HIGHLY RELIABLE SDH/ETHERNET SWITCHABLE 1:N PROTECTION EQUIPMENT FOR TRANSOCEANIC CABLE SYSTEMS

Kazuo Kubo, Yuji Akiyama, Sota Yoshida, Eiichi Horiuchi, Shoichiro Seno, Yoshimasa Baba, Takashi Mizuochi (Information Technology R&D Center, Mitsubishi Electric Corporation) and Hiroaki Munehira (Communication Networks Center, Mitsubishi Electric Corporation)
Email: <Kubo.Kazuo@cj.MitsubishiElectric.co.jp>

Information Technology R&D Center, Mitsubishi Electric Corporation, 5-1-1, Ofuna, Kamakura, Japan

Abstract: In order to support the coexistence of SDH and Ethernet services, we have developed an SDH/Ethernet switchable 1:N protection Line Terminal Equipment, via which system outages can be reduced to less than 1/10 of what they would otherwise be at minimum cost. Its performance is well proven in actual transoceanic cable systems, which achieve high-speed switching in less than 80 ms excluding the propagation delay.

1. INTORODUCTION

Provisioning transparent 10 Gigabit Ethernet (10GbE) services on systems such as the transoceanic cable network is clearly emerging as a key requirement not only for telecom carriers but also for service providers. Terrestrial networks are migrating towards 10GbE, with Ethernet private line or Ethernet private LAN services being typical examples of new network services. Despite this drastic shift from voice to data in transport networks, SDH transport has remained the standard of choice for submarine cable systems.

The redundancy architecture of submarine Line Terminating Equipment (LTE) [1] should be optimized in terms of the system availability and the total cost, as the submarine cable system becomes larger-scale with the increase in the number of multiplexed wavelengths.

In this paper, we describe an LTE with SDH/Ethernet switchable 1:N protection to provide high availability for transoceanic cable systems to support the coexistence of SDH and Ethernet services.

2. 1:N PROTECTION SCHEME TO DYNAMICALY ACCOMMODATE MULTIPLE CLIENT SIGNAL TYPES

Via the 1:N protection function, N pairs of facing transponders (TPNDs) and their working paths are protected by a single pair of facing TPNDs as a protection path. The following are the requirements for this function.

1) MODE SWITCHING FOR DIFFERENT CLIENT SIGNALS

To improve the efficiency and flexibility of submarine cable systems, working TPNDs support both STM64 and 10GbE as client signals. Consequently, these different types of client signals need to be protected by a single pair of TPNDs.

2) SUPPORT OF SWITCHING PRIORITY (PRE-EMPTION)

To protect mission-critical traffic, two levels of switching priorities can be set for each working TPND. In case where multiple failures of working TPNDs occur simultaneously or a single failure occurs in a high priority working TPND when a low priority working path is already switched to protection, the highest priority working path is switched.

Fig. 1 shows the proposed 1:N protection scheme for mixed STM-64 and 10GbE LAN PHY client signals, in which N working paths are protected by a single backup path. The 1:N LTE consists of a 10 Gbit/s TPND, two optical switch cards and a supervisory card. The TPND maps STM-64/OC-192 or 10GbE into standardized OTU2 or OTU2e frames, respectively. When a working TPND failure occurs, the optical switch cards immediately select and bridge a redundant wavelength channel in place of the failed channel.

In the normal condition, the signals transmitted through the left-hand client interfaces bridged to their dedicated TPNDs by couplers (CPLs), transmitted through the λs by the OTN schemes, and received by their corresponding dedicated TPNDs. They are then selected in the right-hand CPLs for reception through the right-hand client interfaces. Upon the failure of any TPND or working path, the failed signal is bridged to the left-hand redundant TPND through the left-hand 1:N optical switch, which can choose the path to be protected. The signal is then transmitted through the protection wavelength and received by the right-hand protection TPND. Afterwards, it is routed by the right-hand 1:N optical switch to the right-hand CPL, where the protected signal is selected. In the process, automatic protection switching (APS) messages are transmitted by the pair of TPNDs used for protection so that APS can work properly if any working TPND fails.

The STM-64 client signals are wrapped into OTU2 frames and the 10GbE LAN PHY ones are wrapped into OTU2e frames in the TPNDs. The signals are then transported on the corresponding working wavelengths in OTN format. The redundant TPNDs work on either OTU2 or OTU2e in response to the type of client signal to be protected. The transmission speeds for OTU2 and OTU2e are 10.7 Gb/s and 11.1 Gb/s, respectively.

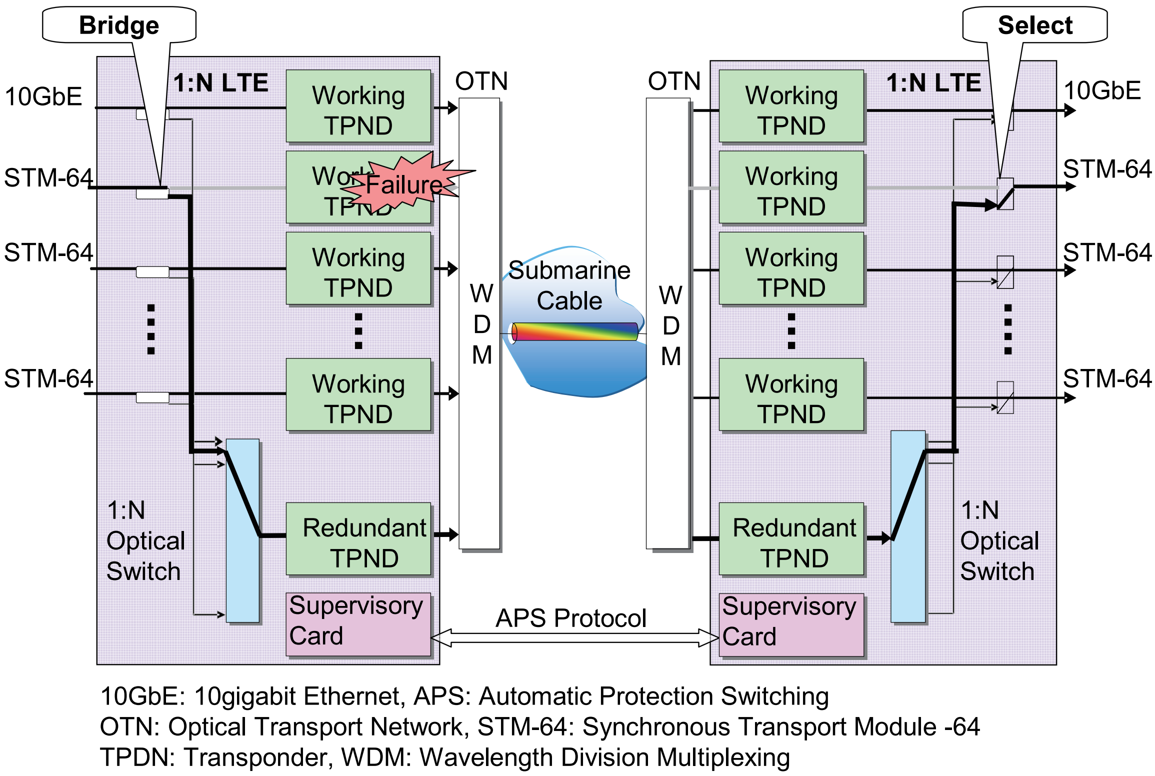

Figure 1 1:N Protection Scheme for STM-64 and 10GbE LAN PHY Client Signals

Fig. 2 shows the configuration of the transponder. To accommodate the difference in OTU2 and OTU2e speeds, the redundant transponders need to change the frequency of their TxPLL, RxPLL etc. depending on the client signal protected, in addition to the settings of the OTU2(e) processors. For the TxPLL and RxPLL, the characteristics of their loop filters are optimized to resolve the trade-off between hit-less switching of the clocks in normal operation and the fast locking of the clock to the different speed during the framing mode change since the narrower the bandwidth of the loop filter, the more stable the hit-less switching, and the wider the filter, the faster the mode change.

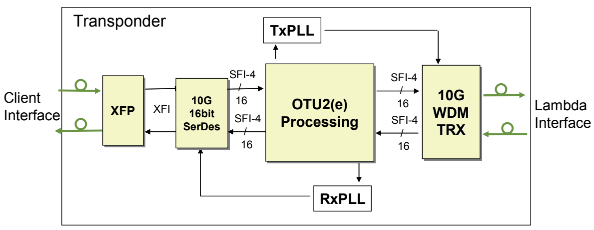

Figure 2 Configuration of the Transponder

Protection switching is established using an extended protocol based on ITU-T Recommendations, the APS algorithm for 1:N protection [2]. Fig. 3 shows a typical APS message flow. To protect both STM-64 and 10GbE LAN PHY client interfaces using a single redundant transponder, the redundant transponder changes its client interface during the APS message flow if its client interface is different from that of the protected channel.

In the case of protection switching with a client interface change, the different times taken by the nodes to change their client interfaces may cause unnecessary alarms at the redundant transponders and prevent normal switching. In order to avoid this, each node suppresses alarm monitoring at the redundant transponder before changing its client interface.

Table 1 shows the features of the 1:N LTE. N can be set via an operations system to any number up to 64. A preemption function for the back-up wavelength channel can also be provided. Figure 4 shows a view of the 1:N LTE.

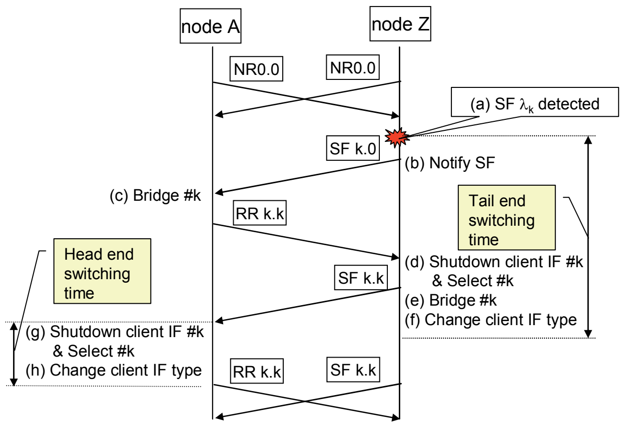

Figure 3 APS Message Flow for Protection Switching

Table 1 Features of 1:N LTE

Item	Description
Protection Method	1:N protection (N=64)
Switching Time	- Less than 100 milliseconds for Fast mode - 11 to 20 seconds for Slow mode
Switching Mode	- Fast - Slow - Disabled
Manual Operation	- Lockout of Protection - Forced Switch - Manual Switch
Self Reversion	- Revertive - Non-Revertive
Pre-emption	- Two priority levels defined for each client interface - Protection of low priority interfaces overridden by high priority interfaces
Extra traffic	Not supported

Figure 4 View of the 1:N LTE

3. EXPERIMENTAL RESULTS

The protection switching time of the 1:N LTE was evaluated. SDH/10GbE analyzers were connected to Network Elements and emulated client network elements. The network analyzer monitored the received optical signal and measured the disruption time during signal failures such as LOS (Loss of Signal) and LOF (Loss of Frame).

Table 2 shows the measured protection switching times. During automatic protection switching, the optical signal is disrupted in both directions. The bidirectional switching time is the duration between the time when either of the directions is disrupted and the time when both directions are completely restored. One redundant TPND can protect either a 10GbE or STM-64 failed working wavelength channel by switching its framing mode in less than 10 ms. This is enabled by a fast phase-locked loop (PLL) and embedded acceleration firmware. We confirmed that when the client interface type was different from that of the current protection channel, the bidirectional protection switching time was less than 80ms excluding the propagation delay.

Table 2 Measured Protection Switching Times

Item	Specification	Experimental results
Switching time without mode change	<20ms (Unidirectional Tail-end)	15ms±1ms
	<80ms (Unidirectional Head-end)	70ms±2ms
	<100ms (Bidirectional)	70ms±2ms
Switching time with mode change from STM-64 to 10GbE	<20ms (Unidirectional Tail-end)	15ms±1ms
	<80ms (Unidirectional Head-end)	75ms±2ms
	<100ms (Bidirectional)	77ms±2ms
Switching time with mode change from 10GbE to STM-64	<20ms (Unidirectional Tail-end)	15ms±1ms
	<80ms (Unidirectional Head-end)	78ms±2ms
	<100ms (Bidirectional)	78ms±2ms

4. CONCLUSION

We have developed an SDH/Ethernet switchable 1:N protection Line Terminal Equipment (LTE) to provide high availability for transoceanic cable systems. The 1:N protection LTE achieves high-speed switching in less than 80 ms, excluding the propagation delay due to the transmission distance. Thanks to this 1:N protection, the system outage per year can be reduced to less than 1/10 of what it would otherwise be, at low cost. The performance of this 1:N LTE has been well proven in actual transoceanic cable systems.

5. REFERENCES

[1] K. Shimokasa *et al.*, Suboptic 2001, Kyoto, Japan, P4.2.1 (2001).
[2] ITU-T Recommendation G.873.1 (2006).