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CONTROL PLANE DESIGN ISSUES OF IP OVER WDM NETWORKS FOR INTERCONNECTION

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ABSTRACT: A critical challenge in an optical network is to provide the capability to instantiate and route lightpaths in real time and to support a variety of protection and restoration capabilities required by the rapidly evolving IP over WDM (wavelength division multiplexing). This requires efficient control plane (CP) mechanisms to dynamically establish and tear down lightpaths. We investigate two different CP architectures and investigate the suitability of each for traffic engineering. We address some service provider requirements and concept based functionality mapping including interconnection network models of CP.

1. INTRODUCTION

Optical communication technology has not only the po-tential for meeting the emerging needs of obtaining information at much faster but also at more reliable rates because of its potentially limitless capabilities – huge bandwidth (nearly 50 terabits per second [1]), low signal distortion, low power requirement, and low cost. The concern is to develop the technology for realizing the promise of optical networking into reality to meet our Internet communication demands for data, video and other multimedia applications. One possible solution is offered by the deployment of Wavelength Division Multiplexing (WDM) technology, a new and very crucial milestone net-work evolution. The speed and capacity of such wavelength routed networks – with hundreds of channels per fiber strand – seem to be more than adequate to satisfy the medium to long term connectivity demands. In this scenario, carriers need powerful, commercially viable and scalable devices and control plane technologies that can dynamically manage traffic demands and balance the network load on the various under lying physical media like fiber links and switching nodes keeping in view their optimal utilization [1].

A critical challenge in an optical network is to provide the capability to instantiate and route lightpaths in real time or almost real time and to support a variety of protection and restoration capabilities required by the rapidly evolving Internet. This requires efficient control mechanisms to dynamically establish and tear down lightpaths. The control protocols have to deliver real-time connection provisioning and minimize blocking probability. Network control (NC) can be classified as centralized or distributed [2]. In centralized NC, the route computation/route control commands are implemented and issued from one place. Each node communicates with a central controller and the controller performs routing and signaling on behalf of all other nodes. In a distributed NC, each node maintains partial or full information about the network state and existing connections. Routing and signaling are performed independently at each node. Therefore, coordination between nodes is needed to alleviate the problem of contention. Basically, there exist two different NC appro-aches for the telecommunication network and the Internet (IP network) [3, 4]. With WDM being extending into a network-layer technology, both the tele-communication and Internet NC approaches are being studied for their applications to optical NC. Additionally, tele-communi-cation and Internet NC have undergone a long period of development and testing to become robust and reliable, making them well suited for adoption for optical network control.

(A) Wavelength Division Multiplexing

WDM optical networking is enabled by a range of techno-logies like extremely high bandwidth (25 THz), low attenuation loss (0.2 dB/Km in 1.55 micron band) and single mode optical fiber allowing long distance transmission. Today's widely installed WDM optical networks are opaque i.e. a signal path between two end users is not completely optical. It suffers from optical-electronic-optical conversions which limits its speed. Hence WDM networks have to shift to all-optical networks.

(B) Ip Over Wdm

With IP remaining the internet backbone of high-capacity networks the next generation networks are IP-over-WDM. Application of WDM technology has introduced the optical layer between the lower physical link layer and upper client layer as given in figure 1.

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In current networks the architecture is that of typical four layers where IP layer performs carrying applications and services, ATM (asynchronous transfer mode) layer looks for traffic engineering, SONET/SDH layer for transport, and WDM for capacity.

The need is a simpler, more cost-efficient network that can transport very large volumes of traffic. IP over WDM is considered as a promising solution for the next generation network. For the smooth, fast, and reliable provisioning and management of Internet services over the optical layer thereafter and achieve the quality of service (QoS) transmission various approaches have been adopted. The approaches can be categorized in three main areas: ones using the control plane only, ones using the management plane only, and ones combing the management and control plane approaches [5]. Most of the research efforts are directed to benefit from the control and signaling mechanisms of the control plane approach in the optical layer, leaving the management functions in a supportive/secondary role. Important requirement for the two layer deployment are efficient and trusted concepts for multilayer, multi-carrier and network engineered proves of their performance and benefits.

In this paper we give overview of two different control plane architectures and their current status of development. We aimed at comparing the concepts and pointing out open issues. We revisit some important requirements from the provider prospective and present concept based functionality mapping including interconnection network models of CP.

2. CONTROL PLANE INTEGRATION

The control plane consists of protocols that are used to support the data plane, which is concerned with the transmission of data. The control plane protocols are concerned with signaling, routing, and network management. Signaling is used to set up, maintain, and tear-down connections.

There are three components of the control plane as that are crucial to setting up lightpaths within the optical network and thus relevant to traffic engineering:

1. Topology and resource discovery: The main purpose of discovery mechanisms is to disseminate network state information, including resource use, network connectivity, link capacity availability, and special constraints.
2. Route computation: This component employs RWA algorithms and traffic engineering functions to select an appropriate route for a requested lightpath.
3. Lightpath management: Lightpath management is concerned with setup and teardown of lightpaths, as well as coordination of protection switching in case of teardown of lightpaths, as well as coordination of protection switching in case of failures.

Control plane (CP) is used in the literature to refer to the set of real-time mechanisms and algorithms needed for call or connection control. It deals mainly with the signaling to set up, supervise, and release calls and connections. We can safely assume that the signaling protocols for connection setup, the routing protocols supporting network discovery, and the protection/recovery mechanisms are the most significant features of the control plane. In this way, it is easier to track all of the recent control plane advances and proposals about the integration of multiple layers such as IP, ATM, SDH, and WDM given in figure 2.

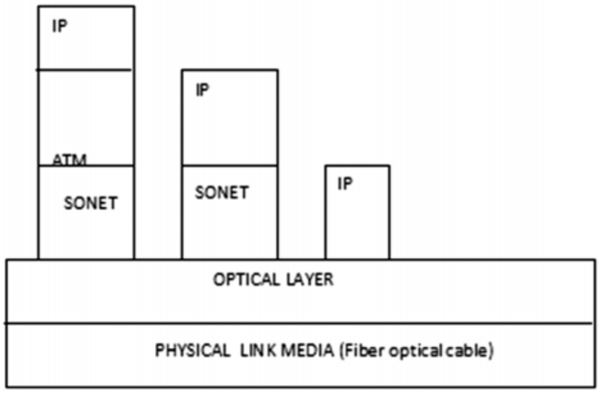

Figure 1: WDM Layered Model.

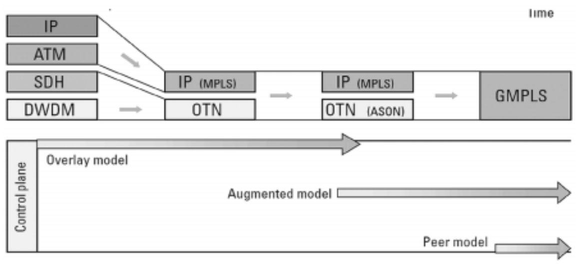

Figure 2: CP Integration.

3. CONTROL PLANE ARCHITECTURE

There are two different control plane architectures that have been put forward. In the first one, the user is isolated from the network via a user network interface (UNI). The user is not aware of the network's topology, its control plane and its data plane. The nodes inside the network interact with each other via a network-node interface (NNI). In the second control plane architecture, all users and nodes run the same set of protocols. A good example of this architecture is the IP network.

ITU-T has followed a formal methodology regarding the integration of the different layers on top of the optical one by first elaborating the requirements for such integration proposing a suitable architecture and then continuing with the corresponding detailed design and implementations. This area is covered by ITU-T study groups 13 and 15 working on the direction of ASON (Automatically Switched optical network) framework [6, 7]. ASON extends the OTN [8] with an efficient control plane that will make significant savings in the capital and operation expenditures of the operators.

Within the first control plane architecture, the following three interfaces have been defined: user-network interface (UNI), internal network-node interface (I-NNI), and external network node interface (E-NNI) as shown in figure 3.

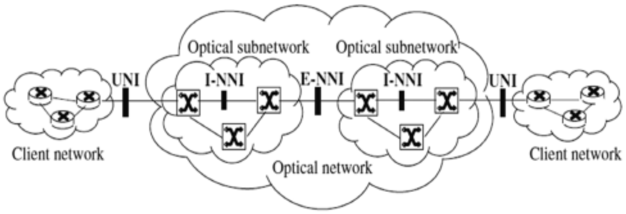

Figure 3: The Interfaces UNI, I-NNI, E-NNI.

The Optical Internetworking Forum (OIF), following the first control plane architecture, has proposed a user-network interface. It is also working on a network-node interface. OIF has specified a UNI which provides signaling procedures for clients to automatically create a connection, delete a connection, and query the status connection over an optical wavelength routing network. The UNI is based on the label distribution protocols LDP and RSVP-TE.

The IETF (Internet Engineering Task Force) has originally proposed the MPLambdaS framework [9], which extends the MPLS (Multi- Protocol Label Switching) ideas to the optical domain, allowing the reuse of the existing Internet protocols with the appropriate extensions. Later on, the IETF extended the MPLambdaS framework, which was limited to MPLS/WDM interaction, to multiple layers by means of the generalized MPLS (GMPLS). IETF has proposed three different control plane models for the transmission of IP traffic over an optical network, which are based on the above two control plane architectures: the peer model, the overlay model, and the augmented model.

The overlay model: It is being considered as one of the most popular model since it offers easiest means of migrating the present day protocols to IP over WDM directly. This is because routing algorithm, topology distribution, and connection setup signaling protocols of the IP and the WDM networks are allowed to work independently. It does not promote the integration of the control plane of the IP and the WDM networks. Only a formal request is passed from the client layer to the server layer (figure 4). However, the implementation complexity of this model is still a burden.

The peer model: The IP network has full topological view of the optical network and just a single routing algorithm instance is running in both the IP and the WDM networks (Figure 5). This model promotes the integration of the control plane of the IP and the WDM networks and is simpler in implementation, but its operation is far more complex than the overlay. In addition, this model can work only in cases where there is a single entity operating and managing the IP and the optical administrative domains [9].

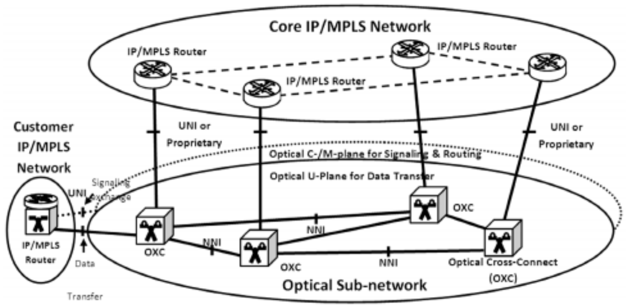

Figure 4: The Overlay Model.

The augmented model: This is a combination of the previous two models. Each layer has its own protocols; however, routing information exchange is allowed between the two layers. This model can be seen as the golden mean, combining the advantages of the peer and overlay model and minimizing their disadvantages at the same time. But the distributed implementation makes it difficult to synchronize between the integrated networking elements to ensure up-to-date and consistent network state information [9].

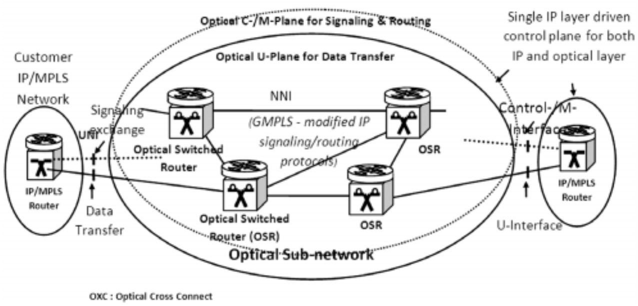

Figure 5: The Peer Model.

4. INTERCONNECTION REQUIREMENTS AND CHALLENGES

At the moment, telecom operators are facing the need to couple their currently deployed equipment with the emerging networking technologies so that they can rapidly and flexibly provide existing services on demand as well as develop infrastructure for new value-added services inherent to the reconfigurable optical layer. This need inevitably leads to the development of a new network management model based on a CP that will form the bridge between the current management plane and the optical transport network itself. The advantages of ASON/GMPLS deployment encompass multiple areas of IP/WDM network management. Most of the important features of IP/WDM networking functionality extended by this deployment are compared with features of the existing functionality in Table 1.

Table 1

Existing IP/WDM Networking	ASON/GMPLS Deployment
Vendor-specific service provisioning	Intervendor service provisioning.
Semimanual nonreal-time domain-by-domain provisioning	Real-time end-to-end provisioning on demand.
Poor information on resource and topology	Full network inventory is maintained.
Billing by ports	Billing by LSPs.
Protection only	Link/path protection and dynamic restoration.
Manual configuration of domains	Domains are advertised automatically.

Automatic on-the-fly provisioning of inter carrier and multivendor domain services, flexible service selection, and dynamic resource allocation and restoration make the approach especially attractive. However, some challenges still exist on the way to further widespread deployment of this model. They belong to such areas as further development/finalization of the standards, persuading carriers to adopt IP technology in the CP, as well as deriving the same economic benefits carriers can get by implementing optical signaling technology. Optical control plane integration can follow two steps. The first one represents a management-based solution with carrier-specific CPs directly coupled with the network management plane through necessary adaptations. While such an approach can be feasible for small-sized networks, its scalability is likely to be difficult, as multiple complex interfaces will be required for the integration when the network has expanded. Additionally, highly dynamic market business requirements make this model expensive to maintain. As the second step, a thin layer above multiple vendor control domains can be provided as mediation between the management plane and vendor specific domains. This layer will represent a carrier-independent common CP communicating with the management plane through a control-management interface. This will simplify the introduction of new administrative domains, as the integration process will be simpler and less expensive to maintain. The internal NNI standard is the most probable candidate for carrying out interworking of different control domains within the same administrative area. Finally, an implementation of interworking between different administrative domains that have both the optical CPs and legacy nonautomatically switched multiple vendor domains. These domains still directly need to be explicitly adopted to communicate with the management planes of their administrative domains. At the same time, the expected implementation of external NNI support by the optical CP will allow for smooth interoperability of both multivendor and intercarrier domains (Figure 6). Under this scenario, the CP and management plane will have to collaborate for the provision of intercarrier end-to-end services. While routing and link management will be carried out by the management planes within each administrative domain, the E-NNI call and connection processing will be done by the optical control plane.

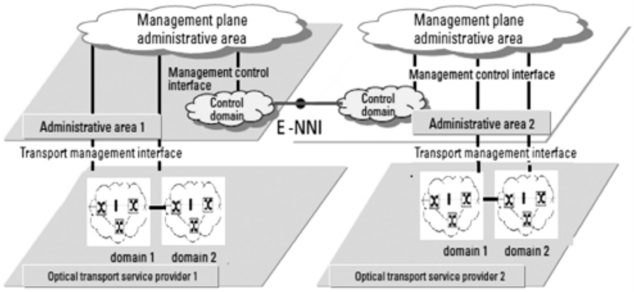

Figure 6: Interconnection CP Provisioning.

5. CONCLUSION

One of the biggest challenges for network operators today is to understand how to exploit and couple the intelligence residing at both the electrical and optical layers, so that they can optimize their network resources and deploy the most advanced services to their end-user customers. The introduction of a CP in transport networks is likely to bring some new advantages namely: Traffic engineering for dynamic allocation of resources to routes, Connection control in a multivendor environment/multi domain, Rapid and flexible service provision, Introduction of supplementary and flexible optical transport services, Automatic optical rerouting and restoration. The internetworking models described in the paper are examples of efforts under way within the industry to harness the powerful features and functionality that emerging optical layer intelligence brings to next-generation networks.

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