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Cisco Connect

NETCONF, YANG, RESTCONF

TECH-SDN-SP: Software Defined Networking for Service Providers

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Agenda

- Brief Overview of XML
- Introduction to NETCONF
- Introduction to YANG
- Introduction to RESTCONF

Brief Overview of XML

What is XML?

- eXtensible Markup Language
- A language to describe data
- Useful for serialization and data classification
- Not a complete programming language or database
- Compare to [traditional] HTML
  - XML: describe data, case-sensitive (similar to: JSON, YAML)
  - HTML: display data, case-insensitive (similar to: TeX, troff)

Sample XML Data


```xml
<person>
    <name>
        <first>Thomas</first>
        <middle>Alva</middle>
        <last>Edison</last>
    </name>
    <occupation>
        Inventor and businessman
    </occupation>
</person>
```

XML Prolog

```
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
```

- *version* – Currently, only 1.0 is valid (mandatory)
- *encoding* – Character set of the data to follow (optional, UTF-8 is default)
- *standalone* – yes if no external DTD is required, no otherwise (optional, no is default)

XML Elements

- XML tags are called *elements*
- Data between start and end tags are the element's *content*
- Element content, including white space are *character data* where as tags are *markup*
- All elements must have start and end tags

```
<ocupation>Inventor and businessman</occupation>
```

- *Attributes* can further describe elements

```
<name first="Thomas" last="Edison"> </name>
```

- *Empty elements* can simply end with a "/>"

```
<name first="Thomas" last="Edison" />
```

XML Comments

- Further explain to the reader what the XML code is trying to describe
- Single and multi-line comments supported
- Comments can be inline with parsed XML
- All comments start with <!-- and end with -->

```
<!-- This is a single line comment -->
<!--
  This is a multi-line comment.
  A multi-line comment spans multiple lines.
-->
<example name="Comment Example">
    <content>
        This text will be parsed as #PCDATA <!-- This text will not. -->
    </content>
</example>
```

XML Namespaces

- Disambiguates elements and attributes from different vocabularies with the same name
- Groups together related elements and attributes for easy processing
- Namespace objects start with a *prefix* followed by a colon (:) followed by the element or attribute name

```
<lab:annotation>
    <lab:documentation>Lab File Version</lab:documentation>
    <lab:docinfo>
      <LabFileMajorVersion>1</LabFileMajorVersion>
      <LabFileMinorVersion>3</LabFileMinorVersion>
    </lab:docinfo>
</lab:annotation>
```

Introduction to NETCONF

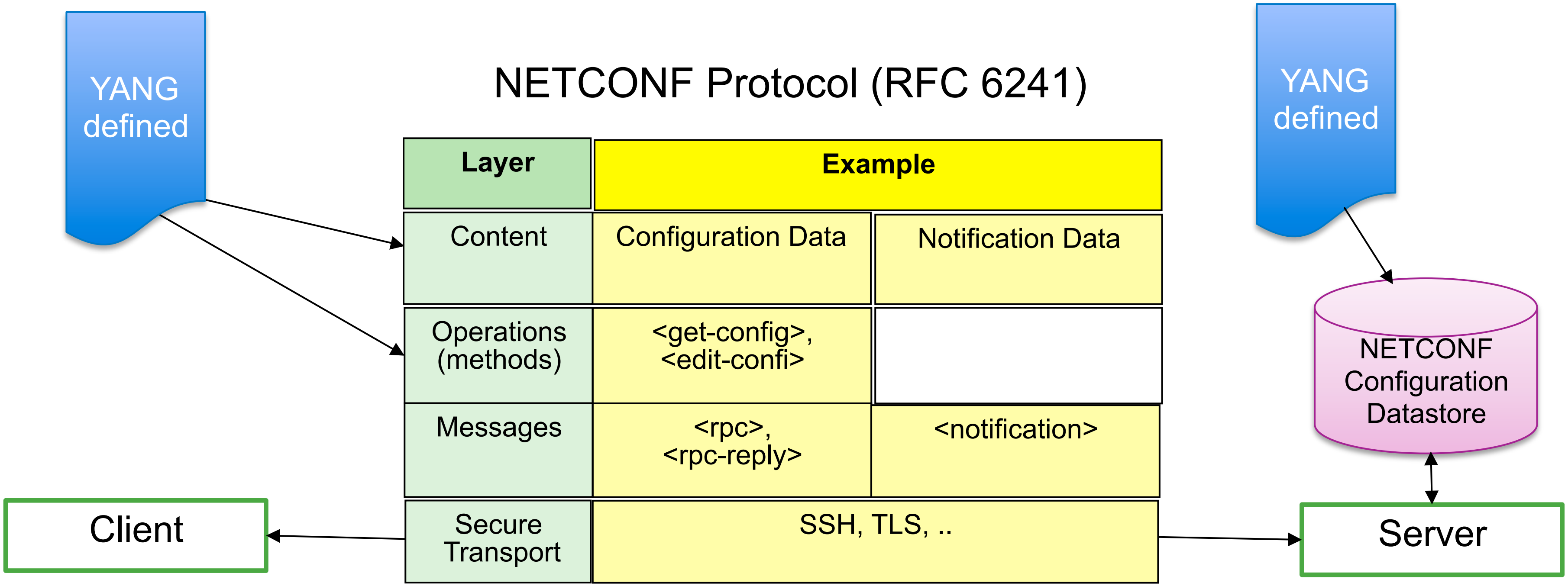
Why NETCONF?

- Typical Network configuration/monitoring still seen in majority of networks
  - Manual typing/scripting proprietary CLIs + backup repository to track changes, labor intensive, expensive, error prone
  - SNMP extensively used for fault handling and monitoring, but failed for configuration tasks

- Some operator’s requirements that paved the way for NETCONF and YANG (detailed in RFC 3535 – “Overview of the 2002 IAB Network Management Workshop”)
  - Must be easy to use
  - Clear distinction between configuration and operational data
  - Must scale to network-wide configurations rather than being focused on single devices
  - Must provide a way to backup and restore configurations
  - Must provide error-checking to ensure consistent configurations
  - Desirable to be able to process and store results using text-management tools like diff and VCS
  - Distinguish between modifying configuration and activating those modifications
  - Desirable to have multiple configuration stores on devices

- Need for move from “The Network is the Record” approach to “Network-wide” configuration database

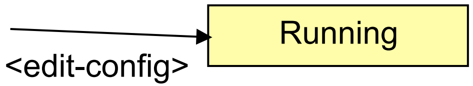
NETCONF – high level concept



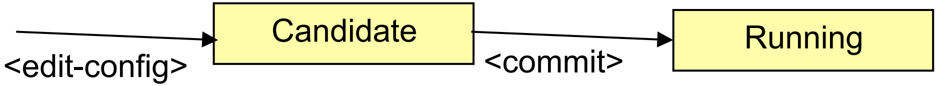
NETCONF Data Stores and Transaction models

- Data stores are named contains that may hold an entire copy of the configuration
- Not all data stores are supported by all devices
- Running is the only mandatory data store
- Not all data stores are writable
- Check the device's capabilities
- To make changes to a non-writeable data store, copy from a writable one
- URL is supported by IOS (for config-copy)

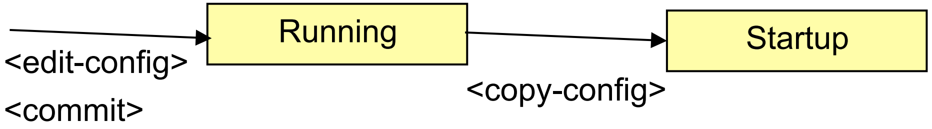
Direct model



Candidate model (optional)



Distinct Startup model (optional)



NETCONF Capabilities

- Capabilities are exchanged in hello messages
- RFC 6241 defines some base capabilities
  - :writable-running – the running data store can be modified directly
  - :candidate – the candidate data store is supported
  - :confirmed-commit – the NETCONF server will support the <cancel-commit> and the <confirmed>, <confirm-timeout>, <persist>, and <persist-id> parameters for the <commit> operation
  - :rollback-on-error – server will rollback the configuration to the previous state if an error is encountered
  - :validate – the server will validate the requested data store or config
  - :startup – the startup data store is supported
  - :url – the URL data store is supported
  - :xpath – filtering can be done using XPATH notation
  - :notification – NETCONF asynchronous event messages (RFC 5277)

NETCONF Capabilities

```
S:<?xml version="1.0" encoding="UTF-8"?>
S: <hello xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
S:   <capabilities>
S:     <capability>
S:       urn:ietf:params:netconf:base:1.1
S:     </capability>
S:     <capability>
S:       urn:ietf:params:ns:netconf:capability:startup:1.0
S:     </capability>
S:   </capabilities>
S:   <session-id>4</session-id>
S: </hello>
S: ]]>]]>

C:<?xml version="1.0" encoding="UTF-8"?>
C: <hello xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
C:   <capabilities>
C:     <capability>
C:       urn:ietf:params:netconf:base:1.1
C:     </capability>
C:   </capabilities>
C: </hello>
C: ]]>]]>
```

NETCONF Protocol Operations

OPERATION	REQ. CAPABILITY	DESCRIPTION	
<get-config>	:base	Retrieve data from the running configuration database	DATA MANIPULATION
<get>	:base	Retrieve data from the running configuration database and/or device statistics	
<edit-config>	:base	Modify a configuration database	
<copy-config>	:base	Copy a configuration database	
<delete-config>	:base	Delete a configuration database	
<discard-changes>	:base and :candidate	Clear all changes from the <candidate/> configuration database and make it match the <running/> configuration database	
<create-subscription>	:notification	Create a NETCONF notification subscription	NOTIFICATION MGMT.
<lock>	:base	Lock a configuration database so only my session can write	LOCKING
<unlock>	:base	Unlock a configuration database so any session can write	
<commit>	:base and :candidate	Commit the contents of the <candidate/> configuration database to the <running/> configuration database	TRANSACTION MGMT.
<cancel-commit>		Cancels an ongoing confirmed commit.	
<close-session>	:base	Terminate this session	SESSION MGMT.
<kill-session>	:base	Terminate another session	

NETCONF Protocol Operations

- Client initiates session (typically over SSH) to Server
- Both sides exchange capabilities using <hello> message
- Operations are wrapped in XML-encoded RPC
- Client performs tasks using set of RPC transactions
- Example: Edit-config for device with <running> and <startup> datastore
  - Lock<running>, lock<startup>, edit-config<running>, copy<running>to<startup>, unlock<startup>,unlock<running>
- Example: Edit-config for device with <candidate> datastore
  - Lock<running>, lock<candidate>, edit-config<candidate>, commit<candidate>, unlock<candidate>,unlock<running>

NETCONF - Flow Breakdown – Request (IOS –XR)

```
<?xml version="1.0" encoding="UTF-8"?>
<rpc message-id="101" xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
```

NETCONF RPC (Message) Layer

```
  <get-config>
```

Operation Layer

```
  <source>
    <running/>
  </source>
  <filter>
    <Configuration>
    </Configuration>
   </filter>
```

Content Layer

```
  </get-config>
</rpc>
```

```
]]>]]>
```

Framing Marker

NETCONF - Flow Breakdown – Response (IOS XR)

```
<?xml version="1.0" encoding="UTF-8"?>
<rpc-reply message-id="11" xmlns="urn:ietf:params:netconf:base:1.0">
```

```
 <data>
```

```
   <xml-config-data>
     <Device-Configuration xmlns="urn:cisco:xml-pi">
       <version>
         <Param>15.2</Param>
       </version>
       <service>
         <timestamps>
           <debug>
             <datetime>
               <msec/>
             </datetime>
           </debug>
         </timestamps>
       </service>
…
```

```
</rpc-reply>
```

```
 ]]>]]>
```

Introduction to YANG

Why YANG?

- In order for NETCONF to be useful as a network-wide protocol, it must have a common data model
- Simply wrapping CLI in XML is not enough as each vendor has its own CLI
- YANG provides the common data model necessary for to consume NETCONF data from any network device
- Each vendor must implement common YANG modules
- Work on defining these modules is happening in the NETMOD group in the IETF

What is YANG?

- YANG is a modeling language defined in RFC 6020
- Used by NETCONF to define the objects and data in requests and replies
- Analogous to XML schema and SMI for SNMP (but more powerful)
- Models configuration, operational, and RPC data
- Provides semantics to better define NETCONF data
  - Constraints (i.e., “MUSTs”)
  - Reusable structures
  - Built-in and derived types
- YANG is extensible and modular
- YANG modules are for NETCONF what MIBs are for SNMP

NETCONF concept versus SNMP

	NETCONF	Differences	SNMP
"Framework"	Definition language: YANG	Ability to express hierarchy (compare MIBs: flat + tables) Richer conditions, constraints Facilities for easier reuse RPC/Action support	Definition language: SMIv2
"Content"	Information model: YANG modules	Import conversion rules exist (MIBs → YANG) "instant content"	Information model: MIB modules
"Payload"	Instantiated info/ transfer syntax: XML	Human readability Dynamic extensibility B2B, Web toolkits	Instantiated info/ transfer syntax: ASN.1 BER
	Management services: Netconf	Bulk vs only incremental ops (manipulation of config files, e.g. edit-config) Transaction support Configuration vs monitoring	Management services: SNMP

or possibly other (no inherent dependency but will require different bindings)

Example of YANG Module

```
module SystemTime {
  namespace "urn:cisco:params:xml:ns:yang:SystemTime";
  prefix "Cisco-SystemTime";
  organization "CISCO";
  contact "MKRAMOLI@CISCO.COM";
  revision "2014-06-16" {
    description
    "Example of YANG Schema";
  }
```

```
typedef time_source {
   type enumeration {
     enum TIME_SOURCE_ERROR {
       value 0;
       description "Error";
     }
     enum TIME_SOURCE_NONE {
       value 1;
       description "Unsynchronized";
     }
     enum TIME_SOURCE_NTP {
       value 2;
       description "NTP protocol";
     }
     enum TIME_SOURCE_MANUAL {
       value 3;
       description "User configured";
     }
     enum TIME_SOURCE_CALENDAR {
       value 4;
       description "HW calendar";
     }
   }
   description "Time source";
 }
```

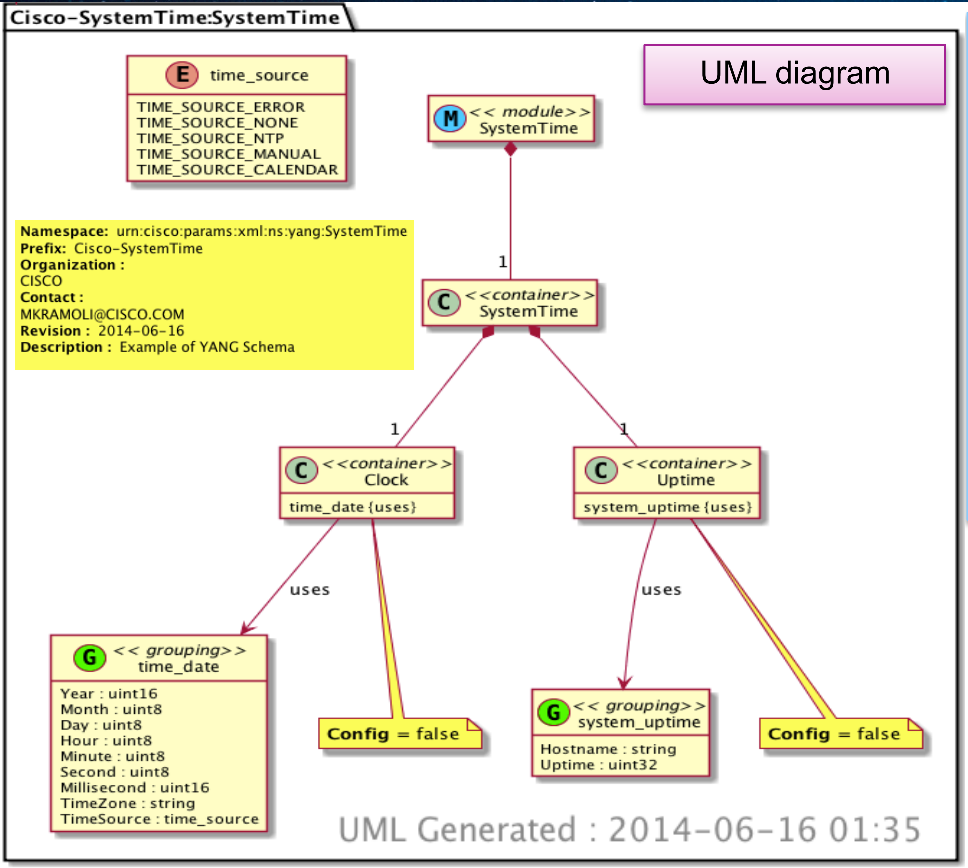
```
container SystemTime {
   description "System time";

   container Clock {
     config false;
     uses "time_date";
     description "System clock";
   }
    container Uptime {
     config false;
     uses "system_uptime";
     description "Sys. uptime";
   }
 }
```

```
grouping system_uptime {
    leaf Hostname {
      type string;
      description "Host name";
    }
    leaf Uptime {
      type uint32;
      description "Seconds Up";
    }
    description "System uptime";
  }
```

```
grouping time_date {
    leaf Year {
      type uint16;
      description "Year [0..65535]";
    }
    leaf Month {
      type uint8;
      description "Month [1..12]";
    }
    leaf Day {
      type uint8;
      description "Day [1..31]";
    }
    leaf Hour {
      type uint8;
      description "Hour [0..23]";
    }
    leaf Minute {
      type uint8;
      description "Minute [0..59]";
    }
    leaf Second {
      type uint8;
      description "Second [0..60]";
    }
    leaf Millisecond {
      type uint16;
      description "Millisecond [0..999]";
    }
    leaf TimeZone {
      type string;
      description "Time zone";
    }
    leaf TimeSource {
      type time_source;
      description "Time source";
    }
    description "Date and time";
  }
```

YANG models and structure



Compact Tree

```
module: SystemTime
   +--rw SystemTime
      +--ro Clock
      |  +--ro Year?          uint16
      |  +--ro Month?         uint8
      |  +--ro Day?           uint8
      |  +--ro Hour?          uint8
      |  +--ro Minute?        uint8
      |  +--ro Second?        uint8
      |  +--ro Millisecond?   uint16
      |  +--ro TimeZone?      string
      |  +--ro TimeSource?    time_source
      +--ro Uptime
         +--ro Hostname?   string
         +--ro Uptime?     uint32
```

- YANG modules
  - Can be Automatically Validated
  - Can be Visualized to UML diagrams, compact Trees, etc.
  - Can be Translated to schemas like DSDL, XSD, etc.
  - Can be Converted to YIN
  - Can be Derived from YIN
  - Can drive Code Generation

YANG model execution in NETCONF

```
S:<?xml version="1.0" encoding="UTF-8"?>
S:<rpc-reply message-id="1" xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
S:    <data>
S:        <Operational>
S:            <SystemTime MajorVersion="1" MinorVersion="0">
S:                <Clock>
S:                    <Year>
S:                        2014
S:                    </Year>
S:                    <Month>
S:                        6
S:                    </Month>
S:                    <Day>
S:                    </Month>
S:                    <Day>
S:                        16
S:                    </Day>
S:                    ..
S:                    ..
S:                    ..
S:                    ..
S:                    <Millisecond>
S:                        476
S:                    </Millisecond>
S:                    <TimeZone>
S:                        UTC
S:                    </TimeZone>
S:                    <TimeSource>
S:                        Calendar
S:                    </TimeSource>
S:                </Clock>
S:            </SystemTime>
S:        </Operational>
S:    </data>
S:</rpc-reply>
S:]]>]]>
```

Response

```
C:<?xml version="1.0" encoding="UTF-8"?>
C:<rpc message-id="1" xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
C:  <get>
C:    <filter>
C:      <Operational>
C:        <SystemTime>
C:          <Clock/>
C:        </SystemTime>
C:      </Operational>
C:    </filter>
C:  </get>
C:</rpc>
C:]]>]]>
```

Query

- Query/Response for System Time aligned with YANG module definition
- Note: screenshots taken from IOS XRv 5.1.1

YANG models – Industry and Cisco

- IETF
  - Interface management [RFC 7223]
  - IP management [draft-ietf-netmod-ip-cfg]
  - System management [draft-ietf-netmod-system-mgmt]
  - SNMP configuration [draft-ietf-netmod-snmp-cfg]
  - Generic OAM [Cisco Involvement, draft-tissa-netmod-oam]
  - OSPF [Cisco Involvement, draft-yeung-netmod-ospf-01]
  - BGP [Cisco Involvement, draft-zhdankin-netmod-bgp-cfg-00]
  - IPFIX configuration [Cisco involvement, RFC6728]
  - ACL configuration [Cisco involvement, draft-huang-netmod-acl-03]
  - Network topology [Cisco involvement, draft-clemm-i2rs-yang-network-topo-00.txt]
  - Routing management [draft-ietf-netmod-routing-cfg]
  - RIB [I2RS] [Cisco involvement, draft-clemm-i2rs-yang-network-topo-00]
  - Netconf monitoring [RFC6022], Netconf access control [RFC6536]

- Cisco: PIM, IPSLA, L2VPN, VLAN, DNA, Synthetic models XR
- Cablelabs: CCAP (Converged Cable Access Point)
- ONF: Openflow Switch Configuration (OF-Config)
- MIBs (for monitoring data) via SMIv2 ->YANG conversion

- YANG@CISCO to be supported over NETCONF, REST, or XMPP
- YANG modules of interest
  - draft-ietf-netmod-system-mgmt
  - draft-ietf-netmod-interfaces-cfg
  - draft-ietf-netmod-ip-cfg
  - draft-ietf-netmod-routing-cfg
  - draft-ietf-ipfix-configuration-model
- Customer-driven modules for VLAN, QoS, environment, and ACL configuration

Introduction to RESTCONF

RESTCONF

- Still an emerging story (draft-bierman-netconf-restconf-4)
- RESTful protocol to access YANG defined data
- Representational State Transfer, i.e. server maintains no session state
- URIs reflect data hierarchy in a Netconf datastore
- HTTP as transport
- Data encaded with either XML or JSON
- Operations

RESTCONF	Netconf
GET	<get-config>, <get>
POST	<edit-config> (“create”)
PUT	<edit-config> (“replace”)
PATCH	<edit-config> (“merge”)
DELETE	<edit-config> (“delete”)
OPTIONS	(discover supported operations)
HEAD	(get without body)

YANG Mapping to JSON

- JSON is a popular compact and easy to parse data format used by many REST APIs
- Subset of YANG compatible XML documents can be translated to JSON text
- Translation driven by YANG data model (must be known in advance)
- YANG datatype information is used to translate leaf values to the most appropriate JSON representation
- Slightly more compact (irrelevant with compression)
- Increased human readability (less noise)

YANG mapping to JSON vs XML

JSON – 214 octets*

```
{
   "ietf-interfaces:interfaces": {
      "interface": [
          {
              "name": "eth0",
              "type": "ethernetCsmacd",
              "location": "0",
              "enabled": true,
              "if-index": 2
          },
          {
              "name": "eth1",
              "type": "ethernetCsmacd",
              "location": "1",
              "enabled": false,
              "if-index": 2
          }
       ]
    }
}
```

XML – 347 octets*

```
<interfaces xmlns:="urn:ietfparams:xml:ns:yang:ietf-interfaces">
    <interface>
        <name>eth0</name>
        <type>ethernetCsmacd</type>
        <location>0</location>
        <enabled>true</enabled>
        <if-index>2</if-index>
    </interface>
    <interface>
        <name>eth1</name>
        <type>ethernetCsmacd</type>
        <location>1</location>
        <enabled>false</enabled>
        <if-index>7</if-index>
    </interface>
</interfaces>
```

*all white space removed

RESTCONF Example

```
C: GET /restconf/operational/opendaylight-inventory:nodes HTTP/1.1
C: Host: example.com

S: HTTP/1.1 200 OK
S: Date: Fri, 6 June 2014 17:01:00 GMT
S: Server: example-server
S: Content-Type: application/json
S:
S:{
S:   "nodes": {
S:       "node": [
S:           {
S:               "flow-node-inventory:hardware": ”Test vSwitch",
S:               "flow-node-inventory:software": "1.1.0",
S:               "id": "openflow:1",
S:               "flow-node-inventory:switch-features": {
S:                   "flow-node-inventory:capabilities": [
S:                   "flow-node-inventory:flow-feature-capability-flow-stats",
S:                   "flow-node-inventory:flow-feature-capability-port-stats”,
S:                   ],
S:                   "flow-node-inventory:max_buffers": 256,
S:                   "flow-node-inventory:max_tables": 255
S:               }
S:           }
S:       ]
S:   }
S:}
```

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