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A. Bierman
YumaWorks, Inc.

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NETCONF Efficiency Extensions
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Abstract

This document describes protocol extensions to improve the efficiency of the Network Configuration Protocol (NETCONF). Protocol capabilities and operations are defined to reduce network usage and transaction complexity.

Status of this Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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Table of Contents

1. Introduction

There is a need for standard mechanisms to allow NETCONF [RFC6241] application designers to manage NETCONF servers more efficiently when used in network environments with poor connectivity, low bandwidth, and/or high latency. In such conditions, it is desirable to minimize network usage wrt/ the size of protocol messages and the number of protocol operations required to perform a network management function.

1.1. Terminology

The keywords "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14, [RFC2119].

1.1.1. NETCONF

The following terms are defined in [RFC6241]:

- candidate configuration datastore
- client
- configuration data
- datastore

- configuration datastore
- protocol operation
- running configuration datastore
- server
- startup configuration datastore

1.1.2. YANG

The following terms are defined in [RFC6020]:

- container
- data node

- key leaf
- leaf
- leaf-list
- list

1.1.3. RESTCONF

The following terms are defined in [RESTCONF]:

- data resource
- datastore resource
- YANG Patch

1.1.4. Terms

The following terms are defined:

- capability ID: An opaque string identifier that represents the current state of the server capability set. A new capability ID is chosen by the server each time the server capability set is altered in any way.

- capability set: The conceptual set of all capability URIs that are active on the server, including all parameters. This set does not include the ":config-id" capability if it is supported.

- config ID: An opaque string identifier that represents the state of the running datastore contents on the server. A new config ID is chosen by the server each time the server running configuration datastore is altered in any way.

- depth filter: A mechanism implemented within the NETCONF server to allow a client to retrieve only a limited number of levels within the a subtree, instead of retrieving the entire subtree.

- time filter: A mechanism implemented within the NETCONF server to allow a client to retrieve only data that has been modified since a specified data and time.

1.1.5. Tree Diagrams

A simplified graphical representation of the data model is used in this document. The meaning of the symbols in these diagrams is as follows:

- Brackets "[" and "]" enclose list keys.

- Abbreviations before data node names: "rw" means configuration (read-write) and "ro" state data (read-only).

- Symbols after data node names: "?" means an optional node and "*" denotes a "list" and "leaf-list".

- Parentheses enclose choice and case nodes, and case nodes are also

marked with a colon (":").

- Ellipsis ("...") stands for contents of subtrees that are not shown.

1.2. Problem Statement

This document attempts to address the following problems with NETCONF protocol procedures.

1.2.1. <hello> Exchange

The server <hello> message can be rather large (e.g., greater than 10,000 bytes), and the information it contains tends to be rather static in practice. If a large number of server connections are lost and then restarted, the quantity of large <hello> messages from every server could impact network performance.

It would be useful if the <hello> message exchange could be enhanced so the server <hello> message size could be minimized. The new <hello> message exchange must be completely backward compatible such that existing client or server implementations will continue to function.

1.2.2. Initial Configuration Retrieval

A client application often needs to retrieve the entire running configuration datastore contents, usually at the start of an editing session. The <rpc-reply> for this <get-config> request can be very large (e.g., greater than 250,000 bytes).

If a large number of server connections are lost and then restarted, the quantity of large <rpc-reply> messages from every server could

severely impact network performance.

It would be useful if the <hello> message exchange could be enhanced so an entity-tag value for the current running datastore configuration is included in the server <hello> message. A client can cache the server configuration identifier and omit an initial <get-config> operation if the value from the server <hello> message matches the cached value.

1.2.3. Message Encoding

NETCONF uses a hard-wired message encoding format, namely XML. However, XML tends to be verbose, especially for YANG data models that have long data node identifiers.

There is no reason for the NETCONF message encoding to be hardwired, except for the <hello> message. It would be useful if the NETCONF protocol could support other message encoding formats, such as JSON [JSON]. The <hello> message exchange could be enhanced so the client and server negotiated the message encoding to use for all other messages via an capability exchange included in both <hello> messages.

1.2.4. Datastore Editing

There are several deficiencies with the NETCONF editing procedures that could be improved.

Multi-operation functions can be required. A single edit can take up to 9 operations. Several operations are required to complete a set of 1 or more edits on a NETCONF server. Each operation uses 1 request and 1 response message. If the candidate datastore is used, then 1 extra operation is required (for the <commit> operation) to activate the edit(s). If the startup datastore is used then 1 extra operation is required (for the <copy-config> operation) to save the running datastore contents in non-volatile storage. If global locking is used, then 2 extra operations are required for each datastore involved (candidate, running, startup) Since the datastore is locked at the start and unlocked at the end of the entire edit operation, these extra roundtrip times are intervals in which the datastore is being locked, but no datastore access is being done.

Obtaining locks can be expensive. If the server has more than 1 datastore (e.g., candidate + running or running + startup), then multiple lock requests are required, since the <lock> and <unlock> operations on affect 1 datastore at a time. This can cause a long delay or even deadlock if multiple clients are attempting to obtain global locks at once. E.g., client 1 holds a lock on the candidate

datastore and is trying to lock the running datastore. At the same

time, client 2 holds a lock on the running datastore and is trying to lock the candidate datastore.

Using locks can be brittle. NETCONF clients are intended to be programmatic, so is not likely that locks will be long-lived. Global locks are designed to be short-lived since they block write access to the entire datastore. If lock collisions do occur, they are likely to be cleared very quickly. It would be useful if the client could request how long to wait for locks to clear instead of immediately rejecting an edit request due to an 'in-use' error.

Edit operations are implied by <config> content. NETCONF uses a default operation and explicit operation attribute within an arbitrarily complete XML subtree to represent a configuration datastore. There are several corner-cases that are not standardized, and very implementation-dependent:

- interpretation of implied operations vs. explicit operations
- order the edits are processed
- handling of nested operation attributes
- handling of duplicate subtrees
- error handling (code points, number of errors, etc.)
- move operations are not explicit and can interpreted as a request to remove and re-add an entry, not just move user-ordered data

Edit operations are not protected against multi-client alterations. It is a simple and common practice to retrieve a configuration data resource, changing 1 or more fields, and then update the resource on the server. Since retrieval and edit operations are separate there is always a chance that another client has altered the resource after the <get-config> operation, but before the <edit-config> operation, by the first client. Each client could be protected if there was an entity tag associated with each data resource, and an edit request could be rejected if the client attempted to edit a different version of the data resource than expected.

There is no bulk-edit support. If the same edit is needed in multiple instances of a particular data resource, then the data must be repeated for each instance in the <edit-config> or <copy-config> request. The request message size could be minimized if there was a way to apply a set of edits to multiple target nodes at once.

There is no confirmed commit support for the running datastore. The ability to backup the running datastore, change it, and revert it unless the client confirms the changes has nothing to do with the candidate datastore. A NETCONF server with limited memory is not

likely to support the candidate datastore. This feature is useful for any type of network-wide configuration change, regardless of device size.

1.2.5. Data Retrieval

NETCONF data retrieval via the <get> and <get-config> operations can be very inefficient. Some vendors do not even support <get> because it can be such a resource-intensive operation and return an enormous amount of data, especially if all server data is requested at once.

A client cannot retrieve just the non-configuration data. The NETCONF <get> operation allows a client to retrieve data from the server but it returns all data, including configuration datastore nodes. The <get-config> operation already returns all configuration datastore nodes.

It was originally thought that <get> should return all nodes so the client would not have to correlate configuration and non-configuration data nodes, since they would be mixed together in the reply. Operational experience has shown that the <get> operation without reasonable filters to reduce the returned data can significantly degrade device performance and return enormous XML instance documents in the <rpc-reply>.

There is no "last-modified" indication or time filtering. The NETCONF protocol has no standard mechanisms to indicate to a client when a datastore was last modified, or to allow a client to retrieve data only if it has been modified since a specified time. This makes polling applications very inefficient because they will regularly burden the server and the network and themselves with retrieval and processing requests for data that has not changed.

There is no simple list instance discovery mechanism. Sometimes the client application wants to discover what data exists on the server, particularly list entries. There is a need for a simple mechanism to retrieve just the key leaf nodes within a subtree. The NETCONF subtree filtering mechanism does provide a very complex way for the client to request just key leafs for specific list entries. A simpler mechanism is needed which will allow the client to discover the list instances present.

There is no subtree depth control. NETCONF filters allow the client to select specific sub-trees within the conceptual datastore on the server. However, sometimes the client does not really need the entire subtree, which may contain many nested list entries, and be

very large. There is sometimes a need to limit the depth of the sub-trees retrieved from the server. A consistent and simple algorithm

for determining what data nodes start a new level is needed.

The content filter specification is not extensible. The NETCONF <get> and <get-config> operations use a hard-coded content filtering mechanism. They use a "type" XML attribute to indicate which of two filter specification types they support, and a "select" XML attribute if the :xpath capability is supported and an XPath [XPATH] expression filter specification is provided.

This design does not allow additional content filter specification types to be supported by an implementation. It does not allow the standard to be easily extended in a modular fashion. In addition, this design does not allow YANG statements to be used to properly describe the protocol operation. The special "get-filter-element-attributes" YANG extension in the ietf-netconf module is not extensible, and it does not really count as proper YANG, since this extension is outside the YANG language definition.

There is no standard metadata or standard way to retrieve metadata. The <with-defaults> parameter allows 1 specific type of metadata to be returned (i.e., 'report-all-tagged' mode). This ad-hoc approach does not scale well and is not extensible. It would be useful if standard and vendor-specific metadata could be identified and retrieved with standard operations.

1.3. Solution

This document defines some NETCONF protocol operations and new capabilities to reduce network usage and increase functionality at the same time.

All NETCONF efficiency extensions are completely backward-compatible with the current definitions in [RFC6241]. An old server will ignore any new <capability> URIs sent by a new client. An old client will ignore any new <capability> URIs sent by the server, and will not use the new operations. No existing operations are affected by the new operations, so the extensions will be transparent to an existing NETCONF client.

1.3.1. Capability ID Exchange

A new capability called "capability-id" is defined to identify the current set of NETCONF <capability> URIs with an opaque string. A client can cache this value for each server that supports this capability, and send the value in a "capability-id" <capability> URI in its <hello> message.

The server will slightly delay sending its <hello> message to attempt

to process the client <hello> first. If the client <hello> is received, and the "capability-id" URI is found and matches the server value, then an abbreviated server <hello> message is sent instead of a full <hello> message. Refer to Section 2.1 for details on the capability ID exchange procedure.

1.3.2. Configuration ID Advertisement

A new capability called "config-id" is defined to identify the current running datastore configuration contents with an opaque string. A client can cache this value for each server that supports this capability, along with a copy of its running configuration. When a new session is started, the client can examine the "config-id" <capability> URI sent by the server. If it is the same as the cached value then the client can use the cached running datastore copy instead of sending an initial <get-config> operation to the server. The :config-id capability is ignored in the calculation of the :capability-id capability. Refer to Section 2.2 for details on configuration ID advertisement.

1.3.3. Message Encoding Negotiation

A new capability called "encoding" is defined to allow a client to request that an alternate message encoding be used for the NETCONF session. The capability is encoded as a comma-separated list of media types. This list is ordered by the client in the order of highest preference first. The server list is unordered. The first match (done in client priority) is the message encoding used for the rest of session. Refer to Section 2.3 for details on message encoding negotiation.

1.3.4. <edit2> Operation

A new NETCONF protocol operation called <edit2> is defined to address the deficiencies described in Section 1.2.4. This operation allows the entire NETCONF edit procedure to be accomplished with 1 request message. The editing procedures are aligned with the resource model defined in [RESTCONF]. Refer to Section 2.4 for details on <edit2> operation.

The "confirmed-commit" procedure has been integrated into the <edit2> operation, and can be supported by any server without requiring support for the candidate datastore. It is optional to implement, based on the "confirmed-edit" capability defined in Section 2.8.

Refer to Section 2.5 for details on the <complete-commit> operation and Section 2.6 for details on the <revert-commit> operation.

1.3.5. <get2> Operation

A new NETCONF protocol operation called <get2> is defined to address the deficiencies described in Section 1.2.5. This operation allows several filter types to be combined to control the data that is returned in the <rpc-reply> message, and an extensible framework for retrieving metadata associated with datastore or data resources. Refer to Section 2.7 for details on <get2> operation.

2. Definitions

This section defines the NETCONF efficiency extensions:

- :capability-id Capability
- :config-id Capability
- :encoding Capability
- <edit2> Operation
- <complete-commit> Operation
- <revert-commit> Operation
- <get2> Operation

2.1. "capability-id" Capability

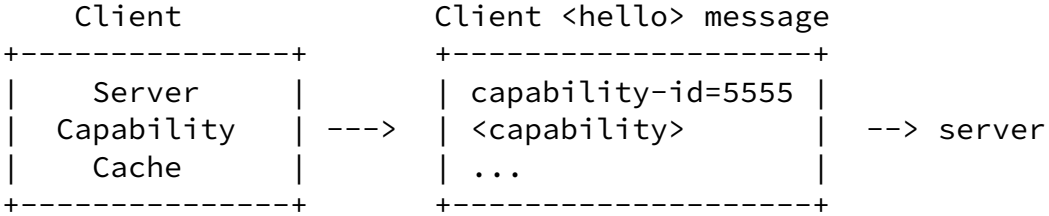
2.1.1. Overview

The :capability-id capability is used by the client to request an abbreviated <hello> message instead of a full <hello> message from

the server.

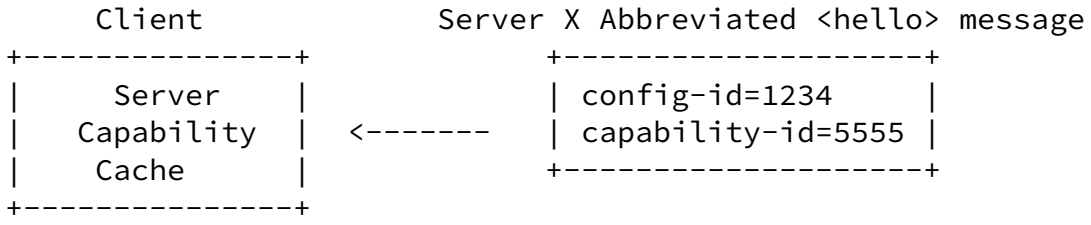
1) Client keeps a cache of server capability sets

2) Client sends <hello> with "capability-id" <capability> set to the cached value



3) Server waits a small interval for the client <hello>.
   It will send either a full <hello> or an abbreviated <hello>

4) Client <hello> received in time and it contains a
   capability-id value that matches the server's current value.
   The server sends an abbreviated <hello> with just 2
   <capability> URIs



5) The client gets the server <hello> and sees that it has
   a capability-id value and it matches the value that
   was sent by the client. It determines the server returned
   an abbreviated <hello> and uses the cached capability set

The server MUST maintain a capability ID that represents the current state of the capability set. The :config-id capability defined in Section 2.2 is not included in this set of capabilities. It is ignored for purposes capability set identification. Otherwise the :capability-id value would change every time the :config-id value changed.

The server will slightly delay sending its <hello> message to attempt to process the client <hello> first. If the client <hello> is received, and "capability-id" URI is found and matches the server value, then an abbreviated server <hello> message is sent instead of a full <hello> message. Refer to Section 2.1 for details on the capability ID exchange procedure.

2.1.1.1. :capability-id Capability Example

Initially, the client does not know the current capability-id of the server, so it does not include it in its <hello> message to the

```
server:

  # Client requests a new session
  <hello xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
   <capabilities>
    <capability>urn:ietf:params:netconf:base:1.0</capability>
    <capability>urn:ietf:params:netconf:base:1.1</capability>
  </hello>
```

The server delays sending its <hello> message and within 1 second receives the client <hello> message. The server determines that the :capability-id capability is not present in the client <hello> message, so a full server <hello> message is sent, which includes the current "capability-id" URI value for the capability set.

In this example, only a small number of YANG module capabilities are reported. In a real server, there are usually many YANG module capabilities (e.g., 25 - 50) to report. Extra whitespace has been added to the XML for display purposes only.

```
  # Server starts session 1 with full <hello>
  <hello xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
   <capabilities>
    <capability>urn:ietf:params:netconf:base:1.0</capability>
    <capability>urn:ietf:params:netconf:base:1.1</capability>
    <capability>
     urn:ietf:params:netconf:capability:candidate:1.0
    </capability>
    <capability>
     urn:ietf:params:netconf:capability:confirmed-commit:1.0
    </capability>
    <capability>
     urn:ietf:params:netconf:capability:confirmed-commit:1.1
    </capability>
    <capability>
     urn:ietf:params:netconf:capability:rollback-on-error:1.0
    </capability>
    <capability>
     urn:ietf:params:netconf:capability:validate:1.0
    </capability>
    <capability>
     urn:ietf:params:netconf:capability:validate:1.1
    </capability>
    <capability>
```

```
        urn:ietf:params:netconf:capability:url:1.0?scheme=file
      </capability>
      <capability>
        urn:ietf:params:netconf:capability:xpath:1.0
      </capability>
      <capability>
        urn:ietf:params:netconf:capability:notification:1.0
      </capability>
      <capability>
        urn:ietf:params:netconf:capability:interleave:1.0
      </capability>
      <capability>
        urn:ietf:params:netconf:capability:partial-lock:1.0
      </capability>
      <capability>
        urn:ietf:params:netconf:capability:with-defaults:1.0?
          basic-mode=explicit&amp;also-supported=trim,report-all,
          report-all-tagged
      </capability>
      <capability>
        urn:ietf:params:xml:ns:netconf:base:1.0?
        module=ietf-netconf&amp;revision=2011-06-01
      </capability>
      <capability>
        urn:ietf:params:xml:ns:yang:ietf-netconf-ex?
        module=ietf-netconf-ex&amp;revision=2013-10-19
      </capability>
      <capability>
        urn:ietf:params:xml:ns:yang:ietf-inet-types?
        module=ietf-inet-types&amp;revision=2013-07-15
      </capability>
      <capability>
        urn:ietf:params:xml:ns:yang:ietf-netconf-acm?
        module=ietf-netconf-acm&amp;revision=2012-02-22
      </capability>
      <capability>
        urn:ietf:params:xml:ns:yang:ietf-netconf-monitoring?
        module=ietf-netconf-monitoring&amp;revision=2010-10-04
      </capability>
      <capability>
        urn:ietf:params:xml:ns:yang:ietf-netconf-notifications?
        module=ietf-netconf-notifications&amp;revision=2012-02-06
      </capability>
      <capability>
        urn:ietf:params:xml:ns:netconf:partial-lock:1.0?
        module=ietf-netconf-partial-lock&amp;revision=2009-10-19
      </capability>
```

```
      <capability>
```



```
       urn:ietf:params:xml:ns:yang:ietf-netconf-with-defaults?
       module=ietf-netconf-with-defaults&amp;revision=2011-06-01
      </capability>
      <capability>
       urn:ietf:params:xml:ns:yang:ietf-yang-types?
       module=ietf-yang-types&amp;revision=2013-07-15
      </capability>
      <capability>
       http://example.com/ns/example-ex?
       module=example-ex&amp;revision=2013-10-19
      </capability>
      <capability>
       urn:ietf:params:netconf:capability:capability-id:1.0?id=64ae3ffa
      </capability>
      <capability>
       urn:ietf:params:netconf:capability:config-id?id=1455
      </capability>
     </capabilities>
     <session-id>1</session-id>
    </hello>
```

The next time the client starts a session with this server, it includes the server capability ID it saved from session 1:

```
    # Client requests another session
    <hello xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
     <capabilities>
      <capability>urn:ietf:params:netconf:base:1.0</capability>
      <capability>urn:ietf:params:netconf:base:1.1</capability>
      <capability>
       urn:ietf:params:netconf:capability:capability-id:1.0?id=64ae3ffa
      </capability>
    </hello>
```

The server examines the capability-id <capability> URI and determines that the capability ID value matches its own current capability ID value, so it sends an abbreviated <hello> message to the client:

```
     # Server starts session 2 with an abbreviated <hello>
     <hello xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
      <capabilities>
       <capability>
        urn:ietf:params:netconf:capability:capability-id:1.0?id=64ae3ffa
       </capability>
       <capability>
        urn:ietf:params:netconf:capability:config-id?id=2130
       </capability>
      <capabilities>
      <session-id>2</session-id>
     </hello>
```

2.1.2. Dependencies

The :capability-id capability is not dependent on any other capabilities.

2.1.3. Capability Identifier

The :capability-id capability is identified by the following capability string:

urn:ietf:params:netconf:capability:capability-id:1.0

This capability MUST be advertised in every server <hello> message. The :capability-id capability URI MUST contain an "id" argument assigned an opaque string value indicating the current capability ID value for the server capability set. For example:

urn:ietf:params:netconf:capability:capability-id:1.0?id=64ae3ffa

The current config ID value MUST be updated any time a

"netconf-capability-change" event would be generated by the server.

If [RFC6470] is supported, then the "capability-id" leaf defined in Section 2.8 MUST be included in <netconf-capability-change> event notifications.

2.1.4. New Operations

The :capability-id capability does not introduce any new protocol operations.

2.1.5. Modifications to Existing Operations

The <hello> message exchange is modified to allow the server to send an abbreviated capability list. If the client does not send this

capability, or the capability ID value it sends is not the same as the current server capability ID, then there are no changes to the <hello> exchange, as the server will send a full <hello> message to the client, as defined in [RFC6241].

2.1.5.1. Abbreviated <hello> Exchange

If the server supports the :capability-id capability it SHOULD delay sending its <hello> message for a short amount of time. This value (called the "hello delay" parameter) is not specified here because a standard "hello-timeout" parameter is not available to configure NETCONF servers. It is RECOMMENDED that server wait up to 10% of its hello timeout interval for the client to send a <hello> message.

If the <client> message is received before the hello delay timeout occurs, then the server examines the client <hello> and sends either a full <hello> or abbreviated <hello> message right away.

If the hello delay timeout expires before the client <hello> message is received then the server sends a full <hello> message right away.

If the client sends a matching config ID value, the the server MUST send the "capability-id" <capability> and "config-id" <capability> (if supported), in an abbreviated <hello> message. The server SHOULD omit all other <capability> elements in the <hello> message. Otherwise the server MUST send a full <hello> message, which MUST

include a "capability-id" <capability> URI identifying the current capability ID for the server.

2.1.6. Interactions with Other Capabilities

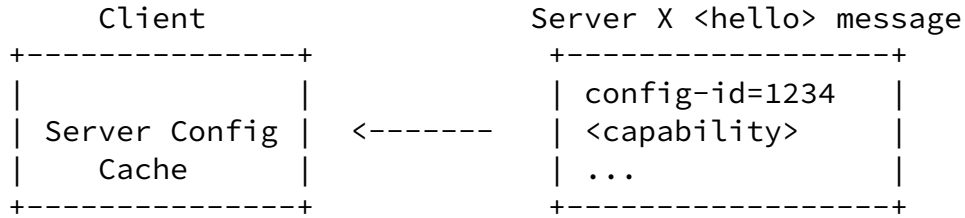
The :capability-id capability interacts with the :config-id capability. The :config-id capability is ignored by the server when calculating a new config ID value. The :config-id capability is also included in abbreviated <hello> messages.

2.2. "config-id" Capability

2.2.1. Overview

The :config-id capability indicates that the server maintains a config ID for the running configuration datastore. This identifier value is selected by the server and treated as an opaque string by the client.

1) Client keeps a cache of server configurations.
2) Server always sends its current config-id value
   in the "config-id" <capability> URI.



3) Client checks cache for server X, config-id=1234.
If found, then OK to use the cached configuration copy.
If not found, then send a <get-config> for the running
configuration to create or update the cached copy.

The server SHOULD save the config ID for the running datastore in non-volatile storage. When the server boots or restarts, the initial

configuration ID SHOULD be the same as the last instantiation, if the server does not support the :startup capability (so the non-volatile stored version mirrors the running datastore). If the server does support the :startup capability, then the initial configuration ID SHOULD be the same as the version last saved to non-volatile storage.

2.2.1.1. :config-id Capability Example

The client may or may not have the current config ID value for the server when a session starts. Only the server <hello> message will include a config-id <capability> URI. This example assumes the abbreviated <hello> message can be sent to the client for brevity.

```
# Client requests another session
<hello xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
 <capabilities>
  <capability>urn:ietf:params:netconf:base:1.0</capability>
  <capability>urn:ietf:params:netconf:base:1.1</capability>
  <capability>
   urn:ietf:params:netconf:capability:capability-id:1.0?id=692267fa
  </capability>
</hello>
```

The server examines the capability-id <capability> URI and determines that the capability ID value matches its own current capability ID value, so it sends an abbreviated <hello> message to the client. The :config-id capability is sent in every server <hello> message. The "id" parameter for the :config-id capability is set to the current config ID for the running datastore on the server:


```
# Server starts session 3 with an abbreviated <hello>
<hello xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
 <capabilities>
  <capability>
   urn:ietf:params:netconf:capability:capability-id:1.0?id=692267fa
  </capability>
  <capability>
   urn:ietf:params:netconf:capability:config-id?id=4284
  </capability>
 <capabilities>
 <session-id>3</session-id>
</hello>
```

2.2.2. Dependencies

The :config-id capability is not dependent on any other capabilities.

2.2.3. Capability Identifier

The :config-id capability is identified by the following capability string:

urn:ietf:params:netconf:capability:config-id:1.0

This capability MUST be advertised in every server <hello> message. The :config-id capability URI MUST contain an "id" argument assigned an opaque string value indicating the current config ID value for the running datastore. For example:

urn:ietf:params:netconf:capability:config-id:1.0?id=6882391

The current config ID value MUST be updated any time a "netconf-config-change" event would be generated by the server.

If [RFC6470] is supported, then the "config-id" leaf defined in Section 2.8 MUST be included in <netconf-config-change> event notifications.

If the "with-metadata" parameter in the <get2> operation specifies the "config-id" identity, then the server MUST return the current config ID for the running datastore, if the "source" parameter identifies the running datastore. The server MAY maintain config IDs for other datastores as well.

2.2.4. New Operations

The :config-id capability does not introduce any new protocol operations.

2.2.5. Modifications to Existing Operations

The :config-id capability does not modify any existing protocol operations.

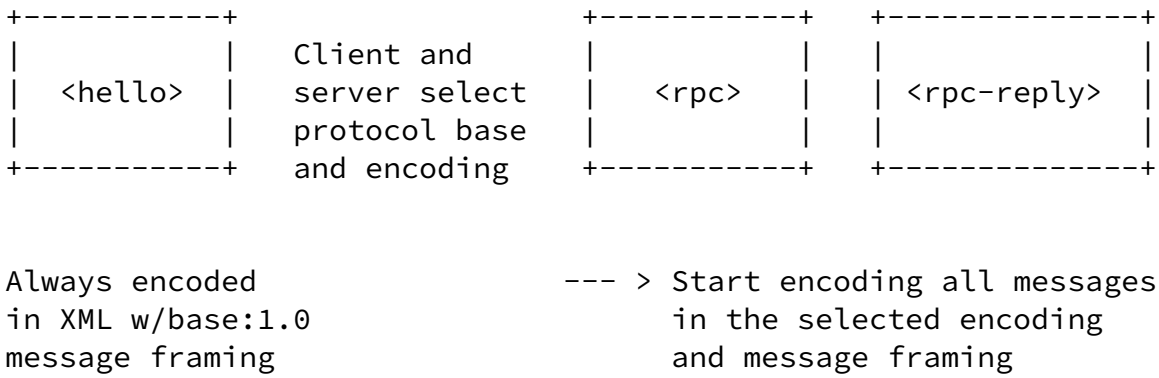
2.2.6. Interactions with Other Capabilities

The :config-id capability does not interact with any other capabilities.

2.3. "encoding" Capability

2.3.1. Overview

The :encoding capability is used by the client to request an alternate message encoding be used instead of XML. The client and server both send a list of media types for the message encodings they support, encoded as a comma-separated list (with no whitespace). The client list is an ordered by preference. The server list is unordered.



Both the client and server will examine the others <hello> message for the "encoding" <capability> URI. If not present, then the default encoding is used, which is XML.

The client list is compared against the server list, checked in the client specified order. If the same media type appears in the server list, then that is the encoding that will be active for the remainder of the session (i.e., starting with the first <rpc> request). All <rpc>, <rpc-reply>, and <notification> messages MUST be encoded in the negotiated encoding.

Both the client and server MUST support the "application/xml" media type to be backward-compatible with [RFC6241].

If "application/json" encoding is used, then the encoding defined in [I-D.lhotka-netmod-json] MUST be used so namespaces will be properly

identified. Any metadata that needs to encoded MUST be encoded according to the procedure defined in [RESTCONF], section 4.4.

The message framing used for the session is unaffected by this capability. The "base1.0" vs. "base1.1" negotiation defined in [RFC6241] determines the message framing that is used for the entire session.

2.3.1.1. :encoding Capability Example

In this example, the client supports the following message encodings, shown in the preferred order.

- Efficient XML Interchange (EXI)
- JSON
- XML

Some extra whitespace has been added for display purposes only.

```
# Client requests a new session with alternate encoding
# also requesting an abbreviated hello
<hello xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
 <capabilities>
  <capability>urn:ietf:params:netconf:base:1.0</capability>
  <capability>urn:ietf:params:netconf:base:1.1</capability>
  <capability>
   urn:ietf:params:netconf:capability:capability-id:1.0?id=64ae3ffa
  </capability>
  <capability>
   urn:ietf:params:netconf:capability:encoding:1.0?
   types=application/exi,application/json,application/xml
  </capability>
</hello>
```

The server supports the following encodings:

- XML
- JSON

Since the most preferred media type in common is "application/json", the JSON encoding used for the remainder of the session.

In this example, the server sends an full <hello> message to the client, truncated for brevity. Extra whitespace has been added for display purposes only.

```
    # Server starts session 4 with JSON encoding
    <hello xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
     <capabilities>
      <capability>urn:ietf:params:netconf:base:1.0</capability>
      <capability>urn:ietf:params:netconf:base:1.1</capability>
      <capability>
       urn:ietf:params:netconf:capability:encoding:1.0?
       types=application/xml,application/json
      </capability>
      <capability>
       urn:ietf:params:netconf:capability:capability-id:1.0?id=64ae3ffa
      </capability>
      <capability>
       urn:ietf:params:netconf:capability:config-id?id=2130
      </capability>
      <!--  rest of URIs ... -->
     <capabilities>
     <session-id>4</session-id>
    </hello>
```

At this point, both the client and server switch to JSON encoding:

```
    # client send a <kill-session> request
    { "ietf-netconf:rpc" : {
        "@message-id" : "201",
        "kill-session" : {
          "session-id" : 42
        }
      }
    }

    # server sends an <ok/> reply
    { "ietf-netconf:rpc-reply" : {
        "@message-id" : "201",
        "ok" : [null]
      }
    }
```

2.3.2. Dependencies

The :encoding capability is not dependent on any other capabilities.

2.3.3. Capability Identifier

The :encoding capability is identified by the following capability string:

urn:ietf:params:netconf:capability:encoding:1.0

This capability MUST be advertised in every server <hello> message. The "encoding" capability URI MUST contain a "types" argument containing a comma-separated list of media types that represent the message encoding formats supported by the server.

If the client supports the :encoding capability, it SHOULD include an "encoding" <capability> URI in its <hello> message. The client MAY omit this capability if XML encoding is desired.

For example (line wrapped for display purposes only)

urn:ietf:params:netconf:capability:encoding:1.0?
types=application/json,application/xml

2.3.4. New Operations

The :encoding capability does not introduce any new protocol operations.

2.3.5. Modifications to Existing Operations

The :encoding capability does not modify any existing protocol operations.

2.3.6. Interactions with Other Capabilities

The :encoding capability does not interact with any other capabilities.

2.4. <edit2> Protocol Operation

The <edit2> operation is specified with a YANG "rpc" statement, defined in Section 2.8. This operation allows the entire NETCONF transaction procedure to be performed in a single operation or multiple operations, depending on the input parameters used.

There are no XML attributes used (e.g., "operation" from RFC 6241, "insert", "value" from RFC 6020). Instead, configuration edits are specified with an edit list, using the YANG Patch mechanism defined in [RESTCONF]. This is used instead of a complete XML instance document, e.g. <config> element, to represent an unordered patch list inferred from the diffs. (Although YANG Patch can be used in this mode if client wants to merge or replace the entire configuration datastore).

2.4.1. <edit2> Input

- target: name of the configuration datastore being edited
- target-resource: XPath node-set expression representing 1 or more target resources within the datastore to edit.
- yang-patch: container of ordered edits to apply to the target resource(s).
- test-only: flag to request that the edit request be validated but no edits should actually be applied
- if-match: if the entity tag for the target resource(s) does not exactly match the supplied value then the edit request is rejected.
- with-locking: if present then the server will provide exclusive write access to this <edit2> operation and possible confirmed-commit procedure.
- max-lock-wait: amount of time the client is willing to wait for locks to clear, if "with-locking" parameter is present.
- activate-now: if present and the target is the candidate datastore, then an implicit <commit> operation will be performed if the edit operation is successfully applied.

- nvstore-now: if present and the server supports the startup datastore, and the edits have been activated in the running datastore, then an implicit <copy-config> operation (from the running to the startup datastore) will be attempted by the server.

- confirmed: request that a confirmed commit be started or extended.

- confirm-timeout: the amount of time for the server to wait for an <edit2> request that extends, a <complete-commit> request to finish, or a <revert-commit> request to cancel a confirmed commit procedure in progress.

- persist: identifier string to use in the "persist-id" parameter to extend, complete, or cancel a confirmed commit procedure.

- persist-id: identifier string to extend a confirmed commit procedure in progress.

2.4.2. <edit2> Output

Positive Response:

This operation returns data containing a "yang-patch-status" report (defined in [RESTCONF]) instead of an "ok" element. This report contains an "ok" element that is present if the entire operation succeeded.

Error Response:

The <rpc-error> element can be returned, e.g., if the message contains invalid parameter syntax. The server MUST report editing errors in the "edit" list within the "yang-patch-status" container.

2.4.3. <edit2> YANG Tree Diagram

```
Key: DRI = data-resource-identifier


+---x edit2
```

```
        +--ro input
        |  +--ro target
        |  |  +--ro (datastore-target)
        |  |     +--:(candidate)
        |  |     |  +--ro candidate?   empty
        |  |     +--:(running)
        |  |        +--ro running?     empty
        |  +--ro target-resource?   yang:xpath1.0
        |  +--ro yang-patch
        |  |  +--ro patch-id?   string
        |  |  +--ro comment?    string
        |  |  +--ro edit [edit-id]
        |  |     +--ro edit-id      string
        |  |     +--ro operation    enumeration
        |  |     +--ro target       data-resource-identifier
        |  |     +--ro point?       data-resource-identifier
        |  |     +--ro where?       enumeration
        |  |     +--ro value
        |  +--ro test-only?         empty
        |  +--ro if-match?          yang-entity-tag
        |  +--ro with-locking?      empty
        |  +--ro max-lock-wait?     uint32
        |  +--ro activate-now?      empty
        |  +--ro nvstore-now?       empty
        |  +--ro confirmed?         empty
        |  +--ro confirm-timeout?   uint32
        |  +--ro persist?           string
```



```
        |  +--ro persist-id?        string
        +--ro output
           +--ro yang-patch-status
              +--ro patch-id?        string
              +--ro (global-status)?
              |  +--:(global-errors)
              |  |  +--ro errors
              |  |        +--ro error
              |  |        +--ro error-type       enumeration
              |  |        +--ro error-tag        string
              |  |        +--ro error-app-tag?   string
              |  |        +--ro error-path?      DRI
              |  |        +--ro error-message?   string
              |  |        +--ro error-info
```

```
|  |
|  +--:(ok)
|     +--ro ok?              empty
+--ro edit-status
   +--ro edit [edit-id]
      +--ro edit-id  string
      +--ro (edit-status-choice)?
         +--:(ok)
         |  +--ro ok?         empty
         +--:(location)
         |  +--ro location?   inet:uri
         +--:(errors)
            +--ro errors
               +--ro error
                  +--ro error-type       enumeration
                  +--ro error-tag        string
                  +--ro error-app-tag?   string
                  +--ro error-path?      DRI
                  +--ro error-message?   string
                  +--ro error-info
```

2.4.4. <edit2> Example

In this example, an "all-in-one" YANG Patch edit is shown. the following conditions apply:

- The server supports the :candidate and :startup capabilities
- The "example-ex" YANG module is supported by the server

The starting state of the "/forests" data structure is described in Appendix B.2. The client is adding an "oak" tree and changing the location of the "birch" tree in the "north" forest.


```
<rpc message-id="101"
   xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <edit2 xmlns="urn:ietf:params:xml:ns:yang:ietf-netconf-ex"
    xmlns:ex="http://example.com/ns/example-ex">
    <target><candidate/></target>
    <target-resource>
      /ex:forests/ex:forest[ex:name='north']
```

```
          </target-resource>
          <yang-patch>
            <patch-id>north-forest-patch</patch-id>
            <comment>
              Add an oak tree and change location of the birch tree
            </comment>
            <edit>
              <edit-id>oak</edit-id>
              <operation>create</operation>
              <target>/ex:trees</target>
              <value>
                <ex:tree>
                  <ex:name>oak</ex:name>
                  <ex:location>hillside</ex:location>
                </ex:tree>
              </value>
            </edit>
            <edit>
              <edit-id>birch</edit-id>
              <operation>merge</operation>
              <target>/ex:trees/ex:tree/birch</target>
              <value>
                <ex:location>west valley</ex:location>
              </value>
            </edit>
          </yang-patch>
          <activate-now/>
          <nvstore-now/>
        </edit2>
      </rpc>
```

The edit succeeds, and the "yang-patch-status" container is returned to the client with the <location> path expression of the new palm tree resource, and <ok/> status for the birch tree edit:

```
<rpc-reply message-id="101"
   xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <yang-patch-status
    xmlns="urn:ietf:params:xml:ns:yang:ietf-netconf-ex"
    xmlns:ex="http://example.com/ns/example-ex">
    <patch-id>north-forest patch</patch-id>
    <ok/>
    <edit-status>
      <edit>
        <edit-id>oak</edit-id>
        <location>
          /ex:forests/ex:forest/north/ex:trees/ex:tree/oak
        </location>
      </edit>
      <edit>
        <edit-id>birch</edit-id>
        <ok/>
      </edit>
    </edit-status>
  </yang-patch-status>
</rpc-reply>
```

Refer to Appendix B.3 for additional <edit2> protocol operation examples.

2.5. <complete-commit> Operation

A new NETCONF protocol operation called <complete-commit> is defined to complete a confirmed commit procedure.

2.5.1. <complete-commit> Input

There is one optional parameter for this protocol operation:

- persist-id: an identifier string that MUST match the "persist" value, if it was used in the confirmed-commit procedure.

2.5.2. <complete-commit> Output

Positive Response:

The there is a confirmed-commit procedure in progress and it is successfully completed, then an <ok/> element is returned.

Negative Response: An <rpc-error> response is sent if the request cannot be completed for any reason.

2.5.3. <complete-commit> YANG Tree Diagram

```
     +---x complete-commit
        +--ro input
           +--ro persist-id?   string
```

2.5.4. <complete-commit> Example

In this example, the client has previously started a confirmed commit procedure using the "persist" parameter set to the value "abcdef".

```
  <rpc message-id="102"
    xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
    <complete-commit
      xmlns="urn:ietf:params:xml:ns:yang:ietf-netconf-ex">
      <persist-id>abcdef</persist-id>
    </complete-commit>
  </rpc>


  <rpc-reply message-id="102"
    xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
    <ok/>
  </rpc-reply>
```

2.6. <revert-commit> Operation

A new NETCONF protocol operation called <revert-commit> is defined to cancel a confirmed commit procedure and revert the running datastore. The <cancel-commit> operation in [RFC6241] cannot be used because it requires the implementation of the candidate capability.

2.6.1. <revert-commit> Input

There is one optional parameter for this protocol operation:

- persist-id: an identifier string that MUST match the "persist" value, if it was used in the confirmed-commit procedure.

2.6.2. <revert-commit> Output

Positive Response:

If there is a confirmed-commit procedure in progress and it is successfully cancelled, and the running datastore successfully reverted, then an <ok/> element is returned.

Negative Response: An <rpc-error> response is sent if the request

cannot be completed for any reason.

2.6.3. <revert-commit> YANG Tree Diagram

```
  +---x revert-commit
     +--ro input
        +--ro persist-id?   string
```

2.6.4. <revert-commit> Example

In this example, the client has previously started a confirmed commit procedure using the "persist" parameter set to the value "abcdef".

```
  <rpc message-id="103"
    xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
    <revert-commit
      xmlns="urn:ietf:params:xml:ns:yang:ietf-netconf-ex">
      <persist-id>abcdef</persist-id>
    </revert-commit>
  </rpc>


  <rpc-reply message-id="103"
    xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
    <ok/>
  </rpc-reply>
```

2.7. <get2> Protocol Operation

The <get2> operation is specified with a YANG "rpc" statement, defined in Section 2.8. A specific datastore is selected for the source of the retrieval operation. Several different types of filters are provided. Filters are combined in a conceptual "logical-AND" operation, and are optional to use by the client. Not all filtering mechanisms are mandatory-to-implement for the server.

2.7.1. Depth Filters

A depth filter indicates how many subtree levels should be returned in the <rpc-reply>. This filter is specified with the "depth" input parameter for the <get2> protocol operation. The default "0" indicates that all levels from the requested subtrees should be returned.

A new level is started for each YANG data node within the requested subtree. All top level data nodes are considered to be child nodes (level 1) of a conceptual <config> root.

If no content filters are provided, then level 1 is considered to include all top-level data nodes within the source datastore. Otherwise only the levels in selected subtrees will be considered, and not any additional top-level data nodes.

If the depth requested is equal to "1", then only the requested data nodes (or top-level data nodes) will be returned. This mechanism can be used to detect the existence of containers and list entries within a particular subtree, without returning any of the descendant nodes.

Higher depth values indicates the number of descendant nodes to include in the response. For example, if the depth requested is equal to "2", then only the requested data nodes (or top-level data nodes) and their immediate child data nodes will be returned.

2.7.2. Time Filters

A time filter specifies that data should only be returned if the last-modified timestamp for the target datastore is more recent than the timestamp specified in the "if-modified-since" parameter.

If this feature is supported, then the server will maintain a "last-modified" timestamp for the running datastore. The server MAY support additional nested timestamps for data nodes within the datastore. The server MAY support timestamps for other datastores.

When a request containing the "if-modified-since" parameter is received, the server will compare that timestamp to the "last-modified" timestamp for the source datastore. If it is greater

than the specified value then data may be returned (depending on other filters). If the datastore timestamp value is less than or equal to the specified value, then an empty <data> element will be returned in the <rpc-reply>.

If the "full-delta" parameter is present, and the server maintains "last-modified" timestamps for any data nodes within the source datastore, then the same type of comparison will be done for the data node to determine if it should be included in the response. If no "last-modified" timestamp is maintained for a data node, then the server will use the "last-modified" timestamp for its nearest ancestor, or for the datastore itself if there are none.

2.7.3. <get2> Input

- source: A container indicating the conceptual datastore for the retrieval request.

- filter-spec: A choice indicating the content filter specification for the retrieval request.

- keys-only: A leaf indicating that only the key leafs, combined with other filtering criteria, should be returned.

- if-modified-since: A leaf indicating the time filter specification for the retrieval request, according to the procedures in Section 2.7.2.

- full-delta: If present and the "if-modified-since" parameter is also present, then the entire datastore will be filtered by last modification time, not just the entire datastore.

- depth: A leaf indicating the subtree depth level for the retrieval request, according to the procedures in Section 2.7.1.

- with-defaults: A leaf indicating the type of defaults handling requested, according to procedures in [RFC6243].

- with-metadata: A leaf-list indicating the specific metadata that the server should add to the response, such as "last-modified" or

"etag", encoded in XML according to the schema in Section 2.9.

- o with-locking: if present then the server will provide exclusive write access to this <get2> operation so the target datastore is not modified during the entire retrieval operation.

- o max-lock-wait: amount of time the client is willing to wait for locks to clear, if "with-locking" parameter is present.

2.7.4. <get2> Output

Positive Response: A <data> element is returned which contains the data corresponding to the input parameters specified in the request. The child nodes of the <data> container correspond to top-level YANG data nodes.

If the server supports the "timestamps" YANG feature, and the target is the running datastore, then a "last-modified" attribute SHOULD be included in the <rpc-reply> element.

Negative Response: An <rpc-error> response is sent if the request cannot be completed for any reason.

2.7.5. <get2> YANG Tree Diagram

```
      +---x get2
         +--ro input
         |  +--ro source
         |  |  +--ro (datastore-source)?
         |  |     +--:(candidate)
         |  |     |  +--ro candidate?   empty
         |  |     +--:(running)
         |  |     |  +--ro running?     empty
         |  |     +--:(startup)
         |  |     |  +--ro startup?     empty
         |  |     +--:(url)
         |  |     |  +--ro url?         inet:uri
         |  |     +--:(operational)
```

```
|  |        +--ro operational? empty
|  +--ro (filter-spec)?
|  |  +--:(subtree-filter)
|  |  |  +--ro subtree-filter
|  |  +--:(xpath-filter)
|  |     +--ro xpath-filter?        yang:xpath1.0
|  +--ro keys-only?            empty
|  +--ro if-modified-since?    yang:date-and-time
|  +--ro full-delta?           empty
|  +--ro depth?                uint32
|  +--ro with-defaults?        with-defaults-mode
|  +--ro with-metadata*        identityref
|  +--ro with-locking?         empty
|  +--ro max-lock-wait?        uint32
+--ro output
   +--ro data
```

2.7.6. <get2> Example

In this example, the retrieval the "forests" resource is shown. the following conditions apply:

- The server supports the :candidate and :startup capabilities
- The "example-ex" YANG module is supported by the server

The starting state of the "/forests" data structure is described in Appendix B.2. The client is retrieving just the "forests" node, along with the "last-modified" and "etag" metadata for that node. The "config-id" for the datastore is also requested. Locking is requested (with a maximum lock wait time of 5 seconds), just to make sure the metadata does not change during the request.


```
<rpc message-id="104"
  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <get2 xmlns="urn:ietf:params:xml:ns:yang:ietf-netconf-ex"
    xmlns:ncex="urn:ietf:params:xml:ns:yang:ietf-netconf-ex">
    <subtree-filter>
      <forests xmlns="http://example.com/ns/example-ex" />
    </subtree-filter>
    <depth>1</depth>
```

```
        <with-metadata>ncex:timestamps</with-metadata>
        <with-metadata>ncex:etags</with-metadata>
        <with-metadata>ncex:config-id</with-metadata>
        <with-locking />
        <max-lock-wait>5</max-lock-wait>
      </get2>
    </rpc>
```

The server has a "forests" node so this node is returned along with the requested metadata for the node. Note that the XML namespace for the "ncex" metadata is the XSD target namespace defined in Section 2.9, not the YANG namespace URI defined in Section 2.8.

```
    <rpc-reply message-id="104"
      xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
      <data xmlns="urn:ietf:params:xml:ns:yang:ietf-netconf-ex"
            xmlns:m="urn:ietf:params:xml:ns:netconf:netconf-ex:1.0"
            m:last-modified="2012-09-09T02:00:00Z"
            m:config-id="3aee5601">
        <forests xmlns="http://example.com/ns/example-ex"
                 m:last-modified="2012-09-09T02:00:00Z"
                 m:etag="3aee5601" />
      </data>
    </rpc-reply>
```

Refer to Appendix B.4 for additional <get2> protocol operation examples.

2.8. NETCONF-EX YANG Module

This module imports the "with-defaults-parameters" grouping from [RFC6243].

Several YANG features are imported from [RFC6241]. These correspond to the NETCONF capabilities (e.g., candidate, url, startup, xpath) but defined as YANG features instead of URIs.

Some data types are imported from [RFC6991]:

- date-and-time

- uri
- xpath1.0

Several YANG groupings are imported from [RESTCONF]:

- errors
- yang-patch
- pang-patch-status

Two notifications are augmented from [RFC6470].

- netconf-capability-change
- netconf-configuration-change

RFC Ed.: update the date below with the date of RFC publication and remove this note.

<CODE BEGINS> file "ietf-netconf-ex@2013-10-19.yang"

```
module ietf-netconf-ex {

  namespace "urn:ietf:params:xml:ns:yang:ietf-netconf-ex";
  prefix ncex;

  import ietf-inet-types {
    prefix inet;
  }

  import ietf-netconf {
    prefix nc;
  }

  import ietf-netconf-notifications {
    prefix ncn;
  }

  import ietf-netconf-with-defaults {
    prefix ncwd;
  }

  import ietf-restconf {
    prefix rc;
  }

  import ietf-yang-types {
    prefix yang;
  }
```

```
     organization
       "IETF NETCONF (Network Configuration Protocol) Working Group";

     contact
       "WG Web:   <http://tools.ietf.org/wg/netconf/>
        WG List:  <mailto:netconf@ietf.org>

        WG Chair: Mehmet Ersue
                  <mailto:mehmet.ersue@nsn.com>

        WG Chair: Bert Wijnen
                  <mailto:bertietf@bwijnen.net>

        Editor:   Andy Bierman
                  <mailto:andy@yumaworks.com>";

     description
       "This module contains a collection of YANG definitions for the
        efficient operation of a NETCONF server. Protocol operations
        are defined to reduce network usage and transaction complexity.

        Copyright (c) 2013 IETF Trust and the persons identified as
        authors of the code.  All rights reserved.

        Redistribution and use in source and binary forms, with or
        without modification, is permitted pursuant to, and subject
        to the license terms contained in, the Simplified BSD License
        set forth in Section 4.c of the IETF Trust's Legal Provisions
        Relating to IETF Documents
        (http://trustee.ietf.org/license-info).

        This version of this YANG module is part of RFC XXXX; see
        the RFC itself for full legal notices.";

     // RFC Ed.: replace XXXX with actual RFC number and remove this
     // note.

     // RFC Ed.: remove this note
     // Note: extracted from
     // draft-bierman-netconf-efficiency-extensions-00.txt

     // RFC Ed.: update the date below with the date of RFC publication
     // and remove this note.
     revision "2013-10-19" {
       description
         "Initial revision. <get2> operation originally published
```

```
          in draft-bierman-netconf-get2-03.txt";
      reference
```



```
        "RFC XXXX: NETCONF Efficiency Extensions";
    }


    /* Features */

    feature timestamps {
      description
        "This feature indicates that the server implements
         the <get2> operations parameters which require
         last modification timestamps to be maintained by
         the server.

         If this feature is advertised then one global
         'last-modified' timestamp for the entire
         running configuration datastore MUST be supported.

         The server MAY support additional timestamps
         for additional datastores and data nodes
         within a datastore.  The 'with-metadata'
         parameter can be used to identify
         which data nodes support a 'last-modified'
         timestamp.";
    }

    feature with-defaults {
      description
        "This feature indicates that the server supports the
         'with-defaults' parameter for the <get2> operation.
         A NETCONF server SHOULD support this feature.";
      reference
        "RFC 6243: With-defaults Capability for NETCONF";
    }

    feature confirmed-edit {
      description
        "This feature indicates that the server supports the
         confirmed commit procedure for the <edit2> protocol
         operation.";
```

```
}

/* Identities */

identity metadata {
  description
    "Base for all metadata identifiers used by the
     'with-metadata' parameter in the <get2> operation.";
```



```
}

identity timestamps {
  base metadata;
  description
     "Describes metadata identifying the last modification
      time of the associated datastore or data resource.";
}

identity etags {
  base metadata;
  description
     "Describes metadata identifying the entity tag value
      of the associated datastore or data resource.";
}

identity config-id {
  base metadata;
  description
     "Describes metadata identifying the config ID
      of the associated datastore or data resource.";
}


/* Typedefs */

typedef yang-entity-tag {
  type string;
  description
    "Contains an opaque string representing a specific instance
     of a datastore or data resource. A client can use this
     string for equality comparisons between yang-entity-tag
```

```
          values.

          If any configuration data node values changes, or the
          relative order of any user-ordered data changes, then
          the server MUST change the entity tag value for the
          running datastore to a different value.  If the server
          maintains entity-tag values for configuration data nodes,
          then the server MUST change the yang-entity-tag value for
          any affected data node.

          Only yang-entity-tag values for the same target resource
          instance can be compared. Only the 'strong entity tag'
          form is required.  A server MAY support the 'weak
          entity tag' form.  If so, then 2 YANG data node resource
          instances are considered to be equivalent if they
          contain the same value subtrees and all user-ordered
```



```
           data nodes share the same relative order.";
        reference
          "RFC 2616, section 3.11.";
      }


      /* Groupings */

      grouping lock-parms {
        description
          "Common parameters to control datastore locking.";

        leaf with-locking {
          type empty;
          description
           "If this parameter is present then the request MUST be
            performed with exclusive write access to all datastores
            involved in the operation.  An 'operation-not-supported'
            error-tag value is returned if the target datastore for
            the operation does not support locking (e.g., 'url' or
            'operational').

            If the server cannot provide exclusive write access
            for the entire requested operation then an 'in-use'
            error-tag value is returned.
```

```
        If the 'max-lock-wait' parameter is also present then
        the server MAY choose to wait up to that amount of
        time attempting to obtain exclusive write access,
        before returning an error.";
      }

      leaf max-lock-wait {
        when "../with-locking" {
          description
            "Only relevant if locking is requested.";
        }
        type uint32 {
          range "1 .. 600";
        }
        units seconds;
        description
         "If this parameter is present and the 'with-locking'
          parameter is also present, then the server MAY wait
          up to the specified number of seconds attempting
          to obtain exclusive write access for the requested
          operation.";
      }
```



```
    }


    /* Protocol Operations */

    rpc get2 {
      description
        "Retrieve NETCONF datastore information";
      input {
        container source {
          description
            "The datastore (or non-configuration data)
             to use for the source for the retrieval operation.";

          choice datastore-source {
            default running;
            description
              "The configuration source for the retrieval operation.
```

```
               The running configuration is the default choice if
               this parameter is not present.";
            leaf candidate {
              if-feature nc:candidate;
              type empty;
              description
                "The candidate configuration datastore is the
                 retrieval source.";
            }
            leaf running {
              type empty;
              description
                "The running configuration datastore is the
                 retrieval source.";
            }
            leaf startup {
              if-feature nc:startup;
              type empty;
              description
                "The startup configuration datastore is the
                 retrieval source.";
            }
            leaf url {
              if-feature nc:url;
              type inet:uri;
              description
                "The URL-based configuration is the
                 retrieval source.";
            }
            leaf operational {
```



```
              type empty;
              description
               "The retrieval source is the collection of all
                operational (non-configuration) data nodes supported
                by the server.

                Any ancestor container and/or list and list key nodes
                are also returned. No other leafs or leaf-lists will
                be included in the reply.

                The server MAY return ancestor container, and/or list
```

```
            and list key nodes that do not contain any
            non-configuration nodes. This can occur for several
            reasons, e.g., the implementation streams replies
            and cannot defer instrumentation or access control
            filtering of descendant data nodes.";
        }
      }
    }

    choice filter-spec {
      description
        "The content filter specification for this request";

      anyxml subtree-filter {
        description
          "This parameter identifies the portions of the
           target datastore to retrieve.";
        reference "RFC 6241, Section 6.";
      }
      leaf xpath-filter {
        if-feature nc:xpath;
        type yang:xpath1.0;
        description
          "This parameter contains an XPath expression
           identifying the portions of the target
           datastore to retrieve.";
      }
    }

    leaf keys-only {
      type empty;
      description
        "This parameter selects only data nodes which
         are key leaf nodes.  Parent container and
         list nodes are also returned, but no other leafs,
         or any leaf-lists will be included in the reply.";
    }
```



```
    leaf if-modified-since {
      if-feature timestamps;
      type yang:date-and-time;
      description
```

```
          "This parameter selects the target datastore
           only if the last-modified timestamp for the
           datastore is more recent than the specified time.
           If not, then an empty <data> element is returned.

           If the target datastore does not maintain a
           last-modified timestamp, then this parameter is
           ignored.";
        }

        leaf full-delta {
          if-feature timestamps;
          type empty;
          description
            "This parameter selects only data nodes which
             have been modified since the specified time.
             It is ignored unless the 'if-modified-since'
             parameter is also provided and the target datastore
             supports a last-modified timestamp.";
        }

        leaf depth {
          type uint32;
          default 0;
          description
            "This parameter selects how many conceptual
             sub-tree levels should be returned in the
             <rpc-reply>.

             If this parameter is equal to '0', then entire
             subtrees will be returned.

             If this parameter is greater than '0', then
             only the specified number of subtree levels will
             be returned.";
        }

        uses ncwd:with-defaults-parameters {
          if-feature with-defaults;
          description
            "This parameter controls the retrieval of
             default values.";
           reference
             "RFC 6243: With-defaults Capability for NETCONF";
```

```
        }

        leaf-list with-metadata {
          type identityref {
            base metadata;
          }
          description
            "This parameter will cause the server to return
             metadata in the <rpc-reply> (e.g. as XML attributes
             in XML encoding) associated with the specified
             metadata identity. If the server does not support
             any specified metadata identifier, then the
             operation fails with an 'invalid-value' error.";
        }

        uses lock-parms {
          description
            "Exclusive write access can be requested to
             ensure that no other sessions modify the
             configuration data during the retrieval operation";
        }

      }

      output {
        anyxml data {
          description
            "Copy of the requested datastore subset which
             matched the filter criteria (if any).
             An empty data container indicates that the
             request did not produce any results.";
        }
      }
    }


    rpc edit2 {
      description
        "Edit NETCONF datastore contents.
         All operations requested in the yang-patch edit list
         are applied, or the target datastore is left unchanged.";

      input {
        container target {
          description
            "The datastore to use as the target for this
             edit operation.";
```

```
          choice datastore-target {
            mandatory true;
            description
              "The configuration target for the edit operation.";

            leaf candidate {
              if-feature nc:candidate;
              type empty;
              description
                "The candidate configuration datastore is the
                 edit target.";
            }
            leaf running {
              if-feature nc:writable-running;
              type empty;
              description
                "The running configuration datastore is the
                 edit target.";
            }
          }
        }

        leaf target-resource {
          if-feature nc:xpath;
          type yang:xpath1.0;
          description
            "This parameter identifies 1 or more data node
             instances for which the yang-patch edits
             will be applied. The target-resource expression
             MUST evaluate to a node-set result.

             Each operation in the yang-patch edit list will
             be applied to each target-resource instance, as if
             it were the document root for the operation.

             If multiple instances are represented by the
             target-resource value, then the server will apply
             all edits to all instances.  If any errors occur,
             then all edits from this request will be undone
             from the target datastore.
```

```
            The user MUST have appropriate write permissions for
            all data accessed by every operation within the edit
            list.

            If this parameter is not present or not supported
            then the target resource is the root node of the
            datastore identified by the 'target' parameter.";
```



```
        }

        uses rc:yang-patch {
          description
            "The yang-patch parameter contains the ordered list
             of edits to perform on the target resource(s).

             The conceptual document root for the 'target'
             parameter is defined to be the value of a data node
             represented by the 'target-resource' parameter or the
             target datastore conceptual root node if that parameter
             is not present.";
        }

        leaf test-only {
          type empty;
          description
            "If this parameter is present the server will not
             actually perform the requested edits. Instead the
             edit request will be validated as if it were going
             to be applied.  Any parameter errors or datastore
             validation errors SHOULD be reported in the response.

             No attempt to apply, activate the edits or save them
             in non-volatile storage will be made if this parameter
             is present.";
        }

        leaf if-match {
          type yang-entity-tag;
          description
            "If this parameter is set, then the entire edit request
             will be rejected unless the entity tag for the target
```

```
            resource matches this value. An rpc-error with
            an 'operation-failed' error-tag value MUST returned,
            and the edit operation MUST NOT be attempted.
            The 'error-app-tag' field SHOULD be set to
            'precondition-failed'.

            If the target datastore does not maintain a
            last-modified timestamp, then this parameter is
            ignored.";
        }

        uses lock-parms {
          description
            "Exclusive write access can be requested to
             ensure that no other sessions modify the
```



```
             configuration data during the edit operation
             and possibly the entire confirmed commit procedure.

             If the 'with-locking' parameter is used to start or
             extend a confirmed commit procedure, then the
             exclusive write access will be maintained until the
             confirmed commit procedure terminates somehow.

             If the 'with-locking' parameter is used for a
             plain edit operation, then exclusive write access
             will be maintained until this operation has completed.";
        }

        leaf activate-now {
          type empty;
          description
            "If present and the edit operation succeeds,
             then the server will activate the configuration
             changes right away. The server will conceptually
             perform a <commit> operation after the edit
             operation. The user MUST have execute
             permission for the <commit> operation or
             the operation fails with an 'access-denied' error.

             This parameter has no affect unless the
             'datasource-target' choice is the 'candidate' leaf.";
```

```
        }

        leaf nvstore-now {
          type empty;
          description
            "If present and the edit operation succeeds,
             and the configuration changes are activated
             in the running datastore, then the server
             will persist the configuration changes right away
             in non-volatile store. The server will conceptually
             perform a <copy-config> operation from the running
             to the startup datastore. The user MUST have execute
             permission for the <copy-config> operation or
             the operation fails with an 'access-denied' error.

             This parameter has no affect unless the
             'startup' capability is supported by the server.";
        }

        leaf confirmed {
          if-feature confirmed-edit;
          type empty;
```



```
          description
            "If the requested edit operation succeeds and the
             configuration changes are applied to the running
             datastore, then a confirmed commit procedure is
             requested by the client.

             A confirmed commit procedure is an <edit2> operation
             that contains this parameter.  The <complete-commit>
             operation is used to complete the confirmed commit
             procedure. The <revert-commit> operation is used
             to cancel the confirmed commit procedure and
             revert the running datastore back to the contents
             before the first confirmed commit operation.

             If no <complete-commit> or <revert-commit> operation
             is invoked within the timeout interval then
             the server will revert the running datastore
             back to the contents before the first confirmed
             edit operation.
```

```
            This is the same as the confirmed commit procedure
            in RFC 6241 except the candidate capability is
            not required.

            The server will save the running datastore contents
            before the edit operation is activated, if there
            is no confirmed edit already in progress.

            If the 'with-locking' parameter is present then
            the server will maintain exclusive write access
            for the specified session until the confirmed
            edit procedure is completed somehow.";
          reference
            "RFC 6241, Section 8.3.4.1";
        }

        leaf confirm-timeout {
          when "../confirmed" {
            description
              "Only relevant if the <confirmed>parameter is present";
          }
          if-feature confirmed-edit;
          type uint32 {
            range "1..max";
          }
          units "seconds";
          default "600";   // 10 minutes
          description
```



```
            "The timeout interval for a confirmed edit procedure.
             If exclusive write access was granted for this confirmed
             commit procedure, then it is removed if the timeout
             occurs and the confirmed commit procedure is terminated.";

          reference "RFC 6241, Section 8.3.4.1";
        }

        leaf persist {
          if-feature confirmed-edit;
          type string;
          description
```

```
            "This parameter is used to make a confirmed commit
             procedure persistent.  A persistent confirmed commit
             is not aborted if the NETCONF session terminates.
             The only way to abort a persistent confirmed commit
             is to let the timer expire,  or to use the
             <revert-commit> operation.

             The value of this parameter is a token that MUST be
             given in the 'persist-id' parameter of the <edit2>,
             <complete-commit>, or <revert-commit> operations in
             order to extend, confirm, or cancel the persistent
             confirmed commit procedure.

             The token SHOULD be a random string.";
          reference "RFC 6241, Section 8.3.4.1";
        }

        leaf persist-id {
          if-feature confirmed-edit;
          type string;
          description
            "This parameter is given in order to extend a persistent
             confirmed edit.  The value must be equal to the value
             given in the 'persist' parameter to the <commit>
             operation. If it does not match, the operation fails
             with an 'invalid-value' error.";
            reference "RFC 6241, Section 8.3.4.1";
        }
      }

      output {
        uses rc:yang-patch-status;
      }
    }
```



```
    rpc complete-commit {
      if-feature confirmed-edit;
      description
        "This operation is used to complete an ongoing confirmed
         commit procedure. If exclusive write access was granted
```

```
          for this confirmed commit procedure, then it is removed
          if this operation is successfully completed.

          If the confirmed commit is persistent, the parameter
          'persist-id' MUST be given, and it MUST match the value of
          the 'persist' parameter given in the <edit2> operation.
          If not confirmed commit procedure is in progress then
          the operation fails with an 'operation-failed' error.";
      reference "RFC 6241, Section 8.4.5.1";

      input {
        leaf persist-id {
          type string;
          description
            "This parameter is given in order to complete a
             persistent confirmed commit procedure. The
             value MUST be equal to the value given in the
             'persist' parameter to the <edit2>  operation.
             If it does not match, the operation fails with
             an 'invalid-value' error.";
        }
      }
    }


    rpc revert-commit {
      if-feature confirmed-edit;
      description
        "This operation is used to cancel an ongoing confirmed commit.
         If exclusive write access was granted for this confirmed
         commit procedure, then it is removed if this operation
         is successfully completed.

         If the confirmed commit is persistent, the parameter
         'persist-id' MUST be given, and it MUST match the value of
         the 'persist' parameter.  If not confirmed commit
         procedure is in progress then the operation fails
         with an 'operation-failed' error.";
      reference "RFC 6241, Section 8.4.4.1";

      input {
        leaf persist-id {
          type string;
```

```
        description
          "This parameter is given in order to cancel a persistent
           confirmed commit and revert the running configuration
           datastore to its state before the confirmed commit
           procedure started.  The value MUST be equal to the value
           given in the 'persist' parameter to the <edit2>
           operation.

           If it does not match, the operation fails with an
          'invalid-value' error.";
      }
    }
  }


  /* Notifications */

  augment /ncn:netconf-capability-change {
    description
      "Add the updated capability-id capability value
       to a capability change event.";

    leaf capability-id {
      type string;
      description
        "Contains the new capability ID for the server,
         representing the capability set after the
         capability changes.";
    }
  }

  augment /ncn:netconf-config-change {
    description
      "Add the updated config-id capability value
       to a configuration change event.";

    leaf config-id {
      type string;
      description
        "Contains the new configuration ID for the
         running datastore on the server, representing
         the datastore after the configuration changes.";
    }
  }



}
```

<CODE ENDS>

2.9. XSD for NETCONF-EX Metadata

The following XML Schema document [XSD] defines the "last-modified" and "etag" attributes, described within this document. The "last-modified" attribute is only relevant if the server supports the "timestamps" YANG feature within the "ietf-netconf-ex" YANG module.

The "last-modified" attribute uses the XSD data type "dateTime", in accordance with Section 3.2.7.1 of XML Schema Part 2: Datatypes. This is equivalent to the YANG data type "date-and-time".

The "etag" attribute uses the XSD data type "string", in accordance with the "yang-entity-tag" YANG typedef defined in Section 2.8.

The "config-id" attribute uses the XSD data type "string".

<CODE BEGINS> file "netconf-ex.xsd"

```
 <?xml version="1.0" encoding="UTF-8"?>
 <xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema"
   xmlns="urn:ietf:params:xml:ns:netconf:netconf-ex:1.0"
   targetNamespace="urn:ietf:params:xml:ns:netconf:netconf-ex:1.0"
   elementFormDefault="qualified"
   attributeFormDefault="unqualified"
   xml:lang="en">

  <xs:annotation>
    <xs:documentation>
      This schema defines the syntax for the "last-modified"
      and "etag" attributes described within this document.
    </xs:documentation>
  </xs:annotation>

  <!--
    config-id attribute
    -->
  <xs:attribute name="config-id" type="xs:string">
    <xs:annotation>
      <xs:documentation>
        This attribute indicates the current config ID
```

```
          for the running configuration datastore,
          corresponding to the XML element containing this attribute.
        </xs:documentation>
      </xs:annotation>
    </xs:attribute>
```



```
    <!--
      last-modified attribute
      -->
    <xs:attribute name="last-modified" type="xs:dateTime">
      <xs:annotation>
        <xs:documentation>
          This attribute indicates the date and time when
          a modification was last detected by the server
          for the datastore or data node corresponding to
          the XML element containing this attribute.
        </xs:documentation>
      </xs:annotation>
    </xs:attribute>

    <!--
      etag attribute
      -->
    <xs:attribute name="etag" type="xs:string">
      <xs:annotation>
        <xs:documentation>
          This attribute indicates the entity tag
          for the datastore or data node corresponding to
          the XML element containing this attribute.
        </xs:documentation>
      </xs:annotation>
    </xs:attribute>

  </xs:schema>

<CODE ENDS>
```

3. IANA Considerations

3.1. NETCONF-EX XML Namespace

This document registers a URI in the IETF XML registry [RFC3688]. Following the format in RFC 3688, the following registration is requested:

```
URI: urn:ietf:params:xml:ns:netconf:netconf-ex:1.0
Registrant Contact: The NETCONF WG of the IETF.
XML: N/A, the requested URI is an XML namespace.
```

3.2. NETCONF-EX XML Schema

This document registers a URI for the NETCONF XML schema in the IETF XML registry [RFC3688].

```
// RFC Ed. remove this line and uncomment next line when published
//IANA has updated the following URI to reference this document.

URI: urn:ietf:params:xml:schema:netconf-ex
```

3.3. NETCONF-EX YANG Module

This document registers 1 YANG module in the YANG Module Names registry [RFC6020].

```
name:         ietf-netconf-ex
```

```
    namespace:    urn:ietf:params:xml:ns:yang:ietf-netconf-ex
    prefix:       ncex
    // RFC Ed. remove this line and replace XXXX in next line
    reference:    RFC XXXX
```


4. Security Considerations

This document does not introduce any new security concerns in addition to those specified in [RFC6241], section 9.

5. Normative References

[I-D.lhotka-netmod-json]
Lhotka, L., "Modeling JSON Text with YANG", draft-lhotka-netmod-yang-json-02 (work in progress), September 2013.

[JSON] Bray, T., Ed., "The JSON Data Interchange Format", draft-ietf-json-rfc4627bis-03 (work in progress), September 2013.

[RESTCONF]
Bierman, A., Bjorklund, M., Watsen, K., and R. Fernando, "RESTCONF Protocol", draft-bierman-netconf-restconf-02

(work in progress), October 2013.

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

[RFC3688] Mealling, M., "The IETF XML Registry", BCP 81, RFC 3688, January 2004.

[RFC6020] Bjorklund, M., "YANG - A Data Modeling Language for the Network Configuration Protocol (NETCONF)", RFC 6020, October 2010.

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[RFC6243] Bierman, A. and B. Lengyel, "With-defaults Capability for NETCONF", RFC 6243, June 2011.

[RFC6470] Bierman, A., "Network Configuration Protocol (NETCONF) Base Notifications", RFC 6470, February 2012.

[RFC6991] Schoenwaelder, J., "Common YANG Data Types", RFC 6991, July 2013.

[XPATH] Clark, J. and S. DeRose, "XML Path Language (XPath) Version 1.0", World Wide Web Consortium Recommendation REC-xpath-19991116, November 1999, <http://www.w3.org/TR/1999/REC-xpath-19991116>.

[XSD] Malhotra, A. and P. Biron, "XML Schema Part 2: Datatypes Second Edition", World Wide Web Consortium Recommendation REC-xmlschema-2-20041028, October 2004, <http://www.w3.org/TR/2004/REC-xmlschema-2-20041028>.

Appendix A. Open Issues

A.1. resource-identifier-type

The resource-identifier-type typedef from yang-patch is a RESTCONF path expression, not an XPath path expression. The error-path parameter also uses RESTCONF path strings. Should either or both of

these be XPath instead?

A.2. no YANG for top-level message nodes

The YANG module of the node is needed for JSON encoding, but there is no YANG schema definition for the <rpc>, <rpc-reply>, or <notification> elements. The namespace for <rpc> and <rpc-reply> is "ietf-netconf", but no module name at all exists for the <notification> element.

A.3. only 1 location returned per edit

The bulk edit mode of <edit2> can allow multiple sub-resources to be created at once. YANG Patch does not support bulk editing, so only one "location" leaf is allowed to be returned in the "yang-patch-status" response for a bulk edit

A.4. config-id attribute

Should the "config-id" (etag for the running datastore root) be returned in every <get2> response or only if requested? (Currently only if requested.)

A.5. <get2> nodeset retrieval

Should there be a retrieval mode for <get2> where only the nodes in an XPath node-set are returned? NETCONF returns all ancestor nodes and all ancestor or sibling key leafs as well. Sometime the XPath designer knows the context of the result node-set (e.g. path expression for 1 instance of a nested list). The XML scaffolding can add a lot of extra bytes to the <rpc-reply>.

Appendix B. Additional Examples

B.1. YANG Module Used in Examples

The "example-ex" YANG module models a collection of forests. Each forest has a collection of trees. For simplicity, only 1 tree of each type is allowed in a forest.

```
   +--rw forests
      +--rw forest [name]
         +--rw name          string
         +--ro tree-count?   uint32
         +--rw trees
            +--rw tree [name]
               +--rw name        string
               +--rw location?   string
               +--ro height?     decimal64
```

```
module example-ex {

  namespace "http://example.com/ns/example-ex";
  prefix ex;
  organization "Example, Inc.";
  contact "support@example.com";

  description "Module used in NETCONF-EX examples.";
  revision 2013-10-19 {
    description "Initial version";
    reference "Example Spec 12.44";
  }

  container forests {
    description "A collection of forests";

    list forest {
      key name;
      description "A single forest";

      leaf name {
        type string;
        description "The forest name";
      }

      leaf tree-count {
        type uint32;
        config false;
        description "The number of trees in this forest";
```

```
        }

        container trees {
          description "A collection of trees";

          list tree {
            key name;
            description "A single tree";

            leaf name {
              type string;
              description "The tree name";
            }
            leaf location {
              type string;
              description "The tree location";
            }

            leaf height {
              type decimal64 {
                fraction-digits 3;
              }
              units meters;
              config false;
              description "The tree height";
            }
          }  // list tree
        }  // container trees
      } // list forest
    }  // container forests
  }
```

B.2. YANG Data Used in Examples

The follow instances are assumed in the following examples.

```
  list forest: "north":
    list tree: "birch", "ash", "maple"

  list forest: "south":
    list tree: "banyan", "palm"

  leaf "location": "hillside", "west valley", "southwest pasture",
```

"east meadow", "greenhouse"

The forests and trees are configured, which represent trees the company has planted and growing over time.

The operational data (tree height) represents the data that the company monitors for each tree over time.

B.3. <edit2> Examples

B.3.1. Confirmed Commit on the "running" Datastore

In this example, the server supports the :writable-running and :startup capabilities:

```
<rpc message-id="105"
   xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <edit2 xmlns="urn:ietf:params:xml:ns:yang:ietf-netconf-ex"
    xmlns:ex="http://example.com/ns/example-ex">
    <target><running/></target>
    <target-resource>
      /ex:forests/ex:forest[ex:name='north']
    </target-resource>
    <yang-patch>
      <patch-id>oak-tree-patch</patch-id>
      <comment>Create an oak tree</comment>
      <edit>
        <edit-id>oak</edit-id>
        <operation>create</operation>
        <target>/ex:trees</target>
        <value>
          <ex:tree>
            <ex:name>oak</ex:name>
            <ex:location>hillside</ex:location>
          </ex:tree>
        </value>
      </edit>
    </yang-patch>
    <with-locking/>
    <max-lock-wait>10</max-lock-wait>
    <confirmed/>
```

```
        <confirm-timeout>60</confirm-timeout>
        <persist>24ef8829a4</persist>
      </edit2>
    </rpc>
```

The edit succeeds, and the "yang-patch-status" container is returned to the client with the <location> path expression of the new oak tree resource. The candidate and running datastores remain locked after this operation because a confirmed commit procedure is in progress. The startup datastore was not locked during this operation because the "nvstore-now" parameter was not provided.


```
    <rpc-reply message-id="105"
       xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
      <yang-patch-status
        xmlns="urn:ietf:params:xml:ns:yang:ietf-netconf-ex"
        xmlns:ex="http://example.com/ns/example-ex">
        <patch-id>oak-tree-patch</patch-id>
        <ok/>
        <edit-status>
          <edit>
            <edit-id>oak</edit-id>
            <location>
              /ex:forests/ex:forest/north/ex:trees/ex:tree/oak
            </location>
          </edit>
        </edit-status>
      </yang-patch-status>
    </rpc-reply>
```

After configuration verification (e.g., 20 seconds), the client decides to keep these configuration changes and sends a <complete-commit> request.

```
  <rpc message-id="106"
    xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
    <complete-commit
      xmlns="urn:ietf:params:xml:ns:yang:ietf-netconf-ex">
      <persist>24ef8829a4</persist>
    </complete-commit>
  </rpc>
```

The server completes the confirmed commit procedure and returns an "ok" element to indicate success:

```
  <rpc-reply message-id="106"
    xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
    <ok/>
  </rpc-reply>
```

After the operation succeeds, the server releases all locks that were being held to allow exclusive write access for the entire confirmed commit procedure.

The client can now save the activated configuration changes to the startup configuration using the <copy-config> protocol operation, as described in RFC 6241, section 8.7.5.1.

B.3.2. Conditional Editing with "if-match" Parameter

In this example the client is going to change the location of the "palm" tree is the "south" forest. The entity tag for the tree resource is retrieved with the resource:

```
  <rpc message-id="107"
    xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
    <get2 xmlns="urn:ietf:params:xml:ns:yang:ietf-netconf-ex"
      xmlns:ncex="urn:ietf:params:xml:ns:yang:ietf-netconf-ex">
      <xpath-filter> <!-- wrapped for display -->
        /ex:forests/ex:forest[ex:name='south']/ex:trees/
        ex:tree[ex:name='palm']
      </xpath-filter>
      <depth>1</depth>
      <with-metadata>ncex:etags</with-metadata>
    </get2>
  </rpc>
```

The server returns a subtree containing data nodes representing the "palm" tree. The "etag" attribute is returned for this resource and its ancestors. Only the "tree" node itself, as requested with the

```
"depth parameter.

  <rpc-reply message-id="107"
    xmlns="urn:ietf:params:xml:ns:netconf:base:1.0"
    xmlns:lm="urn:ietf:params:xml:ns:netconf:netconf-ex:1.0">
    <data xmlns="urn:ietf:params:xml:ns:yang:ietf-netconf-ex"
    lm:last-modified="2012-09-09T02:00:00Z">
      <forests xmlns="http://example.com/ns/example-ex"
        lm:etag="34ef6892">
        <forest lm:etag="ef11eb99">
          <name>south</name>
          <trees lm:etag="ef11eb99">
            <tree lm:etag="3477cc82" />
          </trees>
        </forest>
      </forests>
    </data>
  </rpc-reply>

The client then edits the list entry (e.g, reassigns tree location)
but submits an "if-match" parameter with the "etag" value it received
for the tree resource being edited:
```



```
   <rpc message-id="108"
      xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
     <edit2 xmlns="urn:ietf:params:xml:ns:yang:ietf-netconf-ex"
       xmlns:ex="http://example.com/ns/example-ex">
       <target><candidate/></target>
       <target-resource> <!-- wrapped for display -->
         /ex:forests/ex:forest[ex:name='south']/ex:trees
         /ex:tree[ex:name='palm']
       </target-resource>
       <yang-patch>
         <patch-id>move-palm-tree</patch-id>
         <comment>Move the palm tree</comment>
         <edit>
           <edit-id>palm</edit-id>
           <operation>merge</operation>
```

```
            <target>/</target>
            <value>
              <ex:location>greenhouse</ex:location>
            </value>
          </edit>
        </yang-patch>
        <if-match>3477cc82</if-match>
        <with-locking/>
        <max-lock-wait>10</max-lock-wait>
        <activate-now/>
        <nvstore-now/>
      </edit2>
    </rpc>
```

In this example the tree resource has been edited by another client since the <get2> reply for this client, so the edit request is not even attempted. Instead an "operation-failed" is returned:


```
    <rpc-reply message-id="108"
       xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
      <yang-patch-status
        xmlns="urn:ietf:params:xml:ns:yang:ietf-netconf-ex"
        xmlns:ex="http://example.com/ns/example-ex">
        <patch-id>move-palm-tree</patch-id>
        <errors>
          <error>
```

```
            <error-type>protocol</error-type>
            <error-tag>operation-failed</error-tag>
            <error-app-tag>precondition-failed</error-app-tag>
            <error-path>  <!-- wrapped for display -->
              /ex:forests/ex:forest[ex:name='south']/ex:trees/
              ex:tree[ex:name='palm']
            </error-path>
            <error-message xml:lang="en">
              if-match precondition failed
            </error-message>
          </error>
        </errors>
      </yang-patch-status>
    </rpc-reply>
```

B.3.3. Bulk Editing with "target-resource" Parameter

In this example, the server supports the :candidate and :startup capabilities, so all 3 datastores (including running) are locked for the <edit2> operation. There is a new pine tree for each forest that is being created and sent to the greenhouse.


```
    <rpc message-id="109"
```

```
       xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
      <edit2 xmlns="urn:ietf:params:xml:ns:yang:ietf-netconf-ex"
        xmlns:ex="http://example.com/ns/example-ex">
        <target><candidate/></target>
        <target-resource>
          /ex:forests/ex:forest
        </target-resource>
        <yang-patch>
          <patch-id>pine-tree-patch</patch-id>
          <comment>Add 2 new pine trees to greenhouse</comment>
          <edit>
            <edit-id>pine</edit-id>
            <operation>create</operation>
            <target>/ex:trees</target>
            <value>
              <ex:tree>
                <ex:name>pine</ex:name>
                <ex:location>greenhouse</ex:location>
              </ex:tree>
            </value>
          </edit>
        </yang-patch>
        <with-locking/>
        <max-lock-wait>10</max-lock-wait>
        <activate-now/>
        <nvstore-now/>
      </edit2>
    </rpc>
```

The edit succeeds, and the "yang-patch-status" container is returned to the client with the status information.

```
<rpc-reply message-id="109"
   xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <yang-patch-status
    xmlns="urn:ietf:params:xml:ns:yang:ietf-netconf-ex"
    xmlns:ex="http://example.com/ns/example-ex">
    <patch-id>pine-tree-patch</patch-id>
    <ok/>
    <edit-status>
      <edit>
        <edit-id>pine</edit-id>
        <location>
          /ex:forests/ex:forest/north/ex:trees/ex:tree/pine
        </location>
        <!-- FIXME: multiple location nodes not currenty
             supported by YANG Patch!
          <location>
            /ex:forests/ex:forest/south/ex:trees/ex:tree/pine
          </location>
        -->
      </edit>
    </edit-status>
  </yang-patch-status>
</rpc-reply>
```

B.3.4. Edit Validation with "test-only" Parameter

In this example, the client is checking if it can change the location field in the "palm" tree list entry by using the "test-only" parameter:

```
      <rpc message-id="110"
         xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
        <edit2 xmlns="urn:ietf:params:xml:ns:yang:ietf-netconf-ex"
          xmlns:ex="http://example.com/ns/example-ex">
          <target><candidate/></target>
          <target-resource>
            /ex:forests/ex:forest[ex:name='south']/ex:trees
          </target-resource>
          <yang-patch>
            <patch-id>palm-tree-move</patch-id>
            <comment>Move the palm tree to riverside</comment>
            <edit>
              <edit-id>palm</edit-id>
              <operation>merge</operation>
              <target>/ex:tree/palm</target>
              <value>
                <ex:location>riverside</ex:location>
              </value>
            </edit>
          </yang-patch>
          <test-only/>
        </edit2>
      </rpc>
```

Since "riverside" is not a supported location, an "invalid-value" error is returned for the requested edit operation:

```
      <rpc-reply message-id="110"
         xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
        <yang-patch-status
          xmlns="urn:ietf:params:xml:ns:yang:ietf-netconf-ex"
          xmlns:ex="http://example.com/ns/example-ex">
          <patch-id>palm-tree-move</patch-id>
          <edit-status>
            <edit>
              <edit-id>palm</edit-id>
              <errors>
                <error>
                  <error-type>protocol</error-type>
                  <error-tag>invalid-value</error-tag>
                  <error-path>  <!-- wrapped for display -->
                    /ex:forests/ex:forest[ex:name='south']/ex:trees/
                    ex:tree[ex:name='palm']
                  </error-path>
                  <error-message xml:lang="en">
                    value is invalid
                  </error-message>
                </error>
              </errors>
            </edit>
          </edit-status>
        </yang-patch-status>
      </rpc-reply>
```

B.4. <get2> Examples

B.4.1. If-Modified-Since Non-Empty Filter Retrieval

In this example, the running datastore was last modified at

"2012-09-09T01:43:27Z" because the forest named "north" was modified at this time.

- The forest named "north" was last modified after the specified "if-modified-since" timestamp.

- The forest named "south" was last modified before the specified "if-modified-since" timestamp.

- The server maintains a last-modified timestamp for the running datastore and the "forest" list entries.

- The client is requesting only the changed entries after 2012-09-09T01:43:27Z, so the "full-delta" parameter is set.

- The client is also requesting that timestamps be returned within the data nodes. If any part of the "forest" subtree is modified then this timestamp will be updated.

```
  <rpc message-id="111"
    xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
    <get2 xmlns="urn:ietf:params:xml:ns:yang:ietf-netconf-ex"
      xmlns:ncex="urn:ietf:params:xml:ns:yang:ietf-netconf-ex">
      <subtree-filter>
        <forests xmlns="http://example.com/ns/example-ex" />
      </subtree-filter>
      <if-modified-since>2012-09-09T01:43:27Z</if-modified-since>
      <full-delta/>
      <with-metadata>ncex:timestamps</with-metadata>
    </get2>
  </rpc>

  <rpc-reply message-id="111"
    xmlns="urn:ietf:params:xml:ns:netconf:base:1.0"
    xmlns:lm="urn:ietf:params:xml:ns:netconf:netconf-ex:1.0">
    <data xmlns="urn:ietf:params:xml:ns:yang:ietf-netconf-ex"
    lm:last-modified="2012-09-09T02:00:00Z">
      <forests xmlns="http://example.com/ns/example-ex">
        <forest lm:last-modified="2012-09-09T02:00:00Z">
```

```
            <name>north</name>
            <trees>
              <tree>
                <name>birch</name>
                <location>hillside</location>
              </tree>
              <tree>
                <name>ash</name>
                <location>southwest pasture</location>
              </tree>
              <tree>
                <name>maple</name>
                <location>east meadow</location>
              </tree>
            </trees>
          </forest>
        </forests>
      </data>
    </rpc-reply>
```


B.4.2. If-Modified-Since Empty Filter Retrieval

In this example the client has changed the "if-modified-since" timestamp to a time in the future.

- No "forest" list entry has been modified since this time so an empty data node is returned.
- Note that the "last-modified" timestamp is returned for the node representing the datastore, even though no data nodes have been modified since the specified time. This allows the client to easily retrieve the last-modified timestamp for the entire datastore.

```
    <rpc message-id="112"
      xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
      <get2 xmlns="urn:ietf:params:xml:ns:yang:ietf-netconf-ex"
```

```
        xmlns:ncex="urn:ietf:params:xml:ns:yang:ietf-netconf-ex">
        <subtree-filter>
          <forests xmlns="http://example.com/ns/example-ex" />
        </subtree-filter>
        <if-modified-since>2012-09-09T03:43:27Z</if-modified-since>
        <with-metadata>ncex:timestamps</with-metadata>
      </get2>
    </rpc>

    <rpc-reply message-id="112"
      xmlns="urn:ietf:params:xml:ns:netconf:base:1.0"
      xmlns:lm="urn:ietf:params:xml:ns:netconf:netconf-ex:1.0">
      <data xmlns="urn:ietf:params:xml:ns:yang:ietf-netconf-ex"
        lm:last-modified="2012-09-09T02:00:00Z" />
    </rpc-reply>
```

B.4.3. Keys Only Filter Retrieval

This example retrieves only the names from the "forests" subtree in the running datastore.

- The default source (running) is used.
- The default depth="0" is used to retrieve all subtree levels.
- The "keys-only" leaf is set
- The "forests" subtree is selected. The xpath-filter is used instead of the subtree-filter.

- Whitespace added to xpath-filter element for display purposes only.

```
    <rpc message-id="113"
      xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
      <get2 xmlns="urn:ietf:params:xml:ns:yang:ietf-netconf-ex">
        <xpath-filter xmlns:ex=http://example.com/ns/example-ex">
          /ex:forests
        </xpath-filter>
        <keys-only />
```

```
      </get2>
    </rpc>

    <rpc-reply message-id="113"
      xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
      <data xmlns="urn:ietf:params:xml:ns:yang:ietf-netconf-ex">
        <forests xmlns="http://example.com/ns/example-ex">
          <forest>
            <name>north</name>
            <trees>
              <tree>
                <name>birch</name>
              </tree>
              <tree>
                <name>ash</name>
              </tree>
              <tree>
                <name>maple</name>
              </tree>
            </trees>
          </forest>
          <forest>
            <name>south</name>
            <trees>
              <tree>
                <name>banyan</name>
              </tree>
              <tree>
                <name>palm</name>
              </tree>
            </trees>
          </forest>
        </forests>
      </data>
    </rpc-reply>
```


B.4.4. Test for Node Existence with Depth=1

This example retrieves the "trees" node to determine which forests have any trees.

- Only 1 subtree level is requested, instead of the default of all levels.

- The default source (running) is used.

- The "trees" subtree is selected.

- The depth parameter is set to "1" to only retrieve the requested layer "trees" and its ancestor nodes and the configuration leaf nodes from each "forest" entry.

```
<rpc message-id="114"
  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <get2 xmlns="urn:ietf:params:xml:ns:yang:ietf-netconf-ex">
    <subtree-filter>
      <forests xmlns="http://example.com/ns/example-ex">
        <forest>
          <trees />
        </forest>
      </forests>
    </subtree-filter>
    <depth>1</depth>
  </get2>
</rpc>

<rpc-reply message-id="114"
  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <data xmlns="urn:ietf:params:xml:ns:yang:ietf-netconf-ex">
    <forests xmlns="http://example.com/ns/example-ex">
      <forest>
        <name>north</name>
        <trees />
      </forest>
      <forest>
        <name>south</name>
        <trees />
      </forest>
    </forests>
  </data>
</rpc-reply>
```

B.4.5. Retrieve Only Non-Configuration Data Nodes

This example retrieves only the name leafs from the "forest" list within the "forests" subtree, in the running datastore.

- The "source" leaf is set to the "operational" data source
- The "forests" subtree is selected

```
<rpc message-id="115"
  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <get2 xmlns="urn:ietf:params:xml:ns:yang:ietf-netconf-ex">
    <source><operational/></source>
    <subtree-filter>
      <forests xmlns="http://example.com/ns/example-ex" />
    </subtree-filter>
  </get2>
</rpc>

<rpc-reply message-id="115"
  xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
  <data xmlns="urn:ietf:params:xml:ns:yang:ietf-netconf-ex">
    <forests xmlns="http://example.com/ns/example-ex">
      <forest>
        <name>north</name>
        <trees>
          <tree>
            <name>birch</name>
            <height>41.013</height>
          </tree>
          <tree>
            <name>ash</name>
            <height>16.523</height>
          </tree>
          <tree>
            <name>maple</name>
            <height>51.204</height>
          </tree>
        </trees>
      </forest>
      <forest>
        <name>south</name>
        <trees>
          <tree>
            <name>banyan</name>
            <height>91.433</height>
          </tree>
          <tree>
            <name>palm</name>
```

```
              <height>83.439</height>
            </tree>
          </trees>
        </forest>
      </forests>
    </data>
  </rpc-reply>
```


Author's Address

Andy Bierman
YumaWorks, Inc.

Email: andy@yumaworks.com