OPS Area Working Group
Internet-Draft
Intended status: Informational
Expires: February 25, 2018

Q. Wu
W. Liu
Huawei Technologies
A. Farrel
Juniper Networks

August 24, 2017

Service Models Explained
draft-ietf-opsawg-service-model-explained-02

Abstract

The IETF has produced many data modules in the YANG modeling language. The majority of these modules are used to construct data models to model devices or monolithic functions.

A small number of YANG modules have been defined to model services (for example, the Layer Three Virtual Private Network Service Model produced by the L3SM working group and documented in RFC 8049).

This document describes service models as used within the IETF, and also shows where a service model might fit into a Software Defined Networking architecture. Note that service models do not make any assumption of how a service is actually engineered and delivered for a customer; details of how network protocols and devices are engineered to deliver a service are captured in other models that are not exposed through the Customer-Provider Interface.

Status of This Memo

Copyright Notice

Table of Contents

1. Introduction

In recent years the number of data modules written in the YANG modeling language [RFC6020] for configuration and monitoring has blossomed. Many of these are used for device-level configuration (for example, [RFC7223]) or for control of monolithic functions or protocol instances (for example, [RFC7407]).

Within the context of Software Defined Networking (SDN) [RFC7149] [RFC7426] YANG data models may be used on the interface between a controller and network devices, and between network orchestrators and controllers. There may also be a hierarchy of such components with super controllers, domain controllers, and device controllers all exchanging information and instructions using YANG models.

There has been interest in using YANG to define and document data models that describe services in a portable way that is independent of which network operator uses the model. For example, the Layer Three Virtual Private Network Service Model (L3SM) [RFC8049]. Such models may be used in manual and even paper-driven service request processes with a gradual transition to IT-based mechanisms. Ultimately they could be used in online, software-driven dynamic systems, and eventually as part of an SDN system.

This document explains the scope and purpose of service models within the IETF and describes how a service model can be used by a network operator. Equally, this document clarifies what a service model is not, and dispels some common misconceptions.

The document also shows where a service model might fit into an SDN architecture, but it is important to note that a service model does not require or preclude the use of SDN. Note that service models do not make any assumption of how a service is actually engineered and delivered to a customer; details of how network protocols and devices are engineered to deliver a service are captured in other models that are not exposed through the Customer-Provider Interface.

In summary, a service model is a formal representation of the data elements that describe a network service as that service is described to or requested by a customer of a network operator. Details included in the service model include a description of the service as experienced by the customer, but not features of how that service is delivered or realized by the service provider.

Other work on classifying YANG data models has been done in [RFC8199]. That document provides an important reference for this document, and also uses the term "service model". Section 6.1 in this document provides a comparison between these two uses of the same terminology.

2. Terms and Concepts

Readers should familiarize themselves with the description and classification of YANG models provided in [RFC8199].

The following terms are used in this document:

Network Operator: This term is used to refer to the company that owns and operates one or more networks that provide Internet connectivity services and/or other services.

Customer: This term refers to someone who purchases a service (including connectivity) from a network operator. In the context of this document, a customer is usually a company that runs their own network or computing platforms and wishes to connect to the Internet or between sites. Such a customer may operate an enterprise network or a data center. Sometimes this term may also be used to refer to the individual in such a company who contracts to buy services from a network operator. A customer as described here is a separate commercial operation from the network operator, but some companies may operate with internal customers so that, for example, an IP/MPLS packet network may be the customer of an optical transport network.

Service: A network operator delivers one or more services to a customer. A service in the context of this document (sometimes called a Network Service) is some form of connectivity between customer sites and the Internet, or between customer sites across the network operator's network and across the Internet. However, a distinction should be drawn between the parameters that describe a service as included in a customer service model (q.v.) and a Service Level Agreement (SLA) as discussed in Section 5 and Section 7.2.

A service may be limited to simple connectivity (such as IP-based Internet access), may be a tunnel (such as a virtual circuit), or may be a more complex connectivity model (such as a multi-site virtual private network). Services may be further enhanced by additional functions providing security, load-balancing, accounting, and so forth. Additionally, services usually include guarantees of quality, throughput, and fault reporting.

This document makes a distinction between a service as delivered to a customer (that is, the service as discussed on the interface between a customer and the network operator) and the service as realized within the network (as described in [RFC8199]). This distinction is discussed further in Section 6.

Readers may also refer to [RFC7297] for an example of how an IP connectivity service may be characterized.

Data Model: The concepts of information models and data models are described in [RFC3444]. That document defines a data model by contrasting it with the definition of an information model as follows:

The main purpose of an information model is to model managed objects at a conceptual level, independent of any specific implementations or protocols used to transport the data. The degree of specificity (or detail) of the abstractions defined in the information model depends on the modeling needs of its designers. In order to make the overall design as clear as possible, an information model should hide all protocol and implementation details. Another important characteristic of an information model is that it defines relationships between managed objects.

Data models, conversely, are defined at a lower level of abstraction and include many details. They are intended for implementors and include protocol-specific constructs.

Service Model: A service model is a specific type of data model. It describes a service and the parameters of the service in a portable way. The service model may be divided into two categories:

Customer Service Model: A customer service model is used to describe a service as offered or delivered to a customer by a network operator. It can be used by a human (via a user interface such as a GUI, web form, or CLI) or by software to configure or request a service, and may equally be consumed by a human (such as via an order fulfillment system) or by a software component. Such models are sometimes referred to simply as "service models" [RFC8049]. A customer service model is expressed as a core set of parameters that are common across network operators: additional features that are specific to the offerings of individual network operators would be defined in extensions or augmentations of the model. Except where specific technology details (such as encapsulations, or mechanisms applied on access links) are directly pertinent to the customer, customer service models are technology agnostic so that the customer does not have influence over or knowledge of how the network operator engineers the service.

An example of where such details are relevant to the customer are when they describe the behavior or interactions on the interface between the equipment at the customer site (often referred to as the Customer Edge or CE equipment) and the equipment at the network operator's site (usually referred to as the Provider Edge or PE equipment).

Service Delivery Model: A service delivery model is used by a network operator to define and manage how a service is engineered in the network. It can be used by a human operator (such as via a management station) or by a software tool to instruct network components. Such models are sometimes referred to as "network service models" [RFC8199] and are consumed by "external systems" such as Operations Support System (OSS). A service delivery model is expressed as a core set of parameters that are common across a network type and technology: additional features that are specific to the configuration of individual vendor equipment or proprietary protocols would be defined in extensions or augmentations of the model. Service delivery models include technology-specific modules.

The distinction between a customer service model and a service delivery model needs to be repeatedly clarified. A customer service model is not a data model used to directly configure network devices, protocols, or functions: it is not something that is sent to network devices (i.e., routers or switches) for processing. Equally, a customer service model is not a data model that describes how a network operator realizes and delivers the service described by the model. This distinction is discussed further in later sections.

3. Using Service Models

As already indicated, customer service models are used on the interface between customers and network operators. This is shown simply in Figure 1.

The language in which a customer service model is described is a choice for whoever specifies the model. The IETF uses the YANG data modeling language defined in [RFC6020].

The encoding and communication protocol used to exchange a customer service model between customer and network operator are deployment- and implementation-specific. The IETF has standardized the NETCONF protocol [RFC6241] and the RESTCONF protocol [RFC8040] for interactions "on the wire" between software components with data encoded in XML or JSON. However, co-located software components might use an internal API, while systems with more direct human interactions might use web pages or even paper forms.

```
            --------------       Customer       ----------------------
           |              |    Service Model    |                      |
           |   Customer   | <-----------------> |   Network Operator   |
           |              |                     |                      |
            --------------                      ----------------------
```

Figure 1: The Customer Service Models used on the Interface between Customers and Network Operators

How a network operator processes a customer's service request described with a customer service model depends on the commercial and operational tools, processes, and policies used by the network operator. These may vary considerably from one network operator to another.

However, the intent is that the network operator maps the service request into configuration and operational parameters that control one or more networks to deliver the requested services. That means that the network operator (or software run by the network operator) takes the information in the customer service model and determines how to deliver the service by enabling and configuring network protocols and devices. They may achieve this by constructing service delivery models and passing them to network orchestrators or controllers. The use of standard customer service models eases service delivery by means of automation.

The practicality of customer service models has been repeatedly debated. It has been suggested that network operators have radically different business modes and widely diverse commercial offerings making a common customer service model is impractical. However, the L3SM [RFC8049] results from the consensus of multiple individuals working at network operators and offers a common core of service options that can be augmented according to the needs of individual network operators.

It has also been suggested that there should be a single, base customer service module, and that details of individual services should be offered as extensions or augmentations of this. It is quite possible that a number of service parameters (such as the identity and postal address of a customer) will be common and it would be a mistake to define them multiple times, once in each customer service model. However, the distinction between a 'module' and a 'model' should be considered at this point: modules are how the data for models is logically broken out and documented especially for re-use in multiple models.

4. Service Models in an SDN Context

In an SDN system, the management of network resources and protocols is performed by software systems that determine how best to utilize the network. Figure 2 shows a sample architectural view of an SDN system where network elements are programmed by a component called an "SDN controller" (or "controller" for short), and where controllers are instructed by an orchestrator that has a wider view of the whole of, or part of, a network. The internal organization of an SDN control plane is deployment-specific.

```
                  ------------------
                 |                  |
                 |   Orchestrator   |
                 |                  |
                 .------------------.
                .          :         .
               .           :          .
    ------------     ------------     ------------
   |            |   |            |   |            |
   | Controller |   | Controller |   | Controller |
   |            |   |            |   |            |
    ------------     ------------     ------------
       :              .       .               :
       :             .         .              :
       :            .           .             :
   ---------     ---------   ---------     ---------
  | Network |   | Network | | Network |   | Network |
  | Element |   | Element | | Element |   | Element |
   ---------     ---------   ---------     ---------
```

Figure 2: A Sample SDN Architecture

But a customer's service request is (or should be) technology-agnostic. That is, there should be an independence between the behavior and functions that a customer requests and the technology that the network operator has available to deliver the service. The orchestrator must map the service request to its view, and this mapping may include a choice of which networks and technologies to use depending on which service features have been requested.

One implementation option to achieve this mapping is to split the orchestration function between a "Service Orchestrator" and a "Network Orchestrator" as shown in Figure 3.

```
                                                 Customer
                            ------------------   Service  ----------
                           |                  |  Model   |          |
                           |     Service      |<-------->| Customer |
                           |   Orchestrator   |    (a)   |          |
                           |                  |           ----------
                            ------------------
                               .          .
                              .            .        (b)   -----------
                             . (b)          .      ......|Application|
                            .                .     :     |  BSS/OSS  |
                           .                  .    :      -----------
                          .  Service Delivery  .   :
                          .       Model        .   :
                 ------------------    ------------------
                |                  |  |                  |
                |     Network      |  |     Network      |
                |   Orchestrator   |  |   Orchestrator   |
                |                  |  |                  |
                .------------------    ------------------.
               .         :                       :        .
              .          : Network Configuration :         .
              .          :        Model          :         .
      ------------     ------------     ------------    ------------
     |            |   |            |   |            |  |            |
     | Controller |   | Controller |   | Controller |  | Controller |
     |            |   |            |   |            |  |            |
      ------------     ------------     ------------    ------------
         :              .       .                 :            :
         :             .         .      Device    :            :
         :            .           . Configuration :            :
         :            .           .     Model     :            :
     ---------     ---------   ---------     ---------      ---------
    | Network |   | Network | | Network |   | Network |    | Network |
    | Element |   | Element | | Element |   | Element |    | Element |
     ---------     ---------   ---------     ---------      ---------
```

Figure 3: An Example SDN Architecture with a Service Orchestrator

Figure 3 also shows where different data models might be applied within the architecture.

The split between control components that exposes a "service interface" is present in many figures showing extended SDN architectures:

- o Figure 1 of [RFC7426] shows a separation of the "Application Plane", the "Network Services Abstraction Layer (NSAL)", and the "Control Plane". It marks the "Service Interface" as situated between the NSAL and the control plane.

- o Figure 1 of [RFC7491] shows an interface between an "Application Service Coordinator" and an "Application-Based Network Operations Controller".

- o Figure 1 of [RFC8199] shows an interface from an OSS or a Business Support System (BSS) that is expressed in "Network Service YANG Models".

This can all lead to some confusion around the definition of a "service interface" and a "service model". Some previous literature considers the interface northbound of the Network Orchestrator (labeled "(b)" in Figure 3) to be a "service interface" used by an application, but the service described at this interface is network-centric and is aware of many features such as topology, technology, and operator policy. Thus, we make a distinction between this type of service interface and the more abstract service interface (labeled "(a)" in Figure 3) where the service is described by a service model and the interaction is between customer and network operator. Further discussion of this point is provided in Section 5.

5. Possible Causes of Confusion

In discussing service models, there are several possible causes of confusion:

- o The services we are discussing are services provided by network operators to customers. This is a completely different thing to "Foo as a Service" (for example, Infrastructure as a Service (IaaS)) where a service provider offers a service at some location that is reached across a network. The confusion arises not only because of the use of the word "service", but also because network operators may offer value-added services as well as network connection services to their customers.

- o Network operation is completely out of scope in the discussion of services between a network operator and a customer. That means that the customer service model does not reveal to the customer anything about how the network operator delivers the service. The model does not expose details of technology or network resources used to provide the service. For example, in the simple case of point-to-point virtual link connectivity provided by a network tunnel (such as an MPLS pseudowire) the network operator does not expose the path through the network that the tunnel follows. Of

course, this does not preclude the network operator from taking guidance from the customer (such as to avoid routing traffic through a particular country) or from disclosing specific details (such as might be revealed by a route trace), but these are not standard features of the service as described in the customer service model.

- The network operator may use further data models (service delivery models) that help to describe how the service is realized in the network. These models might be used on the interface between the Service Orchestrator and the Network Orchestrator as shown in Figure 3 and might include many of the pieces of information from the customer service model alongside protocol parameters and device configuration information. [RFC8199] also terms these data models as "service models" or "Network Service YANG Models" and a comparison is provided in Section 6.1. It is important that the Service Orchestrator should be able to map from a customer service model to these service delivery models, but they are not the same things.

- Commercial terms are generally not a good subject for standardization. It is possible that some network operators will enhance standard customer service models to include commercial information, but the way this is done is likely to vary widely between network operators. Thus, this feature is out of scope for standardized customer service models.

- Service Level Agreements (SLAs) have a high degree of overlap with the definition of services present in customer service models. Requests for specific bandwidth, for example, might be present in a customer service model, and agreement to deliver a service is a commitment to the description of the service in the customer service model. However, SLAs typically include a number of fine-grained details about how services are allowed to vary, by how much, and how often. SLAs are also linked to commercial terms with penalties and so forth, and so are also not good topics for standardization. As with commercial terms, it is expected that some network operators will enhance standard customer service models to include SLA parameters either using their own work or depending on material from standards bodies that specialize in this topic, but this feature is out of scope for the IETF's customer service models.

  If a network operator chooses to express an SLA using a data model, that model might be referenced as an extension or an augmentation of the customer service model.

6. Comparison With Other Work

Other work has classified YANG models, produced parallel architectures, and developed a range of YANG models. This section briefly examines that other work and shows how it fits with the description of service models introduced in this document.

6.1. Comparison With Network Service Models

As previously noted, [RFC8199] provides a classification of YANG data models. It introduces the term "Network Service YANG Module" to identify the type of model used to "describe the configuration, state data, operations and notifications of abstract representations of services implemented on one or multiple network elements." These are service delivery models as described in this document, that is, they are the models used on the interface between the Service Orchestrator or OSS/BSS and the Network Orchestrator as shown in Figure 3.

Figure 1 of [RFC8199] can be modified to make this more clear and to add an additional example of a Network Service YANG model as shown in Figure 4. This figure illustrates a functional architecture and an implementation might choose to make different distinctions and separations between components so that the functional units and interfaces illustrated might fall within a single implementation.

```
          +---------------+
          |               |
          |   Customers   |
          |               |
          +---------------+

      - - - - - - - - - - - - - -
     Customer Service YANG Modules

     +---------------------------------------------------------+
     |                                                         |
     |  +----------------------+                               |
     |  |                      |    Operations and Business   |
     |  | Service Orchestrator |        Support Systems        |
     |  |                      |           (OSS/BSS)           |
     |  +----------------------+                               |
     |                                                         |
     |                                                         |
     +---------------------------------------------------------+

     - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
     Network Service YANG Modules

    +------------+   +-------------+   +-------------+   +-------------+
    |            |   |             |   |             |   |             |
    |  - L2VPN   |   |   - L2VPN   |   |    EVPN     |   |    L3VPN    |
    |  - VPWS    |   |   - VPLS    |   |             |   |             |
    |            |   |             |   |             |   |             |
    +------------+   +-------------+   +-------------+   +-------------+

     - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
     Network Element YANG Modules

     +------------+  +------------+  +-------------+  +------------+
     |            |  |            |  |             |  |            |
     |    MPLS    |  |    BGP     |  | IPv4 / IPv6 |  |  Ethernet  |
     |            |  |            |  |             |  |            |
     +------------+  +------------+  +-------------+  +------------+

       L2VPN: Layer 2 Virtual Private Network
       L3VPN: Layer 3 Virtual Private Network
       VPWS: Virtual Private Wire Service
       VPLS: Virtual Private LAN Service
```

Figure 4: YANG Module Layers Showing Service Models

6.2. Service Delivery and Network Element Model Work

A number of IETF working groups are developing YANG models related to services. These models focus on how the network operator configures the network through protocols and devices to deliver a service. Some of these models are classified as service delivery models while others have details that are related to specific element configuration and so are classed as network element models (also called device models).

A sample set of these models is listed here:

- [I-D.dhjain-bess-bgp-l3vpn-yang] defines a YANG model that can be used to configure and manage BGP L3VPNs.

- [I-D.ietf-bess-l2vpn-yang] documents a YANG model that it is expected will be used by the management tools run by the network operators in order to manage and monitor the network resources that they use to deliver L2VPN services.

- [I-D.ietf-bess-evpn-yang] defines YANG models for delivering an Ethernet VPN service.

6.3. Customer Service Model Work

Several initiatives within the IETF are developing customer service models. The most advanced presents the L3VPN service as described by a network operator to a customer. The L3SM is described as in Figure 5 which is reproduced from [RFC8049]. As can be seen, the L3SM is a customer service model as described in this document.

```
               L3VPN-SVC |
                 MODEL   |
                         |
                      +------------------+         +-----+
                      |   Orchestration  | < --- > | OSS |
                      +------------------+         +-----+
                         |            |
                 +----------------+   |
                 | Config manager |   |
                 +----------------+   |
                         |            |
                         | Netconf/CLI ...
                         |            |
           +------------------------------------------------+
                                Network
```

Figure 5: The L3SM Service Architecture

A Layer Two VPN service model (L2SM) is defined in [I-D.ietf-l2sm-l2vpn-service-model]. That model's usage is described as in Figure 6 which is a reproduction of Figure 5 from that document. As can be seen, the L2SM is a customer service model as described in this document.

```
             ----------------------------
            | Customer Service Requester |
             ----------------------------
                     |
         L2VPN       |
         Service     |
         Model       |
                     |
               -----------------------
              | Service Orchestration |
               -----------------------
                     |
                     |     Service            +-------------+
                     |     Delivery    +------->| Application |
                     |     Model       |        |   BSS/OSS   |
                     |                 V        +-------------+
               -----------------------
              | Network Orchestration |
               -----------------------
                     |            |
         +----------------+   |
         | Config manager |   |
         +----------------+   |  Device
                     |            |  Models
                     |            |
      --------------------------------------------
                        Network
```

Figure 6: The L2SM Service Architecture

6.4. The MEF Architecture

The MEF Forum has developed an architecture for network management and operation. It is documented as the Lifecycle Service Orchestration (LSO) Reference Architecture and illustrated in Figure 2 of [MEF-55].

The work of the MEF Forum embraces all aspects of Lifecycle Service Orchestration including billing, SLAs, order management, and life-cycle management. The IETF's work on service models is typically smaller offering a simple, self-contained service YANG module. Thus, it may be impractical to fit IETF service models into the MEF Forum LSO architecture. This does not invalidate either approach, but only observes that they are different.

7. Further Concepts

This section introduces a few further, more advanced concepts

7.1. Technology Agnostic

Service models should generally be technology agnostic. That is to say, the customer should not care how the service is provided so long as the service is delivered.

However, some technologies reach the customer site and make a difference to the type of service delivered. Such features do need to be described in the service model.

Two examples are:

- o The data passed between customer equipment and network operator equipment will be encapsulated in a specific way, and that data plane type forms part of the service.

- o Protocols that are run between customer equipment and network operator equipment (for example, Operations, Administration, and Maintenance protocols, protocols for discovery, or protocols for exchanging routing information) need to be selected and configured as part of the service description.

7.2. Relationship to Policy

Policy appears as a crucial function in many places during network orchestration. A Service Orchestrator will, for example, apply the network operator's policies to determine how to provide a service for a particular customer (possibly considering commercial terms). However, the policies within a service model are limited to those over which a customer has direct influence and that are acted on by the network operator.

The policies that express desired behavior of services on occurrence of specific events are close to SLA definitions: they should only be included in the base service model where they are common to all network operators' offerings. Policies that describe who at a customer may request or modify services (that is, authorization) are close to commercial terms: they, too, should only be included in the base service model where they are common to all network operators' offerings.

As with commercial terms and SLAs discussed in Section 5 it is expected that some network operators will enhance standard customer service models to include policy parameters either using their own

work or depending on specific policy models built in the IETF or other standards bodies.

Nevertheless, policy is so important that all service models should be designed to be easily extensible to allow policy components to be added and associated with services as needed.

7.3. Operator-Specific Features

When work on the L3SM was started, there was some doubt as to whether network operators would be able to agree on a common description of the services that they offer to their customers because, in a competitive environment, each markets the services in a different way with different additional features. However, the working group was able to agree on a core set of features that multiple network operators were willing to consider as "common". They also understood that should an individual network operator want to describe additional features (operator-specific features) they could do so by extending or augmenting the L3SM model.

Thus, when a basic description of a core service is agreed and documented in a service model, it is important that that model should be easily extended or augmented by each network operator so that the standardized model can be used in a common way and only the operator-specific features varied from one environment to another.

7.4. Supporting Multiple Services

Network operators will, in general, offer many different services to their customers. Each would normally be the subject of a separate service model.

It is an implementation and deployment choice whether all service models are processed by a single Service Orchestrator that can coordinate between the different services, or whether each service model is handled by a specialized Service Orchestrator able to provide tuned behavior for a specific service.

It is expected that, over time, certain elements of the service models will be seen to repeat in each model. An example of such an element is the postal address of the customer.

It is anticipated that, while access to such information from each service model is important, the data will be described in its own module and may form part of the service model either by inclusion or by index.

8. Security Considerations

The interface between customer and service provider is a commercial interface and needs to be subject to appropriate confidentiality. Additionally, knowledge of what services are provided to a customer or delivered by a network operator may supply information that can be used in a variety of security attacks.

Clearly, the ability to modify information exchanges between customer and network operator may result in bogus requests, unwarranted billing, and false expectations. Furthermore, in an automated system, modifications to service requests or the injection of bogus requests may lead to attacks on the network and delivery of customer traffic to the wrong place.

Therefore it is important that the protocol interface used to exchange service request information between customer and network operator is subject to authorization, authentication, and encryption. Equally, all external intefaces, such as any of those between the functional components in Figure 3 needs to be correctly secured.

This document discusses modeling the information, not how it is exchanged.

9. Manageability Considerations

This whole document discusses issues related to network management and control.

It is important to observe that automated service provisioning resulting from use of a customer service model may result in rapid and significant changes in traffic load within a network and that that might have an effect on other services carried in a network.

It is expected, therefore, that a Service Orchestration component has awareness of other service commitments, that the Network Orchestration component will not commit network resources to fulfill a service unless doing so is appropriate, and that a feedback loop will be provided to report on degradation of the network that will impact the service.

The operational state of a service does not form part of a customer service model. However, it is likely that a network operator may want to report some state information about various components of the service, and that could be achieved through extensions to the core service model just as SLA extensions could be made as described in Section 5.

10. IANA Considerations

This document makes no requests for IANA action

11. Acknowledgements

Thanks to Daniel King, Xian Zhang, Michael Scharf, Med Boucadair, and Luis Miguel Contreras Murillo for useful review and comments.

Thanks to Dean Bogdanovic, Tianran Zhou, and Carl Moberg for their help coordinating with [RFC8199].

Many thanks to Jerry Bonner for spotting a tiny, one-word, but critical typo.

12. References

12.1. Normative References

[RFC3444] Pras, A. and J. Schoenwaelder, "On the Difference between Information Models and Data Models", RFC 3444, DOI 10.17487/RFC3444, January 2003, <https://www.rfc-editor.org/info/rfc3444>.

[RFC8199] Bogdanovic, D., Claise, B., and C. Moberg, "YANG Module Classification", RFC 8199, DOI 10.17487/RFC8199, July 2017, <https://www.rfc-editor.org/info/rfc8199>.

12.2. Informative References

[I-D.dhjain-bess-bgp-l3vpn-yang]
Jain, D., Patel, K., Brissette, P., Li, Z., Zhuang, S., Liu, X., Haas, J., Esale, S., and B. Wen, "Yang Data Model for BGP/MPLS L3 VPNs", draft-dhjain-bess-bgp-l3vpn-yang-02 (work in progress), August 2016.

[I-D.ietf-bess-evpn-yang]
Brissette, P., Sajassi, A., Shah, H., Li, Z., Tiruveedhula, K., Hussain, I., and J. Rabadan, "Yang Data Model for EVPN", draft-ietf-bess-evpn-yang-02 (work in progress), March 2017.

[I-D.ietf-bess-l2vpn-yang]
Shah, H., Brissette, P., Chen, I., Hussain, I., Wen, B., and K. Tiruveedhula, "YANG Data Model for MPLS-based L2VPN", draft-ietf-bess-l2vpn-yang-06 (work in progress), June 2017.

[I-D.ietf-l2sm-l2vpn-service-model]
Wen, B., Fioccola, G., Xie, C., and L. Jalil, "A YANG Data Model for L2VPN Service Delivery", draft-ietf-l2sm-l2vpn-service-model-02 (work in progress), July 2017.

[MEF-55] MEF Forum, "Service Operations Specification MEF 55 : Lifecycle Service Orchestration (LSO) Reference Architecture and Framework", March 2016.

[RFC6020] Bjorklund, M., Ed., "YANG - A Data Modeling Language for the Network Configuration Protocol (NETCONF)", RFC 6020, DOI 10.17487/RFC6020, October 2010, <https://www.rfc-editor.org/info/rfc6020>.

[RFC6241] Enns, R., Ed., Bjorklund, M., Ed., Schoenwaelder, J., Ed., and A. Bierman, Ed., "Network Configuration Protocol (NETCONF)", RFC 6241, DOI 10.17487/RFC6241, June 2011, <https://www.rfc-editor.org/info/rfc6241>.

[RFC7149] Boucadair, M. and C. Jacquenet, "Software-Defined Networking: A Perspective from within a Service Provider Environment", RFC 7149, DOI 10.17487/RFC7149, March 2014, <https://www.rfc-editor.org/info/rfc7149>.

[RFC7223] Bjorklund, M., "A YANG Data Model for Interface Management", RFC 7223, DOI 10.17487/RFC7223, May 2014, <https://www.rfc-editor.org/info/rfc7223>.

[RFC7297] Boucadair, M., Jacquenet, C., and N. Wang, "IP Connectivity Provisioning Profile (CPP)", RFC 7297, DOI 10.17487/RFC7297, July 2014, <https://www.rfc-editor.org/info/rfc7297>.

[RFC7407] Bjorklund, M. and J. Schoenwaelder, "A YANG Data Model for SNMP Configuration", RFC 7407, DOI 10.17487/RFC7407, December 2014, <https://www.rfc-editor.org/info/rfc7407>.

[RFC7426] Haleplidis, E., Ed., Pentikousis, K., Ed., Denazis, S., Hadi Salim, J., Meyer, D., and O. Koufopavlou, "Software-Defined Networking (SDN): Layers and Architecture Terminology", RFC 7426, DOI 10.17487/RFC7426, January 2015, <https://www.rfc-editor.org/info/rfc7426>.

[RFC7491] King, D. and A. Farrel, "A PCE-Based Architecture for Application-Based Network Operations", RFC 7491, DOI 10.17487/RFC7491, March 2015, <https://www.rfc-editor.org/info/rfc7491>.

[RFC8040] Bierman, A., Bjorklund, M., and K. Watsen, "RESTCONF Protocol", RFC 8040, DOI 10.17487/RFC8040, January 2017, <https://www.rfc-editor.org/info/rfc8040>.

[RFC8049] Litkowski, S., Tomotaki, L., and K. Ogaki, "YANG Data Model for L3VPN Service Delivery", RFC 8049, DOI 10.17487/RFC8049, February 2017, <https://www.rfc-editor.org/info/rfc8049>.

Authors' Addresses

Qin Wu
Huawei Technologies

Email: bill.wu@huawei.com

Will Liu
Huawei Technologies

Email: liushucheng@huawei.com

Adrian Farrel
Juniper Networks

Email: afarrel@juniper.net