

Virtual Network Topology Management for Cross-Layer Provisioning in Multi-Layer Networks

TaeYeon KIM, YooHyeon JEONG, HoYoung SONG

ETRI (Electronics and Telecommunications Research Institute), Korea

tykim@etri.re.kr, yhjeong@etri.re.kr, hsong@etri.re.kr

Abstract— Future networks require virtual network topology management method using distributed PCEs for multi-layer multi-domain path computations. Once a path is established within a lower layer, it can be used as a data link in an upper layer and it can be advertised as a Traffic Engineering Link and exploited in the path computation by an upper layer. This paper presents cross-layer provisioning system architecture and procedures using inter-link and virtual link management methods over the multi-layer network.

Keywords— multi-layer network, PCE, virtual link, TE link

I. INTRODUCTION

Transport network of the future will be multi-layer networks consisting of a lower optical layer and electronic upper layers. The lower layer is realized by reconfigurable WDM while the upper layers are realized by a connection switched technology or by a packet switched technology [1].

Much research has been devoted to methods of carrying IP traffic, which is the majority of Internet traffic, over wavelength-routed WDM networks [2-4]. One approach accommodating IP traffic on a WDM network is to configure a virtual network topology (VNT), which consists of light paths and packet paths and advertised as TE links in the higher-layer network.

Virtual Network Topology Management is the preferred one by the Network Operators since it allows control of the lower layer, thus preventing unconditional and frequent path set up or teardown.

Also, the VNT Manager is defined as the functional element that manages and controls the VNT. Thus, the cooperation between the VNTM and the PCEs (Path Computation Elements) allows the effective set up of paths in Multi-Layer Networks.

In this paper, we present a multi-layer network integrated control platform which controls network elements in order to deliver high-quality IP

premium service traffic over the Packet-Optic network.

The rest of this paper is organized as follows. Section II summarizes inter-layer control reference models. Then, Section III presents cross-layer network path provisioning system architecture and operational procedures. Finally, a brief conclusion is provided in Section IV.

II. CROSS-LAYER CONTROL REFERENCE MODELS

There are some different PCE-based cross-layer path computation methods from the available IETF drafts [5-10]. We assume a Multi-Layer network which consists of multiple nodes capable of its switching region. We denote the upper switching region as higher layer and the lower switching region as lower layer.

We examine Cross-Layer path computation models as well as path control models to draw a practical reference model appropriate for a cross-layer provisioning system to be developed.

A. Cross-Layer Path Computation Model

According to the scope of computation element, one of the two computation models, single PCE and multiple PCE, could be introduced.

To leverage the efficiency and robustness of multi-layered network, single PCE (Path Computation Element) that computes end-to-end paths across multiple layers is required.

If there is a PCE with a large enough knowledge of each layer to construct cross-layer network path, a source node could make a single query to the PCE to set up the path from the source to the destination.

Meanwhile, in a multiple PCE computation model each layer has its own PCE that computes the path within the scope of the given layer. When there are multiple candidate layer border nodes,

optimal path computation requires that all the possible paths transiting different layer border nodes or links to be examined.

This is relatively simple in the single PCE inter-layer path computation model because the PCE has full visibility. In that case the computation is similar to the computation within a single domain of a single layer. In the multiple PCEs over the cross-layer model backward-recursive techniques could be used by regarding layers as separate domains [11].

B. Cross-Layer Path Control Model

A PCE may determine a path with insufficient bandwidth available in the higher-layer network unless new paths are provisioned across the lower-layer network. Furthermore, the modification, re-organization and provisioning of lower-layer paths allow better utilization of lower-layer network resources in order to meet the demands of the higher-layer network. Therefore cross-layer path control needs to be controlled or managed in cooperation with inter-layer path computation.

One approach to control cross-layer path is an integrated PCE based model. A PCE performing path computation over the multiple layers produces cross-layer path and triggers lower network path setup with VNTM. The VNTM uses local policy and management constraints to determine how to process the suggestion from PCE, and may request an ingress node to establish a low-layer path.

In signaling based model, the border node that receives the higher-layer signaling message applies local policy to verify that a new path is acceptable and then initiates establishment of a lower-layer path. It either consults a PCE with responsibility for the lower-layer network or computes the route by itself to expand the loose hop route in the higher-layer path.

Another approach is based on the management entities, NMS (Network Management System) and VNTM. The NMS requests the source node to set up a higher layer path. If there is no TE link in the higher-layer between border nodes, NMS would suggest to the VNTM that a lower-layer path between the border nodes be established and be advertised as a TE link in the higher layer to

support upcoming higher-layer path establishment requests.

III. CROSS-LAYER PATH PROVISIONING SYSTEM

To restructure the current network, which is dependent on the highly costly backbone routers of foreign vendors, more efficient and cost effective way, it is needed to develop an epochal packet-optic integrated network devices and efficient network/traffic control technologies, which can provide QoS guaranteed IP premium services to the users with reasonable price and provide more effective and economical way to operate and manage network to the operators.

For this, we are developing a new technology for the integrated control platform which controls network switches in order to deliver high-quality IP premium service traffic over the Packet-Optic network. Using this technology, we can transport broadband IP premium service traffic, such as an IPTV service, directly via an edge-to-edge PTL (Packet Transport Layer) cut-through path at optical transport network without multi-hop routing at IP network.

Figure 1 illustrates multi-layer network control system architecture which consists of servers and PCEs (path computation elements) performing network path provisioning at the individual layer.

Virtual Network Topology Management functional entity in CPS (Cross-Layer Network Provisioning Server) exercises an inter-layer link management functions such as creation, deletion and monitoring by the request of the operator through user interface.

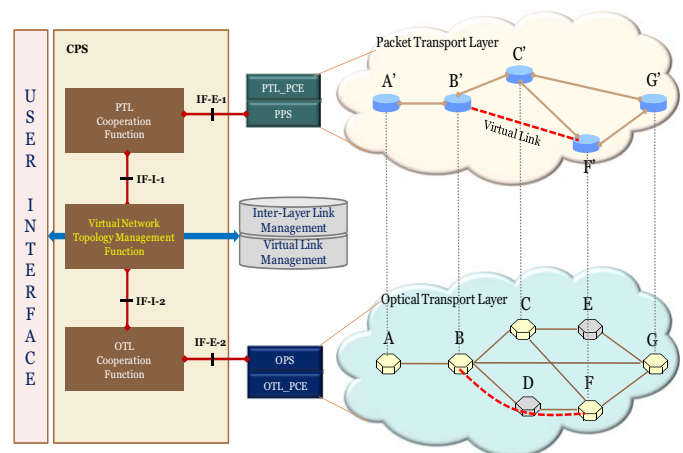


Figure 1. A Cross-Layer Provisioning System Architecture

Virtual link of multi-layer networks is defined as a lower-layer path that is advertised to the upper layer as it were fully established, but it is not established. VNTM manages virtual link to leverage cost-effectiveness of multi-layer networks as well.

PTL coordination function of CPS interacts with PPS (PTL Path Provisioning System) to make certain of the virtual link establishing through its lower layer network. PPS holds the responsibility for provisioning of packet layer path and management of all of information about node, link, interface and status in terms of packet transport layer. PTL_PCE (PTL Path Computation Element) offers an optimized packet layer path to PPS on demand.

OTL coordination function of CPS triggers event to make connection on optical transport layer in case a virtual link was found from a computed path list which consists of consecutive packet layer links. Virtual link would be expanded to effective optical layer path computed by OTL_PCE and set up by the request of OPS (OTL Path Provisioning System). The OPS has control over the provisioning on optical layer path and management of all of information about optical node resources.

As mentioned above, CPS has provisioning coordination functions for each layer supporting establishment of inter-layer path if necessary.

A. Inter-Layer Link Management

The Inter-layer link connection is determined by the types of network node, interface and connection link between the interfaces. For example, in case of a multi-layer network that has its every links interconnected within the same layer nodes, any inter-layer network operation would be impossible although it was composed of multiple layer networks.

The type of inter-layer link connection falls into two categories, one is a fixed optical link connection and the other is a reconfigurable as shown by Figure 2.

There is a interconnection between optical interface of packet layer node and optical layer network node interface in terms of fixed inter-layer link. In this case, clear specification of both nodes

and interface links is required to be managed as an inter-layer link.

Meanwhile reconfigurable inter-layer link corresponds to POTS (Packet Optical Transport System) that has both reconfigurable layer interfaces in a system and operates crossing over the two different layers at the same time. The reconfigurable inter-layer link may represent as an internal connection between the ingress and egress interfaces within a single POTS system.

B. Virtual Link Management

The next step for the cross-layer network provisioning is a composition step of virtual link that is a logical link advertised to the packet layer as an established link. We can expect high utilization of multi-layer network and management flexibility especially in terms of constraints and policy enforcement through this management scheme.

To put it concretely, virtual link is considered to be an actual link of a packet layer and registered as one of the TE links of the packet layer. If any virtual link is included to a computed path as a result of path computation, the optical layer path, virtual link of packet layer, should be established immediately to activate the virtual link.

Therefore, creating the virtual link would be a coupling between packet network layer interfaces and inter-layer link connected to optical network node interface. There are two sets of information to be resolved to make a virtual link connection. One is a set of information for a path confirmation in PTL and the other is for a path provisioning in OTL to accomplish the cross-layer network provisioning.

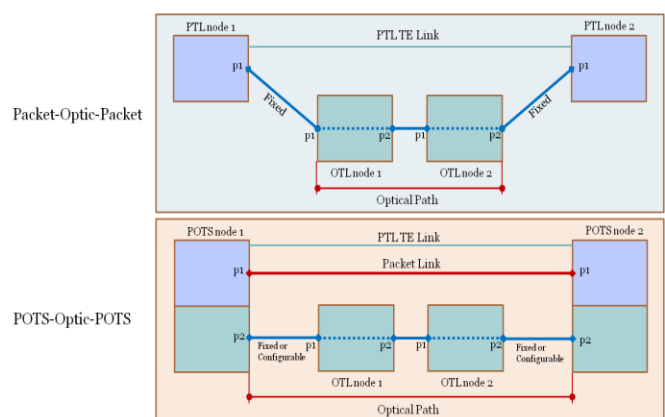


Figure 2. Inter-Layer link configuration types

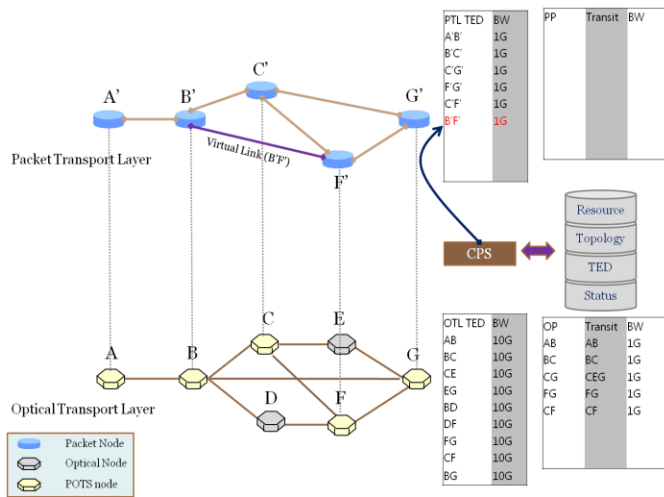


Figure 3. Virtual Link Management Procedure

As can be seen from Figure 3, in order to make B'-F' link into a virtual link over the PTL, B' and F' nodes should have one or more inter-layer links connected to the OTL node. We could get the every information required to make a B-F optical path connection for the virtual link from the inter-layer link database.

The more detail information about B'-F' interfaces such as rack, shelf and port of the B' and F' nodes is necessary for path confirmation request of PPS during the provisioning of cross-layer path. Also ingress interface of B node and egress interface of F node in OTL are needed to establish the correspondent optical network path B-F.

After the collection of the multi-layer topology information to support inter-layer path provisioning, the virtual link should be registered to the TED (Traffic Engineering Database) for PTL eventually so as to be utilized for the computation of the path on demand.

C. Cross-Layer Path Provisioning

In general Path provisioning on the PTL is accomplished by the consecutive connections of active links between the source and the destination. PPS sends path computation request message to the PCE on packet layer in accordance with the path setup request from the user. Path computation results were delivered to the CPS from the PPS and decided whether they contain virtual links or not. Path evaluation process makes use of the information set collected during the link management procedure.

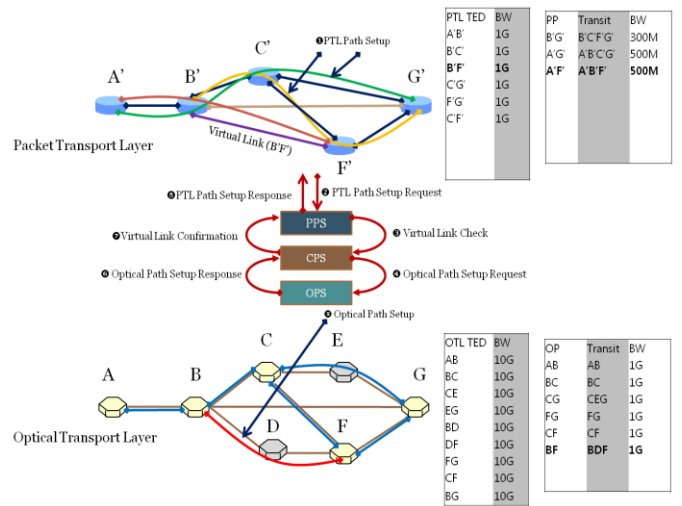


Figure 4. Cross-Layer Provisioning Procedure

When no virtual links is founded in the computed path, it ascertains all of the links constituting the path are active. But if the computed path contains one or more virtual links in it, CPS extracts parameters to establish optical network path from the virtual link information database constructed through link management procedure. Optical path setup request message from the CPS makes OPS to establish desired optical network path for the activation of the virtual link. With the activation of the virtual link, its information would be registered to the TED of packet layer. Thereafter the path provisioning process in the packet layer continues the path setup procedure.

For instance as shown in Figure 4, if CPS finds the virtual link B'-F' from the computed path A'-B'-F' which is a result of the PTL_PCE by the request of PPS, optical path B-F is extracted from the inter-layer link database indicating B' node in PTL is connected to node B in OTL and F' node in PTL is to F node in OTL. Then CPS sends optical path setup request message containing sufficient information to make an establishment of the optical path B-F. The OPS carries out the operation to build an optical path B-F that traverse B, D and F as a result of PCE in OTL.

IV. CONCLUSION

We defined VNTM as an inter-PS (Provisioning Server) management coordinator for cross-layer path provisioning. VNTM analyses the computed path on the upper packet transport layer and investigates the packet layer links construct a PTL

path to know whether any virtual link is included or not.

If any virtual link is founded, VNTM would request to the optical transport layer network server to make up the path corresponding to the virtual link.

VNTM simplifies the interaction between PCEs managing different network layers. Furthermore it exploits the cooperation with the PCEs to define and configure TE (Traffic Engineering) Metrics of Virtual TE Links to improve the network stability at the data and control plane at the lower layer.

The architecture minimizes the usage of Virtual TE Links in the path computation without requiring additional routing protocol extensions to identify Virtual TE Links or the maintenance of large MLN TE Databases.

Acknowledgments

This work was supported by the IT R&D Program of KCC under Project KI001922, R&D on Multi-layer Optical Network Control Platform Technology.

REFERENCES

- [1] S. Koo, G. Sahin, and S. Subramaniam, "Dynamic LSP Provisioning in Overlay, Augmented, and Peer Architectures for IP/MPLS over WDM Networks", INFOCOM 2004
- [2] G. Retvari, P. Fodor, J. Tapolcai, and T. Cinkler, "Multi-layer traffic engineering schemes in GMPLS networks," in *Transparent Optical Networks*, 2005, Proceedings of 2005 7th International Conference, vol. 1, 2005.
- [3] F. Aslam, Z. Uzmi, and A. Farrel, "Interdomain Path Computation: Challenges and Solutions for Label Switched Networks," *Communications Magazine, IEEE*, vol. 45, no. 10, pp. 94–101, 2007.
- [4] P. Castoldi, "Multiple Path Computation Element (PCE) Cooperation for Multi-Layer Traffic Engineering," in *Optical Fiber Communication Conference*, March 2007.
- [5] A. Farrel, J.-P. Vasseur, and J. Ash, "A Path Computation Element (PCE)-Based Architecture," IETF, RFC 4655, Aug. 2006.
- [6] J. Ash, Ed., J. L. Roux, and Ed., "Path Computation Element (PCE) Communication Protocol Generic Requirements," IETF, RFC 4657, Sep. 2006.
- [7] J. Vasseur and J.-L. L. Roux, "Path Computation Element (PCE) communication Protocol (PCEP)," draft-ietf-pce-pcep-08.txt, work in progress, IETF, Jul. 2007.
- [8] E. Oki, J.-L. L. Roux, and A. Farrel, "Framework for PCE-Based Inter-Layer MPLS and GMPLS Traffic Engineering," draft-ietf-pce-interlayer-frwk-05, work in progress, IETF, Sep. 2007.
- [9] K. Shiimoto, D. Papadimitriou, J.L. le Roux, M. Vigoureux, and D. Brungard, "Requirements for GMPLS-based multi-region and multilayer networks (MRN/MLN)," IETF RFC 5212, pp. 1–28, July 2008.
- [10] Y. Lee, G. Bernstein, J. Martensson, T. Takeda, and T. Tsuritani, "PCEP requirements for WSON routing and wavelength assignment," IETF RFC draft, pp. 1–16, September 2009.
- [11] JP. Vasseur, R. Zhang, N. Bitar and JL. Le Roux, "A Backward recursive PCE-based Computation (BRPC) procedure to compute Shortest Constrained Inter-domain Traffic Engineering Label Switched paths," IETF RFC 5441, April 2008.