A Controller Platform for Multi-layer Networks Using Network Abstraction and Control Operators

IIZAWA Yohei, MORIMOTO Masaharu, SHIMONISHI Hideyuki

Abstract

Integrated control of heterogeneous networks including data center and wide-area networks is needed in order to reduce the delay of service setup and to improve the quality of end-to-end communication services with lower cost. However, current control systems cannot be accommodated to evolving communication services because these systems adopt models and control methods for the specific layers.

In order to resolve this issue, NEC proposes an SDN platform for multi-layer networks based on a layer-independent model and control method. In this paper, we apply this platform to the multi-layer control of a packet-optical transport network and integrated control of OpenFlow and VXLAN networks.

Keywords

SDN, multi-layer network, heterogeneous network, integrated control, packet-optical transport, transport network, data center network, OpenFlow, VXLAN

1. Introduction

SDN (Software-Defined Networking) has recently been applied to data center networks. And studies have begun for applying SDN to heterogeneous networks, which are multi-vendor or multi-layer networks including data center networks and wide-area networks.

In those heterogeneous networks, it is aimed to integrate the control of networks in order to lower the operational expenditure and reduce the capital expenditure by improving the efficiency of resource utilization. And shortening the delay of service setup and improving the quality of service are also expected.

However, in the traditional method, the integrated control systems have been built only for the target layers which were previously determined. This has often necessitated redevelopment including modification of the entire control system each time that a target layer is added or the control method in the system is changed. Therefore, it was difficult to accommodate the integrated control systems according to the evolutional change of service requests.

In order to resolve this issue, NEC proposes an SDN platform that can easily build an integrated control system for heterogeneous networks composed of combinations of various layers. An outline of the SDN platform is shown in **Fig. 1**.

The proposed platform is based on the OdenOS platform. The OdenOS abstracts various networks using a model which consists of topology (nodes, ports and links) and flows (end-

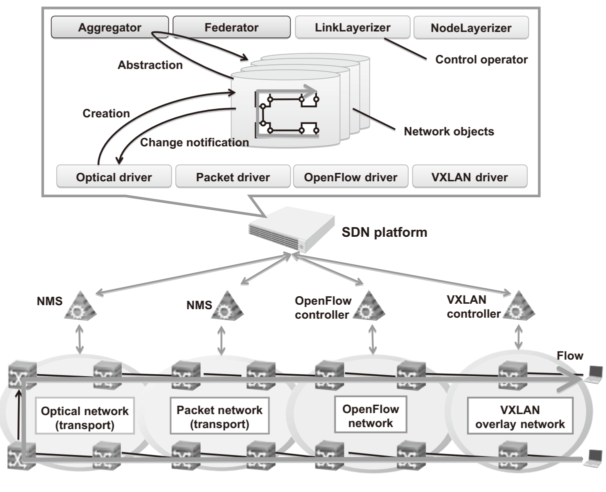

Fig. 1 Outline of SDN platform.

to-end communications), and expresses information specific to each network as attributes. Each physical network is abstracted by a driver, which also generates network objects according to the abstracted model. When a network object is operated, the driver detects it and controls the physical network accordingly. When a control operator such as Federator or Aggregator is applied to network objects, the network objects are further abstracted according to a purpose. Therefore, control functionalities are easily implemented by combining control operators.

This paper introduces the multi-layer control of a packet-optical transport network and the integrated control of a hop-by-hop OpenFlow network and VXLAN network as examples of applications of our SDN platform expanding the OdenOS model and control operators.

2. Multi-layer Control of Packet-Optical Transport Network

A backbone network of a communication carrier that transfers a large volume of data over a long distance is called a transport network. In the transport networks, multi-layer structure is a hot topic, e.g., a combination of an optical layer suitable for long-distance, large-volume transfer and a packet layer featuring high resource utilization.

Integrated, automated control of such a multi-layer network can offer a variety of advantages. For example, reducing the operational expenditure and shortening the delay of service setup by automatic path control of lower layers depending on the situation in the upper layers although those control is currently performed manually. In addition, a multi-layer network has a nested structure. In a lower layer network, paths are set up using links, and are used as links in an upper layer network. In the upper layer network, paths are setup using the links, which are actually paths of lower layer. Therefore, it is also expected to improve the efficiency of resource utilization and the quality of end-to-end communications by selecting the existing paths or the new dedicated paths in the lower layer networks according to the amount of traffic of the upper layer paths.

However, the automation of multi-layer path controls is difficult in the traditional transport networks, due to the differences of models among the equipment of vendors or layers. Many transport networks have been operated via centralized management systems such as NMSs (Network Management Systems) or EMSs (Element Management Systems). These centralized management systems are designed to control and manage the specific equipment of vendors. Thus the models and control methods differ depending on the vendors or on the equipment of each layer.

Therefore, there have not been adequate interfaces for cooperation among layers in the case the equipment of the layers provided by different vendors. For example, in order to automate the path control, it is necessary to set up the paths dynamically in both the upper and lower layer networks according to the service request from the user to the upper layer. This procedure requires the centralized management system of the upper layer network to request dynamic path setup to the centralized management system of the lower layer network. However, a management system of the upper layer network has actually been unable to determine where the paths could be set up because it did not have information on the lower layer network.

Furthermore, many centralized management systems have adopted the models and control methods which were specific to each layer even when the equipment was developed by the same vendor. This has led to the necessity of a large amount of development cost and time because, when it is required to add a new layer, it has been necessary to develop the cooperation functionalities among layers considering the matching of the new layer with other layers, in addition to implementing the model and control method for the new layer.

In order to resolve these issues, we propose a common model among layers based on network abstraction and an inter-layer control method that is made for the common model. With our proposed model, the information in each centralized management system is abstracted to a model, which are the topology (nodes, ports and links) and the flows corresponding to the paths of the transport networks.

The proposed method makes it possible to conceal differences of models between concentrated management systems or layers, and to handle information of each network via a common model. Furthermore, the user's viewpoint network information, which is generated from the lower and upper layer network information, is prepared, in addition to the lower layer and upper layer network information. The user's viewpoint network information is shown to the users of the upper layer network and enables inter-layer control.

The user's viewpoint network information includes virtual resources in the sections to which resources can be added by control of the lower layer paths: These virtual resources have previously been invisible to users. When the user requests the flow setup including virtual resources, the paths required for each layer are set up automatically by controlling the flows of the lower layer and those of the upper layer sequentially. Therefore, the multi-layer path control can be automated.

Fig. 2 shows an outline of an application example of the LinkLayerizer, which is a control operator implementing the proposed method on our SDN platform, to a packet-optical transport network.

The abstraction of network (NW) information is performed by implementing the driver in OdenOS for each network. The LinkLayerizer generates the information of the user's viewpoint NW from the transport network based on the optical NW information and the packet NW information abstracted by the drivers.

The LinkLayerizer retains the information of links in which

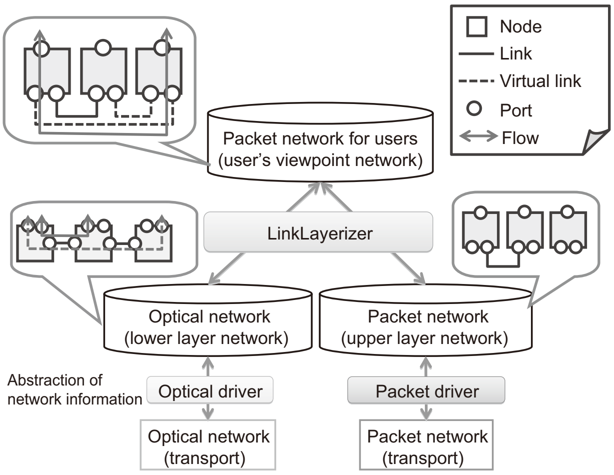

Fig. 2 Example of multi-layer control by LinkLayerizer.

flows of the optical NW are already set up as the immediately available links in the packet NW information and in the user's viewpoint NW information as like traditional methods. In addition to the above, the LinkLayerizer also retains the virtual links, which are distinguished from normal links already set up, in the user's viewpoint NW information. The virtual links are made in the sections to which links can be added by the control of the optical NW. The sections in which the virtual links can be made are identified by path computations. In the path computations, LinkLayerizer adds information specific to the optical NW as the attributes of the ports, for example, the remaining bandwidth and the availability of resources including time slots or wavelengths, and uses the attributes as constraints of the path computations.

The virtual links and the normal links already set up are distinguished by adding an identifier to the link attributes. When the user requests a flow setup with selecting a path containing virtual links, the LinkLayerizer changes the selected virtual links to the normal link by setting up flows in the corresponding sections of the optical NW before setting up the requested flow in the packet NW.

As described above, the LinkLayerizer in our SDN platform automates the multi-layer path setup and achieves a reduction of the operational expenditure and a shortening of the delay of service setup compared to the traditional methods. In addition, the LinkLayerizer enables to implement new layers with a small amount of development cost and time because the LinkLayerizer is a control operator for the abstracted model and the most of the control processes can be commonly used even in the different layers.

3. Control of Linkage between OpenFlow and VXLAN Networks

This section describes the OpenFlow/VXLAN integrated control method that uses a hop-by-hop OpenFlow network as the underlay network ("underlay") and a VXLAN network as the overlay network ("overlay").

The VXLAN is an overlay technology that places VTEPs (Virtual Tunnel End Points) on the edge of a network and encapsulates frames which come from outer ports of the VTEPs (MAC-in-UDP) in order to make virtual layer 2 networks (virtual L2). One of the most significant advantages of the VXLAN is that it can build virtual networks flexibly, without changing the physical network. However, since several virtual L2 networks share the same physical IP network as the underlay, the user requirements of the virtual L2 networks regarding bandwidth guarantees or path separation would be impossible to be achieved.

In order to solve this issue, we propose the OpenFlow/VXLAN integrated control that enables overlay to control underlay flexibly by replacing the physical IP network with a hop-by-hop OpenFlow network and by utilizing the network as a fabric. **Fig. 3** shows an example of multi-layer integrated control that also guarantees the bandwidth requested by the VXLAN overlay in the underlay OpenFlow network.

With our proposed system, virtual networks are generated from the underlay first, and the remaining bandwidths are maintained as resources. Then, the virtual networks of the overlay are generated, the required bandwidths are specified, and the underlay virtual network that can accommodate each of the virtual networks of the overlay is selected and assigned. The automation of the allocation control can improve the utilization efficiency of underlay resources by means of the bandwidth guarantee at the same time as reducing the operations costs of the control.

In order to implement the integrated control as described above in a multi-layer control integrated platform, the underlay and overlay networks are abstracted. The bandwidth required by the virtual network of the overlay, the bandwidth required

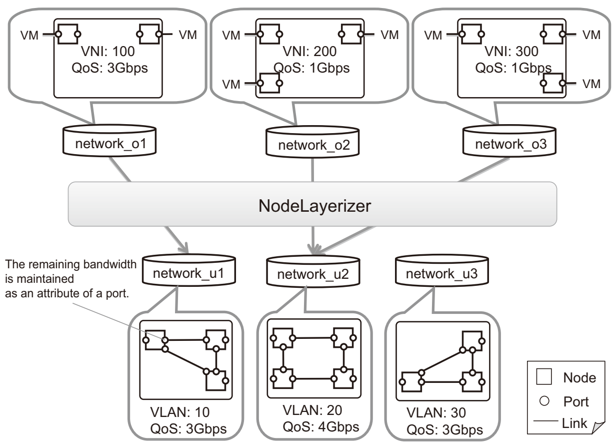

Fig. 3 Example of multi-layer linkage control using the NodeLayerizer.

by the virtual networks of the underlay, and the remaining bandwidths are all expressed as attributes to a port. In addition, the identifier of each virtual network is also expressed as an attribute of a port.

Automatic assignment of an overlay to an underlay is performed using the above network information by the NodeLayerizer operator. The NodeLayerizer selects a single underlay that can accommodate the given overlay. It identifies an accommodation possibility based on the connectivity of the physical topology and the possibility of reserving the bandwidth required by the overlay across all of the VTEP nodes. During assignment processing, the NodeLayerizer subtracts the required bandwidth in the overlay from the remaining bandwidths of ports in the underlay, which means that the remaining bandwidths of each port are maintained automatically.

The NodeLayerizer notifies the identifier of the overlay and underlay to each network. This allows the driver to set the identifiers (such as VLAN) for use in transferring the traffic of the overlay virtual networks via the selected underlay virtual networks.

The development of the NodeLayerizer in such a manner has made it possible to implement the OpenFlow/VXLAN integrated control, which can also guarantee the bandwidth specified in the VXLAN overlay in the underlay.

4. Conclusion

This paper has proposed an SDN platform for controlling heterogeneous networks. We have shown applications of the platform to the multi-layer control of packet-optical transport networks, and the integrated control of hop-by-hop OpenFlow networks and VXLAN networks based on extensions of the OdenOS.

The SDN platform facilitates building integrated control systems of heterogeneous networks with a multi-vendor, multi-layer structure.

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