The Development of Optical Control Plane

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Abstract

In the near future, optical networks will change our network experience. These bandwidth-guaranteed and non-congested *lightpaths*, or *lambdas*, will provide specific research programs and collaboration projects faster and dedicated circuit-switched transmission. However, in order to incorporate with current packet-switched IP service, interfaces for users to subscribe optical channels and for connection setup between difference network domains are required. The optical control plane will furnish not only such interfaces but also management of optical link status as well. In this paper, the status of optical control plane implementation projects in several research networks at present is surveyed. For TWAREN optical network, we investigate its properties and present the control plane design for future development.

Keywords: Optical Internet, control plane, lightpath, TWAREN.

1. Introduction

With the explosion of Internet usage, daily traffic has consumed huge network bandwidth. To meet such tremendous growth, the backbones of major network providers have increased from 100Mbps to 1Gbps, and even 10Gbps today. However, there are specific research programs such as high-resolution medical imaging, video/audio streaming, and high-volume data transfer for grid applications that require not only big pipes but also QoS-guaranteed transfer. Optical networks can provision such dedicated channels for individual use. These channels, called *lightpaths* or *lambdas*, allow packets to be sequentially delivered without jitter and congestion. The basic idea of lightpath connection is just like circuit-switched telcom service. In order to incorporate with current packet-switched IP service, a unified control plane is required for network interfaces [1]. Currently, there are working standards defined by ITU-T, IETF, and Optical Internetworking Forum (OIF). Automatically Switched Optical Networks (ASON) [2] was developed by ITU-T study group 15. It defines a reference architecture model for optical control plane, including several IP over optical interconnection models. GMPLS [3] is a generalized version of MPLS developed by IETF. It contains a set of protocols for routing, signaling, and link management. OIF aims for accelerating the deployment of the inter-operable products using optical networking technologies. Inter-vendor operability has been demonstrated with OIF O-UNI and O-NNI standards in recent network conferences [4].

In recent years, a number of optical network testbeds operated by several national research networks emerged. To provide optical lambda services before the vendors complete the implementation of control plane standards, it is essential to develop user interfaces (usually through web browser) to let users bring up, view, modify, and tear down their own optical lightpaths. There are several such working projects as CA*net 4's User Controlled LightPath (UCLP) Project [5], the Third Joint Research Activity: Bandwidth-on-Demand Project (JRA3-BoD) [6] of GEANT 2 network, and Dynamic Resource Allocation via GMPLS Optical Networks (Dragon) [7] over the Hybrid Optical and Packet Infrastructure (HOPI) testbed. The overview for these projects is given in section 2. In section 3, the TWAREN optical network infrastructure is introduced and the control plane initiatives are discussed. Finally, the discussions are concluded in section 4.

2. Control Plane Projects

For the interconnection between various technologies, we have to define the lightpath other than a channel of light spectrum. A lightpath is a point-to-point channel which the NIC takes as a dedicated line with a given service level guarantee. Examples of a lightpath can be a Premium-class IP flow, a SONET/SDH TDM slot, a WDM wavelength, a MPLS Layer-2 VPN, and any concatenation of the above. [8] Therefore, the control plane should be able to setup and monitor these kinds of lightpaths. In this section, three projects are introduced: UCLP, JRA3-BoD, and Dragon.

2.1 User Controlled LightPath (UCLP)

CA*net 4 is the fourth-generation of the national research and innovation network of Canada. It provisions OC-192 (10Gbps) optical wavelengths across the country. CA*net 4 embodies the concept of a "customer-empowered network" which will place dynamic allocation of network resources in the hands of end users and permit a much greater ability for users to innovate in the development of network-based applications [9]. The network is interconnected with Cisco ONS 15454. With the multi-service provisioning platform, it serves various lightpaths at rates of STS-1, STS-3c, STS-6c, STS-9c, STS-12c, STS-24c, STS-48c, and STS-192c.

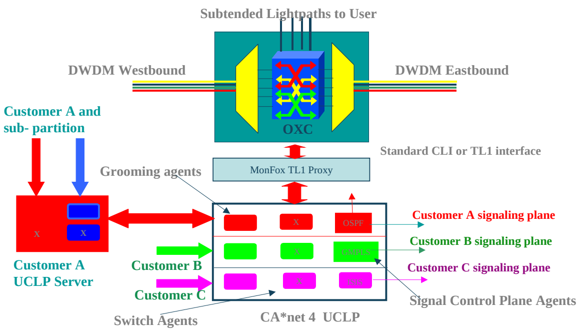


Figure 1. UCLP General Operation

As CA*net 4 takes the thought of customer-controlled network, there is no central control plane. Fig. 1 depicts UCLP's general operation. The optical network elements can be configured through Transaction Language One (TL1) programming interface. There is a TL1 lightpath proxy that accepts TL1 connections from UCLP clients and receives TL1 commands through these connections. It then validates received TL1 commands against a command validation database to verify that the command is allowed for the logged-in user. Finally, the TL1 proxy connects to the network element, forwards the allowed commands, and returns its responses and/or generic messages to the users.

UCLP is developed by four software teams: University of Waterloo, Communications Research Centre of Ottawa University, Universite Quebec a Montreal, and Carleton University.

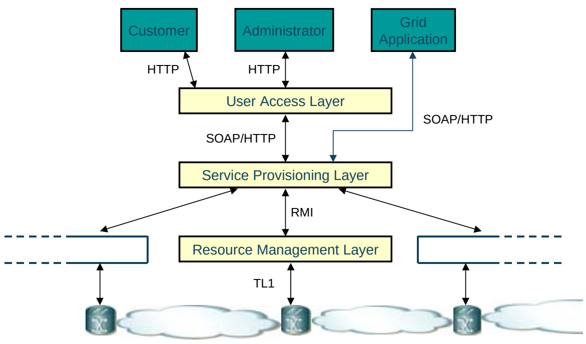


Figure 2. UCLP High-Level Architecture

The UCLP high-level software architecture contains three layers as illustrated in Fig. 2. Resource management layer (RML) is the interface to the network element. There are also resource agents (RA) in this layer that allow users to configure the system by downloading Java code. Each RA associates with exactly one optical cross-connect device. Service provisioning layer (SPL) is responsible for maintaining the databases of user and lightpath information. Three user categories are defined: ordinary users, domain administrators, and system administrators. For the status of lightpaths, it is represented as LightPath Objects (LPOs). Root LPOs are created by domain administrators, while the rest LPOs are created by concatenating and partitioning LPOs based on root LPOs. User access layer (UAL) serves as an HTML interface for users and translates user commands to SPL.

2.2 Dynamic Resource Allocation via GMPLS Optical Networks (DRAGON)

The Hybrid Optical and Packet Infrastructure (HOPI) project's main goal is investigating the next-generation hybrid use of both packet-switched and optical circuit-switched networks. It will propose a white paper for designing the testbed and implement the platform over Abliene IP/MPLS network, National Lambda Rail (NLR), and several regional optical networks in the near future [10]. According to the HOPI's latest white paper, the control plane design is divided into three phases. In phase one, only manually configuration of the lightpath allocations is available. Network engineers use the network management tools provided by vendors to modify the status of lightpaths. After the standards such as GMPLS or the related projects are deployed, an automatic configuration mechanism inside a single network domain can be made possible in the second phase. Finally in the last phase, lightpath connections can be automatically setup/released between different network domains. Extensions to the standard protocols may be required in this phase and the problems like optical peering have to be resolved. HOPI will incorporate and evaluate several phase two projects such as DRAGON and deploy them in the next few years.

Dynamic Resource Allocation via GMPLS Optical Networks (DRAGON) is a NSF project that will implement a GMPLS backbone platform for eScience applications. When deploying optical transport networks with GMPL protocol suites, there are some missing pieces: no simple API for end-to-end signaling, no standardized inter-domain routing, and no integration across non-GMPLS enabled networks. Dragon resolves these issues by developing application specific topology descriptions language (ASTDL) for signaling and creating two components: network aware resource broker (NARB) and virtual label switched router (VLSR).

NARB accommodates peering with IGP/EGP routing protocols to advertise inter-domain service capabilities, performs inter-domain path computation, resource allocation, scheduling, provisioning, proxy signaling services, and authorization/accounting for the requested network services. VLSR serves as the proxy for non-GMPLS capable network segments. Fig. 3 exhibits an example for VLSR abstraction. The VLSR represents the non-GMPLS capable Ethernet and negotiates with other OSPF-TE/RSVP-TE LSR peers. The network devices in the Ethernet segment are controlled by VLSR through SNMP commands.

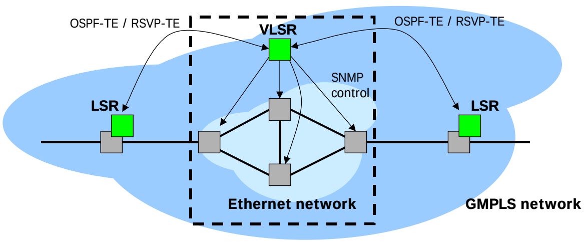


Figure 3. VLSR Abstraction

Fig. 4 shows an end-to-end connection across several network domains. End system uses ASTDL for request signaling to the VLSR of its Ethernet segment. The VLSR and the LSRs in the optical transport network in AS1 have been GMPLS OSPF-TE peers. The signaling inside the AS1 is established by RSVP-TE. For the signaling from AS 1 to AS 3, the NARBs of the domains 1 to domain 3 are then negotiated with the routing, accounting, and resources to be reserved along the path.

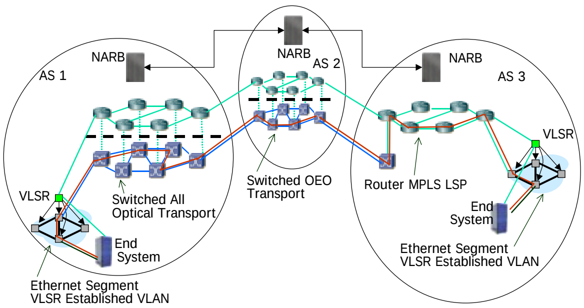


Figure 4. End-to-End Example

2.3 Bandwidth on Demand

GÉANT is the European collaboration project for 26 national research and education networks across 30 countries. The mission of the project is to construct the pan-European multi-gigabit network known as GÉANT network, and support the new network technology development. It is organized with several network activities, service activities, and joint research activities. Starting from 2005, GN2 will provide more services than fully meshed IP network. It includes GRID infrastructure and bandwidth on demand for IP, Layer 2, and optical lightpaths.

The bandwidth on demand is the third joint research activity (JRA3). The objective is to design and implement an automatic control mechanism for provisioning switched point-to-point connections across multiple domains. The management range of the JRA3-BoD is thus multi-domain (participated NRENs and campuses) and multi-technology (IP, MPLS, SDH...). A 2-stage deployment is planned: single-domain manual configuration and multiple-domain automatic configuration. The basic services will be bandwidth creation, deletion, modification, and status enquiry. For the development path, the BoD service will be provided manually initially. Then the provisioning can be made by vendor NMS through standard management interfaces such as SNMP and TL1. After the standard signaling protocols are implemented, the system can be deployed with interfaces like UNI and NNI as shown in Fig. 5. For inter-domain signaling, there are domain controllers that each represents the domain it manage. In addition, the issues like AAA, path computation and topology representation are need to be addressed in the development.

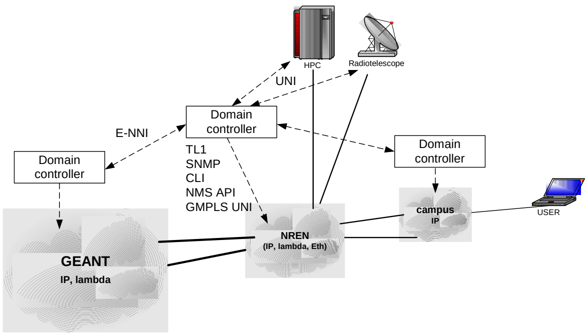


Figure 5. JRA3-BoD Interfaces for Standard Signaling protocols

3. TWAREN Optical Network

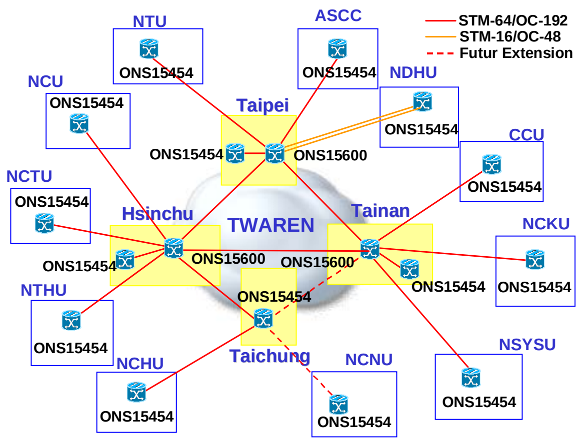
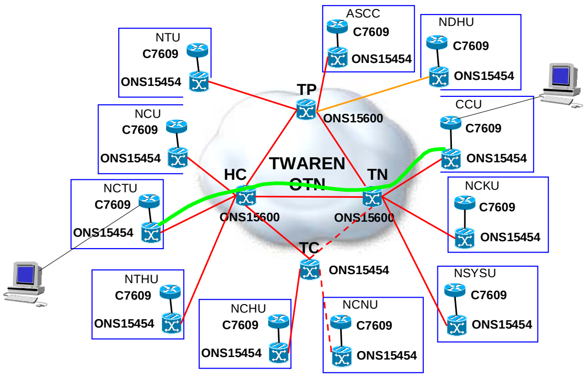


Figure 6. TWAREN Optical Network Architecture

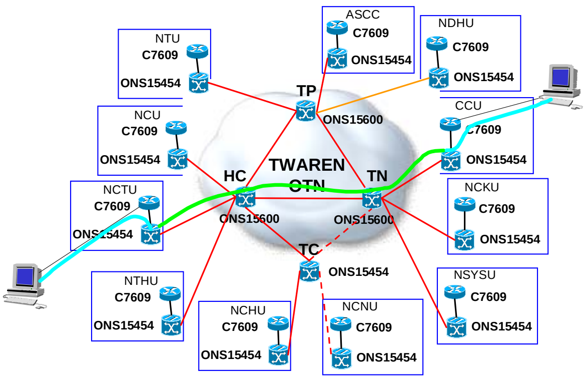
In the year of 2003, the new contract of Taiwan Advanced Research and Education Network (TWAREN) has been made [12]. In addition to constructing an IP packet-switched network as the successor of TANet2, TWAREN comprises a whole new optical-switched backbone. It contains three Cisco ONS 15600 multi-service switching platforms in Taipei, Hsinchu, and Tainan. With another Cisco ONS 15454 multi-service provisioning platform placed in Taichung, the four core nodes form the main optical switching backbone. There are STM-64 links between Taipei-Hsinchu, Hsinchu-Tainan,

Tainan-Taipei, and Hsinchu-Taichung. The Taichung-Tainan link is left for future extension. For distribution, we install Cisco ONS 15454s in the 11 GigaPoPs around the island. Dark fibers are acquired from carrier provider Eastern Broadband Telecom (EBT) as distribution links except the NDHU-Taipei link, which is an STM-16 link from Chunghwa Telecom (CHT). For local distribution, the core nodes in Taipei, Hsinchu, and Tainan are also equipped with one Cisco ONS 15454 at each site.

The TWAREN optical infrastructure is illustrated in Fig. 6. The core is a ring topology and hence reduces the complexity of optical routing and the backup lightpath computation is also easy to resolve. Because all the optical devices are under single administration, there is no inter-domain issue. The provisioning can be manually configured with Cisco Info Center (CIC) management tool. As depicted in Fig. 7(a), the lightpaths through the core optical transport network can be setup directly. In the future, in order to provide end-to-end lightpaths, Layer 2 technologies like MPLS L2 VPN will be configured between end-user and the distribution ONS 15454. Consequently, the full end-to-end lightpath can be obtained by concatenating the L2 VPN and the core lightpath as illustrated in Fig. 7(b).



(a) Core Lightpath



(b) End-to-End Lightpath

Figure 7. Lightpath Provisioning Example

As to the applications on the optical backbone, there are mission-critical projects such as Knowledge Innovation National Grid (KING) and the TWAREN research network. The KING project will integrate grid resources around Taiwan, including e-Learning gird, ecology grid, chronic illness grid, healthcare grid, nano-science grid, biology grid, and access grid. The main computing center is located in Hsinchu and the data storage center/grid operating center will be built in Taichung in the next few years. Major high-performance computing resources are shared through TWAREN backbone and various grid applications are devised simultaneously to demonstrate its usefulness and impact.

The TWAREN research network is designed as the platform for new-technology projects. Like TWAREN production network, each of the four core nodes is equipped with one Cisco GSR 12416, which connects to the core ONS in the same site. Therefore, the core of the research network attains lightpaths from the optical backbone and becomes the primitive consumer of the optical lightpath service.

4. Conclusions

In this paper, the control plane projects of several national research and education networks are examined. The UCLP project of CA*net4 allows user to setup, concatenate, and partition their own leased lightpath objects. The DRGAON project will implement the GMPLS protocol suites. Meanwhile, the multi-domain issue is resolved by placing NARBs for each domain and non-GMPLS network segments can be abstracted by VLSR. The GÉANT's JRA3-BoD will develop an automation switched connection service on user's dynamic demand. For the TWAREN optical network, there is no inter-domain problem. The topology is simple so that routing and backup path computations are no problem. A user-friendly mechanism will be designed and implemented in the next phase. Although it is still in the early stage of optical control plane, both the standard working groups and the projects of NRENs will bring the users with on-demand lightpaths. Undoubtedly, the eScience and high-data rate GRID applications will benefit from such optical circuit-switch channels in the near future.

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