Ethernet | Increased Data Capacity | Compact/Low-power Equipment

Technology Reports

Ethernet Transmission Equipment ERP-SW for All-IP Transmission Paths

While progress is being made in the implementation of All-IP transmission paths, issues have been encountered due to the low efficiency with which IP traffic is accommodated by conventional transmission equipment carrying existing services. To enable us to accommodate increases in capacity and the introduction of IP networks, we have developed Ethernet transmission equipment that can adapt flexibly to increased capacity and IP networks, and can also handle LTE service traffic. With this equipment, we were the first in the world to implement a broadband Ethernet network transmission protocol (IEEE802.3ah). Furthermore, in order to improve the network reliability, we made it possible to detect faults promptly and take swift recovery action, allowing us to provide communication services with stable quality.

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1. Introduction

Traffic levels have recently soared due to the spread of flat-rate communication services and the growing need for high-capacity packet communication services such as video delivery, and service providers have had to adapt flexibly to increases in transmission path capacity and the introduction of IP network technology. It is expected that this trend will continue in the future with the inception of high-speed LTE services with low latency.

Under these circumstances, particularly with regard to LTE transmission paths, when networks are constructed with existing Synchronous Digital Hierarchy (SDH)[*1] equipment such as Fiber Transport Module-DOCOMO (FTM-D) it is necessary to construct a Virtual Container 4 (VC4) path[*2] for communication with each client, and since each path occupies transmission path bandwidth, there has been an issue in that it is not possible for the transmission paths to efficiently accommodate IP traffic in packet units (**Figure 1**(a)).

As the scale of an IP network increases, faults in the network have a greater impact on users. Consequently, there is also a need for transmission equipment that provides users with stable communication services and improves the network reliability while facilitating prompt fault discovery and rapid recovery measures.

Furthermore, in layer 2[*3] that only implement the IEEE802.1ad Provider Bridges (PB) method[*4] used for conventional broadband Ethernet services, only 4,094 Virtual Private Networks

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*1 **SDH**: An ITU-T standard for the speed and format of transmission of signals via optical fibers.
*2 **VC4 path**: A 150 Mbit/s logical path standardized by ITU-T G.707 for SDH transmission.
*3 **Layer 2**: The second layer (data link layer) in the OSI reference model.
*4 **IEEE802.1ad PB method**: A layer 2 relay method that distinguishes between the Virtual LANs (VLANs) of different services by applying service VLAN tags to frames.

(VPNs)[*5] that can be built with a single switch, raising concerns of VPN depletion when accommodating large numbers of services in the future. Layer 2 switches in Ethernet networks also have to learn the Media Access Control (MAC) addresses[*6] of every device on the network, which raises issues due to the increased processing load that has to be carried by network equipment.

In this article, we present an overview of the functions, equipment and network configuration of Ethernet Ring Protection-Switch (ERP-SW), which is a high-capacity layer 2 switch that we developed to address these issues.

2. Network Configuration

ERP-SW is based on a ring-shaped configuration, and performs the role of connecting between the base station equipment and higher-level routers (**Figure 2**). This ring-shaped configuration is adopted because it reduces running costs by cutting the number of optical fibers connecting between buildings, and because it provides path redundancy.

It is also possible to combine multiple rings and configure them as a single Ethernet network, where the ring connected to the higher-level router is called the trunk ring, and the subordinate rings connected to this trunk ring are called branch rings. An evolved NodeB (eNB)[*7] is connected via a dedi-

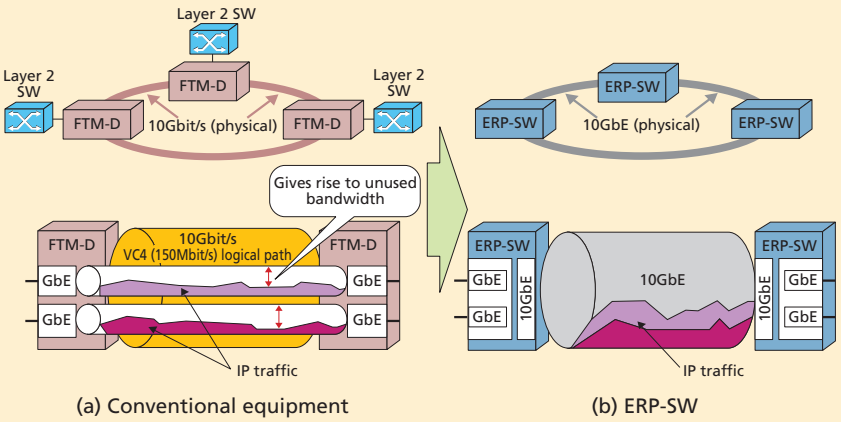

Figure 1 Comparison of ERP-SW with conventional equipment

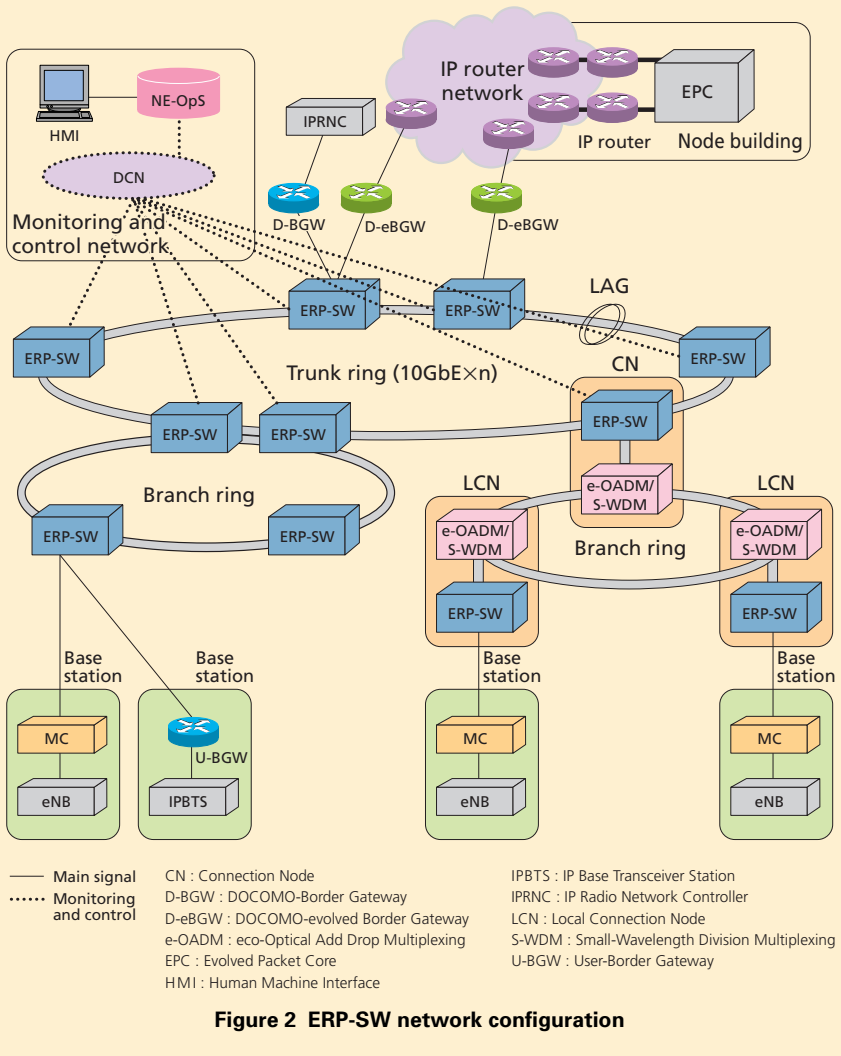

Figure 2 ERP-SW network configuration

*5 **VPN**: A virtual network that establishes a logical connection between IP equipment of the same service.
*6 **MAC address**: A 12-digit fixed physical address allocated to an Ethernet board.
*7 **eNB**: A base station for the LTE radio access system.

cated Media Converter (MC) installed on the base station. The configuration, monitoring and control of the equipment are performed by an Network Element-Operation System (NE-OpS)[*8] via a Data Communication Network (DCN)[*9], whereby it is possible to ascertain the status of the ring and network equipment in real time.

3. ERP-SW Equipment Overview

The ERP-SW allows the installation of multiple line cards with 10Gigabit Ethernet (GbE) and 1GbE physical interfaces, and the transmission path capacity can easily be expanded to match the network's required bandwidth by using an Link Aggregation Group (LAG)[*10]. The device structure can be broadly divided into a management card that performs monitoring control and switching, a line card that transfers frames over 1GbE or 10GbE, a FAN and a power source. Three models are available; these differ in terms of how many line cards they are able to accommodate (**Table 1**).

Due to our efforts to save space and reduce power consumption, this equipment is suitable for colocation[*11] and helps to reduce the installation and set-up costs. Also, the access link connecting the ERP-SW and MC is capable of single-core bidirectional communication using a 1000BASE-BX module, enabling efficient use of the optical fiber core (**Figure 3**). The frame transmission processing performed inside the equipment performs switching at layer 2 by writing the destination MAC addresses of Ethernet frames transmitted from the LTE base station and higher-level routers into a learning table.

4. ERP-SW Equipment Functions

4.1 ERP Function

The ERP function can block off any port[*12] of equipment inside the ring by designating it as a block port, thereby preventing frames from looping inside the ring. When a loop occurs, it not only imposes processing loads on the equipment, but can also affect user traffic by restricting the transmission path bandwidth. Countermeasures to the formation of loops are therefore essential.

When a fault occurs in the ring, the block port is released and traffic is rerouted so as to bypass the faulty link (**Figure 4**).

4.2 High-speed Transmission Path Switching Function

This is a function that switches the transmission path to a redundant path at high speed when switching paths due to the occurrence of a fault or the actions of a network operator. In particular,

Table 1 Three model configurations that can accommodate different numbers of line cards

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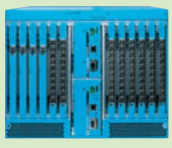
TYPE3			
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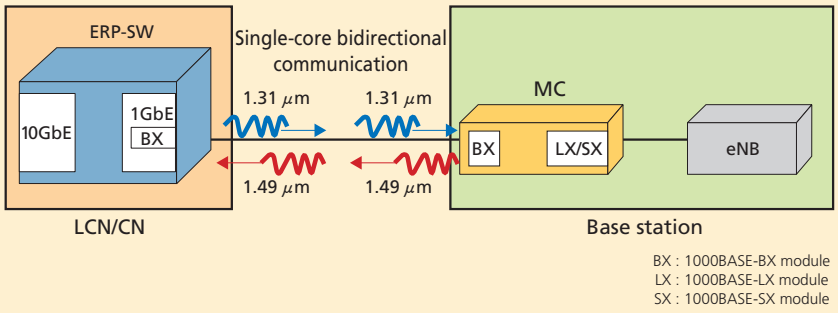

Figure 3 Connection configuration of ERP-SW and MC

*8 **NE-OpS**: General term for a monitoring and control system.
*9 **DCN**: A data transmission network for monitoring and control.
*10 **LAG**: A function that treats multiple physical circuits as a single virtual circuit.
*11 **Colocation**: In this article, colocation refers to the provision of space in which to install equipment and the electrical power needed to operate it.
*12 **Port**: An interface for exchanging data with other equipment.

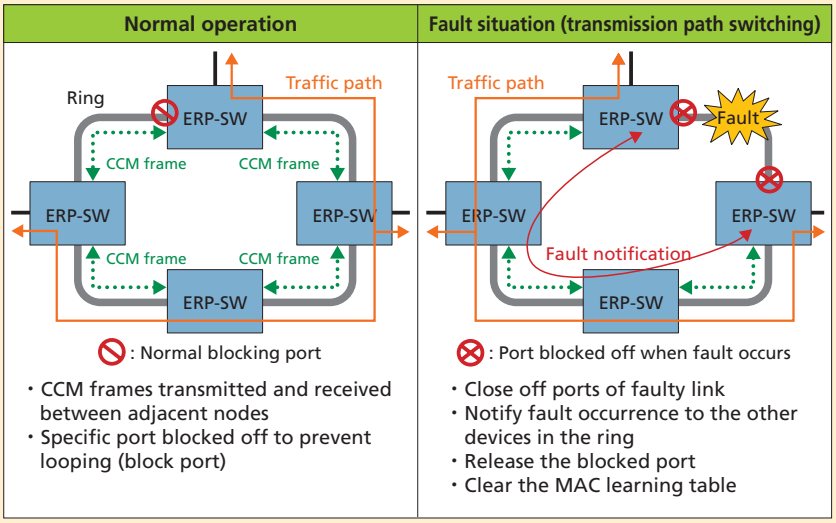

Figure 4 Switching of transmission path when a fault occurs

when a fault has occurred it is important to consider how the effects on users can be reduced. In ERP-SW, ring control frames are circulated inside the ring, and Ethernet-Operation Administration and Maintenance (OAM)[*13] Continuity Check Message (CCM) frames[*14] are transmitted and received between neighboring devices. These CCM frames are used to monitor the routine status of the ring and the status of the equipment connected to it.

Since the CCM frames are transmitted and received at a minimum interval of 3.3 ms, they facilitate the prompt detection of faults and identification of faulty links.

When these frames are not transmitted and received normally, the ERP-SW recognizes that a fault has occurred, closes off the ports operating in both directions on the affected link, and notifies the fault to all the other ERP-SWs in the ring. When an ERP-SW receives this notification, it clears the MAC address learning table and switches the transmission path to a redundant path at high speed.

The routine monitoring of CCM frames also enables the detection of fault states involving one-way disconnections since these frames are exchanged bidirectionally between devices.

4.3 Functions for Monitoring Internal Equipment State

ERP-SW transmits and receives periodically health-check frames between line cards and management cards of the ACT system[*15] and the SBY system[*16] for redundant configuration. In cases where these frames are not transmitted and received normally or are corrupted en route, the fault is reported to NE-OpS and the corresponding location is closed off.

This function prevents the generation of silent faults[*17] where a device is unaware of a fault in its own operation.

4.4 Fault Isolation Function

Conventional methods for isolating faulty link chiefly involve performing Ping[*18] tests between layer 3[*19] devices such as routers, and thus have difficulty identifying the location of a fault in a layer 2 switch in the link.

In our new system, by implementing the Ethernet-OAM functions Continuity Check (CC), Loop Back (LB), Link Trace (LT), Delay Measurement (DM) and Loss Measurement (LM) conforming to IEEE802.1ag or International Telecommunication Union-Telecommunication Standardization Sector (ITU-T) Y.1731[*20], we have made it possible to perform connectivity tests without interrupting services at the layer 2 level, thereby leading to rapid fault isolation.

The Ethernet-OAM functions implemented in the MC have also made it possible for CC and LB to be used for routine monitoring and connectivity checks respectively, even in access links (**Figure 5**).

4.5 Expansion of Broadband Ethernet

In the layer 2 switches of conventional PB methods, there have been issues such as VPN depletion and increased switch processing loads. The

*13 **OAM**: Functions for maintenance and operational management in a network.
*14 **CCM frame**: Frames transmitted and received when performing connectivity checks between devices.
*15 **ACT system**: The parts of a redundant hardware configuration that are actually being used.
*16 **SBY system**: The parts of a redundant hardware configuration that are currently on standby.
*17 **Silent fault**: Failures that the maintenance personnel cannot detect such as those caused by breakdowns of the fault detection package and main processor, so that the equipment itself cannot recognize the faults.
*18 **Ping**: A function for checking connectivity by sending a packet to the host computer of the other party and receiving a reply to that packet.

ERP-SW is the world's first system that solves these issues by making prompt use of the IEEE802.1ah Provider Backbone Bridges (PBB) method[*21].

The PBB method is an encapsulation method for inserting one MAC frame inside another MAC frame, which is used for the transmission of frames inside a ring network. When a user frame enters a PBB network, it is tagged with I-TAG[*22], B-MAC address[*23] and B-TAG[*24] information.

Frames are transmitted based on the B-MAC address which can be freely set in the ERP-SW. This means the ERP-SW does not have to learn all the user MAC addresses but just the B-MAC address of each ERP-SW unit (**Figure 6**). This mechanism reduces the processing load on the ERP-SW.

It is also possible to configure up to 65,000 VPNs using I-TAGs and B-TAGs.

The basic function of the PBB method is that it acts to discard frames when the B-MAC address set in a device matches the destination B-MAC address of a frame received by this device. This suppresses the occurrence of loops inside the ring.

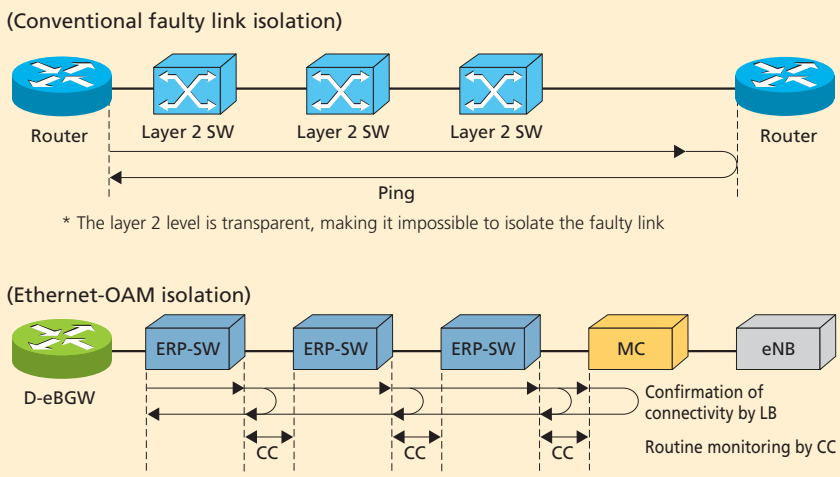

Figure 5 Isolation of faults by Ethernet-OAM

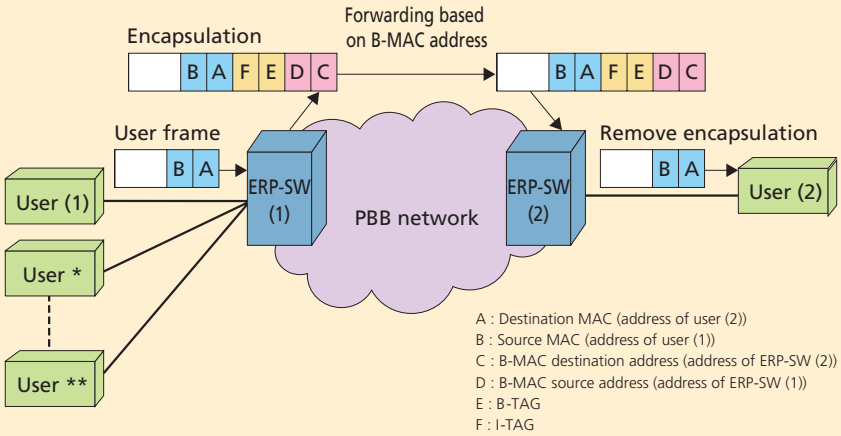

Figure 6 PBB frame forwarding

5. Conclusion

In this article, we have described the functions, equipment and network configuration of ERP-SW that enable it to provide high-quality communication services that can also be used as LTE transmission path equipment.

ERP-SW uses a 10GbE interface and LAG bandwidth acceleration to respond to the demand for transmission paths with increased capacity. However, since the initiation of the LTE service is expected to cause further increases in traffic and greater demands for increased capacity, we will continue to study the extension of this technology to 40GbE and 100GbE interfaces.

*19 **Layer 3**: The third layer (IP layer) in the OSI reference model.
*20 **ITU-T Y.1731**: A standard specification for Ethernet-OAM functions, where CC and LB perform connectivity checks, LT gathers path information, DM measures the delay times and LM measures the frame loss.
*21 **IEEE802.1ah PBB method**: A layer 2 connection method that uses encapsulation where one MAC frame is inserted inside another.
*22 **I-TAG**: A tag that identifies a service used in a PBB network.
*23 **B-MAC address**: A MAC address used in a PBB network.
*24 **B-TAG**: A VLAN tag for path control in a PBB network.