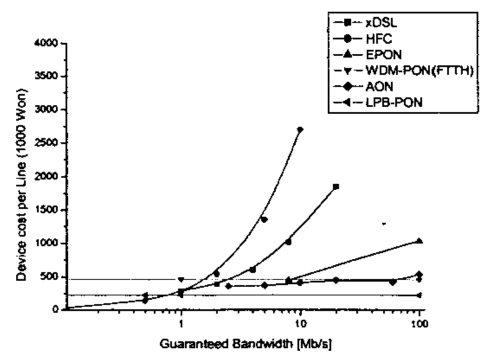

Figure 1. Cost Trends of Access Network Technologies

2. LPB-PON Architecture

Transmission line from OLT to ONT is composed of downstream trailer and upstream trailer (see Figure 2). Each trailer attaches specific header to control up/downstream. Downstream trailer serve information, but upstream trailer put in un-modulated optical signal. Un-modulated optical signal is modulated in ONT's transmit circuit. Each trailer size is determined by ONT's requirement or traffic conditions. Downstream trailer is composed of Idle Set (ISET), Down Stream Trailer Header (DSTH), and payload. ISET is located after non data section for synchronization. DSTH is a specific pattern for downstream trailer's detection. DSTH uses unused codes of 10B(802.3z) code group. Upstream trailer is composed of Up Stream Trailer Header (USTH), Front Gap (FGAP), ISET, payload, Up Stream Trailer End (USTE), and Rear Gap (RGAP). USTH is a specific pattern for upstream trailer's detection. USTH uses 10B (802.3z) code group.

USTH offer the start point of upstream payload and distinguishes upstream from downstream. FGAP is changed by ONT's processing time to take in upstream payload. RGAP avoid the overlap between upstream trailer and downstream trailer. Trailer period is not fixed for various traffic conditions. This is good for dynamic bandwidth allocation and offers most suitable data communication environment.

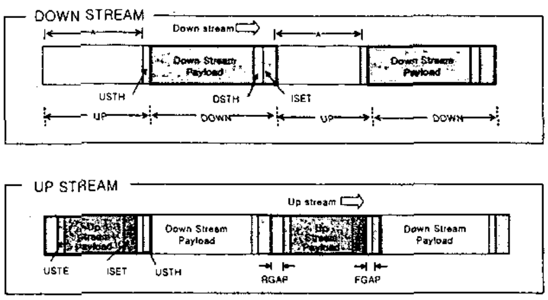

Figure 2. Frame Structure in LPB-PON

Figure 3. shows the layer structure and the function of layer in OLT. Trailer Control Engine (TCE) layer insert between legacy Physical Coding Sublayer (PCS) and Physical Medium Attachment (PMA). TCE inserts USTH/DSTH and detects USTH/DSTH.

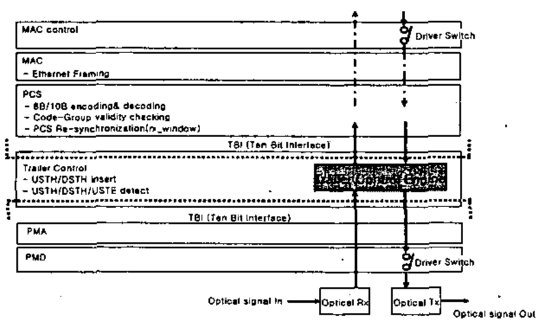

Figure 3. TCE layer of OLT in LPB-PON

Figure 4. shows layer structure and functional blocks in ONT. TCE detects USTH/DSTH, DSTH swaps K28.5 code, and then TCE insert USTE in ONT.

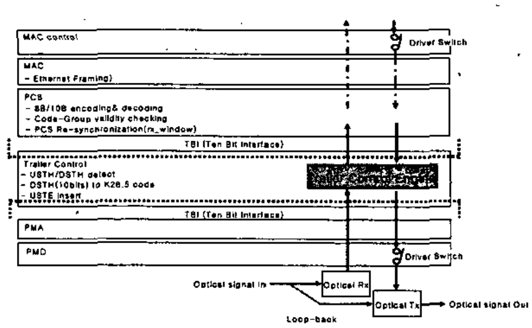

Figure 4. TCE layer of ONT in LPB-PON

3. SPSL Algorithm

The proposed Simple Polling with Service Level (SPSL) scheme incorporates the SLA into MAC protocol design. In our SPSL scheme, the OLT is the central controller that polls ONTs by sending polling messages periodically to each ONT to grant transmission windows. After receiving the polling message, ONTs begin to send data to OLT. The ONTs are divided into disjoint groups according to the SLA between provider and users. OLT maintains an Entry Table that keeps the sequence of entries being polled. Each entry possesses a bandwidth unit that will be allocated to ONTs. According to the Table, OLT polls ONTs one by one in the order of the entry sequence.

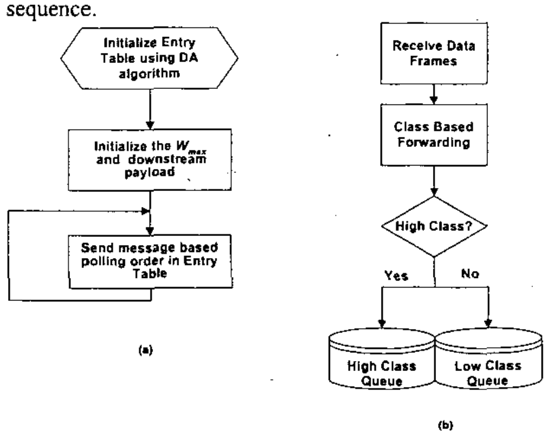

Figure 5. Flowchart of OLT in SPSL Algorithm

In this section, we give a high-level overview of the proposed algorithm :

1. Initially, OLT initializes the List according to the SLA between provider and subscribers, and uses distribution algorithm to initialize the Entry Table and distribute entries to bandwidth guaranteed ONTs. OLT is initialized according to the system parameter of maximum transmission window size W_{max} in upstream payload. Also, OLT is initialized the system parameter of downstream payload size. Because upstream and downstream share bandwidth in proposed LPB-PON scheme.
2. OLT starts to poll bandwidth guaranteed ONTs in the order as determined in Entry Table.
3. On receiving polling message, the ONT will:

A. If polling address same ONT ID, then the ONT accept polling message and other ONTs just receive downstream data. Polled ONT will:

i. Get the granted window size *G*;

ii. Get the buffer length *L* (including 3 level buffers);

iii. Decide the number of data frames for transmission:

B. If L is less than *G*, the ONT can send all data frames in the buffer;

i. If L is larger than *G*, the ONT can only send data frames up to *G*;

ii. Send data frames in the buffer of the evaluated amount.

4. OLT keeps on receiving data frames transmitted from ONTs. On receiving a loop-backed polling message from ONT, the OLT will:

A. First, ignored downstream payload;

B. Get the upstream payload;

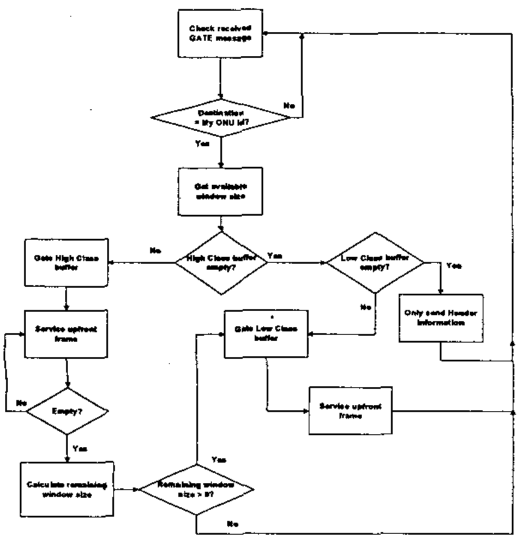

Figure 6. Flowchart of OLT in SPSL Algorithm

4. Simulation Results

In this section, we present simulation results. The simulation design for the SBA model is same as that for the SPSL scheme and there is no difference on bandwidth requirements from the ONTs. In the SBA scheme, All ONTs send data by the round robin scheme from ONT1 to ONT16. We obtain the simulation results as follows. The LPB-PON shares the bandwidth between the OLT and ONTs. We assume that Up/Downstream trailer ratio is same. Downstream services are 500Mbps and ONTs share remaining 500Mbps bandwidth. The OLT fully use 500Mbps and polling ONTs. The ONTs reflect downstream trailer and send data to upstream trailer by bandwidth allocation algorithm. R_U is link speed from OLT to splitter. R_D is link speed from splitter to ONT. N is number of ONT.

Parameter	Value
R_U , R_D	1. 25 Gbps link
N	16
Table entry	50
ONU1 ~ONU6 (Class1)	5 entries
ONU7 ~ ONU 11 (Class2)	3 entries
ONU12 ~ ONU 16 (Class3)	1 entry

Table 1. Simulation Parameter

Figure 7. shows the relationship between the poling period for different kinds of ONTs and the entire network load. It shows the delay for SPSL-Class1 is the lowest. SBA algorithm and SPSL-Class2 are similar value. The delay for SPSL-Class3 is the highest. Discrimination in delay is available in SPSL , but SBA can't control delay for various subscribers.

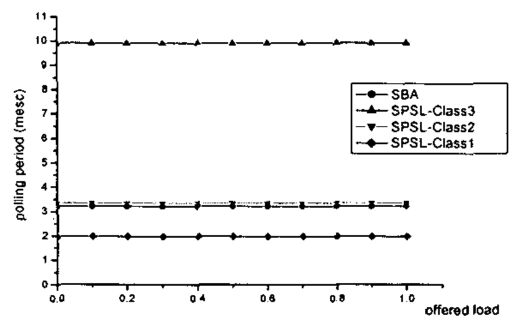

Figure 7. Relationship between the Offered Load and Poling Period for Different SBA and SPSL

Figure 8. shows the relationship between the network throughput, SBA and SPSL, and the offered load for different bandwidth allocation scheme. All throughputs increase as the network load rises. The throughput of SPSL scheme is very similar to that of SBA scheme when the load is very low. When the load is larger the 0.3, the throughput of SPSL increases more rapidly than the throughput of SBA scheme. Bandwidth of the Class3 is at most 10Mbps in SPSL scheme. Except SPSL-Class3, All ONTs have very similar value in both SPSL and SBA scheme. However, as the goes beyond load 0.3, ONT16 with 1 entry shows maximum throughput, 10Mbps while the throughput for other SPSL-Class1, SPSL -Class2, and SBA continues to increase proportional to the offered load up to 1.0.

Figure 9. presents the average queuing delay versus offered load both SBA and SPSL bandwidth allocation scheme. The curve of SPSL-ONT12$\sim$16 with 1 entry increases very slowly below the load of 0.3. And it keeps

increasing until load of 1.0. Others have small queuing delay because their can process to offered load up to 0.8~1.0. As you see, Class1 is the least queuing delay for the best quality. Class2 and SBA is similar queuing delay and higher than class1.

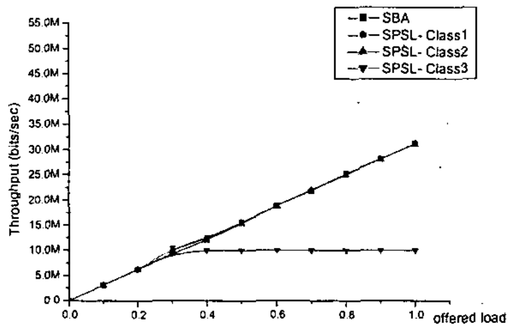

Figure 8. Average Throughput vs Offered Load for Different kinds of ONTs

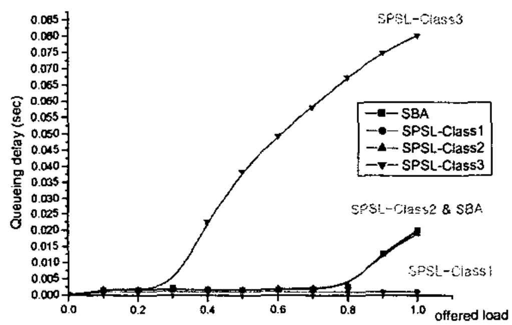

Figure 9. Average Queuing delay vs Offered Load for Different Algorithms

5. Conclusions

The WDM-PON is an attractive next generation optical access network solution. However, WDM-PON requires inexpensive and less use of wavelength dependent devices. The most advantage of WDM-PON in access network is enormous capacity and guaranteed minimum bandwidth. Therefore, the cost effective architecture and frame structure of WDM-PON is the key point of this thesis. In the proposed LPB-PON architecture, the OLT generates the Up/Downstream trailer and ONTs reflects the trailer. Each trailer attaches particular header to control of the upstream and downstream.

The OPNET modeling and simulation compares the performance of proposed bandwidth allocation algorithm with SBA scheme. As a result of OPNET simulation, we can obtain the results of throughput, utilization, average queuing delay, average queue size, and unused bandwidth. At the non-busy network condition when the offered load is less than 0.3, SBA and SPSL scheme show a similar performance. As a result, the proposed SPSL-scheme is suitable for guaranteed service rate for business and residence subscribers.

ACKNOWLEDGEMENT

This work was supported in part by the KT, Electronics and Telecommunication Research Institute (ETRI), and the Korea Science and Engineering Foundation (KOSEF).

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