10 ns High-speed PLZT optical content distribution system having slot-switch and GMPLS controller

Masahiro Hayashitani\(^{1(a)}\), Teruo Kasahara\(^{1}\), Daisuke Ishii\(^{1}\), Yutaka Arakawa\(^{1}\), Satoru Okamoto\(^{1}\), Naoaki Yamanaka\(^{1}\), Naganori Takezawa\(^{2}\), and Keiichi Nashimoto\(^{2}\)

\(^{1}\) Keio University, 3–14–1 Hiyoshi, Kohoku-ku, Yokohama, 223–8522, Japan
\(^{2}\) Nozomi Photonics Co., Ltd., KSP R&D C333 3–2–1 Sakado, Takatsu-ku, Kawasaki, 213–0012, Japan
\(^{a)}\) hayashitani@yamanaka.ics.keio.ac.jp

Abstract: We have developed the high-speed PLZT ((Pb,La)(Zr,Ti)\(_3\) optical content distribution system having slot-switch and GMPLS controller in the 1X8 distribution switch. The switching speed of our developed system is less than 10 nsec and the world fastest switching time in the optical switch with more than 8 outputs. The system can switch transparent time slot whose size can range from 10 nsec to 1 sec. Each slot is reserved very quickly by an extended Resource reSerVation Protocol (RSVP) message that is now being standardized for the GMPLS control plane. According to calculations, the proposed system can handle more than 500 users with minimum receiving power of \(-18\) dBm, which is about an 8 fold improvement over Passive Optical Network (PON). We consider that the system well supports content distribution in the access network.

Keywords: GMPLS, PLZT, slot-switch

Classification: Photonics devices, circuits, and systems

References

1 Introduction

In Japan, Fiber To The Home (FTTH) subscribers exceeded 5 million in 2006 and will reach about 20 million in 2008 [1]. The spread of ultra-high speed access networks will enable us to transfer bulk contents like High Definition (HD) movie files. In order to transfer bulk contents, we consider that the optical slot switching network is the best approach because a network user can, in a very short period, access large bandwidth. Therefore, we have developed a PLZT ((Pb,La)(Zr,Ti)O$_3$) optical content distribution system that uses optically transparent slot-switch and Generalized Multi-Protocol Label Switching (GMPLS) [2] controller. The PLZT switch [3, 4, 5] can improve the bandwidth utilization compared to conventional optical switches like the Micro Electro Mechanical System (MEMS) switch because its switching time is so short. GMPLS is a set of network control protocols targeting the realization of the next generation high performance transport network. Unlike Time Division Multiplexing (TDM), GMPLS enables the slot switching network to reserve and release slots dynamically, and it realizes the distributed control of optical switches in the network. Our developed system can activate the switch very quickly slot by slot according to an extended Resource reSerVation Protocol (RSVP) message from the GMPLS control plane. According to calculations, the proposed system can handle over 500 users with minimum receiving power of $-18$ dBm. This yields an 8 times larger network than possible with Passive Optical Network (PON). We consider this system well supports content distribution in the access network.

2 Architecture

Our developed switch system is the result of a collaboration between Keio Univ. and Nozomi Photonics. Figure 1 (a) shows a picture of the switch system with the controller. The system consists of a control unit and an optical switch unit. The control unit is a Linux-based PC with GMPLS software and is connected to the optical switch unit that has a PLZT switch via a serial link. Figure 1 (b) shows a block diagram of the system. The optical switch unit consists of an ultra-high speed driver board, a fast driver, and an optical switch body. The driver board includes an FPGA that has a pair of 4000 slot pattern memory banks. It reads and writes the banks based on signals from the controller and sends the appropriate switching pattern signal to the fast driver. The fast driver sends switch signals to the switch body upon receiving signals from the controller board.
Fig. 1. The PLZT switch system with GMPLS controller.

We explain the operation of this system when the system receives an RSVP signal. The system gets the absolute time information or frame information from the service provider which is the root of the access network. However, in this prototype switch system, the information is distributed from the master switch system, the root of the switch system. In addition, each switch is synchronized by the frame edge trigger signal from the master switch system in the guard time between slots. This guard time is determined by the switching time and propagation delay among switches. The protocol controller receiving the RSVP signal from the GMPLS network converts the signal into a signal which the optical switch unit can receive, and the controller sends the converted signal to the driver board in the optical switch unit via the serial link. The driver board receiving the converted signal stores the reservation information in the memory banks. When the time comes that the slot is assigned, the optical switch unit reads the reservation information from the memory banks and sends the information to the optical switch. The optical switch knows where port the system switch from the information, and the switch system can switch to the desired port in the guard time according to the information. This is the operation of this switch system. Therefore, the switch system can activate the switch by slot according to an extended RESV message from the GMPLS control plane.

Table I shows the specifications of the switch system. In Table I, 1 configuration means a 24-bit switch control signal and 1 memory bank can store 4000 configurations. In addition, the table shows that the system has two memory banks. This enables the system to write a switch control signal in one bank while reading the other bank. When the controller board receives a new slot reservation signal, the two memory banks enable the system to write the reservation signal without having to stop reading the bank. Therefore,
Table I. The specifications of the switch system.

<table>
<thead>
<tr>
<th>item</th>
<th>numerical value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switch Size</td>
<td>1X8</td>
</tr>
<tr>
<td>Switching Speed</td>
<td>Less than 10nsec</td>
</tr>
<tr>
<td>Switch Loss</td>
<td>about 15 dB</td>
</tr>
<tr>
<td>Slot Number</td>
<td>4000 Configuration</td>
</tr>
<tr>
<td>Slot Period</td>
<td>From 1 Hz to 100 MHz</td>
</tr>
<tr>
<td>Memory Bank</td>
<td>2 banks (Switch in 1 clock)</td>
</tr>
<tr>
<td>Line Bitrate</td>
<td>1 Gbps</td>
</tr>
</tbody>
</table>

the system can realize slot switching without a break.

3 Target Application

We consider that our developed system well supports content distribution in the access network. We call this the Switched Distribution Slot Network (SDSN). As shown in Figure 2, SDSN has a tree topology and the character in the slot represents the client for content distribution. The PLZT switch system selects an output port based on an extended RSVP message from the GMPLS control plane. Each system gets the absolute time information from the master switch system, the service provider in Fig. 2, in order to know the control timing for switching. In Fig. 2, SW1, the master switch system, receives RSVP signals from Service Provider for Client B, A, and C, in that order. And SW1 reserves slots on a first-come-first-served basis. SW2, and SW3 reserves slots by RSVP signal including the order of slot assignment from SW1. We explain the switching operation of SW1. First, The slot for Client B is switched to SW3 in the guard time according to the absolute time information. Next the slot for Client A is switched to SW2, and the slot for Client C is switched to SW3 in each guard time. Like SW1, the slots are switched to the desire port in other SWs according to the information from the master switch system. In Fig. 2, the slots are only for downlink. However, the slots are bi-directional and can be used for uplink. We are now trying to consider SDSN can change the ratio of slots for uplink and downlink according to traffic condition. Figure 3 compares the scalability of PON and of SDSN. The experimental 1X8 switch device has about 10 - 15 dB loss today. This loss is caused by fabrication and driver capability and may be improved near future. So, we assume a 1X8 switch in SDSN, and switch loss is 6 dB [6] which is the best ideal loss of the switch device. This figure shows that SDSN can cover many more subscribers than PON. If the permissible loss of switches or couplers is 18 dB, SDSN can handle over 500 subscribers while PON can handle only 64 subscribers. Moreover, SDSN can realize a transparent and secure network because the service provider in SDSN sends data to just the client requesting it.

In order to realize SDSN, we need to consider the clock recovery in the client. SDSN uses GMPLS for the slot reservation. So, the signal for the client
is not continuous and the high-speed clock recovery in the client is important. Ultra-fast clock recovery like [7] enables us to realize SDSN. However, in order to realize SDSN, there are remaining challenges. For example, we have to consider the specification of preamble for the clock recovery. In addition, we also need to consider the economic efficiency to realize SDSN. SDSN uses optical switches in place of couplers. SDSN using the optical switch can cover many more subscribers than PON using the coupler. However, the optical switch is more expensive than the couplers. For example, we consider the case of Fig. 3. In Fig. 3, SDSN can handle 512 subscribers while PON can handle only 64 subscribers. However, SDSN needs 73 optical switches to handle 512 subscribers. The switch cost for each subscriber is about the price of 0.14 switch and expensive now. If the number of subscribers increases, the SDSN that can cover many subscribers would be important. This would lead the reduction of switch cost.

Therefore, SDSN has the advantages of coverage area and security. The
advantage of coverage enables to reduce the service provider that has a lot of contents. And, in SDSN, data is not spitted and is sent to just the client requesting it. Therefore, SDSN is suitable for content distribution in the access network. Meanwhile, PON has the advantages of cost and broadcast service. It is important to use two schemes as the situation demands.

4 Conclusion

We have developed the world fastest (less than 10nsec) high-speed PLZT optical content distribution system based on optical signal transparent switch and GMPLS controller. Our developed system can activate the switch very quickly slot by slot according to an extended RSVP message from the GMPLS control plane. According to the calculation results, the proposed system can handle over 500 users with minimum receiving power of −18 dBm, which represents a 8 times larger network than PON. We believe that this system well supports content distribution in the access network because of its coverage and security.

Acknowledgments

This work was supported by Global COE Program “High-Level Global Co-operation for Leading-Edge Platform on Access Spaces (C12)”. 