GMPLS based Multilayer Service Network Architecture

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***Abstract*:-** GMPLS grew out of MPLS, a packet-switching technology designed to improve the efficiency of data networks. In this paper, we discuss the GMPLS technology, analyze its application. GMPLS is an advanced protocol which is essential for managing a diverse and complex network, because service deployment and service provisioning are manual, lengthy and costly processes. GMPLS has caused technical challenges in its deployment in optical networks. These challenges can be generalized into two areas: label assignment and wavelength conversion capability. The inability of the optical switch to perform wavelength conversion has yielded a routing problem. The incompatibility of optical devices has violated the algorithms of path determination. It results in a high blocking factor call along the path and high latency; these would eventually prejudice the performance of optical networks.

Keywords:- *GMPLS network, GMPLS based multi layer service network architecture*

I. INTRODUCTION

The rapid development of optical networks is always driven by ever-increasing user demands for new applications as well as continuous advances in enabling technologies. In the past ten years, we have witnessed the huge success and explosive growth of the Internet, which has attracted a large number of users surging into the Internet. Individual users are using the Internet insatiately for information, communication, and entertainment, while enterprise users are increasingly relying on the Internet for their daily business operations. As a result, Internet traffic has experienced an exponential growth in the past ten years, which is consuming more and more network bandwidth .On the other hand, the emergence of time-critical multimedia applications, such as Internet telephony, video conferencing, video on demand, and interactive gaming, is also swallowing up a large amount of network bandwidth. All these facts are imposing a tremendous demand for bandwidth capacity on the underlying telecommunications infrastructure. Traffic engineering (TE) is an interesting application in IP-based networks. TE main objective is to optimize the performance of a network through an efficient utilization of network resources. The optimization may include the careful creation of new label switched paths (LSP) through an appropriate path selection mechanism, the rerouting of existing LSPs to decrease network congestion and the splitting of traffic between many parallel LSPs. Early load balancing schemes provided website visitors with the appearance of one server on a single URL while actually distributing traffic to a cluster of servers offering identical content. Early implementations included crude load sharing, such as round robin DNS, where a name server would offer one of several IP addresses in response to a hostname query, or inflexible and proprietary solutions such as that employed in early Netscape Navigator versions, which turned client requests for www.netscape.com into www1.netscape.com, www2.netscape.com, and so on, for Netscape's exclusive benefit . The next phase was the first generation of 'intelligent' L4 load balancing appliances that made more sophisticated decisions about which cluster member should receive an incoming request, instead of indiscriminately spreading the load evenly regardless of the respective availability and load of cluster members. According to IETF RFC 3272, TE schemes for congestion control can be classified according to the response time scale and their congestion management policies. Most of the proposed schemes are preventive, they allocate paths in the network in order to prevent congestion. To meet the unprecedented demand for bandwidth capacity, a bandwidth revolution has taken place in telecommunications networks with the introduction of fiber optics. As the core of this revolution, optical fibers have proved to be an excellent physical transmission medium for providing huge bandwidth capacity. GMPLS has evolved from MPLS, the original IETF standard intended to enhance the forwarding performance and traffic engineering intelligence of packet based (ATM, IP) networks. GMPLS extends these switch capabilities so that it is not only packet switch capable, but also time division multiplex capable, fiber switch capable and lambda switch capable.

II. GMPLS TECHNOLOGY

The continuously growing demand on high bandwidth communication requires new area networks which are able to provide the necessary transmission capacity. In this context, the rapid advancement of evolution in optical technologies makes it possible to move beyond point-to-point WDM (Wavelength division multiplexing) transmission systems to an all-optical backbone network that can take full advantage of the bandwidth available by eliminating the need for per hop packet forwarding. Advances in optical transmission, switching, and wavelength division multiplexing techniques have enabled next generation networks to be able to operate at several Terabits per second. WDM is an optical multiplexing technique that partitions the optical fiber bandwidth into multi-gigabit wavelength channels, each of which can be individually switched and routed. WDM network is shown in Fig. 1.

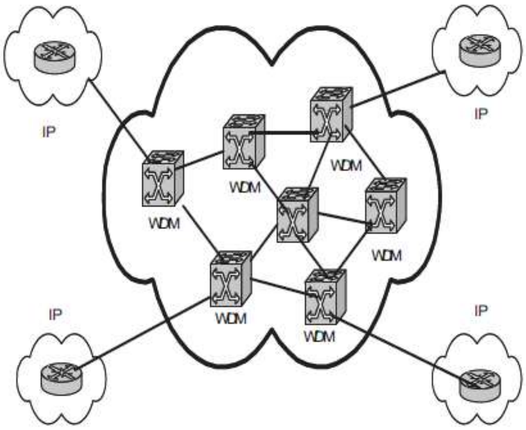

Figure 1. WDM optical network

Multi-Protocol Label Switching is growing in popularity as a set of protocols for provisioning and managing core networks. The networks may be data-centric like those of ISPs, voice-centric like those of traditional telecommunications companies, or a converged network that combines voice and data. At least around the edges, all these networks are converging on a model that uses the Internet Protocol to transport data.

In the last few years the commercial availability of transparent optical switches has paved the way for the development of novel optical network architectures, whose main characteristic is the ability to create and tear down optical paths automatically. WDM has become a technology of choice for meeting the tremendous bandwidth demand in the telecommunications infrastructure. Optical networks employing WDM technology have been widely considered a promising network infrastructure for next-generation communications networks and optical Internet. This poses the architectural question of how to support thousands of clients connected to a single unified virtual environment that is not rigidly partitioned. To address this question, we consider the distributed virtual environment as a distributed database where clients are remote sites with the server being a concurrency and replication controller. A fundamental problem in distributed databases is the quality of the communication channel. In connections they are set-up between an ingress-egress pair of routers. Each connection request arrives at an ingress router (or at a Network Management System in the case of a centralized route computation), which determines the explicit route for the LSP according to the current topology and to the available capacities at the IP layer. As a result, GMPLS simplifies network operation and management by automating end-to-end provisioning of connections, managing network resources, and providing the level of QoS that is expected in the new, sophisticated applications.

GMPLS protocol architecture is as shown in Fig. 2.

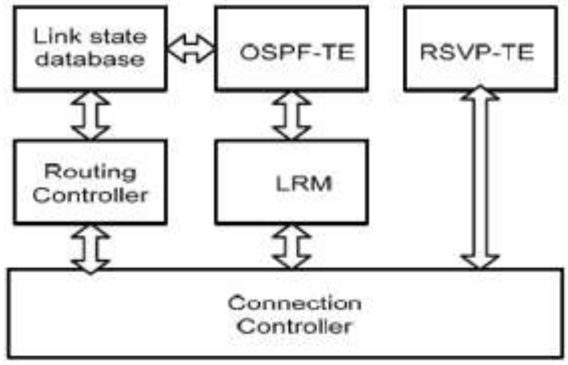

Figure 2. GMPLS protocol architecture

A WDM network that shares a common transmission medium and employs a simple broadcasting mechanism for transmitting and receiving optical signals between network nodes is referred to as a broadcast-and-select WDM network. An optical network with load balancing function is shown in Fig. 3.

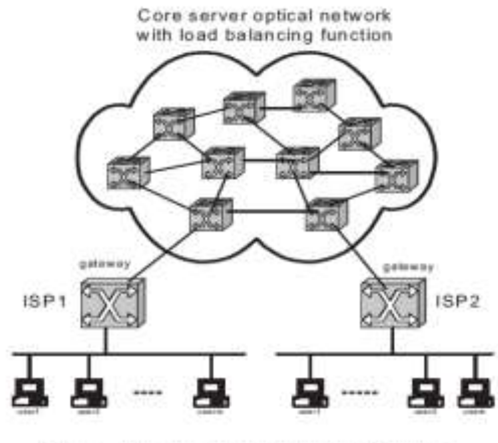

Figure 3. Optical network with load balancing function

The most popular topologies for a broadcast-and-select WDM network are the star topology and the bus topology. In the star topology, a number of nodes are connected to a passive star coupler by WDM fiber links. Each node has one or more optical transmitters and receivers, which can be either fixed-tuned or tunable. A node transmits its signal on an available wavelength. Different nodes can transmit their signals on different wavelengths simultaneously and independently. The star coupler receives and combines all the signals and broadcasts them to all the nodes in the network. To receive a signal, a node tunes one of its receivers to the wavelength on which the signal is transmitted. Given an optical network with connection requests arriving dynamically, the objective of the on-line algorithm is to balance the allocation of the already established LSPs in the network to reduce the rejection probability for future traffic demands.

III. APPLICATION OF GMPLS TECHNOLOGY

GMPLS is no exception, and as a result has already been implemented on a number of different vendors' devices. Reflecting the priorities of its supporters, GMPLS is strongly focused on delivering features that are needed now. Few GMPLS drafts contain full FSM (finite state machine) descriptions for their protocols, rigid descriptions of all the possible types of errors and how they are handled, or abstract models showing information flows between components in the network. Any important omissions are expected to be found in review or in interoperability testing, and corrected. All the nodes and links that constitute the GMPLS network share the same IP address space and information is shared freely between nodes. In other words, GMPLS implies a trusted environment as shown in Fig.4.

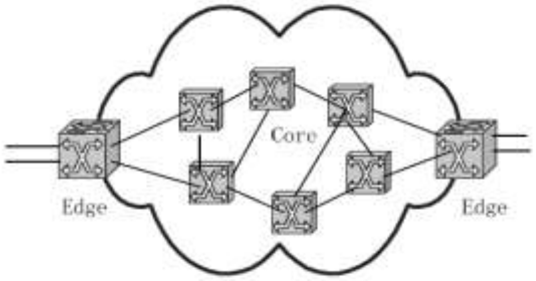

Figure 4. GMPLS network

GMPLS extends MPLS to provide the control for devices in any of following domains: packet, time, wavelength, and fiber. In this way, data from multiple layers are switched over Label Switched Paths (LSPs). The router is equipped with optical-to-electrical and electrical-to optical converters used respectively to terminate and generate optical signals. These interfaces are directly connected to the input and output ports of the optical switch, while the remaining ports accommodate the fibers linking to neighboring nodes. GMPLS node is shown in Fig. 5.

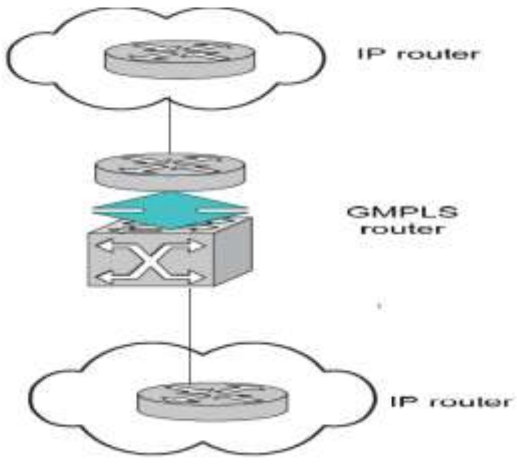

Figure 5. GMPLS node structure

The router, the intelligent management entity controlling the switch, decides which ports need to be terminated and which ones transparently switched. GMPLS further extends the features of MPLS by operating at extremely high-speed rates in optical networks. In addition it enhances path establishment and set-up operations. The inheritance from MPLS gives it the credibility to be able to survive against competitive service providers. Different types of traffic switched among different domains, for instances, packet, cell by label, time by time slot in repeating cycle, wavelength by lambda, physical space by fiber. All these flow into optical network and GMPLS is used for the associated switching and control components. The techniques used by electronic equipment are based on exchanging configuration messages between the devices. If the elements are not directly connected together, different algorithms can be implemented to optimize the message exchange by retransmitting at intermediate nodes. With metro networks becoming increasingly difficult to operate, GMPLS provides the ability to automate many of the network functions that are directly related to the operational complexities. These functions include end-to-end provisioning of services, network resource discovery, bandwidth assignment and service creation.

Traffic engineering parameters relating to SONET protection support, available bandwidth, route diversity and quality of service, are distributed throughout the network allowing every node in the network to have full visibility and configuration status of every other node - ultimately making the optical network intelligent. Therefore, as service providers introduce new network elements into their networks, add/remove facilities, or turn up new circuits, the control plane will automatically distribute and update the network with the new information. The complexity of current metro overlay architectures means the provisioning of connections often requires a substantial amount of coordination among operations staff located throughout the network. Capacity is assessed, optimal connection and restoration paths are determined, and the connection must be fully tested once it is established. GMPLS, on the other hand, uses advanced routing (OSPF, IS-IS) and signaling protocols (RSVP, CRLDP) to build intelligence into the network such that it is sufficiently self discovered to dynamically advertise the availability or lack of resources throughout the network. With this capability, multi-hop connections, with optimal routes and backup paths, can be established in a single provisioning step. All nodes initialize and start communication with other link participants regarding necessary properties and attributes. Topology protocol starts up and finally, every node knows about the entire network topology. This step also includes information distribution about resource usage at each node. A WDM network with GMPLS is as shown in Fig. 6.

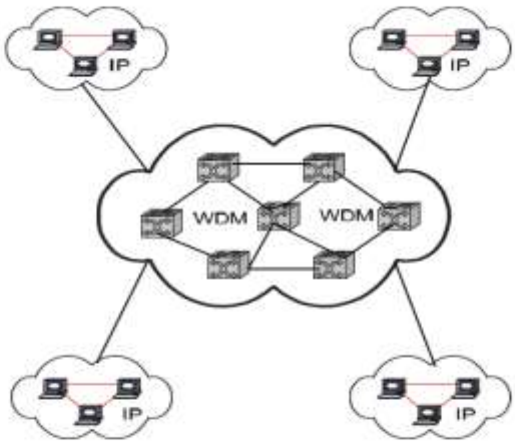

Figure 6. WDM network with GMPLS

The GMPLS is one of the most important concepts of the next-generation transport networks. WDM optical networks utilize light paths to exchange information between source destination node-pairs. A light path is an all optical continuous channel established between a node-pair. The success of GMPLS provides a solution that enhances IP by its remarkably advanced features particularly the improvement in data transfer rate. GMPLS can be well classified, managed and policed across different types of optical communication networks.

IV. GMPLS BASED MULTY LAYER SERVICE NETWORK ARCHITECTURE

Carriers are providing variety of packet based services over high speed access lines at the order of Gbps for customers in Japan. Enterprise and academic users are already used to the high speed and extending their requirements both at higher speed and to lower layers from IP to layer 2 and then 1 following their application diversity. WDM based large capacity optical network systems are wide spread and network operators and users both need efficient use of the optical network's capacity to accommodate such growing needs. Especially, efficient provisioning of variable layers' services require accommodation of them over as small number of optical networks as possible to avoid excess optical network deployment, instead it requires dynamic manage and control of the optical network according to varying service requirement. We propose a Multi Layer Service Network (MLSNW) Architecture realizing accommodation of multiple different services over a dynamically controlled optical network with logically multiplexed packet and optical domains, GMPLS, newly standardized PCE (Path Computation Element), and centralized control for coordination. We then show our experimental result of coordination, especially the dynamic control of the optical network according to the packet layer's traffic demand change. Lastly we report Japan's academic backbone network SINET3, which applies the above mentioned techniques and to provide Layer1-on-demand service first in the operational mode in Japan.

A. IP over Optical networking challenges and proposed MLSNW architecture

Major challenges in IP over Optical networking are;

1. The network has to flexibly accommodate different layers over a common optical network
2. The network has to optimize the end-to-end path over optical and non-optical (e.g., packet) layers, maximize the utilization for changing demands and failures, both by coordinating layers. It is especially challenging for dynamic multilayer/domain coordination.
3. When considering future promising networking, it is required to economically provide huge bandwidth service on requests utilizing the same network resources among many requests. We have already proposed the basic MLSNW architecture which accommodates multiple packet layers' services over a single GMPLS based optical network. The basic architecture satisfies the requirements 1 and 2, but detailed mechanism was for further study especially about coordination. It also lacked techniques for requirement 3 especially on how to provide on demand layer 1 service.

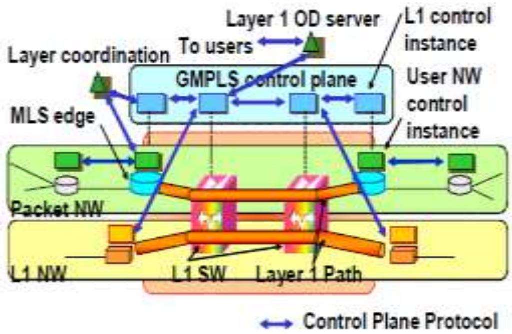

Figure 1: Multi Layer Service Network Architecture

Our extended MLSNW architecture (figure 1) includes the key technical components as follows;

1. Packet based (non GMPLS) layers and GMPLS based Optical layer interfaces at border Multi Layer Service (MLS) edge nodes with packet and GMPLS instances for controlling packet and optical layers.

2. Multiple layer coordination is realized by multilayer Path Computation Element (PCE) and optical network configuration controller, or "virtual network topology (VNT) manager." They are detailed functional blocks for layer coordination. For example, when the VNT manager detects the packet layer traffic growing rapidly to exceed network capacity, then it asks for additional optical paths routes to PCE. PCE knows multiple layer network resource status, and therefore replies with the best end-to-end routes. If there is

no path existing along the route, then the VNT manager creates a new one.
If the MLS edge receives a packet layer path control signal (such as MPLS RSVP-TE PATH message), a similar process follows.

3. GMPLS is combined with a management capability to provide Layer1 on-demand service. The user asks for an on-demand optical path to the management capability (L1OD server). Then based on the optical network resource and the user's request, the server calculates a best available route for the request. The calculation can be done in a separate entity (e.g., PCE). If the request is accepted and the start time arrives, the server signals the optical network to set up the actual path.

B. Experimental IP over Optical network coordination

We implemented the above mentioned PCE and VNT manager and carried out a laboratory test. When packet layer traffic grows, the PCE detects the growth via SNMP from the packet node and calculates the best route for additional optical path. The VNT manager then provides the optical path according to the PCE calculation result successfully. For some numerical experiments, a path can be set up in about 30 seconds after detecting traffic exceeds threshold. Figure 2 shows the experimental server (PCE and VNT manager) GUI. The upper right-hand viewgraph shows packet layer traffic pattern and middle right hand viewgraph shows the used rates of physical links. The bottom topology map shows L1 topology and optical paths, and upper one shows packet layer topology, and this is when a new path was just added (a bold line between the top and bottom nodes) for rerouting packet layer route from congested path.

C. Japan's first operational L1OD in SINET3

Figure 8 shows an overview of the SINET3 network architecture. The network is composed of:

1. 70+ GMPLS enabled Layer1(TDM) nodes.
2. L1 BOD server based on Linux server with www server for the end-user interface via web for requesting reservation
3. L1 BOD traffic engineering engine (path calculation) working with request handling and network resource DB functions within the server The L1 BOD server accepts user request for an L1 path for future. It calculates the best route and if there will be enough resource it then registers the route for the starting time. The L1 BOD server then signals the one of the edge L1 switch at the edge of the requested Layer1 path via a TL1 based interface. The L1 switch starts path set up via GMPLS signalling (Semi Permanent Connection).

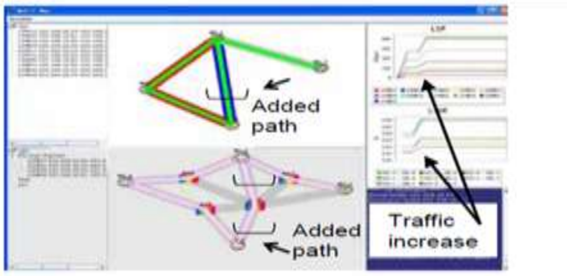

Figure 2: PCE and VNT manager (GUI)

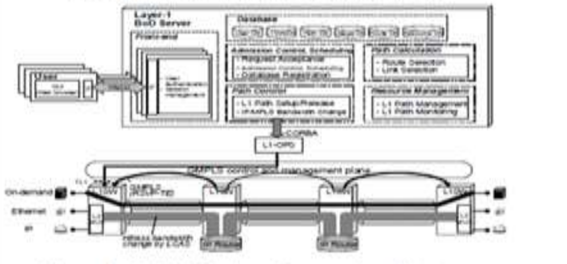

Figure 8: SINET3 L1-on-Demand architecture

V. CONCLUTION

We study GMPLS technology and GMPLS based Multi Layer Service Network Architecture for the advanced IP over Optical network provides greater flexibility, efficiency, and new L1OD service capability.

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