OPTICAL INTERNETWORKING FORUM

Framework for Transport SDN: Components and APIs

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Abstract:
This document defines a framework for the implementation of SDN in Carrier Networks, including identifying a number of candidate open interfaces for SDN Networks based on comparison of the SDN layered architecture and the ASON functional element model for optical network control planes. This framework has been validated in a recent prototype demonstration sponsored jointly by the OIF and ONF..

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Abbreviations and Definitions

ASON – Automatic Switched Optical Network

API – Application Programming Interface

NBI – NorthBound Interface

ONF – Open Networking Foundation

PCE – Path Computation Element

REST – REpresentational State Transfer

SBI – SouthBound Interface

SNP – Subnetwork Point

SNPP – Subnetwork Point Pool

1 Executive Summary

This document defines a framework for the implementation of SDN in Carrier Networks, including identifying a number of candidate open interfaces for SDN Networks based on comparison of the SDN layered architecture and the ASON functional element model for optical network control planes. This framework has been validated in a recent prototype demonstration sponsored jointly by the OIF and ONF [1].

NorthBound Interfaces (NBI) are an area of particular importance; by providing access to ASON functional elements, the NBI will open up access to the network control plane and provide greater programmability of service support, improving the speed of service deployment and overall manageability of the network. Candidate points of interoperability at the NBI identified in this framework include Call Control, Connection Control, Routing Control/Topology and Routing Control/Path Computation. A variety of SouthBound Interface (SBI) protocols will coexist in Carrier Networks, including but not limited to the OpenFlow protocol, with extensions for optical networks.

Protocols for some of the interfaces identified for SDN have already been specified, either directly (i.e. an API specified by a standards body) or indirectly (i.e. the functional messaging defined by a standard but without API or protocol specification). This document assesses where controller interfaces correspond to already existing protocols. In addition to these existing protocols, there are potential benefits from defining also new REST-based interfaces and using a common information model across protocols.

2 Introduction: SDN and its implementation for Carrier Networks

The high level architecture of SDN is shown in Figure 1 below:

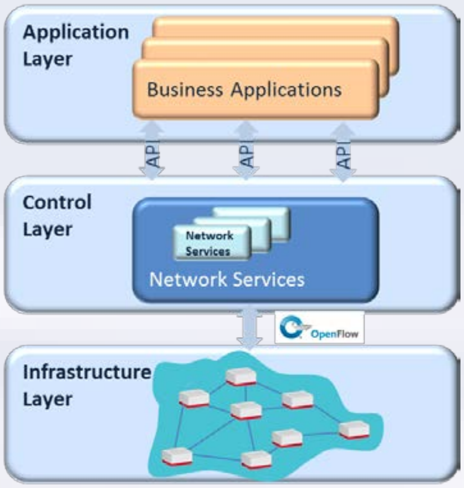

Figure 1: SDN Architecture[1]

SDN identifies interfaces separating infrastructure and control layers, and control layer from application layer. The interface between infrastructure and control layers is termed the Southbound Interface or SBI, the interface between control and application layers is termed the Northbound Interface or NBI.

For Carrier Networks, which are typically multi-domain and multi-technology in nature, exhibiting significant diversity in the equipment and protocol interfaces supported, the application of the SDN architecture is likely to be as shown in Figure 2 below:

- the Infrastructure Layer of the SDN architecture will consist of multiple domains of Network Elements from different vendors, such as Ethernet switches, OTN ODU switches and OTN OCh switches. A particular Infrastructure Layer domain may support an internal distributed control plane (e.g. GMPLS or ASON) to support streamlined discovery, connection provisioning and recovery;

- the Control Layer of the SDN architecture will consist of multiple Domain-level Controllers and may in some cases include a Parent or Network Operator Controller, using a variety of protocols as the SBI to communicate with the Infrastructure Layer elements;

[1] https://www.opennetworking.org/images/stories/downloads/sdn-resources/solution-briefs/sb-of-enabled-transport-sdn.pdf

- the Application Layer of the SDN architecture will include a variety of Carrier software applications, as well as support of client applications; one particular application for internal purposes is the Network Orchestrator, an application that uses the NBI offered by the Control Layer to obtain topology information and request service across the network, orchestrating the creation of the service across multiple network domains.

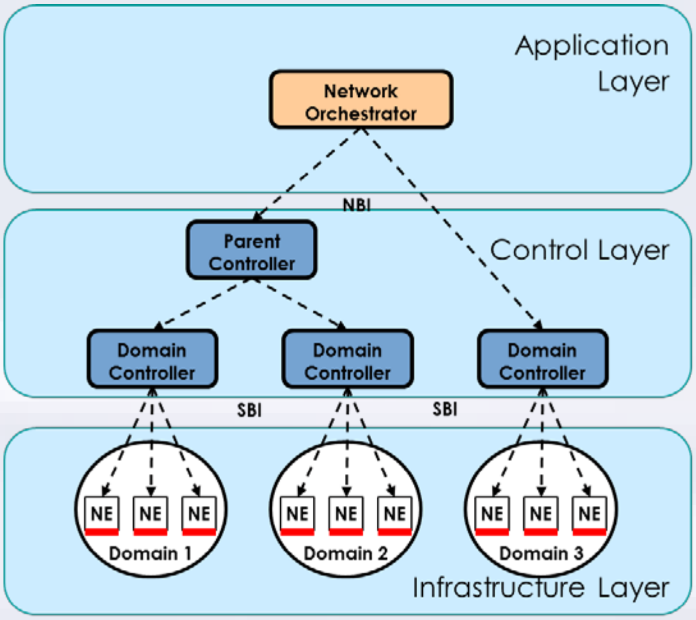

Figure 2: SDN Layer Implementation

A prototype multi-vendor, multi-carrier implementation of this architecture was recently successfully tested through the sponsorship of OIF and ONF [1]. One of the key findings was that this framework allows SDN to be deployed over a network with multiple, diverse domains, and that the separation of the NBI and SBI enables the framework to be applied over greenfield (i.e., OpenFlow) and brownfield environments, including domains controlled by management systems and domains using existing distributed control planes between network elements. The NBIs identified in this document as initial points of interoperability enable applications to access network topology information and provision new services across domains in a consistent, efficient and rapid manner.

3 ASON Control Plane Decomposition

It is useful to refer to the ITU-T ASON functional element model of network control for clearer definition of how User Applications interact with Network Applications and Resource Functions in transport networks.

The programmability of SDN will be enabled by allowing some of the internal interfaces used by Network Applications (e.g. ASON) in the past to be opened up, making it possible for applications to selectively access different service processing and making it simpler to deploy or modify new service processing in the controller. Figure 3 below illustrates the functional control components identified in the ITU-T ASON Architecture [2].

It should be noted that the analysis in this paper is based on existing ASON architecture, however ITU-T has work in progress to develop a Recommendation on the Architecture for SDN control of transport networks which may in future update the functional element model used in this decomposition.

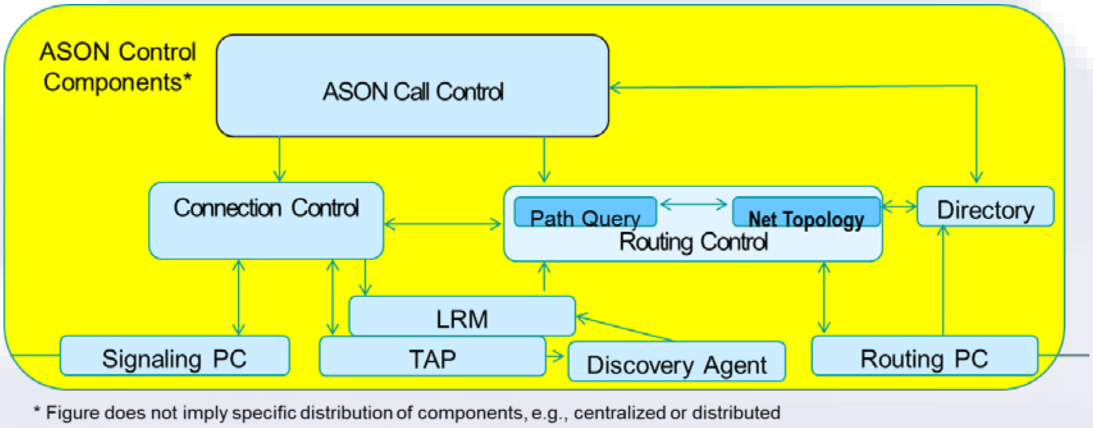

Figure 3: ASON Control Plane Decomposition

3.1 Connection Controller

The connection controller is responsible for coordination among the Link Resource Manager, Routing Controller, and both peer and subordinate Connection Controllers for the purpose of the management and supervision of connection set-ups, releases and the modification of connection parameters for existing connections.

3.2 Routing Controller

The role of the routing controller is to:

– respond to requests for path (route) information needed to set up connections. This information can range from end-to-end path details to a next hop. The route can be computed by one or more cooperating RCs;

– respond to requests for topology (SNPs and their abstractions) information for network management purposes.

In other words, the Routing Controller can provide a Path Computation Entity function (responding to requests for path information) or provide topology information directly in order to enable path computation by an application.

The resources from a single network layer in the scope of an RC are understood to be in the routing database. Protocols or even direct configuration are means that an RC can use to populate the routing database.

3.3 Link Resource Manager

The LRM components are responsible for the management of an SNPP link; including the assignment and unassignment of SNP link connections (to a connection), managing resource reservation, configuration of policing and shaping functions (if required), providing topology and status information.

3.4 Call Controller

Calls are controlled by means of call controllers. There are two types of call controller components in ASON, the Calling/Called Party Call Controller associated with the end system and the Network Call Controller associated with the control of services across the network or across domain boundaries.

3.5 Directory Service

The Directory Service Component is responsible for identifier resolution and coordination among peer Directory Service components. The role of this component is to provide mappings between identifier spaces for other components.

3.6 Discovery Agent

The federation of Discovery Agents operates in the transport plane name space, and provides for separation between that space and the control plane names.

3.7 Termination/Adaptation Performer

The TAP is collocated with the adaptation and termination function. It provides the control plane (the LRM) with a view of the status and utilization of the resource supporting a link, and hides any hardware and technology with specific details of the adaptation and termination control.

3.8 Protocol Controllers

The protocol controller provides the function of mapping the parameters of the abstract interfaces of the control components into messages that are carried by a protocol to support interconnection via an interface.

4 Candidate Points of Interoperability at the NBI

The primary points of interoperability between application and control for initial SDN deployment are the interfaces to Connection Control, Routing Control and Call Control.

4.1 Virtualization and Abstraction

The interface to applications may support virtualization and abstraction of the network resources. The term “virtual” is used to mean a subset, where a network resource can be in multiple subsets. This is the semantic generally meant by “virtual private networks”. In this semantic, resources for a virtual network may themselves be virtual as resource sharing can recurse. Users of a VPN are confined to communicating with users in that VPN. The resources that a VPN shares, may be dedicated to that VPN or it can be shared among multiple VPNs. In the shared case, when the resource is allocated to a specific VPN, it may be unavailable to the other VPNs.

Descriptions of topologies that are not the exact resources use the term “abstract” and mean a representation where some of the topology details aren’t visible. In the OIF multilayer amendments [3, 4] “An abstract node is a logical representation of potential connectivity between points in a given layer; topological details are summarized within an abstract node.” Topology abstraction is used in subnetwork recursion and is known in routing protocols as “summarize topology” information. It also appears in the interface to PCE in [5] where a PCE may not have detailed views of the topology and have to make requests to other PCEs with more detailed topology information (less abstract or non-abstract).

Support of virtualization and abstraction for specific services may benefit from a standard interface to the Controller for abstraction configuration.

4.2 Call Control and Connection Control

Figure 4 below shows the interfaces to Connection Control and Call Control. The interface to Call Control enables an application to request, modify and release a service. The interface to Call Control can potentially support greater programmability of services, for example, allowing the application to select between different Call Control “programs” that support different bindings to API events (e.g., failure notifications) or allowing the introduction of new Call Control programs or algorithms. The programmability of Call Control services can in this way enable the addition of new behaviors that support new service provider offerings. The selection of a particular Call Control program may be determined in the API by a parameter such as Service Level.

In addition, the application may be presented with a virtualized or abstracted view of the network and use the Call Control interface to control service that is based on this view.

The interface to Connection Control, on the other hand, is typically an internal interface used by Call Control to set up connections necessary to support the Call service. An external interface to Connection Control may be, for example, to an external Call Control Application.

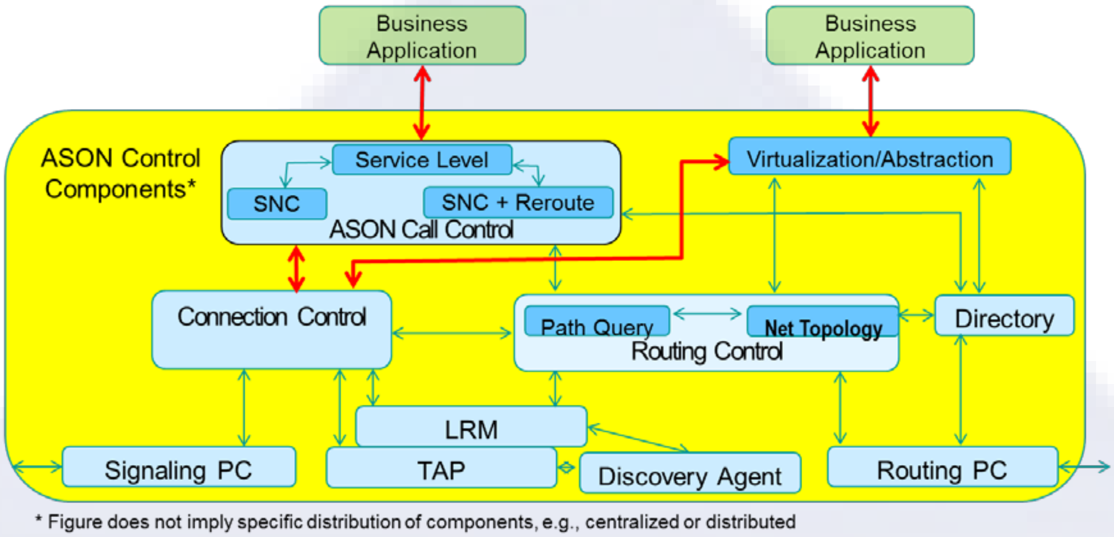

Figure 4: Interfaces to Connection and Call Control

4.3 Routing Control

Figure 5 below shows the interfaces to Routing Control. There are two interfaces to Routing Control described in [6]:

1. Route Query, or Path Computation Interface – this interface allows the application to request a route or path from the Control Layer prior to requesting establishment of a connectivity service.
2. Network Topology Interface – this interface allows the application to request network topology information directly from the Control Layer. This topology information may be abstracted from the underlying network topology for policy or business reasons.

The Route Query and Topology APIs provide significant value by offering a window into the network. The APIs convey information about links/arcs, nodes/vertices and reachability and may also convey opaque data targeted for specific applications. Potential use cases include support for predicting congestion points, identification of paths between endpoints and what-if scenarios based on link failures.

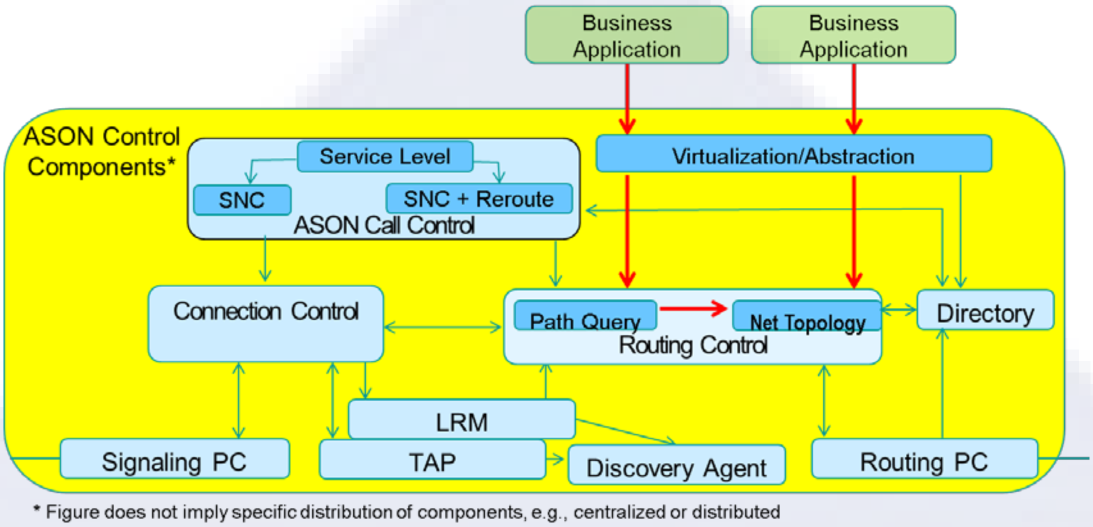

Figure 5: Interfaces to Routing Control

5 SouthBound and East/West Interfaces

The SouthBound Interface between the SDN Control Layer and Infrastructure Layer supports the control of network elements, either individually or as integrated domains. As Carrier Networks will support a variety of network elements and administratively defined domains, the SBI will need to accommodate a variety of different protocols. A number of protocols have been defined in ONF, IETF and other organizations that will play a role in the SBI due to the need to integrate existing domains into a carrier's SDN environment.

East/West Interfaces support interaction between peer entities such as SDN Controllers belonging to different organizations that need to cooperate to support a service, using a federated relationship as identified in the ITU-T ASON model. East/West Interfaces for SDN are still in the early discussion stages as the implementation of SDN within a single carrier network is still the current focus of work. The OIF's current E-NNI IAs provide for potential East/West interfaces.

6 Opportunities for future work

Other interfaces shown in Figure 3 may be suitable interoperability points for SDN purposes. Work on these interfaces is for future study.

As discussed above, East/West Interfaces are expected to be a future area needing significant work.

7 Relation to other standards

A number of related interfaces and protocols have been defined in standards bodies and forums:

OIF

OIF has developed a number of Implementation Agreements designed for client-to-network signaling and network domain-to-domain exchange of signaling and routing information. The OIF UNI 2.0 and E-NNI 2.0 IAs provide functionality that corresponds to a Call Control NBI and East/West Interface, respectively, although in a distributed control context [7, 8].

ONF

The ONF Architecture Framework Working Group has developed an Architecture specification [9] with a full description of the SDN Architecture, including the use of hierarchy in controllers and the application of abstraction and virtualization in SDN.

The ONF Optical Transport Working Group has defined extensions to the OpenFlow protocol to allow an OpenFlow controller to control establishment of flows across a Layer 0 or Layer 1 switch and has work in progress looking at functional requirements for Transport Network APIs.

ONF also has projects on Common Information Modeling and NBI definition for SDN.

IETF

IETF has developed numerous protocols for distributed control within a network, including OSPF [10] for distribution of routing information and RSVP-TE [11] for resource reservation/signaling in a distributed control environment. A profile of RSVP-TE has been specified for client-to-network use, commonly known as the GMPLS UNI [12], and this provides functionality corresponding to a Call Control NBI in a distributed control context, similar to the OIF UNI.

IETF has also developed protocols for support of more centralized functions, esp. PCEP [13] for support of path computation request/response and BGP-LS for distribution of network topology information to clients. PCEP includes a variant (stateful, initiating) that allows clients to request creation of paths across the network from a central PCE. IETF has also defined a scheme for support of virtualized Layer 1 networking capabilities (L1VPN) [14].

I2RS is an effort currently underway in IETF to facilitate real-time or event driven interaction with the routing system by, e.g., a network controller, through a collection of protocol-based control or management interfaces.

Open Grid Forum

The Open Grid Forum (OGF) has defined an interface for controlling network services across a multi-domain environment of optical research networks [15]. This follows a hierarchical model similar to the SDN framework proposed in Figure 2 above.

ITU-T

Within ITU-T SG13 is the lead study group on SDN. They have developed Recs. Y.3300 [16] and Y.3320 [17], and are currently progressing on several other SDN draft Recommendations. SG11, SG16, and SG17, are studying aspects of signaling, packet flow, and security as they relate to SDN. The Joint Coordination Activity on SDN (JCA-SDN) looks at SDN standardization activities with ITU-T and also collaborates with other Standards Development Organizations that are undertaking SDN standardization. They maintain a roadmap of SDN activities with in SDOs [18].

SG15 is studying "Transport aspects of SDN" and is progressing draft Recommendation "Architecture for SDN control of Transport Networks", aligned with the ONF's "SDN architecture", Issue 1, and draft Recommendation "Common Control Aspects" on common aspects of the interaction between the ASON control plane, SDN controller plane, management plane and transport plane. Similar to the OIF SDN Framework project, ASON components are the basis of the functions described in both Recommendations. The draft Recommendation "Generic Information Model" is being developed in close collaboration with ONF and their Core Information Model. The intent is that they will be aligned.

<u>Other</u>

A number of interface protocols exist for management plane control of connections across optical transport networks, such as TL1, CORBA and TMF MTOSI.

<u>REST-based Interfaces</u>

Additional interfaces may be developed for SDN that make use of newer interface paradigms such as REST, which allow simpler and faster interface development with more widely available debugging tools. REST is a well-known and commonly used paradigm for application interfaces. Recent experience with prototyping and testing of REST-based interfaces has indicated significant potential benefits compared to older bit-oriented protocol stacks [1]

Another area of work affecting protocol use is the development of a common information model across the different protocols. ONF currently has a project to develop such an information model and will work in coordination with ITU-T and TMF in this area. A common information model should simplify mapping between the different protocols and result in more consistent behavior and access to functions and information.

8 Conclusion

This document defines a framework for SDN implementation in Carrier Transport Networks, based on the SDN Architecture defined by ONF. It takes into account the functional element model defined in ITU-T ASON specifications and the potential open interfaces between the control and application layers of the SDN architecture. Key initial points of interoperability include the interfaces to Call and Connection Control functional elements as well as the interfaces to Routing Control for access to Path Query functions and Network Topology information. For client applications, these interfaces may be filtered through virtualization and/or abstraction for policy and efficiency reasons.

This framework allows SDN to be deployed over a network with multiple, diverse domains, and that the separation of the NBI and SBI enables the framework to be applied over greenfield and brownfield environments, including domains controlled by management systems and domains using existing distributed control planes between network elements. The NBIs identified in this document as initial points of interoperability enable applications to access network topology information and provision new services across domains in a consistent, efficient and rapid manner.

A number of existing protocols are candidates to be used at these interfaces, although some were designed for a distributed control environment rather than an SDN environment. New protocols will also be developed using REST paradigms that will offer improved development times and debugging ability compared to older protocols, while a common information model will support more consistent behavior and access to functions across protocol.

9 References

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