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Architecture of an Enhanced Packet-Optical Transport System

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Abstract

This paper describes an upcoming technology, currently under development, based on packet-optical transport. We present an enhanced packet optical transport system (ePOTS) to cope with the CAPEX/OPEX issues of current networks, and explain the system's major features, its potential services, and network deployment scenarios. Our results show that ePOTS can provide multimedia services efficiently and reduce the network cost by around one-third that of a multiprotocol label switching network.

Keywords: *PTL, P-OTS, PBB-TE, MPLS-TP, CAPEX, OPEX, Cut-through, Premium IP*

1. Introduction

With the advent of Internet protocol television (IP-TV), and furthermore, the increasing appearance of multimedia services such as user-created content (UCC), the volume of premium IP traffic is steeply rising. The current transport network is likely to face a difficulty in digesting this ever increasing traffic. According to a market report [1], it is expected that the current network capability will no longer accommodate the ever increasing traffic within the next several years. However, it seems that network providers are unwilling to invest capital in the expansion of their network capability Since increases in sales are not necessarily connected to immediate revenue increases. Accordingly, we believe that it is necessary to simplify the network architecture and upgrade the network quality in the direction of minimizing the capital expenditure (CAPEX) and operational expense (OPEX) to address these current issues.

If we look carefully into the current network architecture, it has some weakness for accommodating premium IP traffic. These flaws are multi-hop routing, low quality of service (QoS) based on best-effort service, complexity in network management, and circuit-based transport. We further examine the Korean domestic network in section V through network deployment scenarios.

In current networks, IP, Ethernet, and circuit networks including time-division multiplexing (TDM) and dense wavelength division multiplexing (DWDM) systems run together; however, the equipment composing each network are placed at different locations and are managed independently. This network environment hinders network facility expansion, complicates the operation and management, and requires a larger space and greater energy consumption. In addition, the network resource control is ineffective, and in particular, the network resource control between layers is not an easy job. With this network, if we try to create various types of service quality, the OPEX will necessarily increase. Under the current network environment, to satisfy the OPEX and its issues, as well as adapt to new services, the design of a new system that controls multi-layer network resources in an integrated manner is inevitable.

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As most services are moving forward to a packet-based paradigm, the circuit transport network based on Ethernet over SDH (EoS) is now evolving into a packet-based transport network. As a part of this evolution, packet transport layer (PTL) technology has been emerging and is widely spreading. The PTL is starting to be considered an effective way of conducting premium services. PTL is sometimes referred to as layer 1.5 since it supports the functions of layer 1 (*i.e.*, circuit transport) and layer 2 (*i.e.*, packet transport). The legacy circuit transport network is inefficient in packet delivery where packet services are dominant. When Internet service through a legacy circuit-based system like a multi-service provisioning platform (MSPP) is provided, owing to no statistical multiplexing gain, the delivery cost will increase. In the leased line service, network providers are unable to provide the proper bandwidth required by service providers owing to the discrete and rough bandwidth granularity that the circuit network itself possesses, which increases the network usage cost.

Relating to PTL technology, a multi-protocol label switch-transport profile (MPLS-TP) and provider backbone bridge- traffic engineering (PBB-TE) have been developed. The recommendations associated with PBB-TE have already been announced in IEEE 802.1Qay [2], and MPLS-TP related work has been conducted in IETF [3].

With the combination of a physical layer and packet layer, a packet-optical transport system, referred to as an "enhanced packet optical transport system," which is capable of providing an optimal path for a packet transport, is introduced, which allows all IP-based next-generation network (NGN) or multimedia services to be effectively supported.

In Section II, current network issues and ETRI's particular approaches are introduced. In Section III, the network architecture of the enhanced packet optical transport system and its network management and CAPAX/OPEX aspects are explained. In Section IV, the services are described. In Section V, network deployment scenarios are suggested, and finally, a summary and some concluding remarks are given in Section VI.

2. Network Issues and ETRI's Approach

Since the MSPP was introduced in the early 2000s, the packet transport system has evolved into the packet-optical transport system (P-OTS). Figure 1 illustrates the key features of P-OTS at each evolving step, and at the last step we predicted ePOTS. When the MSPP first came out, the circuit network for voice services and the packet network for data services were distinctly separated. The MSPP carried both Ethernet traffic and TDM. The MSPP was improved to the multiservice transport platform (MSTP) with WDM switches and a TDM control function; the MSTP then evolved into P-OTS, with circuit-like packet bearers such as PBB-TE or MPLS-TP. However, P-OTS, especially PBB-TE, only covers layer 2 services.

P-OTS has gained more attention recently because network providers are putting an effort into lower power consumption. If DWDM, TDM, and connection-oriented Ethernet are collocated and designed to be an integrated form, it would be straightforward to achieve less power consumption and smaller space. In addition, resource assignment will be more effective.

P-OTS will rapidly make inroads into the existing synchronous digital hierarchy/synchronous optical network (SDH/SONET) market in metro regions. With an annual growth rate of 4.3% for the transport equipment, the market size of P-OTS has sharply increased up to 109.7% annually since 2008, while the SDH/SONET market has tended to decline after its peak in 2007 [4]. The appearance of this integrated

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network has resulted in the creation of a new network control protocol such as GMPLS controlled Ethernet label switching (GELS).

Over the last several years, ITU-T NGN-GSI (NGN - global standard initiative) has developed an NGN architecture focusing on the transport control function of NGN. The goal of this activity is to make the current IP-based services exploit the packet transport network technology.

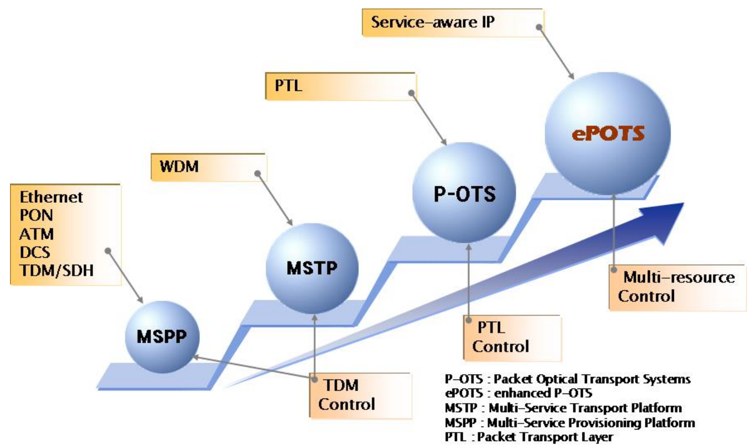

Figure 1. Packet transport system development status and direction

The ePOTS is an integrated switching system with combination of a packet switch and an optical switch; it has a manager to control the network. ePOTS has an IP flow-aware and multi-resource control function, and in particular, its multi-resource control function allows a network operator to set up a cut-through path with packet and optical switches

The multi-layer control function controlling multiple transport layers combined with DWDM, TDM, Ethernet, and IP layer will be described in section III. The cut-through path will alleviate the traffic concentration phenomena in the star network topology; it also resolves the multi-hop issues by redirecting the transit traffic via PTL tunnels. This will be explained in detail in section III as well.

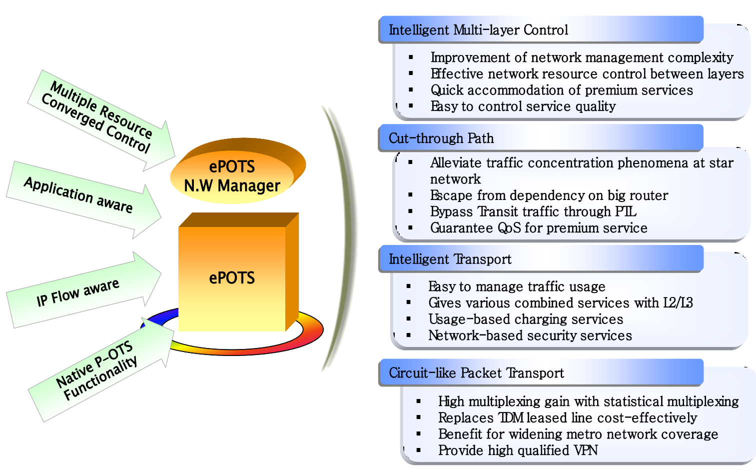

Figure 2. ePOTS design concept

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IP flow-awareness is applicable to usage-based charging services, network-based security services, and other services combined with layers 2 and 3. A circuit-like packet transport is connection-oriented. It will replace the TDM-based leased-line service with layer-2 virtual private network (L2VPN) services in a cost-effective and higher reliability way. This will address the metro network issues such as the bandwidth inefficiency of a circuit network and the QoS weakness of a packet network.

The ePOTS is expected to be deployed in metro areas in the early stage because it is more competitive than MSPP in the metro region. A detailed description for deployment scenarios is given in Section V.

3. The ePOTS Features

3.1. Network Architecture

Figure 3 shows the ePOTS systems covering access, metro, and core networks. The ePOTS systems are composed of three different types depending on their roles, i.e., the ePOTS-core, ePOTS-edge, and ePOTS-RT (remote terminal).

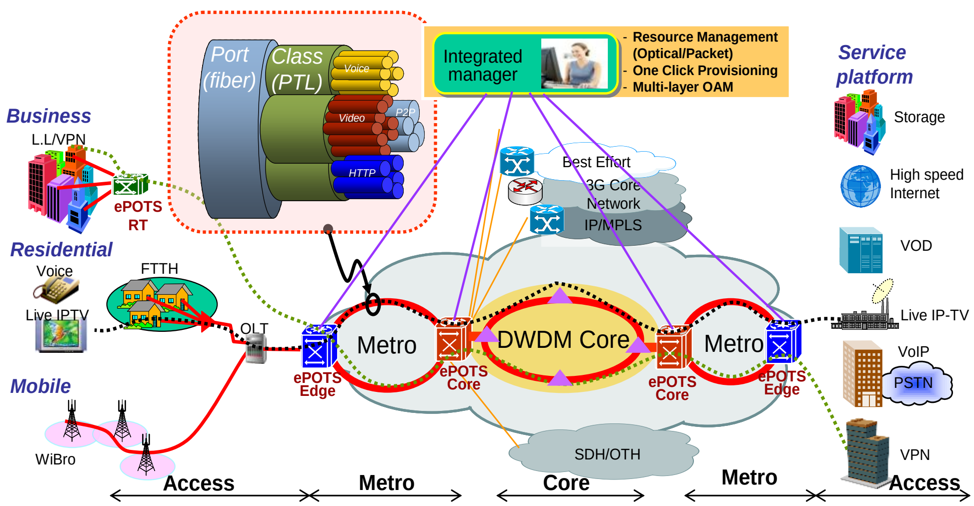

Figure 3. ePOTS network architecture

The ePOTS-core will interwork with legacy networks such as best-effort, IP/MPLS, 3G/4G mobile core, and a SDH/DWDM network. It will be connected with another ePOTS-core using a DWDM network. The core also gathers the ePOTS-edge data, and the gathered data are distributed to another ePOTS-edge by PTL and optical switch in core. The ePOTS-edge distinguishes IP and Ethernet traffic and they are mapped into the PTL PBB-TE or MPLS-TP. They are delivered through an Ethernet link for a short reach and for a long haul transmission, the PTL signal is mapped into the OTL.

The main application of ePTOS-RT in Korea would be a leased-line service for Internet cafés, private lines for local authorities, or a VPN for small businesses.

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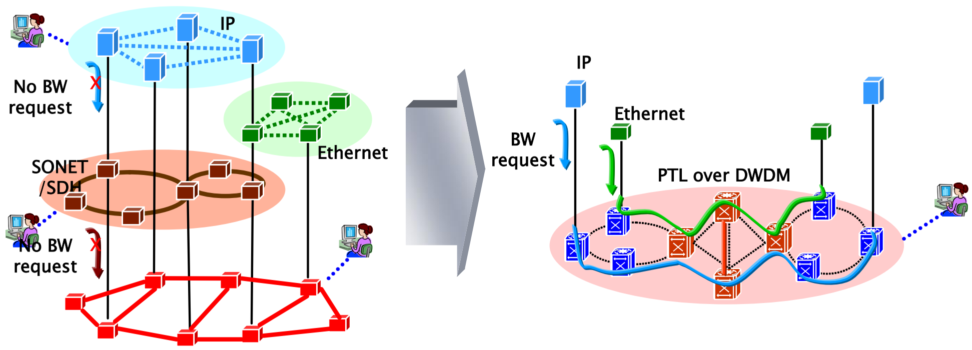

Figure 4. ePOTS network management

3.2. Network Management

The integrated manager controls the entire ePOTS systems deployed in core, metro and access network. Figure 4 illustrates the management concept of the ePOTS network. The left side of Figure 4 shows the legacy, in which each layer is managed by its own management system. No collaboration exists between layers, and differently skilled technicians are required to run the network. As the ePOTS permits the IP or Ethernet to directly access the PTL, which is in turn mapped into an OTL, assignment of the required bandwidth is done simultaneously from layer1 to layer 3.

The ePOTS manager calculates the shortest path between end points, and then sets up a connection. When the network resource are insufficient between two points, the lowest layer's resource is first assigned followed by the higher layer's resources is done. The network resource information are gathered and analyzed in the integrated manager. Periodically, path optimization for the inefficient paths is conducted and updated to reduce transition hops. Finally, the ePOTS manager performs alarm-storm-prevention for the failure caused by lower layer not to propagate to higher layer. For example, when the optical fiber is cut off, the failure is propagated to the TDM, PTL, Ethernet, and the IP layer in a sequence.

3.3. CAPEX and OPEX

There are currently no outstanding services to trigger network upgrades. For this reason, network providers do not invest in new facilities but try to reduce the CAPEX and OPEX. At the aspect of OPEX, the ePOTS system will have benefit as it is capable of controlling the IP, Ethernet, TDM, and optical link in a row. To address the CAPEX issues, we brought in the cut-through path concept for the IP connectivity. As most Internet traffic in Korea is concentrated at a center node, the traffic load of the center node is extremely great and requires bigger routers as the Internet traffic keep increasing. Around 70% of Internet traffic in Korea is the transit traffic, and the every transit traffic is routed in the middle of network. If this transit traffic can be delivered without IP routing, the router in the core network can be as small as 40-50% of the current one. This result leads to a reduction of 65-75% in CAPEX [7]; the packets will also not experience multi-hop routing.

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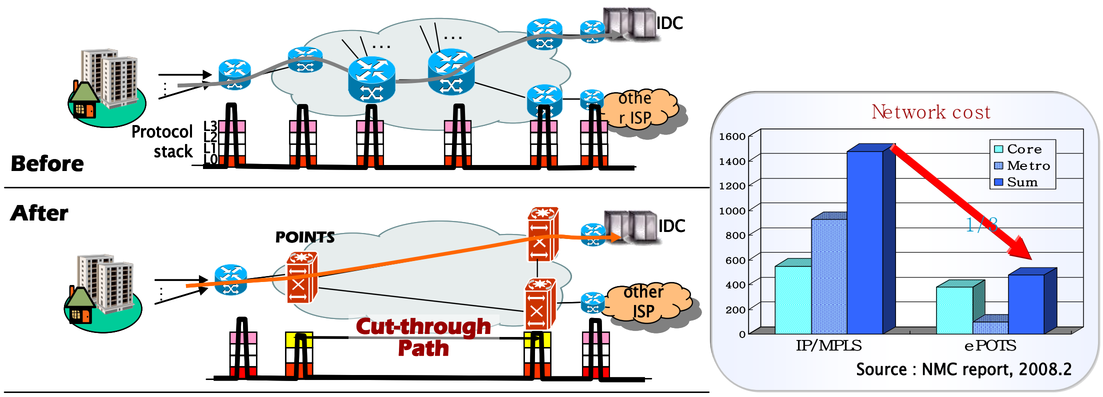

Figure 5. Cut-through paths in the ePOTS network

In Figure 5 the ingress traffic in the core network is linked to the destination through the cut-through paths. In the middle of the network, PTL switching takes place, while IP routing or Ethernet switching does not occur.

The right side of Figure 5 shows a cost comparison between the IP/MPLS and ePOTS. We took a Korean domestic network as an evaluation model, which was hierarchically composed of 384 central offices, 48 metro points of presence (POPs), two regional nodes, and two centre nodes. We assumed that the traffic capacity required in one central office is around 0.75Gbit/s per 10,000 subscribers, which implies 133kbit/s per one subscriber for the Internet, 400kbit/s for Video on Demand (VoD), 0.75Gbit/s for enterprise Internet, and 0.75Gbit/s for L2VPN service. We reflected the market prices currently quoted for IP/MPLS routers and carrier Ethernet switches. It was determined that most carrier Ethernet equipment is 56%-70% cheaper than routers. In metro regions, ePOTS has significant competiveness as heavy traffic such as VoD, L2VPN, and private enterprise networks can be bypassed without an IP router.

4. Services

Basically, the ePOTS can supports carrier Ethernet services such as E-Line (Ethernet-line) and E-LAN (Ethernet-LAN), which the Metro Ethernet Forum (MEF) recommends in its technical specification, MEF6 [8]. These are intended for a leased line or L2VPN service for enterprises. With E-LAN, network elements at the network edge can be connected to each other. In other words, beyond a single metro region, a huge area network covering the entire network will be established. The nodes designated as E-LAN service nodes are given an identical group identifier, and multipoint-to-multipoint connections are virtually formed with the aid of PTL connections.

Table 1. ePOTS services

Services	Remarks
E-Line + Internet	- Private leased lines - Internet access - Usage-based charging
E-LAN	-Service classes based on SLA (Premium, Silver, Bronze, Standard)
VPLS	-Virtual Private LAN service
Multicasting	- PTL multicasting for live IPTV
Mobile backhaul	- 4G LTE, WiMax backhaul
Security	-Network protection from MAC attack

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Table 1 shows the services that the ePOTS network supports. On top of the basic Ethernet services, multicasting, mobile backhaul, and security services are supported.

VPLS is a wide area LAN service. VPLS is different from E-LAN in that the ePOTS at the edge node performs standard bridge functions such as media access control (MAC) learning and a split horizon rule without using a provider link state bridging (PLSB) protocol. Its characteristics are similar to those of the VPLS of the IP/MPLS router, but the label switched path (LSP) tunnel is provisioned by the ePOTS network manager.

Multicasting is largely for a bundle service. A set of IP-TV channels is carried through a single PTL tunnel without an IP multicasting protocol. ePOTS can be used for a mobile backhaul network between eNodeB and gateways in an long-term evolution (LTE) or radio access network (RAN) controller and a base station in worldwide interoperability for microwave access (WiMAX). In terms of security issues, we take into account MAC attacks such as malicious multicasting data, invalid source MAC, and storm attacks. In our next study, we will expand the security features of ePOTS including user authentication, blocking peer-to-peer P2P traffic, fairness control for wireless multimedia traffic, traffic control for quality of experience (QoE), and other services using a deep-packet-inspection.

5. Network Deployment Scenarios

The domestic carriers in Korea are trying to minimize the number of central offices through direct access from POP to subscribers with a passive optical network (PON). Nevertheless, rural areas not covered will inevitably have to run stand-alone central offices. We envision three phases of network deployment scenarios, as shown in Figure 6.

At the beginning step, ePOTS will be installed between the POP and stand-alone central office. This will replace the EoS-based MSPP and layer 2/layer 3 switches, whereas the core network will still remain unchanged with legacy equipment. In other words, best-effort, IP/MPLS, and optical cross connect (OXC) over a WDM network will still exist as the costs of a legacy network. Network providers will offer Internet, P2P, or VoD services with a best-effort network; VoIP, IP-TV, WiMAX (4G), or L2VPN services with an IP/MPLS premium network; and circuit-based leased line services for enterprises with OXC. At this step, ePOTS at the POP will play the role of identifying services and connecting each individual network best-effort, IP/MPLS or OXC+WDM network. At the extension step, ePOTS will expand into the core network, and still coexist with the IP/MPLS and the best-effort networks. However, the best-effort network will gradually shrink and ePOTS will replace the OXC. During this period, light traffic such as VoIP will be transported over an IP/MPLS, while heavy traffic such as real IP-TV, L2VPN, or leased lines will be carried by the ePOTS. Otherwise, an IP/MPLS and ePOTS will share IP-TV and L2VPN services. These two systems can coexist since an IP/MPLS router has an advantage of IP delivery, and a PTL switch is beneficial for Ethernet-type services. At the completion step, the ePOTS network will cover all premium IP services, and will eventually replace the legacy system. The router will only be placed at a POP, while ePOTS will put in place a core network.

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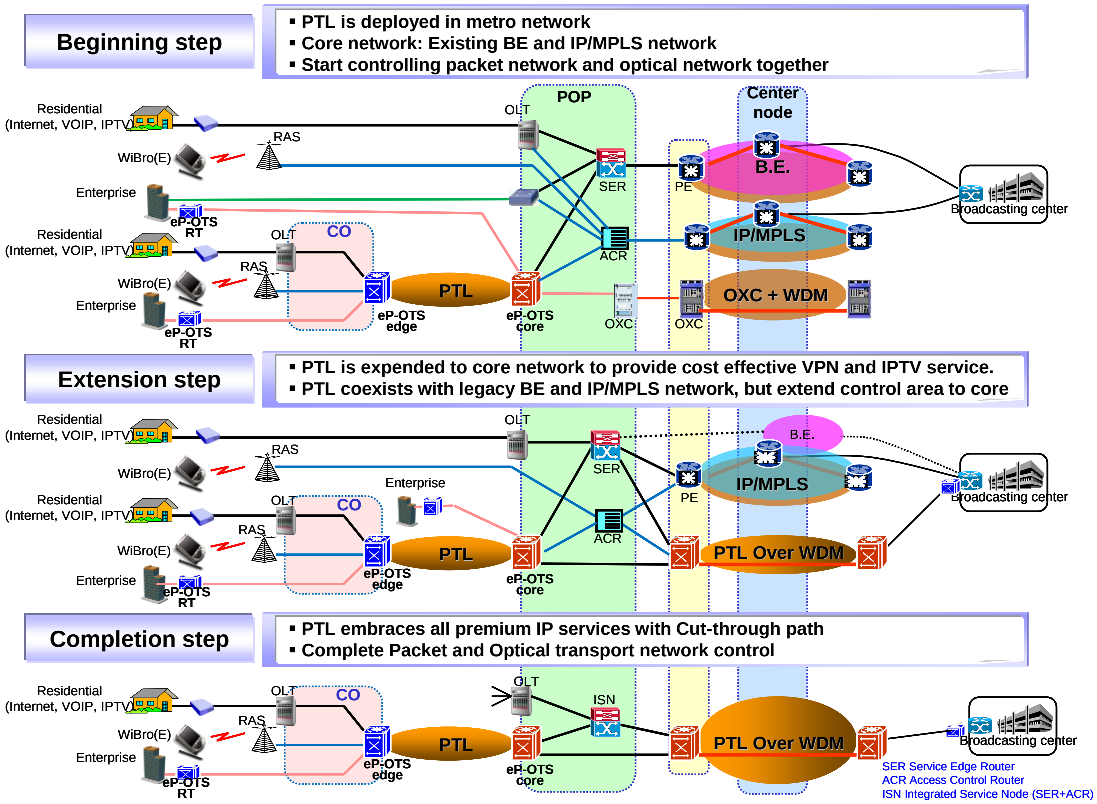

Figure 6. Network deployment scenarios

6. Conclusions

We introduced a system following P-OTS, which performs multiple resource control and supports various services such as Ethernet-based E-Line and E-LAN services, as well as MPLS-based VPLS service. PTL multicasting is also considered for a bundled IP-TV service. We presented the architecture of an ePOTS network covering access, metro, and core networks. Through a centralized network manager, network resources related to layers 1 through 3 are controlled simultaneously. With respect to the CAPEX/OPEX, the network composed of ePOTS was beneficial to up to one-third of the IP/MPLS. In addition, we assumed that the network deployment scenarios will take place in three steps. We foresee that the ePOTS will start deploying in metro regions, and will gradually replace existing legacy equipment. We envisioned network providers to take at least three incremental deployment phases when upgrading their networks. Ultimately, PTL over WDM will cover the entire core network by replacing IP/MPLS and OXC.

References

[1] GLG news, "New revenue opportunities for Converged Ethernet Transport", **(2008)** September 17.
[2] IEEE, "Provider Backbone Bridges Traffic Engineering", 802.1Qay, Draft 4.5, **(2007)** May.
[3] IETF, "MPLS-TP Requirements", draft-jenkins-mpls-mpls-tp-requirements-00, **(2008)** July.
[4] Heavy reading's, "Packet-Enabled Optical Networking Quarterly Market Tracker", **(2008)** April.
[5] ITU-T, "Recommendation Y.2121: Requirements for the support of flow-state-aware transport technology in NGN", **(2008)** January.
[6] J. Song, S. S. Lee and K. -C. Kang, "Scalable network architecture for flow-based traffic control", ETRI Journal, vol. 30, no. 2, **(2008)** April, pp. 205-215.

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[7] K. -K. Lee, J. -d. Ryoo and S. Min, "An Ethernet Ring Protection Method to Minimize Transient traffic by Selective FDB Advertisement", ETRI Journal, vol. 31, no. 5, **(2009)** October, pp. 631-633.
[8] K. Kim, S. Lee, J. Lee and Y. Jang, "Design of a Cos-Effective Hybrid-Type PBEx Providing a High Power Budget in an Asymmetric 10G-EPON", ETRI Journal, vol. 34, no. 6, **(2012)** December, pp. 838-846.
[9] MEF, "Ethernet Service Definition-Phase I", Technical specification MEF 6, **(2004)** June.
[10] IEEE, "Provider Backbone Bridges", 802.1ah, Draft 4.1, **(2008)** April.
[11] ITU-T, "Recommendation Y.1720: Protection switching for MPLS networks", **(2004)** April.
[12] ITU-T, "Recommendation Y.1711: Operation & Maintenance mechanism for MPLS networks", **(2004)** April.
[13] ITU-T, "Recommendation G.8131/Y.1382: Linear protection switching for transport MPLS (T-MPLS) networks", **(2007)** January.
[14] ITU-T, "Recommendation G.8121/Y.1381: Characteristics of Transport MPLS equipment functional blocks", **(2007)** March.
[15] ITU-T, "Recommendation Y.1731: OAM functions and mechanisms for Ethernet based networks", **(2008)** February.
[16] ITU-T, "Recommendation G.8031: Ethernet Protection Switching", **(2006)** June.
[17] ITU-T, "Recommendation Y.2001: General overview of NGN", **(2004)** December.

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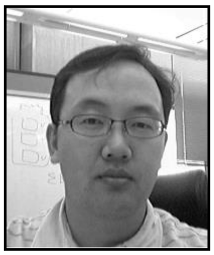

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