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| OF-CONFIG 1.1.1 |
| OpenFlow Management and Configuration Protocol |
| Document Version .1 |
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Contact: [email addresses of people to contact]

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# Introduction

This document describes the motivation, scope, requirements, and specification of the standard configuration and management protocol of an operational context which is capable of containing an OpenFlow 1.3 switch as described in Figure 1. This configuration and management protocol is referred to as OF-CONFIG and is a companion protocol to OpenFlow. This document specifies version 1.1 of OF-CONFIG.



Figure 1: An OpenFlow Configuration Point communicates with an operational context which is capable of supporting an OpenFlow Switch using the OpenFlow Configuration and Management Protocol (OF-CONFIG)

The reader of this document is assumed to be familiar with the OpenFlow protocol and OpenFlow related concepts. Reading the OpenFlow whitepaper (2) and the OpenFlow Specification (1) is recommended prior to reading this document.

It is strongly recommended that switches which implement OF-CONFIG make changes to the OpenFlow logical switch described in this document via OF-CONFIG and limit changes to the OpenFlow logical switche via other methods (e.g. command line interfaces and other legacy management protocols). Future versions may better support other methods of change with detailed notification to the OpenFlow Configuration Point via OF-CONFIG.

# Motivation

The OpenFlow protocol assumes that an OpenFlow datapath (e.g. an Ethernet switch which supports the OpenFlow protocol) has been configured with various artifacts such as the IP addresses of OpenFlow controllers. The motivation for the OpenFlow Configuration Protocol (OF-CONFIG) is to enable the remote configuration of OpenFlow datapaths. While the OpenFlow protocol generally operates on a time-scale of a flow (i.e. as flows are added and deleted), OF-CONFIG operates on a slower time-scale. An example is building forwarding tables and deciding forwarding actions which are done via Openflow protocol while enabling/disabling a port does not need to be done at the timescale of a flow and hence, is done via OF-Config protocol.

OF-CONFIG frames an OpenFlow datapath as an abstraction called an OpenFlow Logical Switch. The OF-CONFIG protocol enables configuration of essential artifacts of an OpenFlow Logical Switch so that an OpenFlow controller can communicate and control the OpenFlow Logical switch via the OpenFlow protocol.

OF-CONFIG 1.1 introduces an operating context for one or more OpenFlow datapaths called an OpenFlow Capable Switch. An OpenFlow Capable Switch is intended to be equivalent to an actual physical or virtual network element (e.g. an Ethernet switch) which is hosting one or more OpenFlow datapaths by partitioning a set of OpenFlow related resources such as ports and queues among the hosted OpenFlow datapaths. The OF-CONFIG protocol enables dynamic association of the OpenFlow related resources of an OpenFlow Capable Switch with specific OpenFlow Logical Switches which are being hosted on the OpenFlow Capable Switch. OF-CONFIG does not specify or report how the partitioning of resources on an OpenFlow Capable Switch is achieved. OF-CONFIG assumes that resources such as ports and queues are partitioned amongst multiple OpenFlow Logical Switches such that each OpenFlow Logical Switch can assume full control over the resources that is assigned to it.

OF-CONFIG 1.1 makes simplifying assumptions about the architecture of OpenFlow switches. The specification is deliberately decoupled from whether the switch supports flowvisor or other virtualization models.

The service which sends OF-CONFIG messages to an OpenFlow Capable Switch is called an OpenFlow Configuration Point. No assumptions are made about the nature of the OpenFlow Configuration Point. For example, it may be a service provided by software acting as an OpenFlow controller or it may by a service provided by a traditional network management framework. Any interaction between the OpenFlow Configuration Points and OpenFlow controllers is outside the scope of OF-CONFIG 1.1.

Figure 2 shows the basic abstractions detailed in OF-CONFIG 1.1 and the lines indicate that the OpenFlow Configuration Points and OpenFlow Capable Switches communicate via OF-CONFIG. The configuration settings then take effect on targeted logical switch(es). OpenFlow Controllers and OpenFlow Logical Switches (i.e. datapaths) communicate via OpenFlow.



Figure 2: Relationship between components defined in this specification, the OF-CONFIG protocol and the OpenFlow protocol

A guiding principle in the development of this specification is to keep the protocol and schema simple and leverage existing protocols and schema models where possible. This helped in quick development of this specification and hopefully will also enable easier adoption, the motivation being to supplement the OpenFlow specification in a meaningful way to further drive the adoption of the software defined networking vision.

# Scope

OF-CONFIG 1.1 is focused on the following functions needed to configure an OpenFlow 1.3 (OFv1.2) datapath:

* The assignment of one or more OpenFlow controllers
* The configuration of queues and ports
* The ability to remotely change some aspects of ports (e.g. up/down)
* Configuration of ceritificates for secure communication between the OpenFlow Logical Switches and OpenFlow Controllers
* Discovery of capabilities of an OpenFlow Logical Switch
* Configuration of a small set of tunnel types such as IP-in-GRE, NV-GRE, VxLAN

While limited in scope, OF-CONFIG 1.1 lays the foundation on top of which various automated and more advanced configurations will be possible in future revisions.Switch discovery, topology discovery, capability configuration, event triggers, versioning, instantiation of OpenFlow Logical Switches, assignment of resources such as ports and queues to OpenFlow Logical Switches, and bootstrap of the OpenFlow capable network are outside the scope of OF-CONFIG 1.1 protocol. These may be included in future versions.

Note that even though this specification refers to OpenFlow 1.3, OF-config 1.1.1 supports previous OPenFlow versions, specifically, OPenFlow 1.0, 1.1 and 1.2.

# Normative Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 (3).

# Terms

The following section lists several terms and definitions used in this document.

## OpenFlow Capable Switch

An OpenFlow Capable switch is a physical or virtual switching device which can act an as operational context for an OpenFlow Logical Switch. OpenFlow Capable Switches contain and manage OpenFlow Resources which may be associated with an OpenFlow Logical Switch context.

## OpenFlow Configuration Point

An OpenFlow Configuration Point configures one or more OpenFlow Capable Switches via the OpenFlow Configuration and Management Protocol (OF-CONFIG).

## OpenFlow Logical Switch

An OpenFlow Logical Switch is a set of resources (e.g. ports) from an OpenFlow Capable Switch which can be associated with a specific OpenFlow Controller. An OpenFlow Logical switch is an instantiation of an OpenFlow Datapath as specified in (1).

## OpenFlow Resource

An OpenFlow Resource is a resource (e.g. port or queue) which is associated with an OpenFlow Capable Switch and may be associated with an OpenFlow Logical Switch.

### OpenFlow Queue

An OpenFlow Queue is a queuing resource of an OpenFlow Logical Switch as described in the OpenFlow specification as the queue component of an OpenFlow datapath.

### OpenFlow Port

An OpenFlow Port is a forwarding interface of an OpenFlow Logical Switch as described in the OpenFlow specification as the port component of an OpenFlow datapath. An Openflow Port may map to a physical port on a physical switch or a logical port on a physical or virtual switch.

## OpenFlow Controller

An OpenFlow Controller is software which controls OpenFlow Logical Switches via the OpenFlow protocol.

# Requirements

This section describes requirements for the design of OF-CONFIG 1.1.

## Requirements from the OpenFlow 1.3 Protocol Specification

The specification of version 1.3 of the OpenFlow protocol (1) includes explicit and implicit requirements for the configuration of OpenFlow switches. In (1) the term ‘configuration’ is used for two different kinds of operations: configuration using the OpenFlow protocol and configuration outside of the OpenFlow protocol. The first kind of configuration is dealt with in (1). OF-CONFIG 1.1 enables other configuration of OpenFlow switches. The specification of OF-CONFIG 1.1 is written with extensibility in mind. This includes versioning and backward compatibility. Whereas the current specification does not explicitly uses versioning, those features are inherent capabilities of the chosen protocol. In a future version OF-CONFIG will make use of these features and will include versioning, which in turn will enable backward compatibility.

### Connection Setup to a Controller

Section 6.2 (Connection Setup) of (1) requires that an OpenFlow switch always initiate the connection to the OpenFlow controller and discusses the process of setting up a connection between the OpenFlow switch and an OpenFlow controller. The switch initiates the connection applying three parameters that need to be configured in advance:

* the IP address of the controller
* the port number at the controller
* the transport protocol to use, either TLS or TCP

OF-CONFIG 1.1 must provide means for configuring these parameters. Note that in future, alternative mechanisms for discovering the OpenFlow controller may be supported.

### Multiple Controllers

Section 6.3 of (1) discusses how a switch deals with multiple controllers simultaneously. This implicitly requires OF-CONFIG 1.1 to provide means for configuring multiple instances of the parameter set listed in 6.1.1 for specifying the connection setup to multiple controllers.

### OpenFlow Logical Switches

The OpenFlow 1.3 protocol specifies various kinds of OpenFlow resources associated with an OpenFlow Logical Switch. The OF-CONFIG protocol must support the configuration of these OpenFlow resources associated with an OpenFlow Logical Switch. Examples of resources include queues and ports that have been assigned to an OpenFlow Logical Switch. It is assumed that OpenFlow Logical Switches have been instantiated out of band, for example, an administrator may have created them upfront. In addition, partitioning/assignment of OpenFlow resources amongst multiple OpenFlow switches that may exist in an OpenFlow Capable Switch has also been done out of band.

### Connection Interruption

Section 6.4 of (1) discusses the choice of two modes the switch should immediately enter after losing contact with all controllers. The modes are

* fail secure mode
* fail standalone mode

OF-CONFIG protocol must provide means for configuring the mode to enter in such a case.

### Encryption

Section 6.5 of (1) discusses encryption of connections to controllers that use TLS. It explicitly states “Each switch must be user-configurable with one certificate for authenticating the controller (controller certificate) and the other for authenticating to the controller (switch certificate)”. Hence, OF-CONFIG must provide means for configuring a switch certificate and a controller certificate for each controller that is configured to use TLS.

### Queues

Section A.3.6 of (1) describes the configuration of queues. Queue in (1) have three parameters that may be configurable:

* min-rate
* max-rate
* experimenter

OF-CONFIG 1.1 must provide means for configuring these parameters.

### Ports

The OpenFlow protocol already contains methods to configure a limited amount of port parameters of OpenFlow switches. The OpenFlow protocol specification (1) does not explicitly require an external configuration means, and therefore we cannot derive the requirement for configuring ports from (1). However, the configuration of ports is an essential step of configuring a network and thus arequirement for OF-CONFIG 1.1. Section A.3.4.3 of (1) defines the following parameters for port configuration:

* no-recveive
* no-forward
* no-packetin
* admin-state

OF-CONFIG 1.1 must provide means for configuring these parameters.

Also defined in Section A.2.1 of the OpenFlow protocol specification (1) are port features. There are four sets of these features for current, advertised, supported, and peer-advertised features. Feature sets current, supported, and peer-advertised contain state information and are not to be configured. Only advertised features could potentially be configured with the following parameters:

* speed
* duplex-mode
* copper-medium
* fiber-medium
* auto-negotiation
* pause
* asymmetric-pause

OF-CONFIG 1.1 must provide means for configuring these advertised features.

Section 4.4 of (1) defines logical ports that are higher level abstratcions and that may include encapsulation. In addition, logical ports support passing of meta data to the controller. OF-CONFIG 1.1 must support the configuration of these logical ports. However, the configuration of logical ports in OF-Config 1.1 is limited to a small number of tunnels (specifically to IPinGRE, VxLAN and NVGRE) that may be used in datacenter scenarios like network virtualization. Future versions of OF-Config will support configuration of additional types of tunnels.

### Capability Discovery

OpenFlow 1.3 describes the various capabilities that an OpenFlow Logical Switch may implement eg there are several actions in OpenFlow 1.3 that are optional. While configuration of these capabilities is outside the scope of OF-CONFIG 1.1, it supports discovery of these capabilities. It is assumed that capabilities have been configured for OpenFlow Logical switches either as part of instantiation of these switches or through some out of band mechanisms.

### Datapath ID

Section A.3.1 of (1) discusses the datapath ID of a switch. It is a 64-bit filed with the lower 48 bit intended for the switch MAC address and the remaining 16 bit left to the switch operator. Although not explicitly requested by (1), OF-CONFIG should provide means for configuring the datapath ID.

## Operational Requirements

The OF-CONFIG 1.1 must meet support the following scenarios:

1. OF-CONFIG 1.1 must support an OpenFlow Capable Switch being configured by multiple OpenFlow Configuration Points.
2. OF-CONFIG 1.1 must support an OpenFlow Configuration Point managing multiple OpenFlow Capable Switches.
3. OF-CONFIG 1.1 must support an OpenFlow Logical Switch being controlled by multiple OpenFlow Controllers.
4. OF-CONFIG 1.1 must support configuring ports and queues of an OpenFlow Capable Switch that have been assigned to an OpenFlow Logical Switch.
5. OF-CONFIG 1.1 must support discovery of capabilities of an OpenFlow Logical Switch.
6. OF-CONFIG 1.1 must support configuration of tunnels such as IP-in-GRE, NVGRE and VxLan that are represented as logical ports of an OpenFlow Logical Switch.

## Requirements for the Switch Management Protocol

OF-CONFIG 1.1 defines a communication standard between an OpenFlow switch and an OpenFlow Configuration Point. It consists of a network management protocol specified in Section 8 and a data model defined in Section 7. This subsection specifies requirements for the network management protocol. Note that these requirements are a superset of the requirements that may be needed for the limited scope of configuration specified in this specifications. The intent for the below requirements is to future proof the protocol choice so that we are able to address the future scenarios without having to modify the protocol choice itself. The protocol must comply with the following requirements:

1. The protocol must be secure providing integrity, privacy, and authentication. Authentication of both ends, switch and configuration point, must be supported.
2. The protocol must support reliable transport of configuration requests and replies.
3. The protocol must support connection setup by the configuration point.
4. The protocol should support connection setup by the switch.
5. The protocol must be able to carry partial switch configurations.
6. The protocol must be able to carry bulk switch configurations.
7. The protocol must support the configuration point setting configuration data at the switch
8. The protocol must support the configuration point retrieving configuration data from the switch.
9. The protocol should support the configuration point retrieving status information from the switch.
10. The protocol must support creation, modification and deletion of configuration information at the switch.
11. The protocol must support reporting on the result of a successful configuration request.
12. The protocol must support reporting error codes for partially or completely failed configuration requests.
13. The protocol should support sending configuration requests independent of the completion of previous requests.
14. The protocol should support transaction capabilities including rollback per operation.
15. The protocol must provide means for asynchronous notifications from the switch to the configuration point. An example may be, even though this scenario is out of scope for OF-CONFIG 1.1, is if an administrator changes a configuration out of band, the switch may need to provide an appropriate notification to the OFCP.
16. The protocol should be extensible.
17. The protocol should support reporting its capabilities.

# Data Model

This section specifies the data model for OF-CONFIG 1.1. Configurations of an OpenFlow Capable Switch or for portions of it are encoded in XML. The data model is structured into classes and attributes of classes. Each class is described in a separate sub-section by

1. a UML diagram giving an overview of the class,
2. a portion of an XML schema extracted from the normative XML schema in Appendix A,
3. an example for XML code encoding an instance of the class,
4. normative constraints for instances of the class extending the XML schema by semantic specifications,
5. a portion of a YANG (9) module extracted from the YANG module in Appendix B.

The full XML schema and the full YANG module are listed in Appendices A and B. Normative for OF-CONFIG 1.1 is the XML schema in Appendix A and the normative constraints in sub-sections 7.X.4. The YANG module in Appendix B incorporates the XML schema specifications as well as the normative constraints.

One of the desing goals of the model is efficient and clear encding of switch configurations in XML. Human readability is a strong feature of XML. But since the XML schema will mainly be created and parsed by the protocol entity, the ease of encoding and parsing was preferred over readability. This implies that in case of a trade-off between cleanness and simplicity of the XML-based configuration and simplicity of the XML schema, usually cleanness and simplicity of the XML-based configuration has been preferred.

OF-CONFIG specific terminology used for describing the model is defined in Section 5. The following UML diagram describes the top-level classes of the data model.



Figure 3: UML Class Diagram for OF-CONFIG Data Model

The core of the model is an OpenFlow Capable Switch that is configured by OpenFlow Configuration Points.

The switch contains a set of resources of different types. For OF-CONFIG 1.1, several types of resources are included in the model: OpenFlow Ports, OpenFlow Queues, External Certificate, Owned Certificate and Flow Table. More resource types may be added in future revisions of OF-CONFIG. OpenFlow resources can be made available for use to OpenFlow Logical Switches.

Instances of OpenFlow logical switches are contained within the OpenFlow Capable Switch. A set of OpenFlow Controllers is assigned to each OpenFlow logical switch.

The data model contains several identifiers, most of them encoded as an XML element <id>. Currently these IDs are defined as strings with required uniqueness in a certain context. Beyond uniqueness requirements, no further guidance is given on how to build these strings. This may be changed in the future. Particularly, the use of Universal Resource Names (URNs) is envisioned. This requires developing a naming scheme for URNs in OF-CONFIG and registering a URN namespace for the ONF. It is expected that recommendations for URN-based identifiers will be introduced by a future version of OF-CONFIG. Since URNs are represented as strings, such recommendations can be made compatible with identifiers in OF-CONFIG v1.1.

When issuing a NETCONF get request all elements in the requested sub-tree must be returned in the result. Those elements that can be modified by a NETCONF edit-config request or retrieved by a NETCONF get-config request are identified in the normative constraints sub-sections 8.X.4.

## OpenFlow Capable Switch

The OpenFlow Capable Switch serves as the root element for an OpenFlow configuration. It has relationships to

* OpenFlow Configuration Points that manage and particularly configure the OpenFlow Capable Switch,
* OpenFlow logical switches that are contained and instantiated within the OpenFlow Capable Switch,
* OpenFlow Resources contained in the OpenFlow Capable Switch that may be used by OpenFlow Logical Switches.

### UML Diagram



Figure 4: Data Model Diagram for OpenFlow Capable Switch

### XML Schema

|  |
| --- |
| <xs:element name="capable-switch">  <xs:annotation>  <xs:documentation>  The OpenFlow Capable Switch serves as the root  element for an OpenFlow configuration. It contains logical  switches and resources that can be assigned to logical  switches. It may have relations to OpenFlow Configuration  Points.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:element name="id" type="inet:uri">  <xs:annotation>  <xs:documentation>  A unique but locally arbitrary identifier that  uniquely identifies a Capable Switch within the context of  potential OpenFlow Configuration Points. It MUST be  persistent across reboots of the OpenFlow Capable Switch.  This element MUST be present in the NETCONF data store.  If this element is not present in a NETCONF &lt;edit-config&gt;  operation 'create', 'merge' or 'replace' and the parent  element does not exist, a 'data-missing' error is  returned.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="config-version" minOccurs="0" type="xs:string">  <xs:annotation>  <xs:documentation>  The maximum supported OF-CONFIG version that is  supported by the OpenFlow Capable Switch. For switches  implementing this version of the OF-CONFIG protocol this  MUST always be 1.1.1.  This object can be used to identify the OF-CONFIG version  a capable switch supports beginning with version 1.1.1 of  OF-CONFIG. In addtion the supported version can be  determined by the namespace the OpenFlow Capable Switch  returns to configuration request of an element (like  capable-switch) that is present in all OF-CONFIG versions  specified so far. This is the only possiblity to identify  OF-CONFIG versions prior to OF-CONFIG 1.1.1.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="configuration-points" minOccurs="0">  <xs:complexType>  <xs:sequence>  <xs:element name="configuration-point" minOccurs="0" maxOccurs="unbounded">  <xs:annotation>  <xs:documentation>  The list of all Configuration Points known to  the OpenFlow Capable Switch that may manage it using  OF-CONFIG.  The element 'id' of OFConfigurationType MUST be unique  within this list.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:group ref="OFConfigurationPointType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  </xs:sequence>  </xs:complexType>  <xs:key name="key\_configuration-points\_capable-switch\_configuration-point">  <xs:selector xpath="of11-config:configuration-point"/>  <xs:field xpath="of11-config:id"/>  </xs:key>  </xs:element>  <xs:element name="resources" minOccurs="0">  <xs:annotation>  <xs:documentation>  A lists containing all resources of the OpenFlow  Capable Switch that can be used by OpenFlow Logical  Switches. Resources are listed here independent of their  actual assignment to OpenFlow Logical Switches. They may  be available to be assigned to an OpenFlow Logical Switch  or already in use by an OpenFlow Logical Switch.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:element name="port" minOccurs="0" maxOccurs="unbounded">  <xs:annotation>  <xs:documentation>  The list contains all port resources of the  OpenFlow Capable Switch.  The element 'resource-id' of OFPortType MUST be unique  within this list.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:group ref="OFPortType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  <xs:element name="queue" minOccurs="0" maxOccurs="unbounded">  <xs:annotation>  <xs:documentation>  The list contains all queue resources of the  OpenFlow Capable Switch.  The element 'resource-id' of OFQueueType MUST be unique  within this list.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:group ref="OFQueueType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  <xs:element name="owned-certificate" minOccurs="0" maxOccurs="unbounded">  <xs:annotation>  <xs:documentation>  The list contains all owned certificate  resources of the OpenFlow Capable Switch.  The element 'resource-id' of OFOwnedCertificateType MUST  be unique within this list.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:group ref="OFOwnedCertificateType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  <xs:element name="external-certificate" minOccurs="0" maxOccurs="unbounded">  <xs:annotation>  <xs:documentation>  The list contains all external certificate  resources of the OpenFlow Capable Switch.  The element 'resource-id' of OFExternalCertificateType  MUST be unique within this list.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:group ref="OFExternalCertificateType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  <xs:element name="flow-table" minOccurs="0" maxOccurs="unbounded">  <xs:annotation>  <xs:documentation>  The list contains all flow table resources of  the OpenFlow Capable Switch.  The element 'resource-id' of OFFlowTableType MUST be  unique within this list.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:group ref="OFFlowTableType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  </xs:sequence>  </xs:complexType>  <xs:key name="key\_resources\_capable-switch\_port">  <xs:selector xpath="of11-config:port"/>  <xs:field xpath="of11-config:resource-id"/>  </xs:key>  <xs:key name="key\_resources\_capable-switch\_queue">  <xs:selector xpath="of11-config:queue"/>  <xs:field xpath="of11-config:resource-id"/>  </xs:key>  <xs:key name="key\_resources\_capable-switch\_owned-certificate">  <xs:selector xpath="of11-config:owned-certificate"/>  <xs:field xpath="of11-config:resource-id"/>  </xs:key>  <xs:key name="key\_resources\_capable-switch\_external-certificate">  <xs:selector xpath="of11-config:external-certificate"/>  <xs:field xpath="of11-config:resource-id"/>  </xs:key>  <xs:key name="key\_resources\_capable-switch\_flow-table">  <xs:selector xpath="of11-config:flow-table"/>  <xs:field xpath="of11-config:resource-id"/>  </xs:key>  </xs:element>  <xs:element name="logical-switches" minOccurs="0">  <xs:annotation>  <xs:documentation>  This element contains a list of all OpenFlow  Logical Switches available at the OpenFlow Capable  Switch.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:element name="switch" minOccurs="0" maxOccurs="unbounded">  <xs:annotation>  <xs:documentation>  The list of all OpenFlow Logical Switches on  the OpenFlow Capable Switch.  The element 'resource-id' of OFLogicalSwitchType MUST be  unique within this list.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:group ref="OFLogicalSwitchType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  </xs:sequence>  </xs:complexType>  <xs:key name="key\_logical-switches\_capable-switch\_switch">  <xs:selector xpath="of11-config:switch"/>  <xs:field xpath="of11-config:id"/>  </xs:key>  </xs:element>  </xs:sequence>  </xs:complexType>  </xs:element> |

### XML Example

|  |
| --- |
| <capable-switch>  <id>CapableSwitch0</id>  <configuration-points>  ...  </configuration-points>  <resources>  ...  </resources>  <logical-switches>  ...  </logical-switches>  </capable-switch> |

### YANG Specification

|  |
| --- |
| container capable-switch {  description "The OpenFlow Capable Switch serves as the root  element for an OpenFlow configuration. It contains logical  switches and resources that can be assigned to logical  switches. It may have relations to OpenFlow Configuration  Points.";  leaf id {  type inet:uri;  mandatory true;  description "A unique but locally arbitrary identifier that  uniquely identifies a Capable Switch within the context of  potential OpenFlow Configuration Points. It MUST be  persistent across reboots of the OpenFlow Capable Switch.  This element MUST be present in the NETCONF data store.  If this element is not present in a NETCONF <edit-config>  operation 'create', 'merge' or 'replace' and the parent  element does not exist, a 'data-missing' error is  returned.";  }  leaf config-version {  type string;  config false;  description "The maximum supported OF-CONFIG version that is  supported by the OpenFlow Capable Switch. For switches  implementing this version of the OF-CONFIG protocol this  MUST always be 1.1.1.  This object can be used to identify the OF-CONFIG version  a capable switch supports beginning with version 1.1.1 of  OF-CONFIG. In addtion the supported version can be  determined by the namespace the OpenFlow Capable Switch  returns to configuration request of an element (like  capable-switch) that is present in all OF-CONFIG versions  specified so far. This is the only possiblity to identify  OF-CONFIG versions prior to OF-CONFIG 1.1.1.";  }  container configuration-points {  list configuration-point {  key "id";  description "The list of all Configuration Points known to  the OpenFlow Capable Switch that may manage it using  OF-CONFIG.  The element 'id' of OFConfigurationType MUST be unique  within this list.";  uses OFConfigurationPointType;  }  }  container resources {  description "A lists containing all resources of the OpenFlow  Capable Switch that can be used by OpenFlow Logical  Switches. Resources are listed here independent of their  actual assignment to OpenFlow Logical Switches. They may  be available to be assigned to an OpenFlow Logical Switch  or already in use by an OpenFlow Logical Switch.";  list port {  must "features/current/rate != 'other' or " +  "(count(current-rate) = 1 and count(max-rate) = 1 and " +  " current-rate > 0 and max-rate > 0)" {  error-message "current-rate and max-rate must be  specified and greater than 0 if rate equals 'other'";  description "current-rate and max-rate can only be  present if rate = 'other', see corresponding leaf  descriptions. If rate = 'other', then both leafs must  be set to values greater than zero.";  }  key "resource-id";  description "The list contains all port resources of the  OpenFlow Capable Switch.  The element 'resource-id' of OFPortType MUST be unique  within this list.";  uses OFPortType;  }  list queue {  key "resource-id";  description "The list contains all queue resources of the  OpenFlow Capable Switch.  The element 'resource-id' of OFQueueType MUST be unique  within this list.";  uses OFQueueType;  }  list owned-certificate {  key "resource-id";  description "The list contains all owned certificate  resources of the OpenFlow Capable Switch.  The element 'resource-id' of OFOwnedCertificateType MUST  be unique within this list.";  uses OFOwnedCertificateType;  }  list external-certificate {  key "resource-id";  description "The list contains all external certificate  resources of the OpenFlow Capable Switch.  The element 'resource-id' of OFExternalCertificateType  MUST be unique within this list.";  uses OFExternalCertificateType;  }  list flow-table {  key "resource-id";  description "The list contains all flow table resources of  the OpenFlow Capable Switch.  The element 'resource-id' of OFFlowTableType MUST be  unique within this list.";  uses OFFlowTableType;  }  }  container logical-switches {  description "This element contains a list of all OpenFlow  Logical Switches available at the OpenFlow Capable  Switch.";  list switch {  key "id";  description "The list of all OpenFlow Logical Switches on  the OpenFlow Capable Switch.  The element 'resource-id' of OFLogicalSwitchType MUST be  unique within this list.";  uses OFLogicalSwitchType;  }  }  } |

## OpenFlow Configuration Point

The Configuration Point is an entity that manages the switch using the OF-CONFIG protocol. Attributes of an OpenFlow Configuration Point allow the OpenFlow Capable Switches to identify a Configuration Point and specify which protocol is used for communication between Configuration Point and OpenFlow Capable Switch. The OpenFlow Capable Switch stores a list of Configuration Points that manage it or have managed it. An OpenFlow Configuration Point is to an OpenFlow Capable Switch what an OpenFlow Controller is to an OpenFlow Logical switch.

Instances of the Configuration Point class are used by switches to connect to a configuration point. Currently the only transport mapping that supports a connection set-up initiated by the switch to be configured is the mapping to the BEEP protocol (5). Other NETCONF transport mappings (6,7,8) may be extended in the future to also support connection set-up in this direction. Nevertheless SSH is used as a default connection protocol because connection initiation by the switch is optional.

### UML Diagram



Figure 5: Data Model Diagram for an OpenFlow Configuration Point

### XML Schema

|  |
| --- |
| <xs:group name="OFConfigurationPointType">  <xs:annotation>  <xs:documentation>  Representation of an OpenFlow Configuration Point.  Instances of the Configuration Point class SHOULD be stored  persistently across reboots of the OpenFlow Capable Switch.    When a connection is established between an OpenFlow Capable  Switch and a Configuration Point the switch MUST store the  connection information in an instance of the Configuration  Point class. If such an instance does not exist, the OpenFlow  Capable Switch MUST create an instance where it then stores  the connection information.    An OpenFlow Capable Switch that cannot initiate a connection  to a configuration point does not have to implement the  Configuration Point class. It SHOULD block attempts to write  to instances of the Configuration Point class with NETCONF  &lt;edit-config&gt; operations.  NETCONF &lt;edit-config&gt; operations MUST be implemented as  follows:  \* The 'id' element MUST be present at all &lt;edit-config&gt;  operations to identify the configuration point.  \* If the operation is 'merge' or 'replace', the element is  created if it does not exist, and its value is set to the  value found in the XML RPC data.  \* If the operation is 'create', the element is created if it  does not exist. If the element already exists, a  'data‑exists' error is returned.  \* If the operation is 'delete', the element is deleted if it  exists. If the element does not exist, a 'data‑missing'  error is returned.  </xs:documentation>  </xs:annotation>  <xs:sequence>  <xs:element name="id" type="OFConfigId">  <xs:annotation>  <xs:documentation>  A unique but locally arbitrary identifier that  identifies a Configuration Point within the context of an  OpenFlow Capable Switch.  This element MUST be present to identify the configuration  point.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="uri" type="inet:uri">  <xs:annotation>  <xs:documentation>  A locator of the Configuration Point. It  identifies the location of the Configuration Point as a  service resource and MUST include all information necessary  for the OpenFlow Capable Switch to connect to the  Configuration Point or re-connect to it should it become  disconnected. Such information MAY include, for example,  protocol, fully qualified domain name, IP address, port  number, etc.  This element MUST be present in the NETCONF data store.  If this element is not present in a NETCONF &lt;edit-config&gt;  operation 'create', 'merge' or 'replace' and the parent  element does not exist, a 'data-missing' error is  returned.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="protocol" type="OFConfigurationPointProtocolType">  <xs:annotation>  <xs:documentation>  The transport protocol that the Configuration  Point uses when communicating via NETCONF with the OpenFlow  Capable Switch.  This element is optional. If it is not present its value  defaults to 'ssh'.  </xs:documentation>  </xs:annotation>  </xs:element>  </xs:sequence>  </xs:group> |

### XML Example

|  |
| --- |
| <configuration-point>  <id>ConfigurationPoint1</id>  <uri>uri0</uri>  <protocol>ssh</protocol>  <configuration-point> |

### YANG Specification

|  |
| --- |
| grouping OFConfigurationPointType {  description "Representation of an OpenFlow Configuration Point.  Instances of the Configuration Point class SHOULD be stored  persistently across reboots of the OpenFlow Capable Switch.    When a connection is established between an OpenFlow Capable  Switch and a Configuration Point the switch MUST store the  connection information in an instance of the Configuration  Point class. If such an instance does not exist, the OpenFlow  Capable Switch MUST create an instance where it then stores  the connection information.    An OpenFlow Capable Switch that cannot initiate a connection  to a configuration point does not have to implement the  Configuration Point class. It SHOULD block attempts to write  to instances of the Configuration Point class with NETCONF  <edit-config> operations.  NETCONF <edit-config> operations MUST be implemented as  follows:  \* The 'id' element MUST be present at all <edit-config>  operations to identify the configuration point.  \* If the operation is 'merge' or 'replace', the element is  created if it does not exist, and its value is set to the  value found in the XML RPC data.  \* If the operation is 'create', the element is created if it  does not exist. If the element already exists, a  'data‑exists' error is returned.  \* If the operation is 'delete', the element is deleted if it  exists. If the element does not exist, a 'data‑missing'  error is returned.";  leaf id {  type OFConfigId;  mandatory true;  description "A unique but locally arbitrary identifier that  identifies a Configuration Point within the context of an  OpenFlow Capable Switch.  This element MUST be present to identify the configuration  point.";  }  leaf uri {  type inet:uri;  mandatory true;  description "A locator of the Configuration Point. It  identifies the location of the Configuration Point as a  service resource and MUST include all information necessary  for the OpenFlow Capable Switch to connect to the  Configuration Point or re-connect to it should it become  disconnected. Such information MAY include, for example,  protocol, fully qualified domain name, IP address, port  number, etc.  This element MUST be present in the NETCONF data store.  If this element is not present in a NETCONF <edit-config>  operation 'create', 'merge' or 'replace' and the parent  element does not exist, a 'data-missing' error is  returned.";  }  leaf protocol {  type OFConfigurationPointProtocolType;  default "ssh";  description "The transport protocol that the Configuration  Point uses when communicating via NETCONF with the OpenFlow  Capable Switch.  This element is optional. If it is not present its value  defaults to 'ssh'.";  reference "The mappings of NETCONF to different transport  protocols are defined in RFC 6242 for SSH, RFC 4743 for  SOAP, RFC 4744 for BEEP, and RFC 5539 for TLS";  }  } |

## OpenFlow Logical Switch

The OpenFlow Logical Switch represents an instant of a logical switch that is available or can be made available on an OpenFlow Capable Switch. An OpenFlow Logical switch is a logical context which behaves as the datapath as described in the OpenFlow specification. The OpenFlow Logical Switch is connected to one or more OpenFlow Controllers via the OpenFlow protocol. It uses resources of the OpenFlow Capable Switch for realizing the capabilities offered via the OpenFlow protocol. The OpenFlow Logical Switch has relationships to

* OpenFlow Controllers that control the OpenFlow Capable Switch
* OpenFlow Resources that are available from the OpenFlow Capable Switch

### UML Diagram



Figure 6: Data Model Diagram for an OpenFlow Logical Switch

### XML Schema

|  |
| --- |
| <xs:complexType name="OFLogicalSwitchType">  <xs:sequence>  <xs:element name="id"  type="OFConfigID"/>  <xs:elementname="capabilities"  type="OFLogicalSwitchCapabilitiesType"/>  <xs:element name="datapath-id"  type="OFConfigID"/>  <xs:element name="enabled"  type="xs:boolean"/>  <xs:element name="check-controller-certificate"  type="xs:boolean"/>  <xs:element name="lost-connection-behavior"  type="OFLogicalSwitchLostConnnectionBehavior"/>  <xs:element name="controllers"  type="OFControllerListType"/>  <xs:element name="resources"  type="OFLogicalSwitchResourceListType"/>  </xs:sequence>  </xs:complexType>  <xs:simpleType name="OFLogicalSwitchLostConnnectionBehavior">  <xs:restriction base="xs:string">  <xs:enumeration value="failSecureMode"/>  <xs:enumeration value="failStandaloneMode"/>  </xs:restriction>  </xs:simpleType>  <xs:complexType name="OFControllerListType">  <xs:sequence>  <xs:element name="controller"  type="OFControllerType"  maxOccurs="unbounded"/>  </xs:sequence>  </xs:complexType>  <xs:complexType name="OFLogicalSwitchResourceListType">  <xs:sequence>  <xs:element name="port"  type="OFConfigID" maxOccurs="unbounded"/>  <xs:element name="queue"  type="OFConfigID"  maxOccurs="unbounded"/>  <xs:element name="certificate"  type="OFConfigID" minOccurs="0" maxOccurs="1"/>  <xs:element name="flow-table"  type="OFConfigID"  maxOccurs="unbounded"/>  </xs:sequence>  </xs:complexType> |

### XML Example

|  |
| --- |
| <logical-switch>  <id>LogicalSwitch5</id>  <capabilities>  ...  <capabilities>  <datapath-id>datapath-id0</datapath-id>  <enabled>true</enabled>  <check-controller-certificate>false</check-controller-certificate>  <lost-connection-behavior>failSecureMode</lost-connection-behavior>  <controllers>  ...  </controllers>  <resources>  <port>port2</port>  <port>port3</port>  <queue>queue0</queue>  <queue>queue1</queue>  <certificate>ownedCertificate4</certificate>  <flow-table>1</flow-table>  <flow-table>2</flow-table>  …  <flow-table>255</flow-table>  </resources>  </logical-switch> |

### Normative Constraints

An OpenFlow Logical Switch is identified by identifier <id>. The identifier MUST be unique within the context of the OpenFlow Capable Switch. It MUST be persistent across reboots of the OpenFlow Capable Switch.

Element <capabilities> contains the capability items the OpenFlow Logical Switch MAY implement. Configuration of these capability items are out of scope of OF-CONFIG1.1. These OpenFlow Logical Switch items MAY be discovered by the configuration point using a NETCONF get-config request. Capability item definition details are included in section 7.4.

Element <datapath-id> identifies the OpenFlow Logical Switch to the OpenFlow controllers that has been assigned to the OpenFlow Logical Switch. The <datapath-id> MUST be unique within the context of OpenFlow Controllers associated with OpenFlow Logical Switch. The <datapath-id>is a string value that MUST be formatted as a sequence of 10 2-digit hexadecimal numbers that are separated by colons, e.g.,01:23:45:67:89:ab:cd:ef:01:23. The case of the hexadecimal digits MUST be ignored.

Element <enabled> denotes the administrative state of the OpenFlow Logical Switch. A value of “false” means the OpenFlow Logical Switch MUST NOT communicate with any OpenFlow Controllers, MUST NOT conduct any OpenFlow processing, and SHOULD NOT be utilizing computational or network resources of the underlying platform.

Element <check-controller-certificate> defines the behavior of the OpenFlow Logical Switch when establishing a connection to a controller. If set to value “false”, the logical switch will connect to a controller without checking any controller certificate. If set to value “true”, then the logical switch will connect to a controller with element <protocol> set to “TLS”, only if the controller provides a certificate that can be verified with one of the certificates stored in the list of <external-certificates> in the OpenFlow Capable Switch.

Element <lost-connection-behavior> defines the behavior of the OpenFlow Logical Switch in case it loses contact with all controllers. Section 6.4 of the OpenFlow specification 1.3 defines two alternative modes in such a case: fails secure mode and fail standalone mode. These are the only allowed values for this element. Default is the fail secure mode.

Element <resources> contains the list of all resources of the OpenFlow Capable Switch that the OpenFlow Logical Switch has exclusive access to. Any resource identified in the <resources>list of a Logical Switch MUST be present in the <resources> list of the OpenFlow Capable Switch containing the OpenFlow Logical Switch. Resources are identified by a <port> element, a <queue> element, a <certificate> element, or a <flow-table> element. Values of these elements MUST match a value of an element <resource-id> of a resource of the OpenFlow Capable Switch.

Any <port>, <queue> or <flow-table> resource identified in the <resources> list of an OpenFlow Logical Switch MUST NOT be identified in the <resources> list of any other OpenFlow Logical Switch.

If there is a <certificate> element present, the logical switch MUST provide the identified certificate when connecting to a controller that has its element <protocol> set to TLS.

The following elements of the OpenFlow Logical Switch can be modified by a NETCONF edit-config request or retrieved by a NETCONF get-config request: <id>, <datapath-id>, <enabled>. Elements in the <resources> list can also be modified and retrieved by those commands.

### YANG Specification

|  |
| --- |
| typedef datapath-id-type {  type string {  pattern  '[0-9a-fA-F]{2}(:[0-9a-fA-F]{2}){7}';  }  description "The datapath-id type represents an OpenFlow datapath identifier.";  }  grouping openflow-logical-switch-grouping {  description "This grouping specifies all properties of an OpenFlow Logical Switch.";  leaf id {  type inet:uri;  mandatory true;  description "An unique but locally arbitrary identifier that identifies a Logical Switch within a Capable Switch and is persistent across reboots of the system.";  }  container capabilities {  description "This container specifies all capability items of an OpenFlow Logical Switch.";  uses openflow-logical-switch-capabilities-grouping;  }  leaf datapath-id {  type datapath-id-type;  mandatory true;  description "The datapath identifier of the Logical Switch that uniquely identifies this Logical Switch in the controller.";  }  leaf enabled {  type boolean;  mandatory true;  description "Specifies if the Logical Switch is enabled.";  }  container controllers {  description "The list of controllers for this Logical switch.";  list controller {  key "id";  unique "id";  description "The list of controllers that are assigned to the OpenFlow Logical Switch.";  uses openflow-controller-grouping;  }  }  container resources {  description "The following lists reference to all resources of the OpenFlow Capable Switch that the OpenFlow Logical Switch has exclusive access to.";  leaf-list port {  type leafref {  path "/capable-switch/resources/port/resource-id";  }  description "The list references to all port resources of the OpenFlow Capable Switch that the OpenFlow Logical Switch has exclusive access to.";  }  leaf-list queue {  type leafref {  path "/capable-switch/resources/queue/resource-id";  }  description "The list references to all queue resources of the OpenFlow Capable Switch that the OpenFlow Logical Switch has exclusive access to.";  }  leaf certificate {  type leafref {  path "/capable-switch/resources/owned-certificate/resource-id";  }  description "The reference to the owned certificate in  the OpenFlow Capable Switch that the OpenFlow Logical  Switch used to identify itself.";  }  leaf-list flow-table {  type leafref {  path "/capable-switch/resources/flow-table/resource-id";  }  description "The list references to all flow table resources of the OpenFlow Capable Switch that the OpenFlow Logical Switch has exclusive access to.";  }  }  } |

## Logical Switch Capabilities

### UML Diagram



Figure 7: Data Model Diagram for an OpenFlow Logical Switch Capabilities

### XML Schema

|  |
| --- |
| <xs:complexType name="OFLogicalSwitchCapabilitiesType">  <xs:sequence>  <xs:element name="max-buffered-packets" type="xs:integer">  <xs:annotation>  <xs:documentation>The maximum number of packets the switch can buffer when sending packets to the controller using packet-in messages. See OpenFlow protocol 1.2 section A.3.1  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="max-tables" type="xs:integer">  <xs:annotation>  <xs:documentation> The number of flow tables supported by the switch. See OpenFlow protocol 1.2 section A.3.1  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="max-ports" type="xs:integer">  <xs:annotation>  <xs:documentation> The number of ports supported by the switch. See OpenFlow protocol 1.2 section A.3.1  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="flow-statistics" type="xs:boolean">  <xs:annotation>  <xs:documentation> Whether the switch supports flow statistics. See OpenFlow protocol 1.2 section A.3.1  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="table-statistics" type="xs:boolean">  <xs:annotation>  <xs:documentation> Whether the switch supports table statistics. See OpenFlow protocol 1.2 section A.3.1  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="port-statistics" type="xs:boolean">  <xs:annotation>  <xs:documentation>Whether the switch supports port statistics. See OpenFlow protocol 1.2 section A.3.1  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="group-statistics" type="xs:boolean">  <xs:annotation>  <xs:documentation> Whether the switch supports group statistics. See OpenFlow protocol 1.2 section A.3.1  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="queue-statistics" type="xs:boolean">  <xs:annotation>  <xs:documentation>Whether the switch supports queue statistics. See OpenFlow protocol 1.2 section A.3.1  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="reassemble-ip-fragments" type="xs:boolean">  <xs:annotation>  <xs:documentation>Whether the switch supports reassemble IP fragments. See OpenFlow protocol 1.2 section A.3.1  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="block-looping-ports" type="xs:boolean">  <xs:annotation>  <xs:documentation>"true" indicates that a switch protocol outside of OpenFlow, such as 802.1D Spanning Tree, will detect topology loops and block ports to prevent packet loops. See OpenFlow protocol 1.2 section A.3.1  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="reserved-port-types"  type="OFReservedPortTypes">  <xs:annotation>  <xs:documentation>Specify generic forwarding actions such as sending to the controller, flooding, or forwarding using non-OpenFlow methods, such as "normal" switch processing. SeeOpenFlow protocol 1.2 section 4.5.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="group-types" type="OFGroupTypes">  <xs:annotation>  <xs:documentation>The group types supported by the switch. SeeOpenFlow protocol 1.2 section 5.4.1.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="group-capabilities" type="OFGroupCapabilities">  <xs:annotation>  <xs:documentation>The group capabilities supported by the switch. SeeOpenFlow protocol 1.2 section A.3.5.9.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="action-types" type="OFActionTypes">  <xs:annotation>  <xs:documentation>The action types supported by the switch. See OpenFlow protocol 1.2 section 5.9 and A.2.5.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="instruction-types" type="OFInstructionTypes">  <xs:annotation>  <xs:documentation>The instruction types supported by the switch. See OpenFlow protocol 1.2 section 5.6.  </xs:documentation>  </xs:annotation>  </xs:element>  </xs:sequence>  </xs:complexType>  <xs:complexType name="OFReservedPortTypes">  <xs:sequence minOccurs="1" maxOccurs="unbounded">  <xs:element name="type" type="OFReservedPortType"/>  </xs:sequence>  </xs:complexType>  <xs:simpleType name="OFReservedPortType">  <xs:restriction base="xs:string">  <xs:enumeration value="all"/>  <xs:enumeration value="controller"/>  <xs:enumeration value="table"/>  <xs:enumeration value="inport"/>  <xs:enumeration value="any"/>  <xs:enumeration value="local"/>  <xs:enumeration value="normal"/>  <xs:enumeration value="flood"/>  </xs:restriction>  </xs:simpleType>  <xs:complexType name="OFGroupTypes">  <xs:sequence minOccurs="1" maxOccurs="unbounded">  <xs:element name="type" type="OFGroupType"/>  </xs:sequence>  </xs:complexType>  <xs:simpleType name="OFGroupType">  <xs:restriction base="xs:string">  <xs:enumeration value="all"/>  <xs:enumeration value="select"/>  <xs:enumeration value="indirect"/>  <xs:enumeration value="fast-failover"/>  </xs:restriction>  </xs:simpleType>  <xs:complexType name="OFGroupCapabilities">  <xs:sequence minOccurs="1" maxOccurs="unbounded">  <xs:element name="capability" type="OFGroupCapability"/>  </xs:sequence>  </xs:complexType>  <xs:simpleType name="OFGroupCapability">  <xs:restriction base="xs:string">  <xs:enumeration value="select-weight"/>  <xs:enumeration value="select-liveness"/>  <xs:enumeration value="chaining"/>  <xs:enumeration value="chaining-check"/>  </xs:restriction>  </xs:simpleType>  <xs:complexType name="OFActionTypes">  <xs:sequence minOccurs="1" maxOccurs="unbounded">  <xs:element name="type" type="OFActionType"/>  </xs:sequence>  </xs:complexType>  <xs:simpleType name="OFActionType">  <xs:restriction base="xs:string">  <xs:enumeration value="output"/>  <xs:enumeration value="copy-ttl-out"/>  <xs:enumeration value="copy-ttl-in"/>  <xs:enumeration value="set-mpls-ttl"/>  <xs:enumeration value="dec-mpls-ttl"/>  <xs:enumeration value="push-vlan"/>  <xs:enumeration value="pop-vlan"/>  <xs:enumeration value="push-mpls"/>  <xs:enumeration value="pop-mpls"/>  <xs:enumeration value="set-queue"/>  <xs:enumeration value="group"/>  <xs:enumeration value="set-nw-ttl"/>  <xs:enumeration value="dec-nw-ttl"/>  <xs:enumeration value="pop-mpls"/>  <xs:enumeration value="set-field"/>  </xs:restriction>  </xs:simpleType>  <xs:complexType name="OFInstructionTypes">  <xs:sequence minOccurs="1" maxOccurs="unbounded">  <xs:element name="type" type="OFInstructionType"/>  </xs:sequence>  </xs:complexType>  <xs:simpleType name="OFInstructionType">  <xs:restriction base="xs:string">  <xs:enumeration value="apply-actions"/>  <xs:enumeration value="clear-actions"/>  <xs:enumeration value="write-actions"/>  <xs:enumeration value="write-metadata"/>  <xs:enumeration value="goto-table"/>  </xs:restriction>  </xs:simpleType> |

### XML Example

|  |
| --- |
| <capabilities>  <max-buffered-packets>512</max-buffered-packets>  <max-tables>1024</max-tables>  <max-ports>2048</max-ports>  <flow-statistics>true</flow-statistics>  <table-statistics>false</table-statistics>  <port-statistics>true</port-statistics>  <group-statistics>false</group-statistics>  <queue-statistics>true</queue-statistics>  <reassemble-ip-fragments>false</reassemble-ip-fragments>  <block-looping-ports>false</block-looping-ports>  <reserved-port-types>  <type>all</type>  </reserved-port-types>  <group-types>  <type>all</type>  </group-types>  <group-capabilities>  <capability>select-weight</capability>  </group-capabilities>  <action-types>  <type>output</type>  </action-types>  <instruction-types>  <type>apply-actions</type>  <type>write-actions</type>  </instruction-types>  </capabilities> |

### Normative Constraints

Element <capabilities> contains the capability items the OpenFlow Logical Switch MAY implement. Configuration of these capability items are out of scope of OF-CONFIG1.1. It is assumed that capabilities have been configured for OpenFlow Logical switches either as part of instantiation of these switches or through some out of band mechanisms.These OpenFlow Logical Switch items can be discovered by the configuration point using a NETCONF get-config request.

Element <max-buffered-packets> denotes the maximum number of packets the logical switch can buffer when sending packets to the controller using packet-in messages.

Element <max-tables> denotes the maximum number of flow tables supported by the logical switch.

Element <max-ports> denotes the maximum number of ports supported by the logical switch.

Element <flow-statistics> indicates whether the logical switch supports flow statistics functionality.

Element <table-statistics> indicates whether the logical switch supports table statistics functionality.

Element <port-statistics> indicates whether the logical switch supports port statistics functionality.

Element <group-statistics> indicates whether the logical switch supports group statistics functionality.

Element <queue-statistics> indicates whether the logical switch supports queue statistics functionality.

Element <reassemble-ip-fragments> indicates whether the logical switch support reassemble IP fragments functionality.

Element <block-looping-ports> indicates whether a switch protocol outside of OpenFlow, such as 802.1D Spanning Tree, will detect topology loops and block ports to prevent packet loops.

Element <reserved-port-types> denotes generic forwarding actions such as sending to the controller, flooding, or forwarding using non-OpenFlow methods, such as "normal" switch processing.

Element <group-types> denotes the group types supported by the OpenFlow logical switch.

Element <group-capabilities> denotes the group capabilities supported by the OpenFlow logical switch.

Element <action-types> denotes the action types supported by the OpenFlow logical switch.

Element <instruction-types> denotes the instruction types supported by the OpenFlow logical switch.

Detailed definitions of these capability items can be found in OpenFlow Switch Specification 1.2[1].

### Yang Specification

|  |
| --- |
| typedef action-type {  description "The types of actions defined in OpenFlow Switch Specification version 1.2.";  type enumeration {  enum output;  enum acopy-ttl-out;  enum copy-ttl-in;  enum set-mpls-ttl;  enum dec-mpls-ttl;  enum push-vlan;  enum pop-vlan;  enum push-mpls;  enum pop-mpls;  enum set-queue;  enum group;  enum set-nw-ttl;  enum dec-nw-ttl;  enum set-field;  }  }  typedef instruction-type {  description "The types of instructions defined in OpenFlow Switch Specification version 1.2.";  type enumeration {  enum apply-actions;  enum clear-actions;  enum write-actions;  enum write-metadata;  enum goto-table;  }  }  grouping openflow-logical-switch-capabilities-grouping {  description "This grouping specifies all properties of an OpenFlow logical switch's capabilities.";  leaf max-buffered-packets {  type uint32;  description "The maximum number of packets the logical switch can buffer when sending packets to the controller using packet-in messages.";  }  leaf max-tables {  type uint8;  description "The number of flow tables supported by the logical switch.";  }  leaf max-ports {  type uint32;  description "The number of flow tables supported by the logical switch.";  }  leaf flow-statistics {  type boolean;  default false;  description "Specifies if the logical switch supports flow statistics.";  }  leaf table-statistics {  type boolean;  default false;  description "Specifies if the logical switch supports table statistics.";  }  leaf port-statistics {  type boolean;  default false;  description "Specifies if the logical switch supports port statistics.";  }  leaf group-statistics {  type boolean;  default false;  description "Specifies if the logical switch supports group statistics.";  }  leaf queue-statistics {  type boolean;  default false;  description "Specifies if the logical switch supports queue statistics.";  }  leaf reassemble-ip-fragments {  type boolean;  default false;  description "Specifies if the logical switch supports reassemble IP fragments.";  }  leaf block-looping-ports {  type boolean;  default false;  description "'true' indicates that a switch protocol outside of OpenFlow, such as 802.1D Spanning Tree, will detect topology loops and block ports to prevent packet loops."  }  container reserved-port-types {  description "Specify generic forwarding actions such as sending to the controller, flooding, or forwarding using non-OpenFlow methods, such as 'normal' switch processing.";  reference "The types of reserved ports are defined in OpenFlow Switch Specification version 1.2.";  leaf-list type {  type enumeration {  enum all;  enum controller;  enum table;  enum inport;  enum any;  enum normal;  enum flood;  }  }  }  container group-types {  description "Specify the group types supported by the logical switch.";  reference "The types of groups are defined in OpenFlow Switch Specification version 1.2.";  leaf-list type {  type enumeration {  enum all;  enum select;  enum indirect;  enum fast-failover;  }  }  }  container group-capabilities {  description "Specify the group capabilities supported by the logical switch.";  reference "The types of group capability are defined in OpenFlow Switch Specification version 1.2.";  leaf-list capability {  type enumeration {  enum select-weight;  enum select-liveness;  enum chaining;  enum chaining-check;  }  }  }  container action-types {  description "Specify the action types supported by the logical switch.";  leaf-list type {  type action-type;  }  }  container instruction-types {  description "Specify the instruction types supported by the logical switch.";  leaf-list type {  type instruction-type;  }  }  } |

## OpenFlow Controller

The OpenFlow Controller class represents an entity that acts as OpenFlow Controller of an OpenFlow Logical Switch. Attributes of the class indicate the role of the controller and parameters of the OpenFlow connection to the controller.

### UML Diagram



Figure 8: Data Model Diagram for an OpenFlow Controller

### XML Schema

|  |
| --- |
| <xs:complexType name="OFControllerType">  <xs:sequence>  <xs:element name="id"  type="OFConfigID"/>  <xs:element name="role"  type="OFControllerRoleType"/>  <xs:element name="ip-address"  type="inet:ip-prefix"/>  <xs:element name="port"  type="inet:port-number"/>  <xs:element name="local-ip-address"  type="inet:ip-address"/>  <xs:element name="local-port"  type="inet:port-number"/>  <xs:element name="protocol"  type="OFControllerProtocolType"/>  <xs:element name="state"  type="OFControllerOpenFlowStateType"/>  </xs:sequence>  </xs:complexType>  <xs:simpleType name="OFControllerRoleType">  <xs:restriction base="xs:string">  <xs:enumeration value="master"/>  <xs:enumeration value="slave"/>  <xs:enumeration value="equal"/>  </xs:restriction>  </xs:simpleType>  <xs:simpleType name="OFControllerProtocolType">  <xs:restriction base="xs:string">  <xs:enumeration value="tcp"/>  <xs:enumeration value="tls"/>  </xs:restriction>  </xs:simpleType>  <xs:complexType name="OFControllerOpenFlowStateType">  <xs:sequence>  <xs:element name="connection-state"  type="OFControllerConnectionStateType"/>  <xs:element name="current-version"  type="OFOpenFlowVersionType"/>  <xs:element name="supported-versions"  type="OFOpenFlowSupportedVersionsType"/>  </xs:sequence>  </xs:complexType>  <xs:simpleType name="OFControllerConnectionStateType">  <xs:restriction base="xs:string">  <xs:enumeration value="up"/>  <xs:enumeration value="down"/>  </xs:restriction>  </xs:simpleType>  <xs:complexType name="OFOpenFlowSupportedVersionsType">  <xs:sequence>  <xs:element name="version" type="OFOpenFlowVersionType"/>  </xs:sequence>  </xs:complexType>  <xs:simpleType name="OFOpenFlowVersionType">  <xs:restriction base="xs:string">  <xs:enumeration value="1.2"/>  <xs:enumeration value="1.1"/>  <xs:enumeration value="1.0"/>  </xs:restriction>  </xs:simpleType> |

### XML Example

|  |
| --- |
| <controller>  <id>Controller3</id>  <role>master</role>  <ip-address>192.168.2.1/26</ip-address>  <port>6633</port>  <local-ip-address>192.168.2.129</local-ip-address>  <local-port>32768</local-port>  <protocol>tcp</protocol>  <state>  <connection-state>up</connection-state>  <current-version>1.2</current-version>  <supported-versions>  <version>1.2</version>  <version>1.1</version>  </supported-versions>  </state>  </controller> |

### Normative Constraints

An OpenFlow Controller is identified by identifier <id>. The identifier MUST be unique within the context of the OpenFlow Capable Switch. It MUST be persistent across reboots of the OpenFlow Capable Switch.

Element <role> indicates the role of the controller. Semantics of these roles are specified in the OpenFlow 1.2 specification. It is RECOMMENDED that the roles of controllers are not configured by OF-CONFIG 1.0 but determined using the OpenFlow 1.2 protocol. Controllers configured by OF-CONFIG 1.0 SHOULD have the default role “equal”. A role other than “equal” MAY be assigned to a controller. Roles “slave” and “equal” MAY be assigned to multiple controllers. Role “master” MUST NOT be assigned to more than one controller.

Elements <ip-address> and <port> indicate the IP address and the port number of the OpenFlow Controller. The port number is optional. If not present, the default port number 6633 is assumed to be used.

Elements <local-ip-address> and <local-port> indicate the IP address and the port number used by the OpenFlow Logical Switch. Both elements are optional.

Element <protocol> indicates the transport protocol used for the OpenFlow connection. OpenFlow supports two transport protocols, TCP and TLS. If this optional element is not present, TLS is assumed to be used.

Element <state> represents various elements of known state of the OpenFlow Controller. Element <connection-state> represents the administrative state of the OpenFlow connection between the OpenFlow Logical Switch and the OpenFlow Controller. A value of “down” means that the OpenFlow Logical Switch MUST NOT communicate with the OpenFlow Controller via theOpenFlow protocol. If the value of <connection-state> is set to up, element <current-version> MUST represent the version of the OpenFlow protocol in use between the OpenFlow Logical Switch and the OpenFlow Controller. The element <supported-versions> represents the versions of the OpenFlow protocol that the OpenFlow Controller supports <supported-versions> SHOULD be set to all versions of the OpenFlow protocol supported by the OpenFlow Controller.

The following elements of the OpenFlow Controller can be modified by a NETCONF edit-config request or retrieved by a NETCONF get-config request: <id>, <role>, <ip-address>, <port>, <local-ip-address>, <local-port>, <protocol>, <connection-state>, <current-version>, <supported-versions>.

### YANG Specification

|  |
| --- |
| typedef openflow-version {  type enumeration {  enum "1.0";  enum "1.1";  enum "1.2";  }  description "This enumeration contains the all OpenFlow versions released so far.";  }  grouping openflow-controller-grouping {  description "This grouping specifies all properties of an OpenFlow Logical Switch Controller.";  leaf id {  type inet:uri;  mandatory true;  description "An unique but locally arbitrary identifier that identifies a controller within a OpenFlow Logical Switch and is persistent across reboots of the system.";  }  leaf role {  type enumeration {  enum master;  enum slave;  enum equal;  }  default equal;  description "The predefined role of the controller.";  }  leaf ip-address {  type inet:ip-address;  mandatory true;  description "The IP address of the controller to connect to.";  }  leaf port {  type inet:port-number;  default 6633;  description "The port number at the controller to connect to.";  }  leaf local-ip-address {  type inet:ip-address;  description "This specifies the source IP for packets sent to this controller and overrides the default IP used.";  }  leaf local-port {  type inet:port-number;  default 0;  description "The port number the switch listens on. If 0 the port is chosen dynamically.";  }  leaf protocol {  type enumeration {  enum "tcp";  enum "tls";  }  default "tcp";  description "The protocol used for connecting to the controller.";  }  container state {  description "This container holds connection state information that indicate if the Logical Switch is connected, what versions are supported, and which one is used.";  leaf connection-state {  type up-down-state-type;  description "This object indicates if the Logical Switch is connected to the controller.";  }  leaf current-version {  type openflow-version;  description "This object contains the current OpenFlow version used between Logical Switch and Controller.";  }  leaf-list supported-versions {  type openflow-version;  description "This list of objects contains all the OpenFlow versions supported the controller.";  }  }  } |

## OpenFlow Resource

OpenFlow Resource is a superclass of OpenFlow Port, OpenFlow Queue, Owned Certificate and External Certificate. The superclass contains the identifier attribute that is inherited by all subclasses in addition to their individual identifiers.

### UML Diagram



Figure 9: Data Model Diagram for an OpenFlow Resource

### XML Schema

|  |
| --- |
| <xs:complexType name="OFResourceType">  <xs:sequence>  <xs:element name="resource-id" type="OFConfigID"/>  </xs:sequence>  </xs:complexType> |

### XML Example

The superclass is not instantiated.

### Normative Constraints

An OpenFlow Resource is identified by identifier <resource-id>. The identifier MUST be unique within the context of the OpenFlow Capable Switch. It MUST be persistent across reboots of the OpenFlow Capable Switch.

### YANG Specification

The base OpenFlow Resource has no specific correspondence in the YANG specification. The <resource-id> property is included in each individual resource.

## OpenFlow Port

The OpenFlow Port is an instance of an OpenFlow resource. It may represent a physical port or a logical port. A logical port represents a tunel endpoint as described in the OpenFlow protocol specification.

An OpenFlow Port contains a port configuration object and a port state object. A physical port contains a list of port feature objects. While there can’t be more than one instance of the Port Configuration and the Port State, there may be multiple Port Features. In the case where a port represents a tunnel endpoint, then the port does not contain Port Feature objects, but a Port tunnel object.

### UML Diagram



Figure 10: Data Model Diagram for an OpenFlow Port

### XML Schema

|  |
| --- |
| <xs:complexType name="OFPortType">  <xs:complexContent>  <xs:extension base="OFResourceType">  <xs:sequence>  <xs:element name="number"  type="xs:unsignedInt"/>  <xs:element name="name"  type="xs:string"/>  <xs:element name="current-rate"  type="xs:unsignedLong"/>  <xs:element name="max-rate"  type="xs:unsignedLong"/>  <xs:element name="configuration"  type="OFPortConfigurationType"/>  <xs:element name="state" type="OFPortStateType"/>  <xs:element name="features"  type="OFPortFeatureMasterList"  minOccurs=”0” maxOccurs=”unbounded”/>  <xs:choice minOccurs=”0” maxOccurs=”1”>  <xs:element name=”tunnel”  type="OFTunnelType"/>  <xs:element name=”ipgre-tunnel”  type="OFIPinGREtunnelType"/>  <xs:element name=”vxlan-tunnel”  type="OFVxLANTunnelType"/>  <xs:element name=”nvgre-tunnel”  type="OFNVGRETunnelType"/>  </xs:choice>  </xs:sequence>  </xs:extension>  </xs:complexContent>  </xs:complexType>  <xs:complexType name="OFPortFeatureMasterList">  <xs:sequence>  <xs:element name="current"  type="OFPortCurrentFeatureListType"/>  <xs:element name="advertised"  type="OFPortOtherFeatureListType"/>  <xs:element name="supported"  type="OFPortOtherFeatureListType"/>  <xs:element name="advertised-peer"  type="OFPortOtherFeatureListType"/>  </xs:sequence>  </xs:complexType>  <xs:complexType name="OFPortConfigurationType">  <xs:sequence>  <xs:element name="admin-state"  type="OFPortStateOptionsType"/>  <xs:element name="no-receive"  type="xs:boolean"/>  <xs:element name="no-forward"  type="xs:boolean"/>  <xs:element name="no-packet-in"  type="xs:boolean"/>  </xs:sequence>  </xs:complexType>  <xs:complexTypename="OFPortStateType">  <xs:sequence>  <xs:element name="oper-state"  type="OFPortStateOptionsType"/>  <xs:element name="blocked"  type="xs:boolean"/>  <xs:element name="live"  type="xs:boolean"/>  </xs:sequence>  </xs:complexType>  <xs:simpleType name="OFPortStateOptionsType">  <xs:restriction base="xs:string">  <xs:enumeration value="up"/>  <xs:enumeration value="down"/>  </xs:restriction>  </xs:simpleType>  <xs:complexTypename="OFPortCurrentFeatureListType">  <xs:sequence>  <xs:element name="rate"  type="OFPortRateType"/>  <xs:element name="auto-negotiate"  type="OFPortAutoNegotiateType"/>  <xs:element name="medium"  type="OFPortMediumType"/>  <xs:element name="pause"  type="OFPortPauseType" />  </xs:sequence>  </xs:complexType>  <xs:complexType name="OFPortOtherFeatureListType">  <xs:sequence>  <xs:element name="rate"  type="OFPortRateType"  maxOccurs="unbounded"/>  <xs:element name="auto-negotiate"  type="OFPortAutoNegotiateType"/>  <xs:element name="medium"  type="OFPortMediumType"  maxOccurs="unbounded"/>  <xs:element name="pause"  type="OFPortPauseType"/>  </xs:sequence>  </xs:complexType>  <xs:complexType name="OFTunnelType">  <xs:sequence>  <xs:choice>  <xs:element name=”local-endpoint-ipv4-address”  type="inet:ipv4-address"/>  <xs:element name=”local-endpoint-ipv6-address”  type="inet:ipv6-address"/>  <xs:element name=”local-endpoint-mac-address”  type="inet:mac-address"/>  </xs:choice>  <xs:choice>  <xs:element name=”remote-endpoint-ipv4-address”  type="inet:ipv4-address"/>  <xs:element name=”remote-endpoint-ipv6-address”  type="inet:ipv6-address"/>  <xs:element name=”remote-endpoint-mac-address”  type="inet:mac-address"/>  </xs:choice>  </xs:sequence>  </xs:complexType>  <xs:complexType name="OFIPinGREtunnelType">  <xs:complexContent>  <xs:extension base="OFTunnelType">  <xs:sequence>  <xs:element name="checksum-present" type="xs:boolean"  default="true"/>  <xs:element name="key-present" type="xs:boolean"  default="true"/>  <xs:element name="key" type="xs:unsignedInt"/>  <xs:element name="sequence-number-present" type="xs:boolean"  default="false"/>  </xs:sequence>  </xs:extension>  </xs:complexContent>  </xs:complexType>  <xs:complexType name="OFVxLANTunnelType">  <xs:complexContent>  <xs:extension base="OFTunnelType">  <xs:sequence>  <xs:element name="vni-valid" type="xs:boolean"  default="true"/>  <xs:element name="vni" type="xs:unsignedInt"/>  <xs:element name="vni-multicast-group" type="inet:ip-address"/>  <xs:element name="udp-source-port" type="xs:unsignedInt"/>  <xs:element name="udp-dest-port" type="xs:unsignedInt"  default=IANA\_VXLAN\_PORT/>  <xs:element name="udp-checksum" type="xs:boolean"  default="false"/>  </xs:sequence>  </xs:extension>  </xs:complexContent>  </xs:complexType>  <xs:complexType name="OFNVGRETunnelType">  <xs:complexContent>  <xs:extension base="OFTunnelType">  <xs:sequence>  <xs:element name="tni" type="xs:unsignedInt"/>  <xs:element name="tni-user" type="xs:unsignedInt"/>  <xs:element name="tni-multicast-group"  type="inet:ip-address"/>  </xs:sequence>  </xs:extension>  </xs:complexContent>  </xs:complexType> |

### XML Examples

|  |
| --- |
| <!-- Example for a physical port -->  <port>  <resource-id>Port214748364</resource-id>  <number>214748364</number>  <name>name0</name>  <current-rate>10000</current-rate>  <max-rate>10000</max-rate>  <configuration>  <admin-state>up</admin-state>  <no-receive>false</no-receive>  <no-forward>false</no-forward>  <no-packet-in>false</no-packet-in>  </configuration>  <state>  <oper-state>up</oper-state>  <blocked>false</blocked>  <live>false</live>  </state>  <features>  <current>  ...  </current>  <advertised>  ...  </advertised>  <supported>  ...  </supported>  <advertised-peer>  ...  </advertised-peer>  </features>  </port>  <!-- Example for a logical port representing a VxLAN tunnel -->  <port>  <resource-id>LogicalPort14</resource-id>  <number>14</number>  <name>logicalPort14VxLAN</name>  <max-rate>10000</max-rate>  <configuration>  <admin-state>up</admin-state>  <no-receive>false</no-receive>  <no-forward>false</no-forward>  <no-packet-in>false</no-packet-in>  </configuration>  <state>  <oper-state>up</oper-state>  <blocked>false</blocked>  <live>true</live>  </state>  <vxlan-tunnel>  <local-endpoint-ipv4-address>  192.0.2.9  </local-endpoint-ipv4-address>  <remote-endpoint-ipv4-address>  192.0.2.112  </remote-endpoint-ipv4-address>  <vni-valid>true</vni-valid>  <vni>15581985</vni>  <udp-source-port>3804</udp-source-port>  <udp-dest-port>3801</udp-dest-port>  <udp-checksum>false</udp-checksum>  </vxlan-tunnel>  </port>  <!-- Example for a logical port representing a NVGRE tunnel -->  <port>  <resource-id>LogicalPort17</resource-id>  <number>17</number>  <name>logicalPort17NVGRE</name>  <max-rate>1000</max-rate>  <configuration>  <admin-state>up</admin-state>  <no-receive>false</no-receive>  <no-forward>false</no-forward>  <no-packet-in>false</no-packet-in>  </configuration>  <state>  <oper-state>up</oper-state>  <blocked>false</blocked>  <live>true</live>  </state>  <nvgre-tunnel>  <local-endpoint-ipv4-address>  192.0.2.7  </local-endpoint-ipv4-address>  <remote-endpoint-ipv4-address>  192.0.2.97  </remote-endpoint-ipv4-address>  <tni>15581985</tni>  <tni-resv>173</tni-resv>  </nvgre-tunnel>  </port> |

### Normative Constraints

An OpenFlow Port is identified by identifier <resource-id> within the context of the OpenFlow Capable Switch and OpenFlow Logical Switches. Element <resource-id> is inherited from superclass OpenFlow Resource.

Element <number> identifies the OpenFlow Port to OpenFlow Controllers. If the OpenFlow Port is associated with an OpenFlow Logical Switch, <number> MUST be unique within the context of the OpenFlow Logical Switch.

Element <name> assists OpenFlow Controllers in identifying OpenFlow Ports. <name> MAY be defined. If the OpenFlow Port is associated with an OpenFlow Logical switch and <name> is defined, <name> MUST be unique within the context of the OpenFlow Logical Switch.

Elements <current-rate> and <max-rate> indicate the current and maximum bit rate of the port. Both values are to be provided in units of kilobit per second (kbps). Those elements are only valid if the element <rate> in the current Port Features has a value of “other”.

#### Port Configuration

Element <configuration> represents the expected behavior of the port based on explicit configuration.

Element <configuration> contains four further elements: <admin-state>, <no-receive>, <no-forward>, <no-packet-in>.

Element <admin-state> represents the configured link state of the port and MUST be set to either up or down.

Element <no-receive> MUST be set to either true or false. A value of “true” means the port is not receiving any traffic.

Element <no-forward>MUST be set to either true or false. A value of “true” means the port is not forwarding any packets.

Element <no-packet-in> MUST be set to either true or false. A value of “true” means port is not receiving any packets.

#### Port State

Element <state> contains three further elements: <oper-state>, <blocked>, <live>.

Element <oper-state> represents the reported link state of the port and MUST have a value of either “up” or “down“.

Element <blocked> MUST have a value of either “true” or “false”. A value of “true” means the port has been blocked from receiving or sending traffic.

Element <live> MUST have a value of either “true” or “false” .A value of “true” means the port is active and sending/receiving packets.

#### Port Features

An OpenFlow Port contains a list of OpenFlow Port Features in element <features>which contains four sub-lists represented by elements <current>, <advertised>, <supported>,<advertised-peer>.These four lists MUST contain the features associated with the OpenFlow Port. The specific semantics of feature membership in each of these four sub-lists are defined in the OpenFlow protocol.

The following elements of the OpenFlow Port can be modified by a NETCONF edit-config request or retrieved by a NETCONF get-config request: <resource-id>, <number>, <name>, <admin-state>, <no-receive>, <no-forward>, <no-packet-in>.

#### Tunnel (Logical Port)

A tunnel endpoint corresponds to a logical OpenFlow port that supports a specific encapsulation method. A common use case for tunnels is to create virtual overlay networks by encapsulating, for example, Layer 2 (Ethernet) traffic in Layer 3 (IP) packets. OF-CONFIG enables the association of logical OpenFlow ports with an associated tunnel type and corresponding parameters for the tunnel.

Element <tunnel> is only present if the port is a logical port that represents a tunnel endpoint. It contains a tunnel type specific element. Currently defined are the following tunnel types: IPinGRE, VxLAN, and NVGRE. All tunnel types have a common set of contained elements: a local and a remote endpoint address (<local-XXX-address> and <remote-XXX-address>) for address types IPv4, IPv6, and MAC..

#### IPinGRE Tunnel

For IP-in-GRE tunnels, further elements may be used. The presence of the checksum, key, and sequence number is indicated by boolean elements <checksum-present>, <key-present>, and <sequence-number-present>. Element <key> indicates the key value used. It should not be present if the value of element <key-present> is ”false”. In an implementation of IP-in-GRE tunnels, the <key> element could be used to set the OXM\_OF\_TUNNEL\_ID match field metadata in the OpenFlow protocol.

#### VXLAN Tunnel

VxLAN tunnel elements are based on the specification current at the time of this writing (draft-mahalingam-dutt-dcops-vxlan-01.txt). The <vni-valid> boolean element indicates how the corresponding flag should be set in packets sent on the tunnel. It SHOULD generally be set to “true”. The <vni> element is the virtual network identifier assigned to all packets sent on the tunnel. ”. A VxLAN implementation may use the <vni> element to set the OXM\_OF\_TUNNEL\_ID match field metadata in the OpenFlow protocol. If IP multicast is used to support broadcast on the tunnel the <vni-multicast-group> element MAY be used to specify the corresponding multicast IP address. The <udp-source-port> element MAY be used to set the outer UDP source port number, e.g., to ensure consistent hashing for ECMP. If <udp-source-port> is absent, it is expected that the source port will be set dynamically during transmission. The <udp-dest-port> SHOULD be set to the IANA assigned well-known port number for VxLAN (pending assignment as of this writing). The <udp-checksum> element is a boolean flag to indicate whether or not the outer UDP checksum should be set. Typically, this element SHOULD be set to “false”.

#### NVGRE Tunnel

NVGRE tunnel elements are based on the specification current at the time of this writing (draft-sridharan-virtualization-nvgre-00.txt). The <tni> element is the tenant network identifier assigned to all packets sent on the tunnel. NVGRE implementations may map the <tni> element to the OXM\_OF\_TUNNEL\_ID match field metadata in the OpenFlow protocol. The <tni-user> element MAY be present – it is used to set the reserved user-defined bits of the GRE key field, e.g., to introduce entropy for the purposes of exploiting path diversity. If IP multicast is used to support broadcast on the tunnel the <tni-multicast-group> element MAY be used to specify the corresponding multicast IP address.

### YANG Specification

|  |
| --- |
| grouping openflow-port-resource-grouping {  description "This grouping specifies all properties of a port resource.";  leaf resource-id {  type inet:uri;  description "A unique but locally arbitrary identifier that identifies a port and is persistent across reboots of the system.";  }  leaf number {  type uint64;  config false;  mandatory true;  description "An unique but locally arbitrary number that identifies a port and is persistent across reboots of the system.";  }  leaf name {  type string {  length "1..16";  }  config false;  description "Textual port name to ease identification of the port at the switch.";  }  leaf current-rate {  when "../features/current/rate='other'" {  description "This element is only allowed if the element rate of the current features has value 'other'.";  }  type uint32;  units "kbit/s";  config false;  description "The current rate in kilobit/second if the current rate selector has value 'other'.";  }  leaf max-rate {  when "../features/current/rate='other'" {  description "This element is only allowed if the element rate of the current features has value 'other'.";  }  type uint32;  units "kbit/s";  config false;  description "The maximum rate in kilobit/second if the current rate selector has value 'other'.";  }  container configuration {  leaf admin-state {  type up-down-state-type;  default up;  description "The administrative state of the port.";  }  leaf no-receive {  type boolean;  default false;  description "Specifies if receiving packets is not enabled on the port.";  }  leaf no-forward {  type boolean;  default false;  description "Specifies if forwarding packets is not enabled on that port.";  }  leaf no-packet-in {  type boolean;  default false;  description "Specifies if sending packet-in messages for incoming packets is not enabled on that port.";  }  }  container state {  config false;  leaf oper-state {  type up-down-state-type;  mandatory true;  description "The operational state of the port.";  }  leaf blocked {  type boolean;  mandatory true;  description "tbd";  }  leaf live {  type boolean;  mandatory true;  description "tbd";  }  }  container features {  container current {  uses openflow-port-current-features-grouping;  config false;  description "The features (rates, duplex, etc.) of the port that are currently in use.";  }  container advertised {  uses openflow-port-other-features-grouping;  description "The features (rates, duplex, etc.) of the port that are advertised to the peer port.";  }  container supported {  uses openflow-port-other-features-grouping;  config false;  description "The features (rates, duplex, etc.) of the port that are supported on the port.";  }  container advertised-peer {  uses openflow-port-other-features-grouping;  config false;  description "The features (rates, duplex, etc.) that are currently advertised by the peer port.";  }  }  grouping openflow-port-base-tunnel-grouping {  description "A grouping with information included in every  supported tunnel type. ";  choice local-endpoint-address {  leaf local-endpoint-ipv4-adress {  type inet:ipv4-address;  description "The IPv4 address of the local tunnel endpoint.";  }  leaf local-endpoint-ipv6-adress {  type inet:ipv6-address;  description "The IPv6 address of the local tunnel endpoint.";  }  leaf local-endpoint-mac-adress {  type yang:mac-address;  description "The MAC address of the local tunnel endpoint.";  }  }  choice remote-endpoint-address {  leaf remote-endpoint-ipv4-adress {  type inet:ipv4-address;  description "The IPv4 address of the remote tunnel endpoint.";  }  leaf remote-endpoint-ipv6-adress {  type inet:ipv6-address;  description "The IPv6 address of the remote tunnel endpoint.";  }  leaf remote-endpoint-mac-adress {  type yang:mac-address;  description "The MAC address of the remote tunnel endpoint.";  }  }  }  choice tunnel-type {  container tunnel {  description "Features of a basic IP-in-GRE tunnel.  Tunnels are modeld as logical ports.";  uses openflow-port-base-tunnel-grouping;  }  container ipgre-tunnel {  description "Features of a IP-in-GRE tunnel with key,  checksum, and sequence number information.";  uses openflow-port-base-tunnel-grouping;  leaf checksum-present {  type boolean;  description "Indicates presence of the GRE checksum.";  default true;  }  leaf key-present {  type boolean;  description "Indicates presence of the GRE key.";  default true;  }  leaf key {  type uint32;  description "The (optional) key of the GRE tunnel.";  }  leaf sequence-number-present {  type boolean;  description "Indicates presence of the GRE sequence number.";  default false;  }  }  container vxlan-tunnel {  description "Features of a VxLAN tunnel.";  uses openflow-port-base-tunnel-grouping;  leaf vni-valid {  type boolean;  description "Indicates how the corresponding flag should be set in packets sent on the tunnel";  default true;  }  leaf vni {  type uint32;  description "Virtual network identifier assigned to all packets sent on the tunnel";  }  leaf vni-multicast-group {  type inet:ip-address;  description "If IP multicast is used to support broadcast on the tunnel this specifies the corresponding multicast IP address";  }  leaf udp-source-port {  type inet:port-number;  description "Specifies the outer UDP source port number .";  }  leaf udp-dest-port {  type inet:port-number;  description "Specifies the outer UDP destination port number, generally the well-known port number for VxLAN";  }  leaf udp-checksum {  type boolean;  description "Boolean flag to indicate whether or not the outer UDP checksum should be set";  default false;  }  }  container nvgre-tunnel {  description "Features of a NVGRE tunnel.";  uses openflow-port-base-tunnel-grouping;  leaf tni {  type uint32;  description "Specifies the tenant network identifier assigned to all packets sent on the tunnel";  }  leaf tni-user {  type uint32;  description "Used to set the reserved user-defined bits of the GRE key field";  }  leaf tni-multicast-group {  type inet:ip-address;  description "If IP multicast is used to support broadcast on the tunnel this specifies the corresponding multicast IP address";  }  }  }  } |

## OpenFlow Port Feature

OpenFlow Port Features includePort Rate, Port Medium, Port Pause, and Port Auto-Negotiate.The normative semantics of these features are described in the OpenFlow protocol specification.

### UML Diagram



Figure 11: Data Model Diagram for an OpenFlow Port Feature

### XML Schema

|  |
| --- |
| <xs:simpleType name="OFPortRateType">  <xs:restriction base="xs:string">  <xs:enumeration value="10Mb-HD"/>  <xs:enumeration value="10Mb-FD"/>  <xs:enumeration value="100Mb-HD"/>  <xs:enumeration value="100Mb-FD"/>  <xs:enumeration value="1Gb-HD"/>  <xs:enumeration value="1Gb-FD"/>  <xs:enumeration value="1 Tb"/>  <xs:enumeration value="Other"/>  </xs:restriction>  </xs:simpleType>  <xs:simpleType name="OFPortAutoNegotiateType">  <xs:restriction base="xs:string">  <xs:enumeration value="enabled"/>  <xs:enumeration value="disabled"/>  </xs:restriction>  </xs:simpleType>  <xs:simpleType name="OFPortMediumType">  <xs:restriction base="xs:string">  <xs:enumeration value="copper"/>  <xs:enumeration value="fiber"/>  </xs:restriction>  </xs:simpleType>  <xs:simpleType name="OFPortPauseType">  <xs:restriction base="xs:string">  <xs:enumeration value="unsupported"/>  <xs:enumeration value="symmetric"/>  <xs:enumeration value="asymmetric"/>  </xs:restriction>  </xs:simpleType> |

### XML Example

|  |
| --- |
| <rate>10Mb-FD</rate>  <auto-negotiate>enabled</auto-negotiate>  <medium>copper</medium>  <pause>symmetric</pause> |

### Normative Constraints

The OpenFlow Port has several attributes configurable via OF-CONFIG protocol. The normative semantics of these attributes are described in the OpenFlow protocol.

Element <rate> MUST indicate a valid forwarding rate. The current Port Feature set MUST contain this element exactly once. The other Port Feature sets MAY contain this element more than once. If this element appears more than once in a Port Feature set than the value MUST be unique within the Port Feature set.

Element <auto-negotiate>MUST indicate an administrative state of the forwarding rate auto-negotiation protocol.

Element <medium> MUST indicate a valid physical medium. The current Port Feature set MUST contain this element exactly once. The other Port Feature sets MAY contain this element more than once. If this element appears more than once in a Port Feature set than the value MUST be unique within the Port Feature set.

Element <pause> MUST indicate the flavor of the pause function by indicating either asymmetric or asymmetric.

The following elements in the advertised Port Feature set can be modified by a NETCONF edit-config request or retrieved by a NETCONF get-config request: <rate>, <auto-negotiate>, <medium>, <pause>.

### YANG Specification

|  |
| --- |
| typedef rate-type {  type enumeration {  enum 10Mb-HD;  enum 10Mb-FD;  enum 100Mb-HD;  enum 100Mb-FD;  enum 1Gb-HD;  enum 1Gb-FD;  enum 10Gb;  enum 40Gb;  enum 100Gb;  enum 1Tb;  enum other;  }  description "Type to specify the rate of a port including the duplex transmission feature. Possible rates are 10Mb, 100Mb, 1Gb, 10Gb, 40Gb, 100Gb, 1Tb or other. Rates of 10Mb, 100Mb and 1Gb can support half or full duplex transmission.";  }  grouping openflow-port-current-features-grouping {  description "The current features of a port.";  leaf rate {  type rate-type;  mandatory true;  description "The transmission rate that is currently used.";  }  leaf auto-negotiate {  type boolean;  mandatory true;  description "Specifies if auto-negotiation of transmission parameters was used for the port.";  }  leaf medium {  type enumeration {  enum copper;  enum fiber;  }  mandatory true;  description "The transmission medium used by the port.";  }  leaf pause {  type enumeration {  enum unsupported;  enum symmetric;  enum asymmetric;  }  mandatory true;  description "Specifies if pausing of transmission is supported at all and if yes if it is asymmetric or symmetric.";  }  }  grouping openflow-port-other-features-grouping {  description "The features of a port that are supported or advertised.";  leaf-list rate {  type rate-type;  min-elements 1;  description "The transmission rate that is supported or advertised. Multiple transmissions rates are allowed.";  }  leaf auto-negotiate {  type boolean;  mandatory true;  description "Specifies if auto-negotiation of transmission parameters is enabled for the port.";  }  leaf-list medium {  type enumeration {  enum copper;  enum fiber;  }  min-elements 1;  description "The transmission medium used by the port. Multiple media are allowed.";  }  leaf pause {  type enumeration {  enum unsupported;  enum symmetric;  enum asymmetric;  }  description "Specifies if pausing of transmission is supported at all and if yes if it is asymmetric or symmetric.";  }  } |

## OpenFlow Queue

The OpenFlow Queue is an instance of an OpenFlow resource. It contains list of queue properties. The OpenFlow Queue is a logical context which represents a queue as described in the OpenFlow protocol specification.

### UML Diagram



Figure 12: Data Model Diagram for an OpenFlow Queue

### XML Schema

|  |
| --- |
| <xs:complexType name="OFQueueType">  <xs:complexContent>  <xs:extension base="OFResourceType">  <xs:sequence maxOccurs="1" minOccurs="1">  <xs:element name="id" type="OFConfigID"/>  <xs:element name="port"  type="OFConfigID"/>  <xs:element name="properties"  type="OFQueuePropertiesType"/>  </xs:sequence>  </xs:extension>  </xs:complexContent>  </xs:complexType>  <xs:complexType name="OFQueuePropertiesType">  <xs:sequence>  <xs:element name="min-rate"  type="OFQueueMinRateType"/>  <xs:element name="max-rate"  type="OFQueueMaxRateType"/>  <xs:element name="experimenter"  type="xs:string"/>  </xs:sequence>  </xs:complexType>  <xs:simpleType name="OFQueueMinRateType">  <xs:restriction base="xs:integer"/>  </xs:simpleType>  <xs:simpleType name="OFQueueMaxRateType">  <xs:restriction base="xs:unsignedLong"/>  </xs:simpleType> |

### XML Example

|  |
| --- |
| <queue>  <resource-id>Queue2</resource-id>  <id>2</id>  <port>4</port>  <properties>  <min-rate>10</min-rate>  <max-rate>500</max-rate>  <experimenter>123498</experimenter>  <experimenter>708</experimenter>  </properties>  </queue> |

### Normative Constraints

An OpenFlow Queue is identified by identifier <resource-id> within the context of the OpenFlow Capable Switch and OpenFlow Logical Switches. Element <resource-id> is inherited from superclass OpenFlow Resource.

Element <id>identifies the OpenFlow Queue to OpenFlow Controllers. If the OpenFlow Queue is associated with a OpenFlow Logical Switch, <id>MUST be unique within the context of the OpenFlow Logical Switch.

Element <port> associates an OpenFlow Queue with an OpenFlow Port. If the OpenFlow Queue is associated with an OpenFlow Logical SwitchS and <port> is non-empty, <port> MUST be set to the value of the <resource-id> of an OpenFlow Port which is associated with the OpenFlow Logical Switch S.

Element <properties> indicates the properties associated with the OpenFlow Queue as defined in the OpenFlow protocol specification. If the OpenFlow Queue is associated with an OpenFlow Logical Switch, <properties>MUST include the properties associated to the OpenFlow Queue. Element <properties> contains three possible elements: <min-rate>, <max-rate>, <experimenter>.

Element <min-rate>MUST indicate the minimum rate of the queue by percentage as an integer representing one tenth of one percent.

Element <max-rate>MUST indicate the minimum rate of the queue by percentage as an integer representing one tenth of one percent.

Element <experimenter>MAY indicate values as defined in the OpenFlow protocol specification.

The following elements of the OpenFlow Port can be modified by a NETCONF edit-config request or retrieved by a NETCONF get-config request: <resource-id>, <id>, <port>, <min-rate>, <max-rate>, <experimenter>.

### YANG Specification

|  |
| --- |
| typedef tenth-of-a-percent {  type uint16 {  range "0..1000";  }  units "1/10 of a percent";  description "This type defines a value in tenth of a percent.";  }  grouping openflow-queue-resource-grouping {  description "This grouping specifies all properties of a queue resource.";  leaf resource-id {  type inet:uri;  description "An unique but locally arbitrary identifier that identifies a queue and is persistent across reboots of the system.";  }  leaf id {  type uint64;  mandatory true;  description "An unique but locally arbitrary number that identifies a queue and is persistent across reboots of the system.";  }  leaf port {  type leafref {  path "/capable-switch/resources/port/resource-id";  }  description "Reference to port resources in the Capable Switch.";  }  container properties {  description "The queue properties currently configured.";  leaf min-rate {  type tenth-of-a-percent;  description "The minimal rate that is reserved for this queue in 1/10 of a percent of the actual rate. If not present a min-rate is not set.";  }  leaf max-rate {  type tenth-of-a-percent;  description "The maximum rate that is reserved for this queue in 1/10 of a percent of the actual rate. If not present the max-rate is not set.";  }  leaf-list experimenter {  type uint32;  description "A list of experimenter identifiers of queue properties used.";  }  }  } |

## External Certificate

Instances of an External Certificate contain a certificate that can be used by an OpenFlow Logical Switch for authenticating a controller when a TLS connection is established.

### UML Diagram



Figure 13: Data Model Diagram for a Certificate

### XML Schema

|  |
| --- |
| <xs:complexType name="OFExternalCertificateType">  <xs:complexContent>  <xs:extension base="OFResourceType">  <xs:sequence maxOccurs="1" minOccurs="1">  <xs:element name="certificate"  type="OFX509CertificateType"/>  </xs:sequence>  </xs:extension>  </xs:complexContent>  </xs:complexType>  <xs:simpleType name="OFX509CertificateType">  <xs:restriction base="base64Binary"></xs:restriction>  </xs:simpleType> |

### XML Example

|  |
| --- |
| <external-certificate>  <resource-id>ownedCertificate3</resource-id>  <certificate>AEF134F56EDB667DFA4320AEF134F56EDB667DFA4320AEF134F  56EDB667DFA4320AEF134F56EDB667DFA4320AEF134F56EDB667DFA4320  ...  AEF134F56EDB667DFA4320AEF134F56EDB667DFA4320AEF134F56EDB667  DFA4320</certificate>  </external-certificate> |

### Normative Constraints

An External Certificate is identified by identifier <resource-id> within the context of the OpenFlow Capable Switch and OpenFlow Logical Switches. Element <resource-id> is inherited from superclass OpenFlow Resource.

Element <certificate> contains an X.509 certificate in DER format base64 encoded.

### YANG Specification

|  |
| --- |
| grouping openflow-external-certificate-grouping {  description "This grouping specifies a certificate that can be used  by an OpenFlow Logical Switch for authenticating a  controller when a TLS connection is established.";  leaf resource-id {  type inet:uri;  description "A unique but locally arbitrary identifier that  identifies an external certificate and is persistent  across reboots of the system.";  }  leaf certificate {  type string;  mandatory true;  description "An X.509 certificate in DER format base64  encoded.";  }  } |

## Owned Certificate

Instances of an Owned Certificate contain a certificate and a private key. It can be used by an OpenFlow Logical Switch for authenticating itself to a controller when a TLS connection is established.

### UML Diagram



Figure 14: Data Model Diagram for Owned Certificate

### XML Schema

|  |
| --- |
| <xs:complexType name="OFOwnedCertificateType">  <xs:complexContent>  <xs:extension base="OFResourceType">  <xs:sequence maxOccurs="1" minOccurs="1">  <xs:element name="certificate"  type="OFX509CertificateType"/>  <xs:element name="private-key"  type="ds:KeyValue"/>  </xs:sequence>  </xs:extension>  </xs:complexContent>  </xs:complexType> |

### XML Example

|  |
| --- |
| <owned-certificate>  <resource-id>ownedCertificate3</resource-id>  <certificate>AEF134F56EDB667DFA4320AEF134F56EDB667DFA4320AEF134F  56EDB667DFA4320AEF134F56EDB667DFA4320AEF134F56EDB667DFA4320  ...  AEF134F56EDB667DFA4320AEF134F56EDB667DFA4320AEF134F56EDB667  DFA4320</certificate>  <private-key>  <ds:RSAKeyValue>  <ds:Modulus>CE45BAF6730F28CDB53534bC4323A333AAF555444DEED233232  ...  </ds:Modulus>  <ds:Exponent>DFA4320AEF134F56EDB66786230900DFA3C6F4443234901234...  </ds:Exponent>  </private-key>  </owned-certificate> |

### Normative Constraints

An Owned Certificate is identified by identifier <resource-id> within the context of the OpenFlow Capable Switch and OpenFlow Logical Switches. Element <resource-id> is inherited from superclass OpenFlow Resource.

Element <certificate> contains an X.509 certificate in DER format base64 encoded. Element <private-key> contains the private key corresponding to the certificate. The private key is encoded as specified in XML-Signature Syntax and Processing (<http://www.w3.org/TR/2001/PR-xmldsig-core-20010820/>). Currently the specification only support DSA and RSA keys.

### YANG Specification

|  |
| --- |
| grouping openflow-owned-certificate-grouping {  description "This grouping specifies a certificate and a private key.  It can be used by an OpenFlow Logical Switch for  authenticating itself to a controller when a TLS  connection is established.";  leaf resource-id {  type inet:uri;  description "A unique but locally arbitrary identifier that  identifies an external certificate and is persistent  across reboots of the system.";  }  leaf certificate {  type string;  mandatory true;  description "An X.509 certificate in DER format base64 encoded.";  }  container private-key {  uses KeyValueType;  description "tbd.";  }  }  grouping KeyValueType {  choice key-type {  mandatory true;  case dsa {  container DSAKeyValue {  uses DSAKeyValueType;  }  }  case rsa {  container RSAKeyValue {  uses RSAKeyValueType;  }  }  }  }  grouping DSAKeyValueType {  leaf P {  when "count(../Q) != 0";  type binary;  mandatory true;  }  leaf Q {  when "count(../P) != 0";  type binary;  mandatory true;  }  leaf J {  type binary;  mandatory true;  }  leaf G {  type binary;  mandatory true;  }  leaf Y {  type binary;  mandatory true;  }  leaf Seed {  when "count(../PgenCounter) != 0";  type binary;  mandatory true;  }  leaf PgenCounter {  when "count(../Seed) != 0";  type binary;  mandatory true;  }  }  grouping RSAKeyValueType {  leaf Modulus {  type binary;  mandatory true;  }  leaf Exponent {  type binary;  mandatory true;  }  } |

## OpenFlow Flow Table

The OpenFlow Flow Table is an instance of an OpenFlow resource. It contains list of flow table properties. The OpenFlow flow table is a logical context which represents a flow table as described in the OpenFlow protocol specification.

### UML Diagram



Figure 15: Data Model Diagram for Flow Table

### XML Schema

|  |
| --- |
| <xs:complexType name="OFFlowTableType">  <xs:complexContent>  <xs:extension base="OFResourceType">  <xs:sequence maxOccurs="1" minOccurs="1">  <xs:element name=”max-entries” type=”xs:integer”/>  <xs:element name="next-tables" type="OFNextFlowTables"/>  <xs:element name="instructions" type="OFFlowTableInstructions"/>  <xs:element name="matches" type="OFFlowTableMatchFields"/>  <xs:element name="write-actions" type="OFFlowTableWriteActions"/>  <xs:element name="apply-actions" type="OFFlowTableApplyActions"/>  <xs:element name="write-setfields" type="OFFlowTableMatchFields"/>  <xs:element name="apply-setfields" type="OFFlowTableMatchFields"/>  <xs:element name="wildcards" type="OFFlowTableMatchFields"/>  <xs:element name="metadata-match" type="xs:hexBinary"/>  <xs:element name="metadata-write" type="xs:hexBinary"/>  </xs:sequence>  </xs:extension>  </xs:complexContent>  </xs:complexType>  <xs:complexType name="OFFlowTableInstructions">  <xs:sequence minOccurs="1" maxOccurs="unbounded">  <xs:element name="type" type="OFInstructionType"/>  </xs:sequence>  </xs:complexType>  <xs:complexType name="OFNextFlowTables">  <xs:sequence minOccurs="1" maxOccurs="unbounded">  <xs:element name="table-id" type="OFConfigID"/>  </xs:sequence>  </xs:complexType>  <xs:complexType name="OFFlowTableMatcheFields">  <xs:sequence minOccurs="1" maxOccurs="unbounded">  <xs:element name="type" type="OFMatchFieldType"/>  </xs:sequence>  </xs:complexType>  <xs:complexType name="OFFlowTableWriteActions">  <xs:sequence minOccurs="1" maxOccurs="unbounded">  <xs:element name="type" type="OFActionType"/>  </xs:sequence>  </xs:complexType>  <xs:complexType name="OFFlowTableApplyActions">  <xs:sequence minOccurs="1" maxOccurs="unbounded">  <xs:element name="type" type="OFActionType"/>  </xs:sequence>  </xs:complexType>  <xs:simpleType name="OFMatchFieldType">  <xs:annotation>  <xs:documentation> The open flow match field types. See OpenFlow protocol 1.2 section A.2.3.7  </xs:documentation>  </xs:annotation>  <xs:restriction base="xs:string">  <xs:enumeration value="input-port"/>  <xs:enumeration value="physical-input-port"/>  <xs:enumeration value="metadata"/>  <xs:enumeration value="ethernet-dest"/>  <xs:enumeration value="ethernet-src"/>  <xs:enumeration value="ethernet-frame-type"/>  <xs:enumeration value="vlan-id"/>  <xs:enumeration value="vlan-priority"/>  <xs:enumeration value="ip-dscp"/>  <xs:enumeration value="ip-ecn"/>  <xs:enumeration value="ip-protocol"/>  <xs:enumeration value="ipv4-src"/>  <xs:enumeration value="ipv4-dest"/>  <xs:enumeration value="tcp-src"/>  <xs:enumeration value="tcp-dest"/>  <xs:enumeration value="udp-src"/>  <xs:enumeration value="udp-dest"/>  <xs:enumeration value="sctp-src"/>  <xs:enumeration value="sctp-dest"/>  <xs:enumeration value="icmpv4-type"/>  <xs:enumeration value="icmpv4-code"/>  <xs:enumeration value="arp-op"/>  <xs:enumeration value="arp-src-ip-address"/>  <xs:enumeration value="arp-target-ip-address"/>  <xs:enumeration value="arp-src-hardware-address"/>  <xs:enumeration value="arp-target-hardware-address"/>  <xs:enumeration value="ipv6-src"/>  <xs:enumeration value="ipv6-dest"/>  <xs:enumeration value="ipv6-flow-label"/>  <xs:enumeration value="icmpv6-type"/>  <xs:enumeration value="icmpv6-code"/>  <xs:enumeration value="ipv6-nd-target"/>  <xs:enumeration value="ipv6-nd-source-link-layer"/>  <xs:enumeration value="ipv6-nd-target-link-layer"/>  <xs:enumeration value="mpls-label"/>  <xs:enumeration value="mpls-tc"/>  </xs:restriction>  </xs:simpleType> |

### XML Example

|  |
| --- |
| <flow-table>  <resource-id>flowtable1</resource-id>  <max-entries>255</max-entries>  <next-tables>  <table-id>100</table-id>  <table-id>101</table-id>  </next-tables>  <instructions>  <type>apply-actions</type>  <type>clear-actions</type>  </instructions>  <matches>  <type>input-port</type>  <type>ethernet-dest</type>  </matches>  <write-actions>  <type>output</type>  <type>pop-mpls</type>  </write-actions>  <apply-actions>  <type>output</type>  <type>set-queue</type>  </apply-actions>  <write-setfields>  <type>ethernet-dest</type>  </write-setfields>  <apply-setfields>  <type>ethernet-dest</type>  </apply-setfields>  <wildcards>  <type> udp-dest</type>  </wildcards>  <metadata-match>30</metadata-match>  </flow-table> |

### Normative Constraints

An OpenFlow Flow Table is identified by identifier<resource-id> within the context of the OpenFlow CapableSwitch and OpenFlow Logical Switches. Element <resource-id> is inherited from superclass OpenFlow Resource.

Element <max-entries> denotes the maximum of flow entries the flow table can support. Due to limitations imposed by modern hardware, the max-entries value should be considered advisory and best effort approximation of the capacity of the table.

Element <next-tables> indicates the array of tables that can be directly reached from the present table using "goto-table" instruction.

Element <instructions> denotes the types of flow instructions supported by the flow table. Flow instructions associated with a flow table entry are executed when a flow matches the flow entry in the flow table.

Element <matches> denotes the types of match fields supported by the flow table. These match fields are defined in OpenFlow Specification version 1.2[1]. An OpenFlow Logical Switch is not required to support all match field types and supported match field types don’t need to be implemented in the same table lookup.

Element <write-actions> specifies the action types which could be merged into the current action set of flow entries of the flow table. The merging operation is performed by “write-action” flow instruction.

Element <apply-actions> specifies the action types which could be immediatedly applied without any change to the action set of flow entries of the flow table. The applying operation is performed by “apply-action” flow instruction.

Element <write-setfields> specifies "set-field" action types supported by the table using "write-actions" instruction.

Element <apply-setfields> specifies "set-field" action types supported by the table using "apply-actions" instruction.

Element <wildcards> specifies the fields for which the table supports wildcarding(omitting).

Element <metadata-match> indicates the bits of the metadata field that the table can match on. It is represented as 64-bit integer in hexadecimal digits([0-9a-fA-F]) format.

Element <metadata-write> indicates the bits of the metadata field that the table can write using the “write-metadata” instruction. It is represented as 64-bit integer in hexadecimal digits([0-9a-fA-F]) format.

### YANG Specification

|  |
| --- |
| typedef match-field-type {  description "The types of match fields defined in OpenFlow Switch Specification version 1.2.";  type enumeration {  enum input-port;  enum physical-input-port;  enum metadata;  enum ethernet-dest;  enum ethernet-src;  enum ethernet-frame-type;  enum vlan-id;  enum vlan-priority;  enum ip-dscp;  enum ip-ecn;  enum ip-protocol;  enum ipv4-src;  enum ipv4-dest;  enum tcp-src;  enum tcp-dest;  enum udp-src;  enum udp-dest;  enum sctp-src;  enum sctp-dest;  enum icmpv4-type;  enum icmpv4-code;  enum arp-op;  num arp-src-ip-address;  enum arp-target-ip-address;  enum arp-src-hardware-address;  enum arp-target-hardware-address;  enum ipv6-src;  enum ipv6-dest;  enum ipv6-flow-label;  enum icmpv6-type;  enum icmpv6-code;  enum ipv6-nd-target;  enum ipv6-nd-source-link-layer;  enum ipv6-nd-target-link-layer;  enum mpls-label;  enum mpls-tc;  }  }  typedef hex-binary {  type binary;  description "hex binary encoded string";  reference "http://www.w3.org/TR/2004/REC-xmlschema-2-20041028/datatypes.html#hexBinary";  }  grouping openflow-flow-table-resource-grouping {  description "Representation of an OpenFlow Flow Table Resource.";  leaf resource-id {  type inet:uri;  description "An unique but locally arbitrary identifier that identifies a flow table and is persistent across reboots of the system.";  }  leaf max-entries {  type uint8;  description "The maximum number of flow entries supported by the flow table.";  }  container next-tables {  leaf-list table-id {  type inet:uri;  }  description "The array of flow table ids that can be directly reached from the present table using "goto-table" instruction.";  }  container instructions {  leaf-list type {  type instruction-type;  }  description "The instruction types supported by the flow table."  }  container matches {  leaf-list type {  type match-field-type;  }  description "The match types supported by the flow table."  }  container write-actions {  leaf-list type {  type action-type;  }  description "The write action types supported by the flow table."  }  container apply-actions {  leaf-list type {  type action-type;  }  description "The apply action types supported by the flow table."  }  container write-setfields {  leaf-list type {  type match-field-type;  }  description "'set-field' action types supported by the table using 'write-actions' instruction.";  }  container apply-setfields {  leaf-list type {  type match-field-type;  }  description "'set-field' action types supported by the table using 'apply-actions' instruction.";  }  container wildcards {  leaf-list type {  type match-field-type;  }  description "The fields for which the table supports wildcarding(omitting).";  }  leaf metadata-match {  type hex-binary;  description "The bits of metadata the flow table can match."  }  leaf metadata-write {  type hex-binary;  description "The bits of metadata the flow table can write."  }  } |

# Binding to NETCONF

The OF-CONFIG1.1 protocol provides a standard way to modify basic OpenFlow configuration for the operation of an OpenFlow logical switch within the context of an OpenFlow Capable Switch. At the same time, it provides vendors the ability to extend and innovate by providing new and improved configuration capabilities. To achieve these goals, OF-CONFIG1.1 requires that devices supporting OF-CONFIG1.1 MUST implement NETCONF protocol (4) as the transport. This in turn implies as specified by NETCONF specification that OpenFlow Capable Switches supporting OF-CONFIG1.1 must implement SSH as a transport protocol. In addition, the OpenFlow Capable Switches implementing OF-CONFIG1.1 protocol may implement additional transports such as Web Services-Management or something else. Future versions of OF-CONFIG may specify binding to these additional transports.

NETCONF is a stable protocol that has been standardized for several years now. It is widely available on various platforms and achieves the needs for OF-CONFIG1.1. NETCONF defines a set of operations on top of a messaging layer (RPC). Below diagram shows the various layers of NETCONF protocol.



Figure 16 NETCONF Layers and Examples

The OpenFlow capable switches MUST support the schema as defined in this specification as the content layer in the above diagram. The schema currently covers basic configuration elements and will be extended in next versions.

The NETCONF protocol meets the OF-CONFIG 1.1 requirements for communication between an OpenFlow Configuration Point and an OpenFlow switch as listed in Section 6.3. In addition, if future needs of OF-CONFIG are not met by NETCONF protocol, NETCONF is extensible which will allow OF-CONFIG to extend NETCONF for its purpose.

1. It supports TLS as communication transport protocol (directly or with SOAP or BEEP in between) that can be used for providing integrity, privacy, and mutual authentication.
2. All specified transport mappings for NETCONF use TLS or TCP as underlying transport protocol and thus provides reliable transport.
3. The common way to establish a connection with NETCONF is from the Configuration Point (configuration point) to the managed device (switch).
4. The NETCONF standard support reversed configuration setup only if BEEP is used as transport protocol.
5. It supports partial switch configuration to the most fine-grain level.
6. It supports full switch configuration with a single operation.
7. It supports setting of configuration data.
8. It supports the retrieval of configuration data.
9. It supports the retrieval of (non-configuration) status data.
10. It supports creation, modification and deletion of configuration information.
11. It supports returning success codes after completing a configuration operation.
12. It supports support reporting error codes for partially or completely failed configuration requests.
13. It supports sending configuration requests independent of the completion of previous requests. Requests may be queued or processed concurrently at a switch. Each request has a request ID. Success or failure indications can be sent independently of other requests individually for each request ID.
14. It supports transaction capabilities including rollback per operation.
15. With its extension defined in RFC 5277 it supports asynchronous notifications from the managed device (switch) to the Configuration Point (configuration point).
16. It is extensible. New operations can be added and its support can be checked by capability retrieval.
17. It supports reporting its capabilities.

## How Data Model is Bound to Netconf

NetConf uses the XML encoding format for requests and responses. More specifically, it uses RPC-based communication model. It uses the <rpc> and <rpc-reply> elements as frames of NetConf requests and responses. The content elements inside of <rpc> element must conform to the OpenFlow Configuraton XML schemas defined in this specification.

All NetConf base protocol operations can be used to retrieve, configure, copy and delete OpenFlow Configuration data stores. These operations are defined in RFC6241. The commonly used operations are:

* edit-config
* get-config
* copy-config
* delete-config

### edit-config

The <edit-config> operation loads all or part of a specifiedconfiguration to the specified target configuration. If the target configuration does not exist, it will be created. The “operation” attribute of elements in the <config> subtree specifies the type of operations to be performed on the element. NetConf supports “create”, “replace”, “merge” and “delete”. The definition of these operations can be found RFC6241.

#### XML Example: Create a Capable-Switch Configuration

This XML example shows an edit-config operation to create a capable-switch configuration.

|  |
| --- |
| <?xmlversion="1.0" encoding="UTF-8"?>  <rpc message-id="1"  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">  <edit-config xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">  <target>  <candidate/>  </target>  <default-operation>merge</default-operation>  <test-option>set</test-option>  <config>  <capable-switch  xmlns:nc="urn:ietf:params:xml:ns:netconf:base:1.0"  nc:operation="create"  xmlns="urn:onf:of12:config:yang">  <id>capable-switch-0</id>  <logical-switches>  <switch>  <id>logic-switch-1</id>  <datapath-id>11:11:11:11:11:11:11:11</datapath-id>  <enabled>true</enabled>  <controllers>  <controller>  <id>controller-0</id>  <role>master</role>  <ip-address>192.168.2.1</ip-address>  <port>6633</port>  <protocol>tcp</protocol>  </controller>  </controllers>  </switch>  </logical-switches>  </capable-switch>  </config>  </edit-config>  </rpc>  <rpc-reply message-id="1"  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">  <ok/>  </rpc-reply> |

#### XML Example: Replace the ip-address Element of Controller

This XML example shows an edit-config operation to replace the ip-address element of controller.

|  |
| --- |
| <?xml version="1.0" encoding="UTF-8"?>  <rpc message-id="1"  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">  <edit-config xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">  <target>  <candidate/>  </target>  <default-operation>merge</default-operation>  <config>  <capable-switch xmlns="urn:onf:of12:config:yang">  <logical-switches>  <switch>  <id>logic-switch-1</id>  <controllers>  <controller>  <id>controller-0</id>  <ip-address operation="replace">10.0.0.10</ip-address>  </controller>  </controllers>  </switch>  </logical-switches>  </capable-switch>  </config>  </edit-config>  </rpc>  <rpc-reply message-id="1"  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">  <ok/>  </rpc-reply> |

RPC request must contain the key leave(s)( id element in this case) to uniquely identify the element being operated in the NetConf datastore scope.

### get-config

This operation is to retrieve all or part of a specified configuration. The filter element identifies the portions of the OpenFlow configuration to retrieve. If this element is unspecified, the entire configuration is returned.

#### XML Example: get-config

|  |
| --- |
| <?xml version="1.0" encoding="UTF-8"?>  <rpc message-id="1"  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">  <get-config xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">  <source>  <running/>  </source>  <filter type="xpath" select="/capable-switch"/>  </get-config>  </rpc>  <rpc-reply message-id="1"  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">  <data>  <capable-switch xmlns="urn:onf:of12:config:yang">  <id>capable-switch-0</id>  <logical-switches>  <switch>  <id>logic-switch-1</id>  <datapath-id>11:11:11:11:11:11:11:11</datapath-id>  <enabled>true</enabled>  <controllers>  <controller>  <id>controller-0</id>  <role>master</role>  <ip-address>192.168.2.1</ip-address>  <port>6633</port>  <protocol>tcp</protocol>  </controller>  </controllers>  </switch>  </logical-switches>  </capable-switch>  </data>  </rpc-reply> |

### copy-config

This operation creates or replaces an entire configuration datastore with the contents of another complete configuration datastore. If the target datastore exists, it is overwritten. Otherwise, a new one is created, if allowed.

#### XML Example: copy-config

|  |
| --- |
| <?xml version="1.0" encoding="UTF-8"?>  <rpc message-id="1"  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">  <copy-config>  <target>  <running/>  </target>  <source>  <url>https://mydomain.com/of-config/new-config.xml</url>  </source>  </copy-config>  </rpc>  <rpc-reply message-id="1"  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">  <ok/>  </rpc-reply> |

### delete-config

This operation deletes a configuration datastore. The <running>configuration datastore cannot be deleted.

#### XML Example: delete-config

|  |
| --- |
| <?xml version="1.0" encoding="UTF-8"?>  <rpc message-id="101"  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">  <delete-config>  <target>  <startup/>  </target>  </delete-config>  </rpc>  <rpc-reply message-id="1"  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">  <ok/>  </rpc-reply> |

## RPC error

OpenFlow Configuration uses NetConf <rpc-error> element(s) defined in RFC6241 to report operation failures. The <rpc-error> element(s) are sent in <rpc-reply> messages if an error occurs during the processing of an <rpc> request. The <rpc-reply> MAY contain multiple <rpc-error> elements. The <rpc-error>element includes the following information:

* error-type: Defines the conceptual layer of the error occurred.
* error-tag: contains a string to identifying the error condition.
* error-severity: contains a string to identifying the error severity.
* error-app-tag: contains a string to identifying the data-model-specific or implementation-specific error condition.
* error-path: contains the absolute XPath expression identifying the element path associated to the specific error being reported.
* error-message: contains error description suitable for human display
* error-info: contains data-model-specific error content

Detailed <rpc-error> definitions can be found in RFC 6241. Specific implementation may define implementation-specific error information and messages inside of error-info as sub-elements.

An example of <rpc-error> element in <rpc-reply> message:

|  |
| --- |
| <?xml version="1.0" encoding="UTF-8"?>  <rpc-reply message-id="101"  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0"  <rpc-error>  <error-type>application</error-type>  <error-tag> missing-element</error-tag>  <error-severity>error</error-severity>  <error-message xml:lang="en">  expected key leaf in list  </error-message>  <error-info>  <bad-element>id</bad-element>  <error-number>383</error-number>  </error-info>  </rpc-error>  </rpc-reply> |

1. XMLSchema

|  |
| --- |
| <?xml version="1.0" encoding="UTF-8"?>  <xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema"  xmlns:yin="urn:ietf:params:xml:schema:yang:yin:1"  targetNamespace="urn:onf:of111:config:yang"  xmlns="urn:onf:of111:config:yang"  elementFormDefault="qualified"  attributeFormDefault="unqualified"  version="2011-12-07"  xml:lang="en"  xmlns:yang="urn:ietf:params:xml:ns:yang:ietf-yang-types"  xmlns:inet="urn:ietf:params:xml:ns:yang:ietf-inet-types"  xmlns:of11-config="urn:onf:of111:config:yang">  <xs:import namespace="urn:ietf:params:xml:ns:yang:ietf-yang-types"  schemaLocation="ietf-yang-types.xsd"/>  <xs:import namespace="urn:ietf:params:xml:ns:yang:ietf-inet-types"  schemaLocation="ietf-inet-types.xsd"/>  <xs:annotation>  <xs:documentation>  This schema was generated from the YANG module of-config1.1.1  by pyang version 1.2.  The schema describes an instance document consisting  of the entire configuration data store, operational  data, rpc operations, and notifications.  This schema can thus NOT be used as-is to  validate NETCONF PDUs.  </xs:documentation>  </xs:annotation>  <xs:annotation>  <xs:documentation>  tbd  NETCONF Operational Considerations  Elements that are configurable, optional and have a default  value MAY be reported by replies to NETCONF &lt;get-config&gt;  requests. All non-configurable values SHOULD be reported by  replies to NETCONF &lt;get&gt; requests.  Attemps to modify non-configurable elements with a NETCONF  &lt;edit-config&gt; operation MUST result in an  'operation-not-supported' error with type 'application'.  When validating an &lt;edit‑config&gt; operation the following  errors MUST be detected:  \* Delete requests for non-existent data. In this case a  'data-missing' error is returned.  \* Create requests for existent data. In this case a  'data-exists' error is returned.  \* If the NETCONF operation creates data nodes under a  'choice', any existing nodes from other branches are  deleted.  </xs:documentation>  </xs:annotation>  <!-- YANG typedefs -->  <xs:simpleType name="OFConfigId">  <xs:annotation>  <xs:documentation>  Generic type of an identifier in OF-CONFIG  </xs:documentation>  </xs:annotation>  <xs:restriction base="inet:uri">  </xs:restriction>  </xs:simpleType>  <xs:simpleType name="OFConfigurationPointProtocolType">  <xs:annotation>  <xs:documentation>  Possible protocols to connect ot an OF  Configuration Point  </xs:documentation>  </xs:annotation>  <xs:restriction base="xs:string">  <xs:enumeration value="ssh"/>  <xs:enumeration value="soap"/>  <xs:enumeration value="tls"/>  <xs:enumeration value="beep"/>  </xs:restriction>  </xs:simpleType>  <xs:simpleType name="OFOpenFlowVersionType">  <xs:annotation>  <xs:documentation>  This enumeration contains the all OpenFlow  versions released so far.  </xs:documentation>  </xs:annotation>  <xs:restriction base="xs:string">  <xs:enumeration value="not-applicable"/>  <xs:enumeration value="1.0"/>  <xs:enumeration value="1.0.1"/>  <xs:enumeration value="1.1"/>  <xs:enumeration value="1.2"/>  <xs:enumeration value="1.3"/>  <xs:enumeration value="1.3.1"/>  </xs:restriction>  </xs:simpleType>  <xs:simpleType name="datapath-id-type">  <xs:annotation>  <xs:documentation>  The datapath-id type represents an OpenFlow  datapath identifier.  </xs:documentation>  </xs:annotation>  <xs:restriction base="xs:string">  <xs:pattern value="[0-9a-fA-F]{2}(:[0-9a-fA-F]{2}){7}"/>  </xs:restriction>  </xs:simpleType>  <xs:simpleType name="OFTenthOfAPercentType">  <xs:annotation>  <xs:documentation>  This type defines a value in tenth of a percent.  </xs:documentation>  </xs:annotation>  <xs:restriction base="xs:unsignedShort">  <xs:minInclusive value="0"/>  <xs:maxInclusive value="1000"/>  </xs:restriction>  </xs:simpleType>  <xs:simpleType name="OFUpDownStateType">  <xs:annotation>  <xs:documentation>  Type to specify state information for a port or a  connection.  </xs:documentation>  </xs:annotation>  <xs:restriction base="xs:string">  <xs:enumeration value="up"/>  <xs:enumeration value="down"/>  </xs:restriction>  </xs:simpleType>  <xs:simpleType name="OFPortRateType">  <xs:annotation>  <xs:documentation>  Type to specify the rate of a port including the  duplex transmission feature. Possible rates are 10Mb, 100Mb,  1Gb, 10Gb, 40Gb, 100Gb, 1Tb or other. Rates of 10Mb, 100Mb  and 1 Gb can support half or full duplex transmission.  </xs:documentation>  </xs:annotation>  <xs:restriction base="xs:string">  <xs:enumeration value="10Mb-HD"/>  <xs:enumeration value="10Mb-FD"/>  <xs:enumeration value="100Mb-HD"/>  <xs:enumeration value="100Mb-FD"/>  <xs:enumeration value="1Gb-HD"/>  <xs:enumeration value="1Gb-FD"/>  <xs:enumeration value="10Gb"/>  <xs:enumeration value="40Gb"/>  <xs:enumeration value="100Gb"/>  <xs:enumeration value="1Tb"/>  <xs:enumeration value="other"/>  </xs:restriction>  </xs:simpleType>  <xs:simpleType name="OFActionType">  <xs:annotation>  <xs:documentation>  The types of actions defined in OpenFlow Switch  Specification versions 1.2, 1.3, and 1.3.1  </xs:documentation>  </xs:annotation>  <xs:restriction base="xs:string">  <xs:enumeration value="output"/>  <xs:enumeration value="copy-ttl-out"/>  <xs:enumeration value="copy-ttl-in"/>  <xs:enumeration value="set-mpls-ttl"/>  <xs:enumeration value="dec-mpls-ttl"/>  <xs:enumeration value="push-vlan"/>  <xs:enumeration value="pop-vlan"/>  <xs:enumeration value="push-mpls"/>  <xs:enumeration value="pop-mpls"/>  <xs:enumeration value="set-queue"/>  <xs:enumeration value="group"/>  <xs:enumeration value="set-nw-ttl"/>  <xs:enumeration value="dec-nw-ttl"/>  <xs:enumeration value="set-field"/>  </xs:restriction>  </xs:simpleType>  <xs:simpleType name="OFInstructionType">  <xs:annotation>  <xs:documentation>  The types of instructions defined in OpenFlow  Switch Specification versions 1.2, 1.3, and 1.3.1.  </xs:documentation>  </xs:annotation>  <xs:restriction base="xs:string">  <xs:enumeration value="apply-actions"/>  <xs:enumeration value="clear-actions"/>  <xs:enumeration value="write-actions"/>  <xs:enumeration value="write-metadata"/>  <xs:enumeration value="goto-table"/>  </xs:restriction>  </xs:simpleType>  <xs:simpleType name="OFMatchFieldType">  <xs:annotation>  <xs:documentation>  The types of match field defined in OpenFlow  Switch Specification versions 1.2, 1.3, and 1.3.1.  </xs:documentation>  </xs:annotation>  <xs:restriction base="xs:string">  <xs:enumeration value="input-port"/>  <xs:enumeration value="physical-input-port"/>  <xs:enumeration value="metadata"/>  <xs:enumeration value="ethernet-dest"/>  <xs:enumeration value="ethernet-src"/>  <xs:enumeration value="ethernet-frame-type"/>  <xs:enumeration value="vlan-id"/>  <xs:enumeration value="vlan-priority"/>  <xs:enumeration value="ip-dscp"/>  <xs:enumeration value="ip-ecn"/>  <xs:enumeration value="ip-protocol"/>  <xs:enumeration value="ipv4-src"/>  <xs:enumeration value="ipv4-dest"/>  <xs:enumeration value="tcp-src"/>  <xs:enumeration value="tcp-dest"/>  <xs:enumeration value="udp-src"/>  <xs:enumeration value="udp-dest"/>  <xs:enumeration value="sctp-src"/>  <xs:enumeration value="sctp-dest"/>  <xs:enumeration value="icmpv4-type"/>  <xs:enumeration value="icmpv4-code"/>  <xs:enumeration value="arp-op"/>  <xs:enumeration value="arp-src-ip-address"/>  <xs:enumeration value="arp-target-ip-address"/>  <xs:enumeration value="arp-src-hardware-address"/>  <xs:enumeration value="arp-target-hardware-address"/>  <xs:enumeration value="ipv6-src"/>  <xs:enumeration value="ipv6-dest"/>  <xs:enumeration value="ipv6-flow-label"/>  <xs:enumeration value="icmpv6-type"/>  <xs:enumeration value="icmpv6-code"/>  <xs:enumeration value="ipv6-nd-target"/>  <xs:enumeration value="ipv6-nd-source-link-layer"/>  <xs:enumeration value="ipv6-nd-target-link-layer"/>  <xs:enumeration value="mpls-label"/>  <xs:enumeration value="mpls-tc"/>  </xs:restriction>  </xs:simpleType>  <xs:simpleType name="hex-binary">  <xs:annotation>  <xs:documentation>  hex binary encoded string  </xs:documentation>  </xs:annotation>  <xs:restriction base="xs:base64Binary">  </xs:restriction>  </xs:simpleType>  <!-- YANG groupings -->  <xs:group name="OFPortCurrentFeatureListType">  <xs:annotation>  <xs:documentation>  The current features of a port.  Elements in the type OFPortCurrentFeatureListType are not  configurable and can only be retrieved by NETCONF &lt;get&gt;  operations. Attemps to modify this element and its children  with a NETCONF &lt;edit-config&gt; operation MUST result in an  'operation-not-supported' error with type 'application'.  </xs:documentation>  </xs:annotation>  <xs:sequence>  <xs:element name="rate" type="OFPortRateType">  <xs:annotation>  <xs:documentation>  The transmission rate that is currently used.  The value MUST indicate a valid forwarding rate.    The current Port Feature set MUST contain this element  exactly once. The other Port Feature sets MAY contain this  element more than once. If this element appears more than  once in a Port Feature set than the value MUST be unique  within the Port Feature set.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="auto-negotiate" type="xs:boolean">  <xs:annotation>  <xs:documentation>  Specifies the administrative state of the  forwarding rate auto-negotiation protocol at this OpenFlow  Port.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="medium">  <xs:annotation>  <xs:documentation>  This element MUST indicate a valid physical  medium used by the OpenFlow Port.    The current Port Feature set MUST contain this element  exactly once. The other Port Feature sets MAY contain this  element more than once. If this element appears more than  once in a Port Feature set than the value MUST be unique  within the Port Feature set.  </xs:documentation>  </xs:annotation>  <xs:simpleType>  <xs:restriction base="xs:string">  <xs:enumeration value="copper"/>  <xs:enumeration value="fiber"/>  </xs:restriction>  </xs:simpleType>  </xs:element>  <xs:element name="pause">  <xs:annotation>  <xs:documentation>  Specifies if pausing of transmission is  supported at all and if yes if it is asymmetric or  symmetric.  </xs:documentation>  </xs:annotation>  <xs:simpleType>  <xs:restriction base="xs:string">  <xs:enumeration value="unsupported"/>  <xs:enumeration value="symmetric"/>  <xs:enumeration value="asymmetric"/>  </xs:restriction>  </xs:simpleType>  </xs:element>  </xs:sequence>  </xs:group>  <xs:group name="OFPortOtherFeatureListType">  <xs:annotation>  <xs:documentation>  The features of a port that are supported or  advertised.  If the elements in the OFPortOtherFeatureListType ares used  as configurable elements the NETCONF &lt;edit-config&gt; operations  MUST be implemented as follows:  \* The 'resource-id' element MUST be present in the path or in  the filter at all &lt;edit-config&gt; operations to identify the  resource.  \* If the operation is 'merge' or 'replace', the element is  created if it does not exist, and its value is set to the  value found in the XML RPC data.  \* If the operation is 'create', the element is created if it  does not exist. If the element already exists, a  'data‑exists' error is returned.  \* If the operation is 'delete', the element is deleted if it  exists. If the element does not exist, a 'data‑missing'  error is returned.  If elements in the type OFPortOtherFeatureListType are used  in an non-configurable way, they only be retrieved by NETCONF  &lt;get&gt; operations. Attemps to modify this element and its  children with a NETCONF &lt;edit-config&gt; operation MUST result  in an 'operation-not-supported' error with type  'application'.  </xs:documentation>  </xs:annotation>  <xs:sequence>  <xs:element name="rate" type="OFPortRateType">  <xs:annotation>  <xs:documentation>  The transmission rate that is supported or  advertised. Multiple transmissions rates are allowed.  At least one element MUST be present in the NETCONF data  store. If none of this elements is are present in a NETCONF  &lt;edit-config&gt; operation 'create', 'merge' or 'replace' and  the parent element does not exist, a 'data-missing' error  is returned.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="auto-negotiate" type="xs:boolean">  <xs:annotation>  <xs:documentation>  Specifies if auto-negotiation of transmission  parameters is enabled for the port.  This element is optional. If this element is not present it  defaults to 'true'.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="medium">  <xs:annotation>  <xs:documentation>  The transmission medium used by the port.  Multiple media are allowed.  At least one element MUST be present in the NETCONF data  store. If none of this elements is are present in a NETCONF  &lt;edit-config&gt; operation 'create', 'merge' or 'replace' and  the parent element does not exist, a 'data-missing' error  is returned.  </xs:documentation>  </xs:annotation>  <xs:simpleType>  <xs:restriction base="xs:string">  <xs:enumeration value="copper"/>  <xs:enumeration value="fiber"/>  </xs:restriction>  </xs:simpleType>  </xs:element>  <xs:element name="pause">  <xs:annotation>  <xs:documentation>  Specifies if pausing of transmission is  supported at all and if yes if it is asymmetric or  symmetric.  This element MUST be present in the NETCONF data store.  If this element is not present in a NETCONF &lt;edit-config&gt;  operation 'create', 'merge' or 'replace' and the parent  element does not exist, a 'data-missing' error is  returned.  </xs:documentation>  </xs:annotation>  <xs:simpleType>  <xs:restriction base="xs:string">  <xs:enumeration value="unsupported"/>  <xs:enumeration value="symmetric"/>  <xs:enumeration value="asymmetric"/>  </xs:restriction>  </xs:simpleType>  </xs:element>  </xs:sequence>  </xs:group>  <xs:group name="DSAKeyValueType">  <xs:annotation>  <xs:documentation>  DSA keys and the DSA signature algorithm are  specified in 'FIPS PUB 186-2, Digital Signature Standard (DSS),  U.S. Department of Commerce/National Institute of Standards and  Technology,  http://csrc.nist.gov/publications/fips/fips186-2/fips186-2.pdf'.  DSA public key values can have the following fields:  P  a prime modulus meeting the requirements of the standard  above  Q  an integer in the range 2\*\*159 &lt; Q &lt; 2\*\*160 which is a  prime divisor of P-1  G  an integer with certain properties with respect to P and Q  J  (P - 1) / Q  Y  G\*\*X mod P (where X is part of the private key and not made  public)  seed  a DSA prime generation seed  pgenCounter  a DSA prime generation counter  Parameter J is avilable for inclusion solely for efficiency as  it is calculatable from P and Q. Parameters seed and  pgenCounter are used in the DSA prime number generation  algorithm specified in the above standard. As such, they are  optional but MUST either both be present or both be absent.  This prime generation algorithm is designed to provide  assurance that a weak prime is not being used and it yields a P  and Q value. Parameters P, Q, and G can be public and common to  a group of users. They might be known from application context.  As such, they are optional but P and Q MUST either both appear  or both be absent. If all of P, Q, seed, and pgenCounter are  present, implementations are not required to check if they are  consistent and are free to use either P and Q or seed and  pgenCounter. All parameters are encoded as base64 values.  </xs:documentation>  </xs:annotation>  <xs:sequence>  <xs:element name="P" type="xs:base64Binary">  <xs:annotation>  <xs:documentation>  This element is optional. It MUST be present in  the NETCONF data store, if the element 'Q' is present.    If element 'Q' is present in a NETCONF &lt;edit-config&gt;  operation 'create', 'merge' or 'replace' and this element  is missing, a 'data-missing' error is returned.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="Q" type="xs:base64Binary">  <xs:annotation>  <xs:documentation>  This element is optional. It MUST be present in  the NETCONF data store, if the element 'P' is present.    If element 'P' is present in a NETCONF &lt;edit-config&gt;  operation 'create', 'merge' or 'replace' and this element  is missing, a 'data-missing' error is returned.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="J" type="xs:base64Binary">  <xs:annotation>  <xs:documentation>  This element is optional.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="G" type="xs:base64Binary">  <xs:annotation>  <xs:documentation>  This element is optional.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="Y" type="xs:base64Binary">  <xs:annotation>  <xs:documentation>  This element MUST be present in the NETCONF data  store. If this element is not present in a NETCONF  &lt;edit-config&gt; operation 'create', 'merge' or 'replace' and  the parent element does not exist, a 'data-missing' error  is returned.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="Seed" type="xs:base64Binary">  <xs:annotation>  <xs:documentation>  This element is optional. It MUST be present in  the NETCONF data store, if the element 'PgenCounter' is  present.    If element 'PgenCounter' is present in a NETCONF  &lt;edit-config&gt; operation 'create', 'merge' or 'replace' and  this element is missing, a 'data-missing' error is  returned.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="PgenCounter" type="xs:base64Binary">  <xs:annotation>  <xs:documentation>  This element is optional. It MUST be present in  the NETCONF data store, if the element 'Seed' is present.    If element 'Seed' is present in a NETCONF &lt;edit-config&gt;  operation 'create', 'merge' or 'replace' and this element  is missing, a 'data-missing' error is returned.  </xs:documentation>  </xs:annotation>  </xs:element>  </xs:sequence>  </xs:group>  <xs:group name="OFPortBaseTunnelType">  <xs:annotation>  <xs:documentation>  A group of common elements that are included  in every supported tunnel type. Tunnels are modeled as  logical ports.  One pair of local/remote endpoints must exist for a tunnel  configuration.  Only elements from one choice must exist at a time.  </xs:documentation>  </xs:annotation>  <xs:sequence>  <xs:choice>  <xs:sequence>  <xs:element name="local-endpoint-ipv4-adress" type="inet:ipv4-address">  <xs:annotation>  <xs:documentation>  The IPv4 address of the local tunnel  endpoint.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="remote-endpoint-ipv4-adress" type="inet:ipv4-address">  <xs:annotation>  <xs:documentation>  The IPv4 address of the remote tunnel  endpoint.  </xs:documentation>  </xs:annotation>  </xs:element>  </xs:sequence>  <xs:sequence>  <xs:element name="local-endpoint-ipv6-adress" type="inet:ipv6-address">  <xs:annotation>  <xs:documentation>  The IPv6 address of the local tunnel  endpoint.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="remote-endpoint-ipv6-adress" type="inet:ipv6-address">  <xs:annotation>  <xs:documentation>  The IPv6 address of the remote tunnel  endpoint.  </xs:documentation>  </xs:annotation>  </xs:element>  </xs:sequence>  <xs:sequence>  <xs:element name="local-endpoint-mac-adress" type="yang:mac-address">  <xs:annotation>  <xs:documentation>  The MAC address of the local tunnel  endpoint.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="remote-endpoint-mac-adress" type="yang:mac-address">  <xs:annotation>  <xs:documentation>  The MAC address of the remote tunnel  endpoint.  </xs:documentation>  </xs:annotation>  </xs:element>  </xs:sequence>  </xs:choice>  </xs:sequence>  </xs:group>  <xs:group name="OFPortIPGRETunnelType">  <xs:annotation>  <xs:documentation>  Properties of a IP-in-GRE tunnel with key,  checksum, and sequence number information.  </xs:documentation>  </xs:annotation>  <xs:sequence>  <xs:group ref="OFPortBaseTunnelType"/>  <xs:element name="checksum-present" type="xs:boolean">  <xs:annotation>  <xs:documentation>  Indicates presence of the GRE checksum.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="key-present" type="xs:boolean">  <xs:annotation>  <xs:documentation>  Indicates presence of the GRE key.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="key" type="xs:unsignedInt">  <xs:annotation>  <xs:documentation>  The (optional) key of the GRE tunnel. It MAY  be used to set the OXM\_OF\_TUNNEL\_ID match field metadata  in the OpenFlow protocol  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="sequence-number-present" type="xs:boolean">  <xs:annotation>  <xs:documentation>  Indicates presence of the GRE sequence  number.  </xs:documentation>  </xs:annotation>  </xs:element>  </xs:sequence>  </xs:group>  <xs:group name="OFPortNVGRETunnelType">  <xs:annotation>  <xs:documentation>  Properties of a NVGRE tunnel.  </xs:documentation>  </xs:annotation>  <xs:sequence>  <xs:group ref="OFPortBaseTunnelType"/>  <xs:element name="tni" type="xs:unsignedInt">  <xs:annotation>  <xs:documentation>  Specifies the tenant network identifier  assigned to all packets sent on the tunnel  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="tni-resv" type="xs:unsignedInt">  <xs:annotation>  <xs:documentation>  Used to set the reserved user-defined bits of  the GRE key field  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="tni-multicast-group" type="inet:ip-address">  <xs:annotation>  <xs:documentation>  If IP multicast is used to support broadcast  on the tunnel this element specifies the corresponding  multicast IP address  </xs:documentation>  </xs:annotation>  </xs:element>  </xs:sequence>  </xs:group>  <xs:group name="OFQueueType">  <xs:annotation>  <xs:documentation>  This grouping specifies all properties of a queue  resource.  NETCONF &lt;edit-config&gt; operations MUST be implemented as  follows:  \* The 'resource-id' element of OFResoureType MUST be present  at all &lt;edit-config&gt; operations to identify the port.  \* If the operation is 'merge' or 'replace', the element is  created if it does not exist, and its value is set to the  value found in the XML RPC data.  \* If the operation is 'create', the element is created if it  does not exist. If the element already exists, a  'data‑exists' error is returned.  \* If the operation is 'delete', the element is deleted if it  exists. If the element does not exist, a 'data‑missing'  error is returned.  </xs:documentation>  </xs:annotation>  <xs:sequence>  <xs:group ref="OFResourceType"/>  <xs:element name="id" type="xs:unsignedLong">  <xs:annotation>  <xs:documentation>  This id identifies the OpenFlow Queue to  OpenFlow Controllers. It is assigned to an OpenFlow Queue  latest when the OpenFlow Queue is associated with and  OpenFlow Logical Switch. If the OpenFlow Queue is  associated with an OpenFlow Logical Switch, this element  MUST be unique within the context of the OpenFlow Logical  Switch.    OpenFlow Capable Switch implementations may choose to  assign values to OpenFlow Queues that are unique within the  context of the OpenFlow Logical Switch. These id can be  used independent of assignments to OpenFlow Logical  Switches.    Other implementations may assign values to this element  only if the OpenFlow Queue is assigned to an OpenFlow  Logical Switch. If no value is currently assigned to this  element then this element MUST NOT be included in replies  to NETCONF &lt;get&gt; requests. Since this element is not  configurable with the NETCONF protocol it MUST NOT be  included in replies to NETCONF &lt;get-config&gt; requests.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="port">  <xs:annotation>  <xs:documentation>  Reference to port resources in the Capable  Switch.    This element associates an OpenFlow Queue with an OpenFlow  Port. If the OpenFlow Queue is associated with an OpenFlow  Logical Switch S and this element is present, then it MUST  be set to the value of element resource-id of an OpenFlow  Port which is associated with the OpenFlow Logical Switch  S.  The element MUST refer to an element at the following path:  /capable-switch/resources/port/resource-id  </xs:documentation>  </xs:annotation>  <xs:simpleType>  <xs:restriction base="inet:uri">  </xs:restriction>  </xs:simpleType>  </xs:element>  <xs:element name="properties">  <xs:annotation>  <xs:documentation>  The queue properties currently configured.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:element name="min-rate" minOccurs="0" type="OFTenthOfAPercentType">  <xs:annotation>  <xs:documentation>  The minimal rate that is reserved for this  queue in 1/10 of a percent of the actual rate.  This element is optional. If not present a min-rate is  not set.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="max-rate" minOccurs="0" type="OFTenthOfAPercentType">  <xs:annotation>  <xs:documentation>  The maximum rate that is reserved for this  queue in 1/10 of a percent of the actual rate.  This element is optional. If not present the max-rate is  not set.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="experimenter" minOccurs="0" maxOccurs="unbounded" type="xs:unsignedInt">  <xs:annotation>  <xs:documentation>  A list of experimenter identifiers of queue  properties used.  This element is optional.  </xs:documentation>  </xs:annotation>  </xs:element>  </xs:sequence>  </xs:complexType>  </xs:element>  </xs:sequence>  </xs:group>  <xs:group name="OFOwnedCertificateType">  <xs:annotation>  <xs:documentation>  This grouping specifies a certificate and a  private key. It can be used by an OpenFlow Logical Switch for  authenticating itself to a controller when a TLS connection  is established.  </xs:documentation>  </xs:annotation>  <xs:sequence>  <xs:group ref="OFResourceType"/>  <xs:element name="certificate" type="xs:string">  <xs:annotation>  <xs:documentation>  An X.509 certificate in DER format base64  encoded.  This element MUST be present in the NETCONF data store.  If this element is not present in a NETCONF &lt;edit-config&gt;  operation 'create', 'merge' or 'replace' and the parent  element does not exist, a 'data-missing' error is  returned.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="private-key">  <xs:annotation>  <xs:documentation>  This element contains the private key  corresponding to the certificate. The private key is  encoded as specified in XML-Signature Syntax and Processing  (http://www.w3.org/TR/2001/PR-xmldsig-core-20010820/).  Currently the specification only support DSA and RSA keys.  This element MUST be present in the NETCONF data store.  If this element is not present in a NETCONF &lt;edit-config&gt;  operation 'create', 'merge' or 'replace' and the parent  element does not exist, a 'data-missing' error is  returned.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:group ref="KeyValueType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  </xs:sequence>  </xs:group>  <xs:group name="OFExternalCertificateType">  <xs:annotation>  <xs:documentation>  This grouping specifies a certificate that can be  used by an OpenFlow Logical Switch for authenticating a  controller when a TLS connection is established.  </xs:documentation>  </xs:annotation>  <xs:sequence>  <xs:group ref="OFResourceType"/>  <xs:element name="certificate" type="xs:string">  <xs:annotation>  <xs:documentation>  An X.509 certificate in DER format base64  encoded.  This element MUST be present in the NETCONF data store.  If this element is not present in a NETCONF &lt;edit-config&gt;  operation 'create', 'merge' or 'replace' and the parent  element does not exist, a 'data-missing' error is  returned.  </xs:documentation>  </xs:annotation>  </xs:element>  </xs:sequence>  </xs:group>  <xs:group name="OFConfigurationPointType">  <xs:annotation>  <xs:documentation>  Representation of an OpenFlow Configuration Point.  Instances of the Configuration Point class SHOULD be stored  persistently across reboots of the OpenFlow Capable Switch.    When a connection is established between an OpenFlow Capable  Switch and a Configuration Point the switch MUST store the  connection information in an instance of the Configuration  Point class. If such an instance does not exist, the OpenFlow  Capable Switch MUST create an instance where it then stores  the connection information.    An OpenFlow Capable Switch that cannot initiate a connection  to a configuration point does not have to implement the  Configuration Point class. It SHOULD block attempts to write  to instances of the Configuration Point class with NETCONF  &lt;edit-config&gt; operations.  NETCONF &lt;edit-config&gt; operations MUST be implemented as  follows:  \* The 'id' element MUST be present at all &lt;edit-config&gt;  operations to identify the configuration point.  \* If the operation is 'merge' or 'replace', the element is  created if it does not exist, and its value is set to the  value found in the XML RPC data.  \* If the operation is 'create', the element is created if it  does not exist. If the element already exists, a  'data‑exists' error is returned.  \* If the operation is 'delete', the element is deleted if it  exists. If the element does not exist, a 'data‑missing'  error is returned.  </xs:documentation>  </xs:annotation>  <xs:sequence>  <xs:element name="id" type="OFConfigId">  <xs:annotation>  <xs:documentation>  A unique but locally arbitrary identifier that  identifies a Configuration Point within the context of an  OpenFlow Capable Switch.  This element MUST be present to identify the configuration  point.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="uri" type="inet:uri">  <xs:annotation>  <xs:documentation>  A locator of the Configuration Point. It  identifies the location of the Configuration Point as a  service resource and MUST include all information necessary  for the OpenFlow Capable Switch to connect to the  Configuration Point or re-connect to it should it become  disconnected. Such information MAY include, for example,  protocol, fully qualified domain name, IP address, port  number, etc.  This element MUST be present in the NETCONF data store.  If this element is not present in a NETCONF &lt;edit-config&gt;  operation 'create', 'merge' or 'replace' and the parent  element does not exist, a 'data-missing' error is  returned.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="protocol" type="OFConfigurationPointProtocolType">  <xs:annotation>  <xs:documentation>  The transport protocol that the Configuration  Point uses when communicating via NETCONF with the OpenFlow  Capable Switch.  This element is optional. If it is not present its value  defaults to 'ssh'.  </xs:documentation>  </xs:annotation>  </xs:element>  </xs:sequence>  </xs:group>  <xs:group name="RSAKeyValueType">  <xs:annotation>  <xs:documentation>  RSA key values have two fields: Modulus and  Exponent.  </xs:documentation>  </xs:annotation>  <xs:sequence>  <xs:element name="Modulus" type="xs:base64Binary">  <xs:annotation>  <xs:documentation>  This element MUST be present in the NETCONF data  store. If this element is not present in a NETCONF  &lt;edit-config&gt; operation 'create', 'merge' or 'replace' and  the parent element does not exist, a 'data-missing' error  is returned.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="Exponent" type="xs:base64Binary">  <xs:annotation>  <xs:documentation>  This element MUST be present in the NETCONF data  store. If this element is not present in a NETCONF  &lt;edit-config&gt; operation 'create', 'merge' or 'replace' and  the parent element does not exist, a 'data-missing' error  is returned.  </xs:documentation>  </xs:annotation>  </xs:element>  </xs:sequence>  </xs:group>  <xs:group name="OFFlowTableType">  <xs:annotation>  <xs:documentation>  Representation of an OpenFlow Flow Table Resource.  Elements in the type OFFlowTableType are not configurable and  can only be retrieved by NETCONF &lt;get&gt; operations. Attemps to  modify this element and its children with a NETCONF  &lt;edit-config&gt; operation MUST result in an  'operation-not-supported' error with type 'application'.  </xs:documentation>  </xs:annotation>  <xs:sequence>  <xs:group ref="OFResourceType"/>  <xs:element name="max-entries" type="xs:unsignedByte">  <xs:annotation>  <xs:documentation>  The maximum number of flow entries supported by  the flow table.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="next-tables">  <xs:annotation>  <xs:documentation>  An array of resource-ids of all flow tables that  can be directly reached from this table using the  'goto-table' instruction.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:element name="table-id" minOccurs="0" maxOccurs="unbounded" type="inet:uri"/>  </xs:sequence>  </xs:complexType>  </xs:element>  <xs:element name="instructions">  <xs:annotation>  <xs:documentation>  The list of all instruction types supported by  the flow table.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:element name="type" minOccurs="0" maxOccurs="unbounded" type="OFInstructionType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  <xs:element name="matches">  <xs:annotation>  <xs:documentation>  The list of all match types supported by the  flow table.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:element name="type" minOccurs="0" maxOccurs="unbounded" type="OFMatchFieldType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  <xs:element name="write-actions">  <xs:annotation>  <xs:documentation>  The list of all write action types supported by  the flow table.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:element name="type" minOccurs="0" maxOccurs="unbounded" type="OFActionType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  <xs:element name="apply-actions">  <xs:annotation>  <xs:documentation>  The list of all apply action types supported by  the flow table.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:element name="type" minOccurs="0" maxOccurs="unbounded" type="OFActionType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  <xs:element name="write-setfields">  <xs:annotation>  <xs:documentation>  The list of all 'set-field' action types  supported by the table using write actions.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:element name="type" minOccurs="0" maxOccurs="unbounded" type="OFMatchFieldType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  <xs:element name="apply-setfields">  <xs:annotation>  <xs:documentation>  The list of all 'set-field' action types  supported by the table using apply actions.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:element name="type" minOccurs="0" maxOccurs="unbounded" type="OFMatchFieldType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  <xs:element name="wildcards">  <xs:annotation>  <xs:documentation>  The list of all fields for which the table  supports wildcarding.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:element name="type" minOccurs="0" maxOccurs="unbounded" type="OFMatchFieldType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  <xs:element name="metadata-match" type="hex-binary">  <xs:annotation>  <xs:documentation>  This element indicates the bits of the metadata  field on which the flow table can match. It is represented  as 64-bit integer in hexadecimal digits([0-9a-fA-F])  format.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="metadata-write" type="hex-binary">  <xs:annotation>  <xs:documentation>  This element indicates the bits of the metadata  field on which flow table can write using the  'write-metadata' instruction. It is represented as  64-bit integer in hexadecimal digits([0-9a-fA-F]) format.  </xs:documentation>  </xs:annotation>  </xs:element>  </xs:sequence>  </xs:group>  <xs:group name="OFLogicalSwitchType">  <xs:annotation>  <xs:documentation>  This grouping specifies all properties of an  OpenFlow Logical Switch.  Elements of type OFLogicalSwitchType cannot be created or  deleted with NETCONF &lt;edit-config&gt; operations 'create' or  'delete'. The other NETCONF &lt;edit-config&gt; operations MUST be  implemented as follows:  \* The 'id' element MUST be present at all &lt;edit-config&gt;  operations to identify the OpenFlow Logical Switch.  \* If the operation is 'merge' or 'replace', and the element  does not exist, a 'data-missing' error is returned. If the  element exists its value is set to the value found in the  XML RPC data.  \* If the operation is 'create', a 'operation-not-supported'  error with type 'application' is returned.  \* If the operation is 'delete', 'operation-not-supported'  error with type 'application' is returned.  </xs:documentation>  </xs:annotation>  <xs:sequence>  <xs:element name="id" type="OFConfigId">  <xs:annotation>  <xs:documentation>  A unique but locally arbitrary identifier that  identifies a Logical Switch within the context of an  OpenFlow Capable Switch. It MUST be persistent across  reboots of the OpenFlow Capable Switch.  This element MUST be present to identify the OpenFlow  Logical Switch.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="capabilities">  <xs:annotation>  <xs:documentation>  This element contains all capability items that  an OpenFlow Logical Switch MAY implement.  This element and its children can only be retrieved by  NETCONF &lt;get&gt; operation since it contain no configuration  data.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:group ref="OFLogicalSwitchCapabilitiesType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  <xs:element name="datapath-id" type="datapath-id-type">  <xs:annotation>  <xs:documentation>  The datapath identifier of the Logical Switch  that uniquely identifies this Logical Switch within the  context of all OpenFlow Controllers associated with the  OpenFlow Logical Switch. The datapath identifier is a  string value that MUST be formatted as a sequence of 8  2-digit hexadecimal numbers that are separated by colons,  for example, '01:23:45:67:89:ab:cd:ef'. When processing a  datapath identifier, the case of the decimal digits MUST be  ignored.  This element MUST be present in the NETCONF data store.  If this element is not present in a NETCONF &lt;edit-config&gt;  operation 'create', 'merge' or 'replace' and the parent  element does not exist, a 'data-missing' error is  returned.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="enabled" type="xs:boolean">  <xs:annotation>  <xs:documentation>  This element indicates the administrative state  of the OpenFlow Logical Switch. A value of 'false' means  the OpenFlow Logical Switch MUST NOT communicate with any  OpenFlow Controllers, MUST NOT conduct any OpenFlow  processing, and SHOULD NOT be utilizing computational or  network resources of the underlying platform.  This element is optional. If this element is not present it  defaults to 'false'.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="check-controller-certificate" type="xs:boolean">  <xs:annotation>  <xs:documentation>  This element indicates the behavior of the  OpenFlow Logical Switch when connecting to an OpenFlow  Controller.    If set to value 'false', the logical switch will connect to  a controller without checking any controller certificate.    If set to value 'true', then the logical switch will  connect to a controller with element &lt;protocol&gt; set to  'TLS', only if the controller provides a certificate that  can be verified with one of the certificates stored in the  list called external-certificates in the OpenFlow Capable  Switch.    If a certificate cannot be validated, the OpenFlow Logical  Switch MUST terminate communication with the corresponding  OpenFlow Controller, MUST NOT conduct any OpenFlow  processing on requests of this OpenFlow controller, and  SHOULD NOT further utilize any computational or network  resources of for dealing with this connection.    If set to value 'true', the OpenFlow Logical Switch MUST  NOT connect to any OpenFlow Controller that does not  provide a certificate. This implies that it cannot connect  to an OpenFlow controller that has the value of element  protocol set to 'TCP'. Only connections with protocol 'TLS'  are possible in this case.  This element is optional. If this element is not present it  defaults to 'false'.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="lost-connection-behavior">  <xs:annotation>  <xs:documentation>  This element indicates the the behavior of the  OpenFlow Logical Switch in case it loses contact with all  OpenFlow Controllers. There are two alternative modes in  such a case: fails secure mode and fail standalone mode as  defined by the OpenFlow protocol specification version 1.2,  section 6.4. These are the only allowed values for this  element. Default is the fail secure mode.  This element is optional. If this element is not present it  defaults to 'failSecureMode'.  </xs:documentation>  </xs:annotation>  <xs:simpleType>  <xs:restriction base="xs:string">  <xs:enumeration value="failSecureMode"/>  <xs:enumeration value="failStandaloneMode"/>  </xs:restriction>  </xs:simpleType>  </xs:element>  <xs:element name="controllers">  <xs:annotation>  <xs:documentation>  The list of controllers for this Logical switch.  The element 'id' of OFControllerType MUST be unique within  this list.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:element name="controller" minOccurs="0" maxOccurs="unbounded">  <xs:annotation>  <xs:documentation>  The list of OpenFlow Controllers that are  assigned to the OpenFlow Logical Switch. The switch MUST  NOT connect to any OpenFlow Controller that is not  contained in this list.  NETCONF &lt;edit-config&gt; operations MUST be implemented as  follows:  \* The 'id' element MUST be present at all &lt;edit-config&gt;  operations to identify the controller.  \* If the operation is 'merge' or 'replace', the element  is created if it does not exist, and its value is set  to the value found in the XML RPC data.  \* If the operation is 'create', the element is created if  it does not exist. If the element already exists, a  'data‑exists' error is returned.  \* If the operation is 'delete', the element is deleted if  it exists. If the element does not exist, a  'data‑missing' error is returned.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:group ref="OFControllerType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  </xs:sequence>  </xs:complexType>  <xs:key name="key\_controllers\_controller">  <xs:selector xpath="of11-config:controller"/>  <xs:field xpath="of11-config:id"/>  </xs:key>  </xs:element>  <xs:element name="resources">  <xs:annotation>  <xs:documentation>  The list of identifiers of all resources of the  OpenFlow Capable Switch that the OpenFlow Logical Switch  has exclusive or non-exclusive access to. A resource is  identified by the value of its resource-identifier element.  For each resource identifier value in this list, there MUST  be an element with a matching resource identifier value in  the resources list of the OpenFlow Capable Switch.    Identifiers of this list are contained in elements  indicating the type of resource: 'port', 'queue',  'certificate', or 'flow-table'. Depending on the type,  different constraints apply. These are specified in  separate descriptions per type.  At present the elements in this lists are not configurable  and can only be retrieved by NETCONF &lt;get&gt; or &lt;get-config&gt;  operations. Attemps to modify this element and its children  with a NETCONF &lt;edit-config&gt; operation MUST result in an  'operation-not-supported' error with type 'application'.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:element name="port" minOccurs="0" maxOccurs="unbounded">  <xs:annotation>  <xs:documentation>  A resource identifier of a port of the  OpenFlow Capable Switch that the OpenFlow Logical Switch  has exclusive access to.  The elements in this list MUST refer to elements at the  following path:  /capable-switch/resources/port/resource-id  Elements in this list MUST be unique. This means each  port element can only be referenced once.  </xs:documentation>  </xs:annotation>  <xs:simpleType>  <xs:restriction base="inet:uri">  </xs:restriction>  </xs:simpleType>  </xs:element>  <xs:element name="queue" minOccurs="0" maxOccurs="unbounded">  <xs:annotation>  <xs:documentation>  A resource identifier of a queue of the  OpenFlow Capable Switch that the OpenFlow Logical Switch  has exclusive access to.  The elements in this list MUST refer to elements at the  following path:  /capable-switch/resources/queue/resource-id  Elements in this list MUST be unique. This means each  queue element can only be referenced once.  </xs:documentation>  </xs:annotation>  <xs:simpleType>  <xs:restriction base="inet:uri">  </xs:restriction>  </xs:simpleType>  </xs:element>  <xs:element name="certificate" minOccurs="0">  <xs:annotation>  <xs:documentation>  The resource identifier of the owned  certificate in the OpenFlow Capable Switch that the  OpenFlow Logical Switch uses to identify itself. This  element MUST NOT occur more than once in an OpenFlow  Logical Switch's resource list.    If no such element is in an OpenFlow Logical Switch's  resource list, then the OpenFlow Logical Switch does not  authenticate itself towards an OpenFloe Controller with a  certificate. If this element is present, then the  OpenFlow Logical Switch MUST provide this certificate for  authentication to an OpenFlow Controller when setting up  a TLS connection.    For TCP connections this element is irrelevant.  The element MUST refer to an element at the following  path:  /capable-switch/resources/owned-certificate/resource-id  </xs:documentation>  </xs:annotation>  <xs:simpleType>  <xs:restriction base="inet:uri">  </xs:restriction>  </xs:simpleType>  </xs:element>  <xs:element name="flow-table" minOccurs="0" maxOccurs="unbounded">  <xs:annotation>  <xs:documentation>  A resource identifier of a flow table of the  OpenFlow Capable Switch that the OpenFlow Logical Switch  has exclusive access to.  The elements in this list MUST refer to elements at the  following path:  /capable-switch/resources/flow-table/resource-id  Elements in this list MUST be unique. This means each  flow-table element can only be referenced once.  </xs:documentation>  </xs:annotation>  <xs:simpleType>  <xs:restriction base="inet:uri">  </xs:restriction>  </xs:simpleType>  </xs:element>  </xs:sequence>  </xs:complexType>  </xs:element>  </xs:sequence>  </xs:group>  <xs:group name="KeyValueType">  <xs:annotation>  <xs:documentation>  The KeyValue element contains a single public key  that may be useful in validating the signature.  NETCONF &lt;edit-config&gt; operations MUST be implemented as  follows:  \* Exactly one of the elemenst 'DSAKeyValue' or 'RSAKeyValue'  all &lt;edit-config&gt; operations.  \* If the operation is 'merge' or 'replace', the element is  created if it does not exist, and its value is set to the  value found in the XML RPC data.  \* If the operation is 'create', the element is created if it  does not exist. If the element already exists, a  'data‑exists' error is returned.  \* If the operation is 'delete', the element is deleted if it  exists. If the element does not exist, a 'data‑missing'  error is returned.  </xs:documentation>  </xs:annotation>  <xs:sequence>  <xs:choice>  <xs:sequence>  <xs:element name="DSAKeyValue">  <xs:complexType>  <xs:sequence>  <xs:group ref="DSAKeyValueType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  </xs:sequence>  <xs:sequence>  <xs:element name="RSAKeyValue">  <xs:complexType>  <xs:sequence>  <xs:group ref="RSAKeyValueType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  </xs:sequence>  </xs:choice>  </xs:sequence>  </xs:group>  <xs:group name="OFLogicalSwitchCapabilitiesType">  <xs:annotation>  <xs:documentation>  This grouping specifies all properties of an  OpenFlow logical switch's capabilities.  Elements in the type OFLogicalSwitchCapabilitiesType are not  configurable and can only be retrieved by NETCONF &lt;get&gt;  operations. Attemps to modify this element and its children  with a NETCONF &lt;edit-config&gt; operation MUST result in an  'operation-not-supported' error with type 'application'.  </xs:documentation>  </xs:annotation>  <xs:sequence>  <xs:element name="max-buffered-packets" type="xs:unsignedInt">  <xs:annotation>  <xs:documentation>  The maximum number of packets the logical switch  can buffer when sending packets to the controller using  packet-in messages.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="max-tables" type="xs:unsignedByte">  <xs:annotation>  <xs:documentation>  The number of flow tables supported by the  logical switch.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="max-ports" type="xs:unsignedInt">  <xs:annotation>  <xs:documentation>  The number of flow tables supported by the  logical switch.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="flow-statistics" type="xs:boolean">  <xs:annotation>  <xs:documentation>  Specifies if the logical switch supports flow  statistics.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="table-statistics" type="xs:boolean">  <xs:annotation>  <xs:documentation>  Specifies if the logical switch supports table  statistics.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="port-statistics" type="xs:boolean">  <xs:annotation>  <xs:documentation>  Specifies if the logical switch supports port  statistics.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="group-statistics" type="xs:boolean">  <xs:annotation>  <xs:documentation>  Specifies if the logical switch supports group  statistics.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="queue-statistics" type="xs:boolean">  <xs:annotation>  <xs:documentation>  Specifies if the logical switch supports queue  statistics.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="reassemble-ip-fragments" type="xs:boolean">  <xs:annotation>  <xs:documentation>  Specifies if the logical switch supports  reassemble IP fragments.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="block-looping-ports" type="xs:boolean">  <xs:annotation>  <xs:documentation>  'true' indicates that a switch protocol outside  of OpenFlow, such as 802.1D Spanning Tree, will detect  topology loops and block ports to prevent packet loops.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="reserved-port-types">  <xs:annotation>  <xs:documentation>  Specify generic forwarding actions such as  sending to the controller, flooding, or forwarding using  non-OpenFlow methods, such as 'normal' switch processing.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:element name="type" minOccurs="0" maxOccurs="unbounded">  <xs:simpleType>  <xs:restriction base="xs:string">  <xs:enumeration value="all"/>  <xs:enumeration value="controller"/>  <xs:enumeration value="table"/>  <xs:enumeration value="inport"/>  <xs:enumeration value="any"/>  <xs:enumeration value="normal"/>  <xs:enumeration value="flood"/>  </xs:restriction>  </xs:simpleType>  </xs:element>  </xs:sequence>  </xs:complexType>  </xs:element>  <xs:element name="group-types">  <xs:annotation>  <xs:documentation>  Specify the group types supported by the logical  switch.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:element name="type" minOccurs="0" maxOccurs="unbounded">  <xs:simpleType>  <xs:restriction base="xs:string">  <xs:enumeration value="all"/>  <xs:enumeration value="select"/>  <xs:enumeration value="indirect"/>  <xs:enumeration value="fast-failover"/>  </xs:restriction>  </xs:simpleType>  </xs:element>  </xs:sequence>  </xs:complexType>  </xs:element>  <xs:element name="group-capabilities">  <xs:annotation>  <xs:documentation>  Specify the group capabilities supported by the  logical switch.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:element name="capability" minOccurs="0" maxOccurs="unbounded">  <xs:simpleType>  <xs:restriction base="xs:string">  <xs:enumeration value="select-weight"/>  <xs:enumeration value="select-liveness"/>  <xs:enumeration value="chaining"/>  <xs:enumeration value="chaining-check"/>  </xs:restriction>  </xs:simpleType>  </xs:element>  </xs:sequence>  </xs:complexType>  </xs:element>  <xs:element name="action-types">  <xs:annotation>  <xs:documentation>  Specify the action types supported by the  logical switch.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:element name="type" minOccurs="0" maxOccurs="unbounded" type="OFActionType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  <xs:element name="instruction-types">  <xs:annotation>  <xs:documentation>  Specify the instruction types supported by the  logical switch.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:element name="type" minOccurs="0" maxOccurs="unbounded" type="OFInstructionType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  </xs:sequence>  </xs:group>  <xs:group name="OFPortType">  <xs:annotation>  <xs:documentation>  This element specifies all properties of an  OpenFlow resource of type OpenFlow Port. It represent a  physical port or a logical port of the OpenFlow Capable  Switch and can be assigned for exclusive use to an OpenFlow  Logical Switch. A logical port represents a tunnel endpoint  as described in the OpenFlow protocol specification versions  1.3 - 1.3.1.  NETCONF &lt;edit-config&gt; operations MUST be implemented as  follows:  \* The 'resource-id' element of OFResoureType MUST be present  at all &lt;edit-config&gt; operations to identify the port.  \* If the operation is 'merge' or 'replace', the element is  created if it does not exist, and its value is set to the  value found in the XML RPC data.  \* If the operation is 'create', the element is created if it  does not exist. If the element already exists, a  'data‑exists' error is returned.  \* If the operation is 'delete', the element is deleted if it  exists. If the element does not exist, a 'data‑missing'  error is returned.  </xs:documentation>  </xs:annotation>  <xs:sequence>  <xs:group ref="OFResourceType"/>  <xs:element name="number" type="xs:unsignedLong">  <xs:annotation>  <xs:documentation>  This number identifies the OpenFlow Port to  OpenFlow Controllers. It is assigned to an OpenFlow Port  latest when the OpenFlow Port is associated with and  OpenFlow Logical Switch. If the OpenFlow Port is  associated with an OpenFlow Logical Switch, this element  MUST be unique within the context of the OpenFlow Logical  Switch.    OpenFlow Capable Switch implementations may choose to  assign values to OpenFlow Ports that are unique within the  context of the OpenFlow Logical Switch. These numbers can  be used independent of assignments to OpenFlow Logical  Switches.    Other implementations may assign values to this element  only if the OpenFlow Port is assigned to an OpenFlow  Logical Switch. If no value is currently assigned to this  element then this element MUST NOT be included in replies  to NETCONF &lt;get&gt; requests. Since this element is not  configurable with the NETCONF protocol it MUST NOT be  included in replies to NETCONF &lt;get-config&gt; requests.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="name">  <xs:annotation>  <xs:documentation>  This element assists OpenFlow Controllers in  identifying OpenFlow Ports.    This element is not to be set by the OP-CONFIG protocol,  but it is set by the switch implementation. It may be set  at start-up time of an OpenFlow Capable Switch or when the  OpenFlow Port is assigned to an OpenFlow Logical Switch.  It MAY also be not set at all. If this element is set to a  value other than the empty string when being assigned to an  OpenFlow Logical Switch, then the value of this element  MUST be unique within the context of the OpenFlow Logical  Switch.    If no value or the empty string is currently assigned to  this element then this element MUST not be included in  replies to NETCONF &lt;get&gt; requests. Since this element is  not configurable with the NETCONF protocol it MUST NOT be  included in replies to NETCONF &lt;get-config&gt; requests.  </xs:documentation>  </xs:annotation>  <xs:simpleType>  <xs:restriction base="xs:string">  <xs:minLength value="1"/>  <xs:maxLength value="16"/>  </xs:restriction>  </xs:simpleType>  </xs:element>  <xs:element name="current-rate" type="xs:unsignedInt">  <xs:annotation>  <xs:documentation>  This element indicates the current bit rate of  the port. Its values is to be provided in units of kilobit  per second (kbps). This element is only valid if the  element called 'rate' in the current Port Features has a  value of 'other'.  Since this element is not configurable with the NETCONF  protocol it MUST NOT be included in replies to NETCONF  &lt;get-config&gt; requests.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="max-rate" type="xs:unsignedInt">  <xs:annotation>  <xs:documentation>  This element indicates the maximum bit rate of  the port. Its values is to be provided in units of kilobit  per second (kbps). This element is only valid if the  element called 'rate' in the current Port Features has a  value of 'other'.  Since this element is not configurable with the NETCONF  protocol it MUST NOT be included in replies to NETCONF  &lt;get-config&gt; requests.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="configuration">  <xs:annotation>  <xs:documentation>  This element represents the general  adminitrative configuration of the OpenFlow Port.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:element name="admin-state" minOccurs="0" type="OFUpDownStateType">  <xs:annotation>  <xs:documentation>  The administrative state of the port. If  true, the port has been administratively brought down and  SHOULD not be used by OpenFlow.  This element is optional. If this element is not present  it defaults to 'up'.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="no-receive" minOccurs="0" type="xs:boolean">  <xs:annotation>  <xs:documentation>  If true, packets received at this OpenFlow  port SHOULD be dropped.  This element is optional. If this element is not present  it defaults to 'false'.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="no-forward" minOccurs="0" type="xs:boolean">  <xs:annotation>  <xs:documentation>  If true, packets forwarded to this OpenFlow  port SHOULD be dropped.  This element is optional. If this element is not present  it defaults to 'false'.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="no-packet-in" minOccurs="0" type="xs:boolean">  <xs:annotation>  <xs:documentation>  If true, packets received on that port that  generate a table miss should never trigger a packet-in  message to the OpenFlow Controller.  This element is optional. If this element is not present  it defaults to 'false'.  </xs:documentation>  </xs:annotation>  </xs:element>  </xs:sequence>  </xs:complexType>  </xs:element>  <xs:element name="state">  <xs:annotation>  <xs:documentation>  This element represents the general operational  state of the OpenFlow Port.  Children of this element are not configurable and can only be  retrieved by NETCONF &lt;get&gt; operations. Attemps to modify this  element and its children with a NETCONF &lt;edit-config&gt;  operation MUST result in an 'operation-not-supported' error  with type 'application'.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:element name="oper-state" minOccurs="0" type="OFUpDownStateType">  <xs:annotation>  <xs:documentation>  If the value of this element is 'down', it  indicates that there is no physical link present.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="blocked" minOccurs="0" type="xs:boolean">  <xs:annotation>  <xs:documentation>  If the value of this element is 'true', it  indicates that a switch protocol outside of OpenFlow,  such as 802.1D Spanning Tree, is preventing the use of  this OpenFlow port for OpenFlow flooding.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="live" minOccurs="0" type="xs:boolean">  <xs:annotation>  <xs:documentation>  If the value of this element is 'true', it  indicates that this OpenFlow Port is live and can be used  for fast failover.  </xs:documentation>  </xs:annotation>  </xs:element>  </xs:sequence>  </xs:complexType>  </xs:element>  <xs:element name="features">  <xs:complexType>  <xs:sequence>  <xs:element name="current" minOccurs="0">  <xs:annotation>  <xs:documentation>  The features (rates, duplex, etc.) of the  port, that are currently in use.  Children of this element are not configurable and can  only be retrieved by NETCONF &lt;get&gt; operations. Attemps to  modify this element and its children with a NETCONF  &lt;edit-config&gt; operation MUST result in an  'operation-not-supported' error with type  'application'.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:group ref="OFPortCurrentFeatureListType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  <xs:element name="advertised" minOccurs="0">  <xs:annotation>  <xs:documentation>  The features (rates, duplex, etc.) of the  port, that are advertised to the peer port.  NETCONF &lt;edit-config&gt; operations MUST be implemented as  follows:  \* The 'resource-id' element of OFResoureType MUST be  present in the path or in the filter at all  &lt;edit-config&gt; operations to identify the port.  \* If the operation is 'merge' or 'replace', the element  is created if it does not exist, and its value is set  to the value found in the XML RPC data.  \* If the operation is 'create', the element is created if  it does not exist. If the element already exists, a  'data‑exists' error is returned.  \* If the operation is 'delete', the element is deleted if  it exists. If the element does not exist, a  'data‑missing' error is returned.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:group ref="OFPortOtherFeatureListType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  <xs:element name="supported" minOccurs="0">  <xs:annotation>  <xs:documentation>  The features (rates, duplex, etc.) of the  port, that are supported on the port.  Children of this element are not configurable and can  only be retrieved by NETCONF &lt;get&gt; operations. Attemps to  modify this element and its children with a NETCONF  &lt;edit-config&gt; operation MUST result in an  'operation-not-supported' error with type  'application'.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:group ref="OFPortOtherFeatureListType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  <xs:element name="advertised-peer" minOccurs="0">  <xs:annotation>  <xs:documentation>  The features (rates, duplex, etc.) that are  currently advertised by the peer port.  Children of this element are not configurable and can  only be retrieved by NETCONF &lt;get&gt; operations. Attemps to  modify this element and its children with a NETCONF  &lt;edit-config&gt; operation MUST result in an  'operation-not-supported' error with type  'application'.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:group ref="OFPortOtherFeatureListType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  </xs:sequence>  </xs:complexType>  </xs:element>  <xs:choice>  <xs:annotation>  <xs:documentation>  Tunnels are modeled as logical ports.  Elements in this choice are not configurable and can only  be retrieved by NETCONF &lt;get&gt; operations. Attemps to modify  this element and its children with a NETCONF &lt;edit-config&gt;  operation MUST result in an 'operation-not-supported' error  with type 'application'.  Only elements from one choice must exist at a time.  </xs:documentation>  </xs:annotation>  <xs:sequence>  <xs:element name="tunnel">  <xs:annotation>  <xs:documentation>  Properties of a basic IP-in-GRE tunnel.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:group ref="OFPortBaseTunnelType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  </xs:sequence>  <xs:sequence>  <xs:element name="ipgre-tunnel">  <xs:annotation>  <xs:documentation>  Properties of a IP-in-GRE tunnel.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:group ref="OFPortIPGRETunnelType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  </xs:sequence>  <xs:sequence>  <xs:element name="vxlan-tunnel">  <xs:annotation>  <xs:documentation>  Properties of a VxLAN tunnel.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:group ref="OFPortVXLANTunnelType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  </xs:sequence>  <xs:sequence>  <xs:element name="nvgre-tunnel">  <xs:annotation>  <xs:documentation>  Properties of a NVGRE tunnel.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:group ref="OFPortNVGRETunnelType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  </xs:sequence>  </xs:choice>  </xs:sequence>  </xs:group>  <xs:group name="OFResourceType">  <xs:annotation>  <xs:documentation>  This element specifies a generic OpenFlow resource  that is used as a basis for specific resources. Even though  this element is not used on its own the following rules for  NETCONF operations MUST be obeyed also by elemnts using this  element.  NETCONF &lt;edit-config&gt; operations MUST be implemented as  follows:  \* The 'id' element MUST be present at all &lt;edit-config&gt;  operations to identify the resource.  \* If the operation is 'merge' or 'replace', the element is  created if it does not exist, and its value is set to the  value found in the XML RPC data.  \* If the operation is 'create', the element is created if it  does not exist. If the element already exists, a  'data‑exists' error is returned.  \* If the operation is 'delete', the element is deleted if it  exists. If the element does not exist, a 'data‑missing'  error is returned.  </xs:documentation>  </xs:annotation>  <xs:sequence>  <xs:element name="resource-id" type="inet:uri">  <xs:annotation>  <xs:documentation>  A unique but locally arbitrary identifier that  uniquely identifies an OpenFlow Port within the context  of an OpenFlow Logical Switch. It MUST be persistent  across reboots of the OpenFlow Capable Switch.  This element MUST be present to identify the OpenFlow  resource.  </xs:documentation>  </xs:annotation>  </xs:element>  </xs:sequence>  </xs:group>  <xs:group name="OFPortVXLANTunnelType">  <xs:annotation>  <xs:documentation>  Properties of a VxLAN tunnel.  </xs:documentation>  </xs:annotation>  <xs:sequence>  <xs:group ref="OFPortBaseTunnelType"/>  <xs:element name="vni-valid" type="xs:boolean">  <xs:annotation>  <xs:documentation>  Indicates how the corresponding flag should be  set in packets sent on the tunnel.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="vni" type="xs:unsignedInt">  <xs:annotation>  <xs:documentation>  Virtual network identifier assigned to all  packets sent on the tunnel. A VxLAN implementation MAY  use the this element to set the OXM\_OF\_TUNNEL\_ID match  field metadata in the OpenFlow protocol.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="vni-multicast-group" type="inet:ip-address">  <xs:annotation>  <xs:documentation>  If IP multicast is used to support broadcast  on the tunnel this specifies the corresponding multicast  IP address  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="udp-source-port" type="inet:port-number">  <xs:annotation>  <xs:documentation>  Specifies the outer UDP source port number.  If this element is absent, the port number MAY be chosen  dynamically.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="udp-dest-port" type="inet:port-number">  <xs:annotation>  <xs:documentation>  Specifies the outer UDP destination port  number. It is intended to reserve a port number for  VxLAN at IANA. As soon as this has been reserved, the  reserved number SHOULD become the default value for this  element.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="udp-checksum" type="xs:boolean">  <xs:annotation>  <xs:documentation>  Boolean flag to indicate whether or not the  outer UDP checksum should be set  </xs:documentation>  </xs:annotation>  </xs:element>  </xs:sequence>  </xs:group>  <xs:group name="OFControllerType">  <xs:annotation>  <xs:documentation>  This grouping specifies all properties of an  OpenFlow Logical Switch Controller.  NETCONF &lt;edit-config&gt; operations MUST be implemented as  follows:  \* The 'id' element MUST be present at all &lt;edit-config&gt;  operations to identify the controller.  \* If the operation is 'merge' or 'replace', the element is  created if it does not exist, and its value is set to the  value found in the XML RPC data.  \* If the operation is 'create', the element is created if it  does not exist. If the element already exists, a  'data‑exists' error is returned.  \* If the operation is 'delete', the element is deleted if it  exists. If the element does not exist, a 'data‑missing'  error is returned.  </xs:documentation>  </xs:annotation>  <xs:sequence>  <xs:element name="id" type="OFConfigId">  <xs:annotation>  <xs:documentation>  A unique but locally arbitrary identifier that  uniquely identifies an OpenFlow Controller within the  context of an OpenFlow Capable Switch. It MUST be  persistent across reboots of the OpenFlow Capable Switch.  This element MUST be present to identify the OpenFlow  controller.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="role">  <xs:annotation>  <xs:documentation>  This element indicates the role of the OpenFlow  Controller. Semantics of these roles are specified in the  OpenFlow specifications 1.0 - 1.3.1. It is RECOMMENDED  that the roles of controllers are not configured by  OF-CONFIG 1.1.1 but determined using the OpenFlow protocol.  OpenFlow Controllers configured by OF-CONFIG 1.1.1 have the  default role 'equal'. A role other than 'equal' MAY be  assigned to a controller. Roles 'slave' and 'equal' MAY be  assigned to multiple controllers. Role 'master' MUST NOT  be assigned to more than one controller.  This element is optional. If this element is not present it  defaults to 'equal'.  </xs:documentation>  </xs:annotation>  <xs:simpleType>  <xs:restriction base="xs:string">  <xs:enumeration value="master"/>  <xs:enumeration value="slave"/>  <xs:enumeration value="equal"/>  </xs:restriction>  </xs:simpleType>  </xs:element>  <xs:element name="ip-address" type="inet:ip-address">  <xs:annotation>  <xs:documentation>  The IP address of the OpenFlow Controller. This  IP address is used by the OpenFlow Logical Switch when  connecting to the OpenFlow Controller.  This element MUST be present in the NETCONF data store.  If this element is not present in a NETCONF &lt;edit-config&gt;  operation 'create', 'merge' or 'replace' and the parent  element does not exist, a 'data-missing' error is  returned.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="port" type="inet:port-number">  <xs:annotation>  <xs:documentation>  The TCP port number at the OpenFlow Controller.  This port number is used by the OpenFlow Logical Switch  when connecting to the OpenFlow Controller using TCP or  TLS. The default value is 6633.  This element is optional. If this element is not present it  defaults to 6633.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="local-ip-address" type="inet:ip-address">  <xs:annotation>  <xs:documentation>  The local IP address of the OpenFlow Logical  Switch when connecting to this OpenFlow Controller. It is  the source IP address of packets sent to this OpenFlow  Controller. If present, this element overrides any default  IP address.      This element is optional. Attempts to set this element to  an IP address that cannot be used by the OpenFlow Logical  Switch MUST result in an 'bad-element' error with type  'application'. The &lt;error-info&gt; element MUST contain the  name of this element in the &lt;bad-element&gt; element.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="local-port" type="inet:port-number">  <xs:annotation>  <xs:documentation>  The local TCP port number of the OpenFlow  Logical Switch when connecting to this OpenFlow Controller.  It is the source TCP port number of packets sent to this  OpenFlow Controller. If this element is not present, then  the port number is chosen arbitrarily by the OpenFlow  Logical Switch.    This element is optional. Attempts to set this element to a  port number that cannot be used by the OpenFlow Logical  Switch MUST result in an 'bad-element' error with type  'application'. The &lt;error-info&gt; element MUST contain the  name of this element in the &lt;bad-element&gt; element.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="protocol">  <xs:annotation>  <xs:documentation>  The default protocol tha the OpenFlow Logical  Switch uses to connect to this OpenFlow Controller. 'tls'  is the default value.  This element is optional. If this element is not present it  defaults to 'tls'.  </xs:documentation>  </xs:annotation>  <xs:simpleType>  <xs:restriction base="xs:string">  <xs:enumeration value="tcp"/>  <xs:enumeration value="tls"/>  </xs:restriction>  </xs:simpleType>  </xs:element>  <xs:element name="state">  <xs:annotation>  <xs:documentation>  This container holds connection state  information that indicate the connection state of the  OpenFlow Logical Switch and the OpenFlow protocol version  used for the connection.  Children of this element are not configurable and can only  be retrieved by NETCONF &lt;get&gt; operations. Attemps to modify  this element and its children with a NETCONF &lt;edit-config&gt;  operation MUST result in an 'operation-not-supported' error  with type 'application'.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:element name="connection-state" minOccurs="0" type="OFUpDownStateType">  <xs:annotation>  <xs:documentation>  This object indicates the connections state of  the OpenFlow Logical Switch to this controller.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="current-version" minOccurs="0" type="OFOpenFlowVersionType">  <xs:annotation>  <xs:documentation>  This object indicates the version of the  OpenFlow protocol used between the OpenFlow Logical  Switch and this Controller. If element connection-state  has value 'up', then this element indicates the actual  version in use. If element connection-state has value  'down', then this element indicates the version number of  the last established connection with this OpenFlow  Controller. The value of this element MAY be persistent  across reboots of the OpenFlow Logical Switch in such a  case. If element connection-state has value 'down'and  there is no information about previous connections to  this OpenFlow controller, then this element is not  present or has the value '0'.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="supported-versions" minOccurs="0" maxOccurs="unbounded" type="OFOpenFlowVersionType">  <xs:annotation>  <xs:documentation>  This list of elements includes one entry for  each OpenFlow protocol version that this OpenFlow  controller supports. It SHOULD contain all  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="local-ip-address-in-use" minOccurs="0" type="inet:ip-address">  <xs:annotation>  <xs:documentation>  The local IP address of the OpenFlow Logical  Switch when connecting to this OpenFlow Controller. It  is the source IP address of packets sent to this OpenFlow  Controller. If present, this element overrides any  default IP address.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="local-port-in-use" minOccurs="0" type="inet:port-number">  <xs:annotation>  <xs:documentation>  The local TCP port number of the OpenFlow  Logical Switch. If element connection-state has value  'up', then this element indicates the actual port number  in use. If element connection-state has value 'down',  then this element indicates the port number used for the  last attempt to establish a connection with this OpenFlow  Controller.???  When connecting to this OpenFlow Controller, it is the  source TCP port number of packets sent to this OpenFlow  Controller. If this element has its defaqult value 0,  then port number is chosen arbitrarily by the OpenFlow  Logical Switch.  </xs:documentation>  </xs:annotation>  </xs:element>  </xs:sequence>  </xs:complexType>  </xs:element>  </xs:sequence>  </xs:group>  <xs:element name="capable-switch">  <xs:annotation>  <xs:documentation>  The OpenFlow Capable Switch serves as the root  element for an OpenFlow configuration. It contains logical  switches and resources that can be assigned to logical  switches. It may have relations to OpenFlow Configuration  Points.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:element name="id" type="inet:uri">  <xs:annotation>  <xs:documentation>  A unique but locally arbitrary identifier that  uniquely identifies a Capable Switch within the context of  potential OpenFlow Configuration Points. It MUST be  persistent across reboots of the OpenFlow Capable Switch.  This element MUST be present in the NETCONF data store.  If this element is not present in a NETCONF &lt;edit-config&gt;  operation 'create', 'merge' or 'replace' and the parent  element does not exist, a 'data-missing' error is  returned.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="config-version" minOccurs="0" type="xs:string">  <xs:annotation>  <xs:documentation>  The maximum supported OF-CONFIG version that is  supported by the OpenFlow Capable Switch. For switches  implementing this version of the OF-CONFIG protocol this  MUST always be 1.1.1.  This object can be used to identify the OF-CONFIG version  a capable switch supports beginning with version 1.1.1 of  OF-CONFIG. In addtion the supported version can be  determined by the namespace the OpenFlow Capable Switch  returns to configuration request of an element (like  capable-switch) that is present in all OF-CONFIG versions  specified so far. This is the only possiblity to identify  OF-CONFIG versions prior to OF-CONFIG 1.1.1.  </xs:documentation>  </xs:annotation>  </xs:element>  <xs:element name="configuration-points" minOccurs="0">  <xs:complexType>  <xs:sequence>  <xs:element name="configuration-point" minOccurs="0" maxOccurs="unbounded">  <xs:annotation>  <xs:documentation>  The list of all Configuration Points known to  the OpenFlow Capable Switch that may manage it using  OF-CONFIG.  The element 'id' of OFConfigurationType MUST be unique  within this list.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:group ref="OFConfigurationPointType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  </xs:sequence>  </xs:complexType>  <xs:key name="key\_configuration-points\_capable-switch\_configuration-point">  <xs:selector xpath="of11-config:configuration-point"/>  <xs:field xpath="of11-config:id"/>  </xs:key>  </xs:element>  <xs:element name="resources" minOccurs="0">  <xs:annotation>  <xs:documentation>  A lists containing all resources of the OpenFlow  Capable Switch that can be used by OpenFlow Logical  Switches. Resources are listed here independent of their  actual assignment to OpenFlow Logical Switches. They may  be available to be assigned to an OpenFlow Logical Switch  or already in use by an OpenFlow Logical Switch.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:element name="port" minOccurs="0" maxOccurs="unbounded">  <xs:annotation>  <xs:documentation>  The list contains all port resources of the  OpenFlow Capable Switch.  The element 'resource-id' of OFPortType MUST be unique  within this list.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:group ref="OFPortType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  <xs:element name="queue" minOccurs="0" maxOccurs="unbounded">  <xs:annotation>  <xs:documentation>  The list contains all queue resources of the  OpenFlow Capable Switch.  The element 'resource-id' of OFQueueType MUST be unique  within this list.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:group ref="OFQueueType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  <xs:element name="owned-certificate" minOccurs="0" maxOccurs="unbounded">  <xs:annotation>  <xs:documentation>  The list contains all owned certificate  resources of the OpenFlow Capable Switch.  The element 'resource-id' of OFOwnedCertificateType MUST  be unique within this list.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:group ref="OFOwnedCertificateType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  <xs:element name="external-certificate" minOccurs="0" maxOccurs="unbounded">  <xs:annotation>  <xs:documentation>  The list contains all external certificate  resources of the OpenFlow Capable Switch.  The element 'resource-id' of OFExternalCertificateType  MUST be unique within this list.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:group ref="OFExternalCertificateType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  <xs:element name="flow-table" minOccurs="0" maxOccurs="unbounded">  <xs:annotation>  <xs:documentation>  The list contains all flow table resources of  the OpenFlow Capable Switch.  The element 'resource-id' of OFFlowTableType MUST be  unique within this list.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:group ref="OFFlowTableType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  </xs:sequence>  </xs:complexType>  <xs:key name="key\_resources\_capable-switch\_port">  <xs:selector xpath="of11-config:port"/>  <xs:field xpath="of11-config:resource-id"/>  </xs:key>  <xs:key name="key\_resources\_capable-switch\_queue">  <xs:selector xpath="of11-config:queue"/>  <xs:field xpath="of11-config:resource-id"/>  </xs:key>  <xs:key name="key\_resources\_capable-switch\_owned-certificate">  <xs:selector xpath="of11-config:owned-certificate"/>  <xs:field xpath="of11-config:resource-id"/>  </xs:key>  <xs:key name="key\_resources\_capable-switch\_external-certificate">  <xs:selector xpath="of11-config:external-certificate"/>  <xs:field xpath="of11-config:resource-id"/>  </xs:key>  <xs:key name="key\_resources\_capable-switch\_flow-table">  <xs:selector xpath="of11-config:flow-table"/>  <xs:field xpath="of11-config:resource-id"/>  </xs:key>  </xs:element>  <xs:element name="logical-switches" minOccurs="0">  <xs:annotation>  <xs:documentation>  This element contains a list of all OpenFlow  Logical Switches available at the OpenFlow Capable  Switch.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:element name="switch" minOccurs="0" maxOccurs="unbounded">  <xs:annotation>  <xs:documentation>  The list of all OpenFlow Logical Switches on  the OpenFlow Capable Switch.  The element 'resource-id' of OFLogicalSwitchType MUST be  unique within this list.  </xs:documentation>  </xs:annotation>  <xs:complexType>  <xs:sequence>  <xs:group ref="OFLogicalSwitchType"/>  </xs:sequence>  </xs:complexType>  </xs:element>  </xs:sequence>  </xs:complexType>  <xs:key name="key\_logical-switches\_capable-switch\_switch">  <xs:selector xpath="of11-config:switch"/>  <xs:field xpath="of11-config:id"/>  </xs:key>  </xs:element>  </xs:sequence>  </xs:complexType>  </xs:element>  </xs:schema> |

1. YANG Specification

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| --- |
| module of-config1.1.1 {  namespace "urn:onf:of111:config:yang";  prefix of11-config;  import ietf-yang-types { prefix yang; }  import ietf-inet-types { prefix inet; }  organization "ONF Config Management Group";  contact "tbd";  description "tbd  NETCONF Operational Considerations  Elements that are configurable, optional and have a default  value MAY be reported by replies to NETCONF <get-config>  requests. All non-configurable values SHOULD be reported by  replies to NETCONF <get> requests.  Attemps to modify non-configurable elements with a NETCONF  <edit-config> operation MUST result in an  'operation-not-supported' error with type 'application'.  When validating an <edit‑config> operation the following  errors MUST be detected:  \* Delete requests for non-existent data. In this case a  'data-missing' error is returned.  \* Create requests for existent data. In this case a  'data-exists' error is returned.  \* If the NETCONF operation creates data nodes under a  'choice', any existing nodes from other branches are  deleted.";  revision 2011-12-07 {  description "First Version";  reference "tbd";  }  /\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*  \* Features  \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*/  /\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*  \* Type definitions  \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*/  typedef OFConfigId {  type inet:uri;  description "Generic type of an identifier in OF-CONFIG";  }  typedef OFConfigurationPointProtocolType {  type enumeration {  enum "ssh";  enum "soap";  enum "tls";  enum "beep";  }  description "Possible protocols to connect ot an OF  Configuration Point";  }  typedef OFOpenFlowVersionType {  type enumeration {  enum "not-applicable";  enum "1.0";  enum "1.0.1";  enum "1.1";  enum "1.2";  enum "1.3";  enum "1.3.1";  }  description "This enumeration contains the all OpenFlow  versions released so far.";  }  typedef datapath-id-type {  type string {  pattern '[0-9a-fA-F]{2}(:[0-9a-fA-F]{2}){7}';  }  description "The datapath-id type represents an OpenFlow  datapath identifier.";  }  typedef OFTenthOfAPercentType {  type uint16 {  range "0..1000";  }  units "1/10 of a percent";  description "This type defines a value in tenth of a percent.";  }  typedef OFUpDownStateType {  type enumeration {  enum up;  enum down;  }  description "Type to specify state information for a port or a  connection.";  }  typedef OFPortRateType {  type enumeration {  enum 10Mb-HD;  enum 10Mb-FD;  enum 100Mb-HD;  enum 100Mb-FD;  enum 1Gb-HD;  enum 1Gb-FD;  enum 10Gb;  enum 40Gb;  enum 100Gb;  enum 1Tb;  enum other;  }  description "Type to specify the rate of a port including the  duplex transmission feature. Possible rates are 10Mb, 100Mb,  1Gb, 10Gb, 40Gb, 100Gb, 1Tb or other. Rates of 10Mb, 100Mb  and 1 Gb can support half or full duplex transmission.";  }  typedef OFActionType {  type enumeration {  enum output;  enum copy-ttl-out;  enum copy-ttl-in;  enum set-mpls-ttl;  enum dec-mpls-ttl;  enum push-vlan;  enum pop-vlan;  enum push-mpls;  enum pop-mpls;  enum set-queue;  enum group;  enum set-nw-ttl;  enum dec-nw-ttl;  enum set-field;  }  description "The types of actions defined in OpenFlow Switch  Specification versions 1.2, 1.3, and 1.3.1";  }  typedef OFInstructionType {  type enumeration {  enum apply-actions;  enum clear-actions;  enum write-actions;  enum write-metadata;  enum goto-table;  }  description "The types of instructions defined in OpenFlow  Switch Specification versions 1.2, 1.3, and 1.3.1.";  }  typedef OFMatchFieldType {  type enumeration {  enum input-port;  enum physical-input-port;  enum metadata;  enum ethernet-dest;  enum ethernet-src;  enum ethernet-frame-type;  enum vlan-id;  enum vlan-priority;  enum ip-dscp;  enum ip-ecn;  enum ip-protocol;  enum ipv4-src;  enum ipv4-dest;  enum tcp-src;  enum tcp-dest;  enum udp-src;  enum udp-dest;  enum sctp-src;  enum sctp-dest;  enum icmpv4-type;  enum icmpv4-code;  enum arp-op;  enum arp-src-ip-address;  enum arp-target-ip-address;  enum arp-src-hardware-address;  enum arp-target-hardware-address;  enum ipv6-src;  enum ipv6-dest;  enum ipv6-flow-label;  enum icmpv6-type;  enum icmpv6-code;  enum ipv6-nd-target;  enum ipv6-nd-source-link-layer;  enum ipv6-nd-target-link-layer;  enum mpls-label;  enum mpls-tc;  }  description "The types of match field defined in OpenFlow  Switch Specification versions 1.2, 1.3, and 1.3.1.";  }  typedef hex-binary {  type binary;  description "hex binary encoded string";  reference "http://www.w3.org/TR/2004/REC-xmlschema-2-20041028/datatypes.html#hexBinary";  }  /\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*  \* Groupings  \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*/  grouping OFConfigurationPointType {  description "Representation of an OpenFlow Configuration Point.  Instances of the Configuration Point class SHOULD be stored  persistently across reboots of the OpenFlow Capable Switch.    When a connection is established between an OpenFlow Capable  Switch and a Configuration Point the switch MUST store the  connection information in an instance of the Configuration  Point class. If such an instance does not exist, the OpenFlow  Capable Switch MUST create an instance where it then stores  the connection information.    An OpenFlow Capable Switch that cannot initiate a connection  to a configuration point does not have to implement the  Configuration Point class. It SHOULD block attempts to write  to instances of the Configuration Point class with NETCONF  <edit-config> operations.  NETCONF <edit-config> operations MUST be implemented as  follows:  \* The 'id' element MUST be present at all <edit-config>  operations to identify the configuration point.  \* If the operation is 'merge' or 'replace', the element is  created if it does not exist, and its value is set to the  value found in the XML RPC data.  \* If the operation is 'create', the element is created if it  does not exist. If the element already exists, a  'data‑exists' error is returned.  \* If the operation is 'delete', the element is deleted if it  exists. If the element does not exist, a 'data‑missing'  error is returned.";  leaf id {  type OFConfigId;  mandatory true;  description "A unique but locally arbitrary identifier that  identifies a Configuration Point within the context of an  OpenFlow Capable Switch.  This element MUST be present to identify the configuration  point.";  }  leaf uri {  type inet:uri;  mandatory true;  description "A locator of the Configuration Point. It  identifies the location of the Configuration Point as a  service resource and MUST include all information necessary  for the OpenFlow Capable Switch to connect to the  Configuration Point or re-connect to it should it become  disconnected. Such information MAY include, for example,  protocol, fully qualified domain name, IP address, port  number, etc.  This element MUST be present in the NETCONF data store.  If this element is not present in a NETCONF <edit-config>  operation 'create', 'merge' or 'replace' and the parent  element does not exist, a 'data-missing' error is  returned.";  }  leaf protocol {  type OFConfigurationPointProtocolType;  default "ssh";  description "The transport protocol that the Configuration  Point uses when communicating via NETCONF with the OpenFlow  Capable Switch.  This element is optional. If it is not present its value  defaults to 'ssh'.";  reference "The mappings of NETCONF to different transport  protocols are defined in RFC 6242 for SSH, RFC 4743 for  SOAP, RFC 4744 for BEEP, and RFC 5539 for TLS";  }  }  grouping OFLogicalSwitchType {  description "This grouping specifies all properties of an  OpenFlow Logical Switch.  Elements of type OFLogicalSwitchType cannot be created or  deleted with NETCONF <edit-config> operations 'create' or  'delete'. The other NETCONF <edit-config> operations MUST be  implemented as follows:  \* The 'id' element MUST be present at all <edit-config>  operations to identify the OpenFlow Logical Switch.  \* If the operation is 'merge' or 'replace', and the element  does not exist, a 'data-missing' error is returned. If the  element exists its value is set to the value found in the  XML RPC data.  \* If the operation is 'create', a 'operation-not-supported'  error with type 'application' is returned.  \* If the operation is 'delete', 'operation-not-supported'  error with type 'application' is returned.";  leaf id {  type OFConfigId;  mandatory true;  description "A unique but locally arbitrary identifier that  identifies a Logical Switch within the context of an  OpenFlow Capable Switch. It MUST be persistent across  reboots of the OpenFlow Capable Switch.  This element MUST be present to identify the OpenFlow  Logical Switch.";  }  container capabilities {  config false;  description "This element contains all capability items that  an OpenFlow Logical Switch MAY implement.  This element and its children can only be retrieved by  NETCONF <get> operation since it contain no configuration  data.";  uses OFLogicalSwitchCapabilitiesType;  }  leaf datapath-id {  type datapath-id-type;  mandatory true;  description "The datapath identifier of the Logical Switch  that uniquely identifies this Logical Switch within the  context of all OpenFlow Controllers associated with the  OpenFlow Logical Switch. The datapath identifier is a  string value that MUST be formatted as a sequence of 8  2-digit hexadecimal numbers that are separated by colons,  for example, '01:23:45:67:89:ab:cd:ef'. When processing a  datapath identifier, the case of the decimal digits MUST be  ignored.  This element MUST be present in the NETCONF data store.  If this element is not present in a NETCONF <edit-config>  operation 'create', 'merge' or 'replace' and the parent  element does not exist, a 'data-missing' error is  returned.";  }  leaf enabled {  type boolean;  default false;  description "This element indicates the administrative state  of the OpenFlow Logical Switch. A value of 'false' means  the OpenFlow Logical Switch MUST NOT communicate with any  OpenFlow Controllers, MUST NOT conduct any OpenFlow  processing, and SHOULD NOT be utilizing computational or  network resources of the underlying platform.  This element is optional. If this element is not present it  defaults to 'false'.";  }  leaf check-controller-certificate {  type boolean;  default false;  description "This element indicates the behavior of the  OpenFlow Logical Switch when connecting to an OpenFlow  Controller.    If set to value 'false', the logical switch will connect to  a controller without checking any controller certificate.    If set to value 'true', then the logical switch will  connect to a controller with element <protocol> set to  'TLS', only if the controller provides a certificate that  can be verified with one of the certificates stored in the  list called external-certificates in the OpenFlow Capable  Switch.    If a certificate cannot be validated, the OpenFlow Logical  Switch MUST terminate communication with the corresponding  OpenFlow Controller, MUST NOT conduct any OpenFlow  processing on requests of this OpenFlow controller, and  SHOULD NOT further utilize any computational or network  resources of for dealing with this connection.    If set to value 'true', the OpenFlow Logical Switch MUST  NOT connect to any OpenFlow Controller that does not  provide a certificate. This implies that it cannot connect  to an OpenFlow controller that has the value of element  protocol set to 'TCP'. Only connections with protocol 'TLS'  are possible in this case.  This element is optional. If this element is not present it  defaults to 'false'.";  }  leaf lost-connection-behavior {  type enumeration {  enum failSecureMode;  enum failStandaloneMode;  }  default failSecureMode;  description "This element indicates the the behavior of the  OpenFlow Logical Switch in case it loses contact with all  OpenFlow Controllers. There are two alternative modes in  such a case: fails secure mode and fail standalone mode as  defined by the OpenFlow protocol specification version 1.2,  section 6.4. These are the only allowed values for this  element. Default is the fail secure mode.  This element is optional. If this element is not present it  defaults to 'failSecureMode'.";  }  container controllers {  description "The list of controllers for this Logical switch.  The element 'id' of OFControllerType MUST be unique within  this list.";  list controller {  key "id";  description "The list of OpenFlow Controllers that are  assigned to the OpenFlow Logical Switch. The switch MUST  NOT connect to any OpenFlow Controller that is not  contained in this list.  NETCONF <edit-config> operations MUST be implemented as  follows:  \* The 'id' element MUST be present at all <edit-config>  operations to identify the controller.  \* If the operation is 'merge' or 'replace', the element  is created if it does not exist, and its value is set  to the value found in the XML RPC data.  \* If the operation is 'create', the element is created if  it does not exist. If the element already exists, a  'data‑exists' error is returned.  \* If the operation is 'delete', the element is deleted if  it exists. If the element does not exist, a  'data‑missing' error is returned.";  uses OFControllerType;  }  }  container resources {  description "The list of identifiers of all resources of the  OpenFlow Capable Switch that the OpenFlow Logical Switch  has exclusive or non-exclusive access to. A resource is  identified by the value of its resource-identifier element.  For each resource identifier value in this list, there MUST  be an element with a matching resource identifier value in  the resources list of the OpenFlow Capable Switch.    Identifiers of this list are contained in elements  indicating the type of resource: 'port', 'queue',  'certificate', or 'flow-table'. Depending on the type,  different constraints apply. These are specified in  separate descriptions per type.  At present the elements in this lists are not configurable  and can only be retrieved by NETCONF <get> or <get-config>  operations. Attemps to modify this element and its children  with a NETCONF <edit-config> operation MUST result in an  'operation-not-supported' error with type 'application'.";  leaf-list port {  type leafref {  path "/capable-switch/resources/port/resource-id";  }  description "A resource identifier of a port of the  OpenFlow Capable Switch that the OpenFlow Logical Switch  has exclusive access to.  The elements in this list MUST refer to elements at the  following path:  /capable-switch/resources/port/resource-id  Elements in this list MUST be unique. This means each  port element can only be referenced once.";  }  leaf-list queue {  type leafref {  path "/capable-switch/resources/queue/resource-id";  }  description "A resource identifier of a queue of the  OpenFlow Capable Switch that the OpenFlow Logical Switch  has exclusive access to.  The elements in this list MUST refer to elements at the  following path:  /capable-switch/resources/queue/resource-id  Elements in this list MUST be unique. This means each  queue element can only be referenced once.";  }  leaf certificate {  type leafref {  path "/capable-switch/resources/owned-certificate/resource-id";  }  description "The resource identifier of the owned  certificate in the OpenFlow Capable Switch that the  OpenFlow Logical Switch uses to identify itself. This  element MUST NOT occur more than once in an OpenFlow  Logical Switch's resource list.    If no such element is in an OpenFlow Logical Switch's  resource list, then the OpenFlow Logical Switch does not  authenticate itself towards an OpenFloe Controller with a  certificate. If this element is present, then the  OpenFlow Logical Switch MUST provide this certificate for  authentication to an OpenFlow Controller when setting up  a TLS connection.    For TCP connections this element is irrelevant.  The element MUST refer to an element at the following  path:  /capable-switch/resources/owned-certificate/resource-id  ";  }  leaf-list flow-table {  type leafref {  path "/capable-switch/resources/flow-table/resource-id";  }  description "A resource identifier of a flow table of the  OpenFlow Capable Switch that the OpenFlow Logical Switch  has exclusive access to.  The elements in this list MUST refer to elements at the  following path:  /capable-switch/resources/flow-table/resource-id  Elements in this list MUST be unique. This means each  flow-table element can only be referenced once.";  }  }  }  grouping OFLogicalSwitchCapabilitiesType {  description "This grouping specifies all properties of an  OpenFlow logical switch's capabilities.  Elements in the type OFLogicalSwitchCapabilitiesType are not  configurable and can only be retrieved by NETCONF <get>  operations. Attemps to modify this element and its children  with a NETCONF <edit-config> operation MUST result in an  'operation-not-supported' error with type 'application'.";  leaf max-buffered-packets {  type uint32;  description "The maximum number of packets the logical switch  can buffer when sending packets to the controller using  packet-in messages.";  }  leaf max-tables {  type uint8;  description "The number of flow tables supported by the  logical switch.";  }  leaf max-ports {  type uint32;  description "The number of flow tables supported by the  logical switch.";  }  leaf flow-statistics {  type boolean;  default false;  description "Specifies if the logical switch supports flow  statistics.";  }  leaf table-statistics {  type boolean;  default false;  description "Specifies if the logical switch supports table  statistics.";  }  leaf port-statistics {  type boolean;  default false;  description "Specifies if the logical switch supports port  statistics.";  }  leaf group-statistics {  type boolean;  default false;  description "Specifies if the logical switch supports group  statistics.";  }  leaf queue-statistics {  type boolean;  default false;  description "Specifies if the logical switch supports queue  statistics.";  }  leaf reassemble-ip-fragments {  type boolean;  default false;  description "Specifies if the logical switch supports  reassemble IP fragments.";  }  leaf block-looping-ports {  type boolean;  default false;  description "'true' indicates that a switch protocol outside  of OpenFlow, such as 802.1D Spanning Tree, will detect  topology loops and block ports to prevent packet loops.";  }  container reserved-port-types {  description "Specify generic forwarding actions such as  sending to the controller, flooding, or forwarding using  non-OpenFlow methods, such as 'normal' switch processing.";  reference "The types of reserved ports are defined in  OpenFlow Switch Specification versions 1.2, 1.3, and  1.3.1.";  leaf-list type {  type enumeration {  enum all;  enum controller;  enum table;  enum inport;  enum any;  enum normal;  enum flood;  }  }  }  container group-types {  description "Specify the group types supported by the logical  switch.";  reference "The types of groups are defined in OpenFlow Switch  Specification versions 1.2, 1.3, and 1.3.1.";  leaf-list type {  type enumeration {  enum all;  enum select;  enum indirect;  enum fast-failover;  }  }  }  container group-capabilities {  description "Specify the group capabilities supported by the  logical switch.";  reference "The types of group capability are defined in  OpenFlow Switch Specification versions 1.2, 1.3, and  1.3.1.";  leaf-list capability {  type enumeration {  enum select-weight;  enum select-liveness;  enum chaining;  enum chaining-check;  }  }  }  container action-types {  description "Specify the action types supported by the  logical switch.";  leaf-list type {  type OFActionType;  }  }  container instruction-types {  description "Specify the instruction types supported by the  logical switch.";  leaf-list type {  type OFInstructionType;  }  }  }  grouping OFControllerType {  description "This grouping specifies all properties of an  OpenFlow Logical Switch Controller.  NETCONF <edit-config> operations MUST be implemented as  follows:  \* The 'id' element MUST be present at all <edit-config>  operations to identify the controller.  \* If the operation is 'merge' or 'replace', the element is  created if it does not exist, and its value is set to the  value found in the XML RPC data.  \* If the operation is 'create', the element is created if it  does not exist. If the element already exists, a  'data‑exists' error is returned.  \* If the operation is 'delete', the element is deleted if it  exists. If the element does not exist, a 'data‑missing'  error is returned.";  leaf id {  type OFConfigId;  mandatory true;  description "A unique but locally arbitrary identifier that  uniquely identifies an OpenFlow Controller within the  context of an OpenFlow Capable Switch. It MUST be  persistent across reboots of the OpenFlow Capable Switch.  This element MUST be present to identify the OpenFlow  controller.";  }  leaf role {  type enumeration {  enum master;  enum slave;  enum equal;  }  default equal;  description "This element indicates the role of the OpenFlow  Controller. Semantics of these roles are specified in the  OpenFlow specifications 1.0 - 1.3.1. It is RECOMMENDED  that the roles of controllers are not configured by  OF-CONFIG 1.1.1 but determined using the OpenFlow protocol.  OpenFlow Controllers configured by OF-CONFIG 1.1.1 have the  default role 'equal'. A role other than 'equal' MAY be  assigned to a controller. Roles 'slave' and 'equal' MAY be  assigned to multiple controllers. Role 'master' MUST NOT  be assigned to more than one controller.  This element is optional. If this element is not present it  defaults to 'equal'.";  }  leaf ip-address {  type inet:ip-address;  mandatory true;  description "The IP address of the OpenFlow Controller. This  IP address is used by the OpenFlow Logical Switch when  connecting to the OpenFlow Controller.  This element MUST be present in the NETCONF data store.  If this element is not present in a NETCONF <edit-config>  operation 'create', 'merge' or 'replace' and the parent  element does not exist, a 'data-missing' error is  returned.";  }  leaf port {  type inet:port-number;  default 6633;  description "The TCP port number at the OpenFlow Controller.  This port number is used by the OpenFlow Logical Switch  when connecting to the OpenFlow Controller using TCP or  TLS. The default value is 6633.  This element is optional. If this element is not present it  defaults to 6633.";  }  leaf local-ip-address {  type inet:ip-address;  description "The local IP address of the OpenFlow Logical  Switch when connecting to this OpenFlow Controller. It is  the source IP address of packets sent to this OpenFlow  Controller. If present, this element overrides any default  IP address.      This element is optional. Attempts to set this element to  an IP address that cannot be used by the OpenFlow Logical  Switch MUST result in an 'bad-element' error with type  'application'. The <error-info> element MUST contain the  name of this element in the <bad-element> element.";  }  leaf local-port {  type inet:port-number;  description "The local TCP port number of the OpenFlow  Logical Switch when connecting to this OpenFlow Controller.  It is the source TCP port number of packets sent to this  OpenFlow Controller. If this element is not present, then  the port number is chosen arbitrarily by the OpenFlow  Logical Switch.    This element is optional. Attempts to set this element to a  port number that cannot be used by the OpenFlow Logical  Switch MUST result in an 'bad-element' error with type  'application'. The <error-info> element MUST contain the  name of this element in the <bad-element> element.";  }  leaf protocol {  type enumeration {  enum "tcp";  enum "tls";  }  default "tls";  description "The default protocol tha the OpenFlow Logical  Switch uses to connect to this OpenFlow Controller. 'tls'  is the default value.  This element is optional. If this element is not present it  defaults to 'tls'.";  }  container state {  config false;  description "This container holds connection state  information that indicate the connection state of the  OpenFlow Logical Switch and the OpenFlow protocol version  used for the connection.  Children of this element are not configurable and can only  be retrieved by NETCONF <get> operations. Attemps to modify  this element and its children with a NETCONF <edit-config>  operation MUST result in an 'operation-not-supported' error  with type 'application'.";  leaf connection-state {  type OFUpDownStateType;  description "This object indicates the connections state of  the OpenFlow Logical Switch to this controller.";  }  leaf current-version {  type OFOpenFlowVersionType;  description "This object indicates the version of the  OpenFlow protocol used between the OpenFlow Logical  Switch and this Controller. If element connection-state  has value 'up', then this element indicates the actual  version in use. If element connection-state has value  'down', then this element indicates the version number of  the last established connection with this OpenFlow  Controller. The value of this element MAY be persistent  across reboots of the OpenFlow Logical Switch in such a  case. If element connection-state has value 'down'and  there is no information about previous connections to  this OpenFlow controller, then this element is not  present or has the value '0'.";  }  leaf-list supported-versions {  type OFOpenFlowVersionType;  description "This list of elements includes one entry for  each OpenFlow protocol version that this OpenFlow  controller supports. It SHOULD contain all";  }  leaf local-ip-address-in-use {  type inet:ip-address;  description "The local IP address of the OpenFlow Logical  Switch when connecting to this OpenFlow Controller. It  is the source IP address of packets sent to this OpenFlow  Controller. If present, this element overrides any  default IP address.";  }  leaf local-port-in-use {  type inet:port-number;  description "The local TCP port number of the OpenFlow  Logical Switch. If element connection-state has value  'up', then this element indicates the actual port number  in use. If element connection-state has value 'down',  then this element indicates the port number used for the  last attempt to establish a connection with this OpenFlow  Controller.???  When connecting to this OpenFlow Controller, it is the  source TCP port number of packets sent to this OpenFlow  Controller. If this element has its defaqult value 0,  then port number is chosen arbitrarily by the OpenFlow  Logical Switch.";  }  }  }  grouping OFResourceType {  description "This element specifies a generic OpenFlow resource  that is used as a basis for specific resources. Even though  this element is not used on its own the following rules for  NETCONF operations MUST be obeyed also by elemnts using this  element.  NETCONF <edit-config> operations MUST be implemented as  follows:  \* The 'id' element MUST be present at all <edit-config>  operations to identify the resource.  \* If the operation is 'merge' or 'replace', the element is  created if it does not exist, and its value is set to the  value found in the XML RPC data.  \* If the operation is 'create', the element is created if it  does not exist. If the element already exists, a  'data‑exists' error is returned.  \* If the operation is 'delete', the element is deleted if it  exists. If the element does not exist, a 'data‑missing'  error is returned.";  leaf resource-id {  type inet:uri;  mandatory true;  description "A unique but locally arbitrary identifier that  uniquely identifies an OpenFlow Port within the context  of an OpenFlow Logical Switch. It MUST be persistent  across reboots of the OpenFlow Capable Switch.  This element MUST be present to identify the OpenFlow  resource.";  }  }  grouping OFPortBaseTunnelType {  description "A group of common elements that are included  in every supported tunnel type. Tunnels are modeled as  logical ports.  One pair of local/remote endpoints must exist for a tunnel  configuration.  Only elements from one choice must exist at a time.";  choice endpoints {  mandatory true;  case v4-endpoints {  leaf local-endpoint-ipv4-adress {  type inet:ipv4-address;  description "The IPv4 address of the local tunnel  endpoint.";  }  leaf remote-endpoint-ipv4-adress {  type inet:ipv4-address;  description "The IPv4 address of the remote tunnel  endpoint.";  }  }  case v6-endpoints {  leaf local-endpoint-ipv6-adress {  type inet:ipv6-address;  description "The IPv6 address of the local tunnel  endpoint.";  }  leaf remote-endpoint-ipv6-adress {  type inet:ipv6-address;  description "The IPv6 address of the remote tunnel  endpoint.";  }  }  case mac-endpoints {  leaf local-endpoint-mac-adress {  type yang:mac-address;  description "The MAC address of the local tunnel  endpoint.";  }  leaf remote-endpoint-mac-adress {  type yang:mac-address;  description "The MAC address of the remote tunnel  endpoint.";  }  }  }  }  grouping OFPortIPGRETunnelType {  description "Properties of a IP-in-GRE tunnel with key,  checksum, and sequence number information.";  uses OFPortBaseTunnelType;  leaf checksum-present {  type boolean;  default true;  description "Indicates presence of the GRE checksum.";  }  leaf key-present {  type boolean;  default true;  description "Indicates presence of the GRE key.";  }  leaf key {  when "../key-present='true'" {  description "This element is only relevant if element  key-present of this IP GRE Tunnel has value 'true'.";  }  type uint32;  mandatory true;  description "The (optional) key of the GRE tunnel. It MAY  be used to set the OXM\_OF\_TUNNEL\_ID match field metadata  in the OpenFlow protocol";  }  leaf sequence-number-present {  type boolean;  default false;  description "Indicates presence of the GRE sequence  number.";  }  }  grouping OFPortVXLANTunnelType {  description "Properties of a VxLAN tunnel.";  uses OFPortBaseTunnelType;  leaf vni-valid {  type boolean;  default true;  description "Indicates how the corresponding flag should be  set in packets sent on the tunnel.";  }  leaf vni {  type uint32;  description "Virtual network identifier assigned to all  packets sent on the tunnel. A VxLAN implementation MAY  use the this element to set the OXM\_OF\_TUNNEL\_ID match  field metadata in the OpenFlow protocol.";  }  leaf vni-multicast-group {  type inet:ip-address;  description "If IP multicast is used to support broadcast  on the tunnel this specifies the corresponding multicast  IP address";  }  leaf udp-source-port {  type inet:port-number;  description "Specifies the outer UDP source port number.  If this element is absent, the port number MAY be chosen  dynamically.";  }  leaf udp-dest-port {  type inet:port-number;  description "Specifies the outer UDP destination port  number. It is intended to reserve a port number for  VxLAN at IANA. As soon as this has been reserved, the  reserved number SHOULD become the default value for this  element.";  }  leaf udp-checksum {  type boolean;  default false;  description "Boolean flag to indicate whether or not the  outer UDP checksum should be set";  }  }    grouping OFPortNVGRETunnelType {  description "Properties of a NVGRE tunnel.";  uses OFPortBaseTunnelType;  leaf tni {  type uint32;  description "Specifies the tenant network identifier  assigned to all packets sent on the tunnel";  }  leaf tni-resv {  type uint32;  description "Used to set the reserved user-defined bits of  the GRE key field";  }  leaf tni-multicast-group {  type inet:ip-address;  description "If IP multicast is used to support broadcast  on the tunnel this element specifies the corresponding  multicast IP address";  }  }  grouping OFPortType {  description "This element specifies all properties of an  OpenFlow resource of type OpenFlow Port. It represent a  physical port or a logical port of the OpenFlow Capable  Switch and can be assigned for exclusive use to an OpenFlow  Logical Switch. A logical port represents a tunnel endpoint  as described in the OpenFlow protocol specification versions  1.3 - 1.3.1.  NETCONF <edit-config> operations MUST be implemented as  follows:  \* The 'resource-id' element of OFResoureType MUST be present  at all <edit-config> operations to identify the port.  \* If the operation is 'merge' or 'replace', the element is  created if it does not exist, and its value is set to the  value found in the XML RPC data.  \* If the operation is 'create', the element is created if it  does not exist. If the element already exists, a  'data‑exists' error is returned.  \* If the operation is 'delete', the element is deleted if it  exists. If the element does not exist, a 'data‑missing'  error is returned.";  uses OFResourceType;  leaf number {  type uint64;  config false;  description "This number identifies the OpenFlow Port to  OpenFlow Controllers. It is assigned to an OpenFlow Port  latest when the OpenFlow Port is associated with and  OpenFlow Logical Switch. If the OpenFlow Port is  associated with an OpenFlow Logical Switch, this element  MUST be unique within the context of the OpenFlow Logical  Switch.    OpenFlow Capable Switch implementations may choose to  assign values to OpenFlow Ports that are unique within the  context of the OpenFlow Logical Switch. These numbers can  be used independent of assignments to OpenFlow Logical  Switches.    Other implementations may assign values to this element  only if the OpenFlow Port is assigned to an OpenFlow  Logical Switch. If no value is currently assigned to this  element then this element MUST NOT be included in replies  to NETCONF <get> requests. Since this element is not  configurable with the NETCONF protocol it MUST NOT be  included in replies to NETCONF <get-config> requests.";  }  leaf name {  type string { length "1..16"; }  config false;  description "This element assists OpenFlow Controllers in  identifying OpenFlow Ports.    This element is not to be set by the OP-CONFIG protocol,  but it is set by the switch implementation. It may be set  at start-up time of an OpenFlow Capable Switch or when the  OpenFlow Port is assigned to an OpenFlow Logical Switch.  It MAY also be not set at all. If this element is set to a  value other than the empty string when being assigned to an  OpenFlow Logical Switch, then the value of this element  MUST be unique within the context of the OpenFlow Logical  Switch.    If no value or the empty string is currently assigned to  this element then this element MUST not be included in  replies to NETCONF <get> requests. Since this element is  not configurable with the NETCONF protocol it MUST NOT be  included in replies to NETCONF <get-config> requests.";  }  leaf current-rate {  when "../features/current/rate='other'" {  description "This element is only valid if the element rate  of the current features has value 'other'.";  }  type uint32;  units "kbit/s";  config false;  description "This element indicates the current bit rate of  the port. Its values is to be provided in units of kilobit  per second (kbps). This element is only valid if the  element called 'rate' in the current Port Features has a  value of 'other'.  Since this element is not configurable with the NETCONF  protocol it MUST NOT be included in replies to NETCONF  <get-config> requests.";  }  leaf max-rate {  when "../features/current/rate='other'" {  description "This element is only valid if the element rate  of the current features has value 'other'.";  }  type uint32;  units "kbit/s";  config false;  description "This element indicates the maximum bit rate of  the port. Its values is to be provided in units of kilobit  per second (kbps). This element is only valid if the  element called 'rate' in the current Port Features has a  value of 'other'.  Since this element is not configurable with the NETCONF  protocol it MUST NOT be included in replies to NETCONF  <get-config> requests.";  }  container configuration {  description "This element represents the general  adminitrative configuration of the OpenFlow Port.";  leaf admin-state {  type OFUpDownStateType;  default 'up';  description "The administrative state of the port. If  true, the port has been administratively brought down and  SHOULD not be used by OpenFlow.  This element is optional. If this element is not present  it defaults to 'up'.";  }  leaf no-receive {  type boolean;  default false;  description "If true, packets received at this OpenFlow  port SHOULD be dropped.  This element is optional. If this element is not present  it defaults to 'false'.";  }  leaf no-forward {  type boolean;  default false;  description "If true, packets forwarded to this OpenFlow  port SHOULD be dropped.  This element is optional. If this element is not present  it defaults to 'false'.";  }  leaf no-packet-in {  type boolean;  default false;  description "If true, packets received on that port that  generate a table miss should never trigger a packet-in  message to the OpenFlow Controller.  This element is optional. If this element is not present  it defaults to 'false'.";  }  }  container state {  config false;  description "This element represents the general operational  state of the OpenFlow Port.  Children of this element are not configurable and can only be  retrieved by NETCONF <get> operations. Attemps to modify this  element and its children with a NETCONF <edit-config>  operation MUST result in an 'operation-not-supported' error  with type 'application'.";  leaf oper-state {  type OFUpDownStateType;  description "If the value of this element is 'down', it  indicates that there is no physical link present.";  }  leaf blocked {  type boolean;  description "If the value of this element is 'true', it  indicates that a switch protocol outside of OpenFlow,  such as 802.1D Spanning Tree, is preventing the use of  this OpenFlow port for OpenFlow flooding.";  }  leaf live {  type boolean;  description "If the value of this element is 'true', it  indicates that this OpenFlow Port is live and can be used  for fast failover.";  }  }  container features {  container current {  uses OFPortCurrentFeatureListType;  config false;  description "The features (rates, duplex, etc.) of the  port, that are currently in use.  Children of this element are not configurable and can  only be retrieved by NETCONF <get> operations. Attemps to  modify this element and its children with a NETCONF  <edit-config> operation MUST result in an  'operation-not-supported' error with type  'application'.";  }  container advertised {  uses OFPortOtherFeatureListType;  description "The features (rates, duplex, etc.) of the  port, that are advertised to the peer port.  NETCONF <edit-config> operations MUST be implemented as  follows:  \* The 'resource-id' element of OFResoureType MUST be  present in the path or in the filter at all  <edit-config> operations to identify the port.  \* If the operation is 'merge' or 'replace', the element  is created if it does not exist, and its value is set  to the value found in the XML RPC data.  \* If the operation is 'create', the element is created if  it does not exist. If the element already exists, a  'data‑exists' error is returned.  \* If the operation is 'delete', the element is deleted if  it exists. If the element does not exist, a  'data‑missing' error is returned.";  }  container supported {  uses OFPortOtherFeatureListType;  config false;  description "The features (rates, duplex, etc.) of the  port, that are supported on the port.  Children of this element are not configurable and can  only be retrieved by NETCONF <get> operations. Attemps to  modify this element and its children with a NETCONF  <edit-config> operation MUST result in an  'operation-not-supported' error with type  'application'.";  }  container advertised-peer {  uses OFPortOtherFeatureListType;  config false;  description "The features (rates, duplex, etc.) that are  currently advertised by the peer port.  Children of this element are not configurable and can  only be retrieved by NETCONF <get> operations. Attemps to  modify this element and its children with a NETCONF  <edit-config> operation MUST result in an  'operation-not-supported' error with type  'application'.";  }  }  choice tunnel-type {  description "Tunnels are modeled as logical ports.  Elements in this choice are not configurable and can only  be retrieved by NETCONF <get> operations. Attemps to modify  this element and its children with a NETCONF <edit-config>  operation MUST result in an 'operation-not-supported' error  with type 'application'.  Only elements from one choice must exist at a time.";  container tunnel {  description "Properties of a basic IP-in-GRE tunnel.";  uses OFPortBaseTunnelType;  }  container ipgre-tunnel {  description "Properties of a IP-in-GRE tunnel.";  uses OFPortIPGRETunnelType;  }  container vxlan-tunnel {  description "Properties of a VxLAN tunnel.";  uses OFPortVXLANTunnelType;  }  container nvgre-tunnel {  description "Properties of a NVGRE tunnel.";  uses OFPortNVGRETunnelType;  }  }  }  grouping OFQueueType {  description "This grouping specifies all properties of a queue  resource.  NETCONF <edit-config> operations MUST be implemented as  follows:  \* The 'resource-id' element of OFResoureType MUST be present  at all <edit-config> operations to identify the port.  \* If the operation is 'merge' or 'replace', the element is  created if it does not exist, and its value is set to the  value found in the XML RPC data.  \* If the operation is 'create', the element is created if it  does not exist. If the element already exists, a  'data‑exists' error is returned.  \* If the operation is 'delete', the element is deleted if it  exists. If the element does not exist, a 'data‑missing'  error is returned.";  uses OFResourceType;  leaf id {  type uint64;  mandatory true;  description "This id identifies the OpenFlow Queue to  OpenFlow Controllers. It is assigned to an OpenFlow Queue  latest when the OpenFlow Queue is associated with and  OpenFlow Logical Switch. If the OpenFlow Queue is  associated with an OpenFlow Logical Switch, this element  MUST be unique within the context of the OpenFlow Logical  Switch.    OpenFlow Capable Switch implementations may choose to  assign values to OpenFlow Queues that are unique within the  context of the OpenFlow Logical Switch. These id can be  used independent of assignments to OpenFlow Logical  Switches.    Other implementations may assign values to this element  only if the OpenFlow Queue is assigned to an OpenFlow  Logical Switch. If no value is currently assigned to this  element then this element MUST NOT be included in replies  to NETCONF <get> requests. Since this element is not  configurable with the NETCONF protocol it MUST NOT be  included in replies to NETCONF <get-config> requests.";  }  leaf port {  type leafref {  path "/capable-switch/resources/port/resource-id";  }  description "Reference to port resources in the Capable  Switch.    This element associates an OpenFlow Queue with an OpenFlow  Port. If the OpenFlow Queue is associated with an OpenFlow  Logical Switch S and this element is present, then it MUST  be set to the value of element resource-id of an OpenFlow  Port which is associated with the OpenFlow Logical Switch  S.  The element MUST refer to an element at the following path:  /capable-switch/resources/port/resource-id";  }  container properties {  description "The queue properties currently configured.";  leaf min-rate {  type OFTenthOfAPercentType;  description "The minimal rate that is reserved for this  queue in 1/10 of a percent of the actual rate.  This element is optional. If not present a min-rate is  not set.";  }  leaf max-rate {  type OFTenthOfAPercentType;  description "The maximum rate that is reserved for this  queue in 1/10 of a percent of the actual rate.  This element is optional. If not present the max-rate is  not set.";  }  leaf-list experimenter {  type uint32;  description "A list of experimenter identifiers of queue  properties used.  This element is optional.";  }  }  }  grouping OFPortCurrentFeatureListType {  description "The current features of a port.  Elements in the type OFPortCurrentFeatureListType are not  configurable and can only be retrieved by NETCONF <get>  operations. Attemps to modify this element and its children  with a NETCONF <edit-config> operation MUST result in an  'operation-not-supported' error with type 'application'.";  leaf rate {  type OFPortRateType;  description "The transmission rate that is currently used.  The value MUST indicate a valid forwarding rate.    The current Port Feature set MUST contain this element  exactly once. The other Port Feature sets MAY contain this  element more than once. If this element appears more than  once in a Port Feature set than the value MUST be unique  within the Port Feature set.";  }  leaf auto-negotiate {  type boolean;  description "Specifies the administrative state of the  forwarding rate auto-negotiation protocol at this OpenFlow  Port.";  }  leaf medium {  type enumeration {  enum copper;  enum fiber;  }  description "This element MUST indicate a valid physical  medium used by the OpenFlow Port.    The current Port Feature set MUST contain this element  exactly once. The other Port Feature sets MAY contain this  element more than once. If this element appears more than  once in a Port Feature set than the value MUST be unique  within the Port Feature set.";  }  leaf pause {  type enumeration {  enum unsupported;  enum symmetric;  enum asymmetric;  }  description "Specifies if pausing of transmission is  supported at all and if yes if it is asymmetric or  symmetric.";  }  }  grouping OFPortOtherFeatureListType {  description "The features of a port that are supported or  advertised.  If the elements in the OFPortOtherFeatureListType ares used  as configurable elements the NETCONF <edit-config> operations  MUST be implemented as follows:  \* The 'resource-id' element MUST be present in the path or in  the filter at all <edit-config> operations to identify the  resource.  \* If the operation is 'merge' or 'replace', the element is  created if it does not exist, and its value is set to the  value found in the XML RPC data.  \* If the operation is 'create', the element is created if it  does not exist. If the element already exists, a  'data‑exists' error is returned.  \* If the operation is 'delete', the element is deleted if it  exists. If the element does not exist, a 'data‑missing'  error is returned.  If elements in the type OFPortOtherFeatureListType are used  in an non-configurable way, they only be retrieved by NETCONF  <get> operations. Attemps to modify this element and its  children with a NETCONF <edit-config> operation MUST result  in an 'operation-not-supported' error with type  'application'.";  leaf-list rate {  type OFPortRateType;  min-elements 1;  description "The transmission rate that is supported or  advertised. Multiple transmissions rates are allowed.  At least one element MUST be present in the NETCONF data  store. If none of this elements is are present in a NETCONF  <edit-config> operation 'create', 'merge' or 'replace' and  the parent element does not exist, a 'data-missing' error  is returned.";  }  leaf auto-negotiate {  type boolean;  default true;  description "Specifies if auto-negotiation of transmission  parameters is enabled for the port.  This element is optional. If this element is not present it  defaults to 'true'.";  }  leaf-list medium {  type enumeration {  enum copper;  enum fiber;  }  min-elements 1;  description "The transmission medium used by the port.  Multiple media are allowed.  At least one element MUST be present in the NETCONF data  store. If none of this elements is are present in a NETCONF  <edit-config> operation 'create', 'merge' or 'replace' and  the parent element does not exist, a 'data-missing' error  is returned.";  }  leaf pause {  type enumeration {  enum unsupported;  enum symmetric;  enum asymmetric;  }  mandatory true;  description "Specifies if pausing of transmission is  supported at all and if yes if it is asymmetric or  symmetric.  This element MUST be present in the NETCONF data store.  If this element is not present in a NETCONF <edit-config>  operation 'create', 'merge' or 'replace' and the parent  element does not exist, a 'data-missing' error is  returned.";  }  }    grouping OFExternalCertificateType {  description "This grouping specifies a certificate that can be  used by an OpenFlow Logical Switch for authenticating a  controller when a TLS connection is established.";  uses OFResourceType;  leaf certificate {  type string;  mandatory true;  description "An X.509 certificate in DER format base64  encoded.  This element MUST be present in the NETCONF data store.  If this element is not present in a NETCONF <edit-config>  operation 'create', 'merge' or 'replace' and the parent  element does not exist, a 'data-missing' error is  returned.";  }  }    grouping OFOwnedCertificateType {  description "This grouping specifies a certificate and a  private key. It can be used by an OpenFlow Logical Switch for  authenticating itself to a controller when a TLS connection  is established.";  uses OFResourceType;  leaf certificate {  type string;  mandatory true;  description "An X.509 certificate in DER format base64  encoded.  This element MUST be present in the NETCONF data store.  If this element is not present in a NETCONF <edit-config>  operation 'create', 'merge' or 'replace' and the parent  element does not exist, a 'data-missing' error is  returned.";  }  container private-key {  uses KeyValueType;  description "This element contains the private key  corresponding to the certificate. The private key is  encoded as specified in XML-Signature Syntax and Processing  (http://www.w3.org/TR/2001/PR-xmldsig-core-20010820/).  Currently the specification only support DSA and RSA keys.  This element MUST be present in the NETCONF data store.  If this element is not present in a NETCONF <edit-config>  operation 'create', 'merge' or 'replace' and the parent  element does not exist, a 'data-missing' error is  returned.";  }  }    grouping KeyValueType {  description "The KeyValue element contains a single public key  that may be useful in validating the signature.  NETCONF <edit-config> operations MUST be implemented as  follows:  \* Exactly one of the elemenst 'DSAKeyValue' or 'RSAKeyValue'  all <edit-config> operations.  \* If the operation is 'merge' or 'replace', the element is  created if it does not exist, and its value is set to the  value found in the XML RPC data.  \* If the operation is 'create', the element is created if it  does not exist. If the element already exists, a  'data‑exists' error is returned.  \* If the operation is 'delete', the element is deleted if it  exists. If the element does not exist, a 'data‑missing'  error is returned.";  choice key-type {  mandatory true;  case dsa {  container DSAKeyValue {  uses DSAKeyValueType;  }  }  case rsa {  container RSAKeyValue {  uses RSAKeyValueType;  }  }  }  }    grouping DSAKeyValueType {  description "DSA keys and the DSA signature algorithm are  specified in 'FIPS PUB 186-2, Digital Signature Standard (DSS),  U.S. Department of Commerce/National Institute of Standards and  Technology,  http://csrc.nist.gov/publications/fips/fips186-2/fips186-2.pdf'.  DSA public key values can have the following fields:  P  a prime modulus meeting the requirements of the standard  above  Q  an integer in the range 2\*\*159 < Q < 2\*\*160 which is a  prime divisor of P-1  G  an integer with certain properties with respect to P and Q  J  (P - 1) / Q  Y  G\*\*X mod P (where X is part of the private key and not made  public)  seed  a DSA prime generation seed  pgenCounter  a DSA prime generation counter  Parameter J is avilable for inclusion solely for efficiency as  it is calculatable from P and Q. Parameters seed and  pgenCounter are used in the DSA prime number generation  algorithm specified in the above standard. As such, they are  optional but MUST either both be present or both be absent.  This prime generation algorithm is designed to provide  assurance that a weak prime is not being used and it yields a P  and Q value. Parameters P, Q, and G can be public and common to  a group of users. They might be known from application context.  As such, they are optional but P and Q MUST either both appear  or both be absent. If all of P, Q, seed, and pgenCounter are  present, implementations are not required to check if they are  consistent and are free to use either P and Q or seed and  pgenCounter. All parameters are encoded as base64 values.";  leaf P {  when "count(../Q) != 0";  type binary;  mandatory true;  description "This element is optional. It MUST be present in  the NETCONF data store, if the element 'Q' is present.    If element 'Q' is present in a NETCONF <edit-config>  operation 'create', 'merge' or 'replace' and this element  is missing, a 'data-missing' error is returned.";  }  leaf Q {  when "count(../P) != 0";  type binary;  mandatory true;  description "This element is optional. It MUST be present in  the NETCONF data store, if the element 'P' is present.    If element 'P' is present in a NETCONF <edit-config>  operation 'create', 'merge' or 'replace' and this element  is missing, a 'data-missing' error is returned.";  }  leaf J {  type binary;  description "This element is optional.";  }  leaf G {  type binary;  description "This element is optional.";  }  leaf Y {  type binary;  mandatory true;  description "This element MUST be present in the NETCONF data  store. If this element is not present in a NETCONF  <edit-config> operation 'create', 'merge' or 'replace' and  the parent element does not exist, a 'data-missing' error  is returned.";  }  leaf Seed {  when "count(../PgenCounter) != 0";  type binary;  mandatory true;  description "This element is optional. It MUST be present in  the NETCONF data store, if the element 'PgenCounter' is  present.    If element 'PgenCounter' is present in a NETCONF  <edit-config> operation 'create', 'merge' or 'replace' and  this element is missing, a 'data-missing' error is  returned.";  }  leaf PgenCounter {  when "count(../Seed) != 0";  type binary;  mandatory true;  description "This element is optional. It MUST be present in  the NETCONF data store, if the element 'Seed' is present.    If element 'Seed' is present in a NETCONF <edit-config>  operation 'create', 'merge' or 'replace' and this element  is missing, a 'data-missing' error is returned.";  }  }    grouping RSAKeyValueType {  description "RSA key values have two fields: Modulus and  Exponent.";  leaf Modulus {  type binary;  mandatory true;  description "This element MUST be present in the NETCONF data  store. If this element is not present in a NETCONF  <edit-config> operation 'create', 'merge' or 'replace' and  the parent element does not exist, a 'data-missing' error  is returned.";  }  leaf Exponent {  type binary;  mandatory true;  description "This element MUST be present in the NETCONF data  store. If this element is not present in a NETCONF  <edit-config> operation 'create', 'merge' or 'replace' and  the parent element does not exist, a 'data-missing' error  is returned.";  }  }    grouping OFFlowTableType {  description "Representation of an OpenFlow Flow Table Resource.  Elements in the type OFFlowTableType are not configurable and  can only be retrieved by NETCONF <get> operations. Attemps to  modify this element and its children with a NETCONF  <edit-config> operation MUST result in an  'operation-not-supported' error with type 'application'.";  uses OFResourceType;  leaf max-entries {  type uint8;  description "The maximum number of flow entries supported by  the flow table.";  }  container next-tables {  leaf-list table-id {  type inet:uri;  }  description "An array of resource-ids of all flow tables that  can be directly reached from this table using the  'goto-table' instruction.";  }  container instructions {  leaf-list type {  type OFInstructionType;  }  description "The list of all instruction types supported by  the flow table.";  }  container matches {  leaf-list type {  type OFMatchFieldType;  }  description "The list of all match types supported by the  flow table.";  }  container write-actions {  leaf-list type {  type OFActionType;  }  description "The list of all write action types supported by  the flow table.";  }  container apply-actions {  leaf-list type {  type OFActionType;  }  description "The list of all apply action types supported by  the flow table.";  }  container write-setfields {  leaf-list type {  type OFMatchFieldType;  }  description "The list of all 'set-field' action types  supported by the table using write actions.";  }  container apply-setfields {  leaf-list type {  type OFMatchFieldType;  }  description "The list of all 'set-field' action types  supported by the table using apply actions.";  }  container wildcards {  leaf-list type {  type OFMatchFieldType;  }  description "The list of all fields for which the table  supports wildcarding.";  }  leaf metadata-match {  type hex-binary;  description "This element indicates the bits of the metadata  field on which the flow table can match. It is represented  as 64-bit integer in hexadecimal digits([0-9a-fA-F])  format.";  }  leaf metadata-write {  type hex-binary;  description "This element indicates the bits of the metadata  field on which flow table can write using the  'write-metadata' instruction. It is represented as  64-bit integer in hexadecimal digits([0-9a-fA-F]) format.";  }  }    /\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*  \* Main container  \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*/  container capable-switch {  description "The OpenFlow Capable Switch serves as the root  element for an OpenFlow configuration. It contains logical  switches and resources that can be assigned to logical  switches. It may have relations to OpenFlow Configuration  Points.";  leaf id {  type inet:uri;  mandatory true;  description "A unique but locally arbitrary identifier that  uniquely identifies a Capable Switch within the context of  potential OpenFlow Configuration Points. It MUST be  persistent across reboots of the OpenFlow Capable Switch.  This element MUST be present in the NETCONF data store.  If this element is not present in a NETCONF <edit-config>  operation 'create', 'merge' or 'replace' and the parent  element does not exist, a 'data-missing' error is  returned.";  }  leaf config-version {  type string;  config false;  description "The maximum supported OF-CONFIG version that is  supported by the OpenFlow Capable Switch. For switches  implementing this version of the OF-CONFIG protocol this  MUST always be 1.1.1.  This object can be used to identify the OF-CONFIG version  a capable switch supports beginning with version 1.1.1 of  OF-CONFIG. In addtion the supported version can be  determined by the namespace the OpenFlow Capable Switch  returns to configuration request of an element (like  capable-switch) that is present in all OF-CONFIG versions  specified so far. This is the only possiblity to identify  OF-CONFIG versions prior to OF-CONFIG 1.1.1.";  }  container configuration-points {  list configuration-point {  key "id";  description "The list of all Configuration Points known to  the OpenFlow Capable Switch that may manage it using  OF-CONFIG.  The element 'id' of OFConfigurationType MUST be unique  within this list.";  uses OFConfigurationPointType;  }  }  container resources {  description "A lists containing all resources of the OpenFlow  Capable Switch that can be used by OpenFlow Logical  Switches. Resources are listed here independent of their  actual assignment to OpenFlow Logical Switches. They may  be available to be assigned to an OpenFlow Logical Switch  or already in use by an OpenFlow Logical Switch.";  list port {  must "features/current/rate != 'other' or " +  "(count(current-rate) = 1 and count(max-rate) = 1 and " +  " current-rate > 0 and max-rate > 0)" {  error-message "current-rate and max-rate must be  specified and greater than 0 if rate equals 'other'";  description "current-rate and max-rate can only be  present if rate = 'other', see corresponding leaf  descriptions. If rate = 'other', then both leafs must  be set to values greater than zero.";  }  key "resource-id";  description "The list contains all port resources of the  OpenFlow Capable Switch.  The element 'resource-id' of OFPortType MUST be unique  within this list.";  uses OFPortType;  }  list queue {  key "resource-id";  description "The list contains all queue resources of the  OpenFlow Capable Switch.  The element 'resource-id' of OFQueueType MUST be unique  within this list.";  uses OFQueueType;  }  list owned-certificate {  key "resource-id";  description "The list contains all owned certificate  resources of the OpenFlow Capable Switch.  The element 'resource-id' of OFOwnedCertificateType MUST  be unique within this list.";  uses OFOwnedCertificateType;  }  list external-certificate {  key "resource-id";  description "The list contains all external certificate  resources of the OpenFlow Capable Switch.  The element 'resource-id' of OFExternalCertificateType  MUST be unique within this list.";  uses OFExternalCertificateType;  }  list flow-table {  key "resource-id";  description "The list contains all flow table resources of  the OpenFlow Capable Switch.  The element 'resource-id' of OFFlowTableType MUST be  unique within this list.";  uses OFFlowTableType;  }  }  container logical-switches {  description "This element contains a list of all OpenFlow  Logical Switches available at the OpenFlow Capable  Switch.";  list switch {  key "id";  description "The list of all OpenFlow Logical Switches on  the OpenFlow Capable Switch.  The element 'resource-id' of OFLogicalSwitchType MUST be  unique within this list.";  uses OFLogicalSwitchType;  }  }  }    } |

1. Bibliography

1. *OpenFlow Specification 1.3.* **Open Networking Foundation.** 2011.

2. *OpenFlow: enabling innovation in campus networks.* **McKeown, Nick, et al., et al.** 2008, ACM SIGCOMM Computer Communication Review, pp. 69-74.

3. **Bradner, S.** RFC 2119. *IETF.* [Online] March 1997. http://www.ietf.org/rfc/rfc2119.txt.

4. **Enns, et al., et al.** RFC 6241. *IETF.* [Online] June 2011. http://tools.ietf.org/rfc/rfc6241.txt.

1. Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| **Version** | **Date** | **Author** | **Notes** |
| rev1 | 2/11/12 | Cyorke | Moved final 1.0 document to new template |
| rev2 | 3/4/12 | Chuan | Added sections 8.1 and 8.2 |
| rev3 | 3/4/12 | Stu | Edited the UML diagram and updated the XML for 7.3 |
| rev4 | 3/4/12 | Carl | Accepted Stu’s changes and fixed formatting in 7.3 |
| rev4b | 3/6/12 | Stu | Updated 7.3.2 AND 7.3.3Added 7.4 Logical Switch Capabilities. |
| rev5 | 3/6/12 | Juergen | Integrate configuration of certificates forTLS authentication between logical switch and controller. Updated textual descriptions, XML schemas, normative text, XML examples, XML schema in section 7 as well as in Appendix A. |
| rev6 | 3/6/12 | Carl | Accepted and formatted changes by Stu and Juergen. |
| rev7 | 3/12/12 | Thomas | Updated the XML schema for certificates |
| rev8 | 3/13/13 | Chuan | Added section 7.12. Moved all flow table capability items to flow table object. Updated all related XML schema and YANG models. |
| rev9 | 3/18/12 | Carl | Accepted and formatted changes by Chuan. |
| rev10 | 3/21/12 | Chuan | Updated UML diagrams. Added new diagrams for certificate, capabilities and flow table |
| rev15 | 3/26/12 | Chuan | Update the Normative constraint changes I added in 7.3.4, 7.4.4, 7.12.4 |
| rev16 | 3/26/12 | Carl | Formatted new material. |

1. Considerations for Next or Future Releases

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| --- | --- | --- |
| **ID** | **Description** | **Priority** |
| F-0001 | Multiple OpenFlow controllers associated with a single OpenFlow capable switch. | P0 |
| F-0002 | Adding additional configuration of queue related attributes beyond what is described in OF 1.1 Section A.2.2 |  |
| F-0003 | OpenFlow Controller configuration and monitoring |  |
| F-0004 | bootstrap/auto-discovery/auto-associate of OpenFlow Capable Switches and the OpenFlow Manager |  |