The Multiple-Path Protection of DWDM Backbone Optical Networks

Fu-Hung Shih, Wen-Ping Chen, and Wen-Shyang Hwang

Abstract

The primary transmission protection technology is still based on the characteristics of SONET/SDH protection mechanisms to date. It belongs to a transmission structure of two fiber path ring. The architecture exists in a serious problem when two fibers are simultaneously broken. Therefore we exert to transfer the principles of SONET/SDH protection mechanisms onto the DWDM technology. This paper proposes and experimentally demonstrates an APS (Automatic Protection Switching) mechanism against distribution fiber breaks in DWDM optical networks. The protection scheme provides protection switching within 50 ms switch over time. The DWDM protection likes O-BLSR (MS-SPRING) or O-UPSR (SNCP) in SONET/SDH protection mechanisms. Nevertheless it is just two path fiber routing transmission. Therefore, in order to simplify the design of the DWDM optical layer and reduce the cost of protection network. We adopt the advantage of OPS (Optical Protection Switching) back-to-back connection protection mechanisms to protect important traffic and channel via building the multiple-path of DWDM backbone protection mechanisms. Once the working fiber get into a fiber cut off, the traffic can be switched to the protection channel automatically for ensure the path connection.

II. OPS Operation Theory

In our system, the OPS includes both transmitter side and receiver side. The description of them as follows:

Transmitter-side

The transmitter side is shown in Fig. 1. The photo diode (PD) detects the INcom power value by O/E converter. The INcom signal and optical supervisory channel (OSC) signal can be combined in fiber by the coupler to form the working and protection path. Besides, the typical frame structure of OSC likes Fig. 2.

I. Introduction

The transmission bandwidth of telecom networks is growing dramatically in recently. With this growing bandwidth and the growing number of subscribers that the network restore force are also growing and important. Especially the DWDM backbone networks protection. In traditional 1+1 optical layer protection is just two fiber path [1-3]. Service providers offer broadband services such as video on demand (VOD) or IP TV on the traditional voice and internet access services. SONET/SDH offers secondary routing protection. In the really experiment, two fibers cut opportunity is really high. Moreover, to repair of fibers cut is longer than replacement of failure equipment. Therefore, how to design the protection mechanisms in infrastructure network is a very important issue. In this paper, a new multiple-path method of protecting DWDM optical networks is studied and implemented. For considering the cost-effective, the design of architecture is simplified and practical.

Fig. 1. OPS Transmitter side structure.

Fig. 2. OPS typical frame structure of OSC.

The FAS is Frame Alignment Signal to confirm synchronization signal. E1 and E2 is voice communication channel. F1 is user define channel. D1 ~ D12 is data communication channel. TS16~TS31 is reserved channel.
**Receiver-side**

The OPS receiver side is shown in Fig. 3. It detects INw (Working path) optical signals real-time whether lower switching level setting threshold value or not via OSC channel. If fiber cuts, the INw signal lower switching level setting threshold value than immediately switching to INp (Protection path) receive the protection signal. In order to make transmission communication rapidly restores and increases service quality. The protection scheme has to protection switching within 50 ms switch over time.

The OPS can remote the management control by SNMP. There are three type operation modes.

- **AUTO** - the optical switch will switch to INp port when the loss of signal of INw (fiber cut) is happen. The optical switch will be switches to INw port if the fiber reconstructed. The scheme is belong to auto reserve type.

- **SEMI-AUTO** - the optical switch will switch to INp port when the loss of signal of INw (fiber cut) is happen. The optical switch will be not switches to INw port if the fiber reconstructed. The scheme is belong to auto non-reserve type.

- **MANUAL** - this is a manual type switching to INp port, or switching come back INw port by remote control via SNMP management. The scheme is belong to manual type.

<table>
<thead>
<tr>
<th>Table 1. The OPS parameters define.</th>
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<tr>
<td>Parameter</td>
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<tr>
<td>OUT com</td>
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<tr>
<td>IN com</td>
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<tr>
<td>IN w</td>
</tr>
<tr>
<td>IN p</td>
</tr>
<tr>
<td>OUT w</td>
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<tr>
<td>OUT p</td>
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<table>
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<th>Table 2. The OPS specifications define.</th>
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<tr>
<td>Item</td>
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<tr>
<td>Transmitter side</td>
</tr>
<tr>
<td>Operating wavelength</td>
</tr>
<tr>
<td>Input Power Range</td>
</tr>
<tr>
<td>OSC wavelength</td>
</tr>
<tr>
<td>Receiver side</td>
</tr>
<tr>
<td>Operating wavelength</td>
</tr>
<tr>
<td>Input Power Range</td>
</tr>
<tr>
<td>Switch level Setting Range (Res=2)</td>
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<tr>
<td>Restoration time</td>
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### III. DWDM General Protection Type

When the loss of light signal of INw or the degradation of signal in channel is detected by the OSC, optical switch switches to INp port to execute the protection scheme. Besides, the architecture must satisfy the following requirements of switching in any case:

- Switch over time within 50 ms in order to minimize the impact of the service.
- The OSC channel is supervision the working and protection path in real-time.
- DWDM side (MUX/DMUX) receiver power must adjust within receiver power range (0dB ~ -18dB).
- Client side (OTU: Optical Transponder Unit) receiver power must adjust within receiver power range (-3dB ~ -18dB).
- OPS switching level: According to the OUT and Client equipment sensitivity setting OPS switching level.

There are four type general protection mechanisms:

- **Channel Protection Mechanism**
  In this case there are working and protection fiber path. And DWDM side has two MAX/ DMAX. The example is show in Fig. 5. When the working path fiber cut then DWDM site-A and DWDM site-B OPS...
will be switching to protection path to retrieve the same traffic.

- **Client Protection Mechanism**
  
  In this Client protection the DWDM site just one path and one MUX/DMUX. The example is show in Fig. 6. In the client side has two tributary cards add/drop. When a working tributary card failure then OPS\(_1\) and OPS\(_2\) switching to protection tributary card to retrieve the same traffic.

![Fig. 6. Client Protection, The working tributary card failure then OPS\(_1\) and OPS\(_2\) will be switching to protection tributary card.](image)

- **Channel and Client Protection Mechanism**
  
  In the Channel and Client protection both the DWDM side and tributary side have working and protection card. The example is show in Fig. 7. When the working path fiber cut then DWDM site-A OPS and DWDM site-B OPS will be switching to protection path. Or a working tributary card failure then DWDM site-A OPS and DWDM site-B OPS will be switching to protection tributary card to retrieve the same traffic.

- **Fiber Protection Mechanism**
  
  The fiber protection must a redundancy fiber for protection. If the working fiber cut, the traffic will be switching to the protection fiber automatically. This is all channels protection. But in this fiber protection the redundancy fiber length must similar working fiber length. And must consider and calculate the power budget is suit with working fiber path [4]. And must considering the OPS insertion loss. The example is show in Fig. 8.

![Fig. 7. Channel and Client Protection, The working tributary card failure then OPS switching to protection path and protection tributary card.](image)
Fiber Protection. If the working fiber cut, the traffic will be switching to the protection fiber automatically.

IV. Multiple-Path Protection

The general protection mechanism has two fiber path or two tributary cards to protection working fiber or working tributary card. We are implemented more than two fiber path protection in the multiple-path protection mechanism. There are two type multiple-path protection mechanisms:

- **8-Type OPS back to back connection protection.**

  We are used OPS back to back connection protection to accomplish four path routing protection scheme. The example is show in Fig. 9. When the path1 is fiber cut then the DWDM site-A OPS and DWDM site-C OPS will be switching to path3 to restore the traffic. In the meantime the path2 is fiber cut then the DWDM site-B OPS and DWDM site-C OPS will be switching to path4 to restore the traffic again. Assume the central office (CO) DWDM site-C between DWDM site-A and DWDM site-B in the general protection type. To use this 8-type back to back OPS connection can reach multiple-path protection mechanism. There are four path can protection this DWDM network. To get up to the backbone DWDM optical networks more safety.

- **Double 8-Type OPS back to back connection protection.**

  The double 8-type protection mechanism is consists of two 8-type OPS back to back protection network parallel connection, it is show in Fig. 10. When the path1 fiber is cut then the DWDM site-A OPS and DWDM site-C OPS will be switching to path3 to restore the traffic. In the meantime the path2 is fiber cut then the DWDM site-B OPS and DWDM site-C OPS will be switching to path4 to restore the traffic. When the path1 and path2 fiber is not reconstruct that the path3 or path4 fiber cut again then the DWDM site-A OPS and DWDM site-B OPS will
be switching to path5 and path6 to restore the traffic. 
In the meantime the path5 is fiber cut again then the 
DWDM site-A OPS3 and DWDM site-C OPS3 will be 
switching to path7 to restore the traffic. 
Simultaneously the path6 fiber cut again. The DWDM 
site-B OPS3 and DWDM site-C OPS3 will be 
switching to path8 to restore the traffic. If there are 
two DWDM backbone rings, we can creation double 
8-type back to back OPS connection protection 
mechanism. This is eight path DWDM backbone 
optical protection network. To get up to the backbone 
DWDM optical networks more security and safety 
goal. The double 8-type OPS back to back protection 
connection working flow chart is like Fig. 11.

V. Simulation and Testing Result
For testing the switching time of APS and bit error 
rate (BER) when the OPS is switching to the 
protection path. The channel speed is operated at 2.5 
Gb/s in the DWDM protection mechanisms. The 
system is simulated that using manual switch and fiber 
cut switch. The description of them as follows:

- Manual switch testing:
  We are remote the OPS that the INw port is 
switched to the INp port via SNMP management in the 
Fig. 5 to Fig. 10. The switching time is only about 2 
ms shown in Fig. 12 (a) and the BER has only 1 ES 
>Error> (Error Second) as the Fig. 13 (a).

- Fiber cut switch testing:
  In order to test the influence of fiber cut off from 
INw port switching to INp port. The Fig. 5 to Fig. 10 
are simulated to be the fiber cut off. The results are 
shown in Fig. 12 (b) and Fig. 13 (b). The switching 
time is 6 ms and the BER is also 1 ES. Besides, in 
order to prove the advantage of our system architecture, 
the general DWDM backbone protection with 8-type 
/double 8-type back to back connection protection 
mechanism is compared as shown in table 3.

Table 3. Comparison of general DWDM backbone 
protection and 8 type (double 8 type) back to back 
connection protection.

<table>
<thead>
<tr>
<th>Protection Type</th>
<th>Path Number</th>
<th>Tributary Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel Protection</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Client Protection</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Channel and Client Protection</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>8 type back to back connection</td>
<td>4</td>
<td>1 or 2</td>
</tr>
<tr>
<td>Double 8 type back to back</td>
<td>8</td>
<td>1 or 2</td>
</tr>
</tbody>
</table>

Fig. 12. (a) The OPS manual switching time testing result. 
(b) The OPS fiber cut switching time testing result.

Fig. 13. (a) The OPS manual switching BER testing result. 
(b) The OPS fiber cut switching BER testing result.
VI. Conclusion

How to design network survivability is still a very important issue in DWDM backbone optical network to date. A fiber has a huge capacity in DWDM system, so the failure of fiber will seriously influence communications. Therefore, this paper proposes a protection mechanism to advance the DWDM network survivability in the optical layer, simplify design of the network protection structure, and reduce the cost. In the general DWDM backbone protection networks that have two fiber paths. We propose a DWDM protection mechanism that adopts the 8-type/double 8-type back to back protection connection. The scheme uses eight paths to build protection for important traffic such as STM-16 (2.5 Gb/s) or GbE (Gigabit Ethernet). Our system architecture can to accomplish very security and safety DWDM backbone optical networks by multiple-path protection. From simulations, the switching demands are finished follow conditions of protection scheme by automatic switching at fiber broken with 2.5 Gb/s traffic in 8-type back to back DWDM backbone protection network:

- Switch over time within 50 ms in order to minimize the impact of the service.
- OSC channel supervision the working and protection path in real time.
- DWDM side (MUX/DMUX) receiver power must adjust within receiver power range (0dB ~ -18dB).
- Client side (OTU: Optical Transponder Unit) receiver power must adjust within receiver power range (-3dB ~ -18dB).
- OPS switch level: According to the OTU and Client equipment sensitivity setting OPS switch level.

Our system not only completely protects the traffic when fiber is broken and, more importantly, it also can to build in older DWDM backbone system which the single mode OTU that upgrade this system more security and safety.

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References


