

Yuma Quickstart Guide

YANG-Based Unified Modular Automation Tools

Client/Server Quickstart Guide

Version 2.1

Last Updated: September 25, 2011

Table Of Contents

Yuma Quickstart Guide

1	Preface.....	3
1.1	Legal Statements.....	3
1.2	Additional Resources.....	3
1.2.1	WEB Sites.....	3
1.2.2	Mailing Lists.....	4
1.3	Conventions Used in this Document.....	4
2	Introduction.....	5
2.1	Intended Audience.....	5
2.2	What is NETCONF and YANG?.....	5
2.3	How Does an Operator Use NETCONF and YANG?.....	6
2.4	How Does a Developer Use NETCONF and YANG?.....	6
3	Getting Started with toaster.yang.....	7
3.1	What is libtoaster?.....	7
3.2	Start the netconfd server.....	7
3.2.1	Configuration Defaults.....	8
3.2.2	SSH Server.....	8
3.2.3	NETCONF Server.....	9
3.3	Start the yangcli client.....	9
3.3.1	Configuration Defaults.....	9
3.3.2	Run yangcli.....	10
3.3.3	Startup Screen.....	10
3.3.4	Command Line Editing.....	10
3.3.5	Escape Commands.....	10
3.4	Getting Context Sensitive Help.....	11
3.4.1	Tab Key for Command Completion.....	11
3.4.2	The '?' and '??' Escape Sequences.....	11
3.4.3	The 'help' Command.....	12
3.5	Start a NETCONF session.....	13
3.5.1	The connect Command.....	13
3.5.2	Fixing Connection Problems.....	14
3.6	Enable Notification Delivery.....	14
3.7	Load the Toaster Module.....	14
3.8	Enable the Toaster.....	15
3.8.1	Lock the Databases.....	16
3.8.2	Create the toaster Container.....	16
3.8.3	Save the Database Changes.....	17
3.8.4	Unlock the Databases.....	17
3.9	Get the Toaster State Information.....	17
3.10	Start Making Toast.....	18
3.11	Stop Making Toast.....	19
3.12	Close the NETCONF Session.....	19
4	Advanced Topics.....	20
4.1	Data Retrieval.....	20
4.1.1	Basic NETCONF Retrieval Operations.....	20

Yuma Quickstart Guide

4.1.2 Default Value Filtering.....	21
4.1.3 Special Retrieval Operations.....	21
4.2 Notifications.....	22
4.2.1 Notification Contents.....	22
4.2.2 Notification Replay.....	24
4.2.3 The interleave capability.....	25
4.3 Database Editing.....	25
4.3.1 The Target Database.....	25
4.3.2 Database Locking.....	26
4.3.3 Non-Volatile Storage.....	26
4.3.4 Editing Commands.....	26
4.4 Access Control.....	27
4.5 Variables.....	28
4.6 Scripts.....	29
5 toaster.yang.....	30

1 Preface

1.1 Legal Statements

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1.2 Additional Resources

This document assumes you have successfully set up the software as described in the printed document:

Yuma Installation Guide

Other documentation includes:

Yuma User Manual

Yuma netconfd Manual

Yuma yangcli Manual

Yuma yangdiff Manual

Yuma yangdump Manual

Yuma Developer Manual

To obtain additional support you may join the yuma-users group on sourceforge.net and send email to this e-mail address:

yuma-users@lists.sourceforge.net

The SourceForge.net Support Page for Yuma can be found at this WEB page:

<http://sourceforge.net/projects/yuma/support>

There are several sources of free information and tools for use with YANG and/or NETCONF.

The following section lists the resources available at this time.

1.2.1 WEB SITES

- **Netconf Central**
 - <http://www.netconfcentral.org/>
 - Yuma Home Page
 - Free information on NETCONF and YANG, tutorials, on-line YANG module validation and documentation database
- **Yuma SourceForce OpenSource Project**
 - <http://sourceforge.net/projects/yuma/>

Yuma Quickstart Guide

- Download Yuma source and binaries; project forums and help
- **Yang Central**
 - <http://www.yang-central.org>
 - Free information and tutorials on YANG, free YANG tools for download
- **NETCONF Working Group Wiki Page**
 - <http://trac.tools.ietf.org/wg/netconf/trac/wiki>
 - Free information on NETCONF standardization activities and NETCONF implementations
- **NETCONF WG Status Page**
 - <http://tools.ietf.org/wg/netconf/>
 - IETF Internet draft status for NETCONF documents
- **libsmi Home Page**
 - <http://www.ibr.cs.tu-bs.de/projects/libsmi/>
 - Free tools such as smidump, to convert SMIv2 to YANG

1.2.2 MAILING LISTS

- **NETCONF Working Group**
 - <http://www.ietf.org/html.charters/netconf-charter.html>
 - Technical issues related to the NETCONF protocol are discussed on the NETCONF WG mailing list. Refer to the instructions on the WEB page for joining the mailing list.
- **NETMOD Working Group**
 - <http://www.ietf.org/html.charters/netmod-charter.html>
 - Technical issues related to the YANG language and YANG data types are discussed on the NETMOD WG mailing list. Refer to the instructions on the WEB page for joining the mailing list.

1.3 Conventions Used in this Document

The following formatting conventions are used throughout this document:

Documentation Conventions

Convention	Description
--foo	CLI parameter foo
<foo>	XML parameter foo
foo	yangcli command or parameter
\$FOO	Environment variable FOO
\$foo	yangcli global variable foo
some text	Example command or PDU
some text	Plain text

2 Introduction



Refer to section 3 of the Yuma User Manual for a complete introduction to Yuma Tools.

This section focuses on the client and server tools within the Yuma Tools programs.

2.1 Intended Audience

This document is intended for users of the Yuma Tools NETCONF client and server programs. It covers the basic usage of the **yangcli** client application and the **netconfd** server.

2.2 What is NETCONF and YANG?

The Yuma Tools suite provides automated support for development and usage of network management information. Information is exchanged in XML encoding within a session between a client and a server.

The IETF "Network Configuration Protocol" (NETCONF) is used to provide the management sessions, operations, and database framework available on the server. The operations, notifications, and the database contents supported by a particular NETCONF server are extensible, and defined with a modular and easy-to-learn language called YANG. The database is used to contain YANG data

structures which represent the configuration of the device containing the NETCONF server. This configuration can be saved in non-volatile storage so the configuration can be restored upon reboot.

The IETF "YANG Data Modeling Language" is used to define the syntax and semantics of the NETCONF operations, notification events, and database content. Machine and human readable semantics and constraints are used by YANG tools (including Yuma Tools) to automate behavior within the NETCONF protocol for clients and servers.

For people familiar with SNMP and SMIv2, NETCONF is like an XML-based, high-level version of SNMP, and a YANG module is like a MIB module, except MIB tables can be nested and much more complex than in SMIv2. Instead of Enterprise IDs and OBJECT-IDENTIFIERS, YANG uses XML namespaces and XPath path expressions to identify module ownership and contents within the protocol PDUs.

2.3 How Does an Operator Use NETCONF and YANG?

An operator uses a NETCONF session almost like it was a CLI session, except there are structured, schema-defined requests and responses, encoded in XML. YANG modules are like MIB modules for CLI content. Instead of ad-hoc unstructured documentation like CLI, NETCONF uses a data definition language to define management modules. The actual modules that a server supports will vary, just like MIB (SMIv2) modules.

The NETCONF protocol is available for many different transports. The most popular is the SSH2 protocol. The 'netconf' subsystem is used (on TCP port 830) to start a special SSH session with the NETCONF server.

Using NETCONF over SSH is just like using CLI over SSH to manage a networking device, except the messages are exchanged in XML, not plain-text. SSH user names and passwords are used for session authentication and authorization.

NETCONF is designed to provide a programmatic interface, so it is usually used with a management application, instead of a direct (raw) SSH terminal application. The **yangcli** program within Yuma Tools is a YANG-driven NETCONF client application that supports scripts, XPath, and many automated features to simplify management of NETCONF servers.

Once a session is started, similar to a CLI session, the operator issues commands (NETCONF operations) to the server, and the server performs each requested operation in order, and returns a status message and/or some data to the client. Notifications can also be received, if the session has requested them with the <create-subscription> operation.

When a NETCONF session starts, a <hello> message is sent by the server that has all the NETCONF capabilities and YANG modules supported by the server. Capabilities are optional protocol mechanisms, beyond those defined in the base protocol (RFC 4741). The client application knows what operations, notification events, and database contents are supported on the server, based on the information in the <hello> message.

NETCONF has a set of basic database (CRUD) operations for managing the configuration database. In addition, any YANG module can define new protocol operations and notification events.

2.4 How Does a Developer Use NETCONF and YANG?

A NETCONF server developer decides what modules need to be supported by the NETCONF server, and implements the device instrumentation code for those modules.

Much of the NETCONF protocol related code is handled by the NETCONF stack, based on the YANG module contents. Therefore, the most important task for a developer is designing a good YANG module.

After the YANG module is written, the **yangdump** program is used to generate the template C code for the server instrumentation library for the YANG module. The device instrumentation code for the YANG

module is then added by the developer. This 'callback code' is called from the NETCONF stack when database operation requests for the object(s) in the YANG module are received by the server.

Once this library is completed, the YANG module and its binary server instrumentation library (SIL) can be loaded into the NETCONF server at run-time. There is no need to recompile the **netconfd** server, or even reboot it.

Once the YANG module and its instrumentation code is completed, it needs be published, so operators and application developers can use the WEB documentation and other tools to access the information in the NETCONF server.

3 Getting Started with toaster.yang

This section will demonstrate the basic operation of Yuma Tools to use a NETCONF session to manage a remote device with a YANG data model. The Yuma Tools programs and libraries must already be installed. Refer to the Yuma Tools Installation Guide if this has not yet been done.

The **yangcli** client program and **netconfd** server program do not need to be installed on the same machine. Usually, they are not installed on the same machine. For simplicity, the server address 'localhost' is used in the examples below.

3.1 What is libtoaster?

There is a sample server instrumentation library (SIL) included, named libtoaster. This is the module-specific server instrumentation code for the management data defined in toaster.yang. This is based on the original TOASTER-MIB by Epilogue. This YANG module provides simple operations to make toast, and some simple NETCONF database objects to enable and monitor the toaster.

The new YANG version of the TOASTER-MIB is different in some ways:

- extensible YANG identities are used to identify the bread type, instead of a hard-wired enumerated list.
- protocol operations (<make-toast> and <cancel-toast>) are instead of an 'up/down' switch within the database. NETCONF databases are intended to contain persistent data structures, and 'actions' such as starting or stopping the toaster are done with new protocol operations, instead of editing the database with the standard operations.
- A simple configuration 'presence container' object is used to enable and disable the toaster service, instead of hard-wiring the toaster service availability.
- A notification is generated when the toast is done or canceled. This notification can be used instead of polling the toaster status object.

The complete text of **toaster.yang** and TOASTER-MIB can be found at the end of this document.

3.2 Start the netconfd server

If the **netconfd** server is already running, then skip this section.

Details for all the **netconfd** configuration parameters can be found in the Yang Tools User Manual.

There is also a sample configuration file (default location):

- **/etc/yuma/sample-netconfd.conf**

Yuma Quickstart Guide

This file contains all the default settings for the configuration parameters.

To change the default settings, copy and edit this file (example commands)

```
mydir> sudo cp /etc/yuma/sample-netconfd.conf  
/etc/yuma/netconfd.conf  
mydir> sudo emacs /etc/yuma/netconfd.conf
```

3.2.1 CONFIGURATION DEFAULTS

To keep the example simple, the default settings will be used:

- the server will accept sessions on TCP port 830
- the target database is <candidate>
- no <startup> database (mirrored NV-save)
- the <validate> operation is supported
- the access control mode is 'enforcing'
- the super user account name is 'superuser'
- the server will search startup-cfg.xml using the default search path
- the default <with-defaults> behavior is 'explicit'
- notification replay is enabled with a buffer size of 1000 events and a maximum message burst per session of 10 notifications
- the <hello> exchange timeout is 10 minutes
- the session idle timeout is 1 hour
- the default session indent amount is 2 spaces
- the default session line-size is 72 characters
- violation of strict YANG XML ordering will not cause errors
- logging level 'info' is enabled and sent to STDOUT

3.2.2 SSH SERVER

To start the NETCONF server, make sure that the **sshd** server is running, and the following configuration is included in **/etc/ssh/sshd_config**.

```
Port 22  
Port 830  
Subsystem netconf /usr/sbin/netconf-subsystem
```

The 'Subsystem' command may be different if **netconf-subsystem** has been installed in a different location than **/usr/local/sbin**. The 'Port 22' command is needed to make sure the SSH server will accept SSH sessions in addition to NETCONF sessions.

3.2.3 NETCONF SERVER

For this example, the superuser account needs to be enabled. This is done with a CLI parameter, and the user name 'joe' is used. Replace 'joe' with your username.

To start the **netconfd** server in the foreground:

```
mydir> /usr/sbin/netconfd --superuser=joe
Starting netconfd...
Copyright (c) 2009, Netconf Central, Inc., All Rights Reserved.

agt: Startup config loaded OK
     Source: /home/joe/data/startup-cfg.xml
```

This example shows that the '\$HOME/data' directory in the data search path contained the startup configuration file. If no startup configuration is available, then the server defaults will be used instead. Any message about 'startup-cfg.xml' not found can be ignored. It just means the server booted with the factory default configuration.

To start the **netconfd** server in the background:

```
mydir> /usr/sbin/netconfd --superuser=joe --log=~ /mylog &
mydir>
```

This example shows that a logfile in the user's home directory called 'mylog' will be used for all server log messages. The '&' at the end causes the command to be run in the background.

3.3 Start the yangcli client

Once the NETCONF server is running, it will accept client sessions. If running **netconfd** interactively on localhost, then start a new terminal window to continue.

3.3.1 CONFIGURATION DEFAULTS

To keep the example simple, the default settings will be used:

- the client will attempt to start sessions on TCP port 830
- the client will attempt to automatically complete partial commands
- the command line history will be automatically loaded upon startup, and saved upon exit
- the client will attempt to automatically load any YANG modules advertised in the server <hello> message
- the client will check before using invalid parameter values
- the plain display mode will be used, with 72 characters per line
- each nest level of displayed data will be indented 2 spaces

Yuma Quickstart Guide

- the XML order of messages sent to the server will be corrected, as needed
- the logging level of 'info' is set, and log messages are sent to STDOUT
- the client will wait 30 seconds for responses

3.3.2 RUN YANGCLI

The yangcli program should be in found in the PATH environment variable.

```
mydir> yangcli
```

If the yangcli program is not found, then try the full path:

```
mydir> /usr/bin/yangcli
```

3.3.3 STARTUP SCREEN

The startup screen shows the following information:

- program version and copyright
- tab key can be used for command and parameter completion
- basic help instructions
- basic statement instructions

3.3.4 COMMAND LINE EDITING

The command lines are stored in a history buffer.

Any previous command line (except a password parameter line) can be recalled and used again.

Any command in the command buffer (current or recalled) can be edited. The default key settings are aligned with the emacs editor. Refer to the Yuma Tools User Manual for more details.

3.3.5 ESCAPE COMMANDS

Not all parameters need to be entered at one time. If yangcli needs more information, based on the initial command line, then 1 or more missing parameters will be requested, in sequence.

It is possible to get help, skip a parameter, or even cancel the entire command during one of these sub-command modes, by using an escape command. This is a 1 or 2 character command, followed by the 'enter' key (as usual to end a command).

Escape Command Summary

command	description
?s	skip the current parameter

Yuma Quickstart Guide

command	description
?c	cancel the current command
?	get help
??	get full help

Using the '?s' command to skip a parameter may cause the <rpc> request to be invalid.

Depending on the setting of the **--bad-data** configuration parameter, this may or may not be allowed. The default setting is to warn and confirm. This configuration parameter also affects parameter values that are invalid according to the YANG module definition.

3.4 Getting Context Sensitive Help

The **yangcli** program provides context-sensitive help based on the current NETCONF session status and the set of YANG modules currently loaded.

When a NETCONF session is active, the set of modules advertised in the <hello> message by the server will be used to generate help text, if available. The '**mgrload**' command can be used to force **yangcli** to use different or additional YANG modules.

If the **yangcli** program does not have the advertised revision of a particular module available in the module search path, and the NETCONF server supports the standard <get-schema> operation, then the module will be retrieved from the server, and used just for that session.

If any features or deviations are advertised for a YANG module, then they will be applied to the modules used just for the current session. The help text and the error checking done for the module will be based on this 'patched' module, not the 'plain' module specified in the capability URI string.

3.4.1 TAB KEY FOR COMMAND COMPLETION

The 'tab' key can be used at any time to see a list of the possible completions that the command interpreter will accept. The list will be displayed for command names and some command parameters.

When a NETCONF session is active, all the NETCONF operations will be available. Additional commands may also be available if the server advertised any YANG modules containing 'rpc' statements.

3.4.2 THE '?' AND '??' ESCAPE SEQUENCES

If a partial command is entered, or if a data structure is being filled, then the help escape sequences are available to get help about that parameter or data node. Use one question mark for help, and two question marks for maximum help.

Help Escape Sequences

sequence	description
?	Print some help text, but not description statements and some other information.
??	Print maximum help text.

Yuma Quickstart Guide

The following example shows the help text for the 'user' parameter for the 'connect' operation:

```
yangcli> connect

Enter string value for leaf <user>
yangcli:connect> ?

    leaf user [NcxUserName]
      length: 1..63
      pattern: [a-z,A-Z][a-z,A-Z,0-9,\-,\_,\.]{0,62}

Enter string value for leaf <user>
yangcli:connect>
```

The type of object, its name, data type, and any restrictions, will be printed.
After that, the previous prompt will be redisplayed.

3.4.3 THE 'HELP' COMMAND

The **help** command can be used to display all kinds of information about the **yangcli** program and the YANG data module contents in use at the time.

Help Command Variants

command	description
help <comand-name> help command <command-name>	Display help for the specified yangcli command or YANG rpc statement.
help commands	Display help text for all commands.
help object <object-name>	Display help text for a YANG database top-level object (only if its module is available).
help notification <notification-name>	Display help text for a YANG notification event (only if its module is available).
help type <type-name>	Display help text for an exported YANG data type (only if its module is available).

Each of the help command variants also accepts a 'help-mode' parameter to control how much help text is displayed:

Help Output Modes

mode	description
--brief	Display minimal help text.
--normal	Display a lot, but not always all the help text available (default mode).
--full	Display all available help text, including description statements.

Yuma Quickstart Guide

The following table shows some valid help commands:

command	description
help help	Get normal help for the help command.
help commands brief	Get a 1 line description of each command.
help object system full	Get all available help for the /system container and all its descendant nodes.
help type NcxIdentifier	Get summary and description of the data type called 'NcxIdentifier'.
help notification sysSessionStart	Get a summary of the 'sysSessionStart' notification, and each of objects in its payload.

3.5 Start a NETCONF session

Each yangcli program instance can run 1 NETCONF session at a time.

If no session is currently active, then the prompt will contain just the program name, indicating that the 'connect' command is available:

```
yangcli>
```

3.5.1 THE CONNECT COMMAND

The 'connect' command is used to start a NETCONF session.

There are 3 mandatory parameters for this command:

- **user:** the system (or SSH) user name to use
- **server:** the IP address or DNS name of the NETCONF server to use
- **password:** the password string to use

Make sure you have a user name and password already configured on the NETCONF server.

If a partial command is given, then yangcli will prompt for any missing mandatory parameters. In this example, the complete command is given at once:

```
yangcli> connect server=localhost user=guest password=yangrocks
```

After this command is entered, **yangcli** will generate some informational log messages to the screen.

If the session is started successfully, a summary of the server session capabilities and available modules should be displayed. Also, the command prompt will change to indicate that a NETCONF session is currently active.

```
yangcli guest@localhost>
```

At this point any command supported by the server can be entered, in addition to any **yangcli** command (except 'connect').

3.5.2 FIXING CONNECTION PROBLEMS

If the session did not start correctly, check the error messages to fix the problem. Some common problems:

- Make sure the **netconfd** program is running.
- Make sure the **netconf-subsystem** program is properly installed.
- Check if the SSH configuration contains the portion for NETCONF.
- If the SSH configuration looks correct, then try restarting the SSH server to make sure that configuration file is the one being used.
- If the SSH server seems to be running correctly, then check if any firewall or other security mechanism is blocking TCP port 830. If so, either enable TCP port 830, or enable port 22 on the NETCONF server (by restarting the server), and include 'port=22' in the 'connect' command parameters.
- If no firewall or other security measure is blocking TCP port 830, try to establish a normal SSH session with the server.
- If a normal SSH session works correctly, then check the log messages on the NETCONF server for more information.

3.6 Enable Notification Delivery

In order to receive the 'toastDone' notification event, a notification subscription has to be enabled. A default NETCONF notification stream can be started with the 'create-subscription' command:

```
yangcli guest@localhost> create-subscription  
RPC OK Reply 2 for session 1:  
yangcli guest@localhost>
```

Depending on other activity within the NETCONF server, it is possible other notification events, such as 'sysSessionStart' or 'sysSessionEnd' will be generated. Notifications are displayed in their entirety, but not during 'rpc reply output'. If a command is being entered, the notification will be displayed, and then the command line restored.

3.7 Load the Toaster Module

The toaster module is not a core system module, and is not available automatically. The module has to be explicitly loaded by the NETCONF client.

Yuma Quickstart Guide

To load the server-supported version of the toaster module, use the 'load' command:

```
yangcli guest@localhost> load toaster

RPC Data Reply 2 for session 1:

rpc-reply {
  mod-revision 2009-11-20
}

Incoming notification:
notification {
  eventTime 2009-12-28T00:44:45Z
  sysCapabilityChange {
    changed-by {
      userName guest
      sessionId 1
      remoteHost 127.0.0.1
    }
    added-capability
    http://netconfcentral.com/ns/toaster?
module=toaster&revision=2009-11-20
  }
  sequence-id 3
}

yangcli guest@localhost>
```

If the module was successfully loaded, then a data response will be sent, containing the revision date of the toaster module that was loaded. This response will be returned even if the module was already loaded.

Note that the 'sysCapabilityChange' notification event will only be sent if the module has not already been loaded into the server. In this case, it was not advertised in the <hello> message for this session, and the toaster module needs to be loaded manually into yangcli with the 'mgrload' command:

```
yangcli guest@localhost> mgrload toaster

Load module 'toaster' OK

yangcli guest@localhost>
```

3.8 Enable the Toaster

Try to make some toast, using the 'make-toast' command:

```
yangcli guest@localhost> make-toast

RPC Error Reply 4 for session 1:

rpc-reply {
  rpc-error {
```


Yuma Quickstart Guide

```
error-type protocol
error-tag resource-denied
error-severity error
error-app-tag no-access
error-message 'resource denied'
error-info {
    error-number 269
}
}
yangcli guest@localhost>
```

What happened?

A 'resource-denied' error was returned instead of 'OK', because the toaster service is not enabled yet. A node has to be created in the NETCONF database before the 'make-toast' command can be used.

3.8.1 LOCK THE DATABASES

The first step is to lock the NETCONF databases for writing. Locks do not affect read operations.

The yangcli program has a high-level command to deal with locking, called 'get-locks'. It will handle retries for any missing locks, until an overall timeout occurs or all the locks needed are acquired.

```
yangcli guest@localhost> get-locks

Sending <lock> operations for get-locks...

get-locks finished OK
yangcli guest@localhost>
```

3.8.2 CREATE THE TOASTER CONTAINER

The toaster module uses a simple YANG 'presence' container to configure the toaster service.

Once the /toaster container is created, the read-only nodes within that container will be maintained by the server, and the toaster service will be enabled.

The first step is to create the /toaster node in the <candidate> configuration database:

```
yangcli guest@localhost> create /toaster

Filling container /toaster:
RPC OK Reply 5 for session 1:

yangcli guest@localhost>
```

Now the /toaster node is created in the <candidate> database.

3.8.3 SAVE THE DATABASE CHANGES

In order to activate these changes, the 'save' command needs to be issued.

This is a high-level **yangcli** operation that issues the 'commit' or 'copy-config' operation, depending on the database target for the current session.

```
yangcli guest@localhost> save

Saving configuration to non-volatile storage
RPC OK Reply 6 for session 1:

Incoming notification:
  notification {
    eventTime 2009-12-28T00:59:58Z
    sysConfigChange {
      userName guest
      sessionId 1
      remoteHost 127.0.0.1
      edit {
        target /toast:toaster
        operation create
      }
    }
    sequence-id 4
  }
```

The 'RPC OK' message indicate that the server successfully saved the configuration.

The 'sysConfigChange' notification indicates what was changed in the running configuration, and who made the change(s).

The toaster server should now be enabled.

3.8.4 UNLOCK THE DATABASES

The database locks need to be released as soon as possible after the edits are completed or discarded.

The high-level command 'release-locks' must be used if 'get-locks' was used to acquire the database locks.

```
yangcli guest@localhost> release-locks

Sending <unlock> operations for release-locks...

yangcli guest@localhost>
```

3.9 Get the Toaster State Information

To discover the toaster model and its current status, the 'sget' or 'xget' commands can be used to retrieve just the toaster portion of the conceptual state data available on the server.

The 'sget' command is high-level subtree filter handler for the <get> operation:

Yuma Quickstart Guide

```
yangcli guest@localhost> sget /toaster
```

The 'xget' command is high-level XPath filter handler for the <get> operation. It is only available if the NETCONF server supports the **:xpath** capability (like **netconfd**).

```
yangcli guest@localhost> xget /toaster
```

Both commands should return the same data:

```
Filling container /toaster:
RPC Data Reply 7 for session 1:

rpc-reply {
  data {
    toaster {
      toasterManufacturer 'Acme, Inc.'
      toasterModelNumber 'Super Toastamatic 2000'
      toasterStatus up
    }
  }
}
```

This data shows that the 'Super Toastamatic 2000' is ready to make toast!

3.10 Start Making Toast

Now that the toaster is enabled, the 'make-toast' command should work.

Instead of using the default parameter values, let's make a frozen waffle a little less done than normal:

```
yangcli guest@localhost> make-toast toasterDoneness=4
toasterToastType=toast:frozen-waffle

RPC OK Reply 8 for session 1:
```

At this point the toaster timer is running, and the simulated waffle is cooking,
After about 40 seconds, the 'toastDone' notification should be received:

```
Incoming notification:
notification {
```

Yuma Quickstart Guide

```
eventTime 2009-12-29T01:20:05Z
toastDone {
  toastStatus done
}
sequence-id 5
}
```

This 'toastDone' event shows that the toast was completed, and is ready to eat.

3.11 Stop Making Toast

What if you change your mind, and want wheat toast instead of a waffle?

Repeat the previous command (Control-P should recall the previous command):

```
yangcli guest@localhost> make-toast toasterDoneness=4  
toasterToastType=toast:frozen-waffle  
  
RPC OK Reply 9 for session 1:
```

Now enter the 'cancel-toast' command right away, before the waffle finishes:

```
yangcli guest@localhost> cancel-toast  
  
RPC OK Reply 10 for session 1:  
  
Incoming notification:  
  notification {  
    eventTime 2009-12-29T01:24:36Z  
    toastDone {  
      toastStatus cancelled  
    }  
    sequence-id 6  
  }
```

This 'toastDone' event shows that the toast was cancelled.

3.12 Close the NETCONF Session

To close the NETCONF session, use the 'close-session' command:

```
yangcli guest@localhost> close-session  
  
RPC OK Reply 11 for session 1:  
  
ses: session 1 shut by remote peer
```

Yuma Quickstart Guide

```
yangcli>
```

Note that the prompt returned to the default form, once the session was dropped by the NETCONF server.

To terminate the yangcli program, use the 'quit' command:

```
yangcli> quit
```

```
mydir>
```

4 Advanced Topics

This section introduces some advanced features of the NETCONF protocol and YANG data modeling language.

4.1 Data Retrieval

4.1.1 BASIC NETCONF RETRIEVAL OPERATIONS

The NETCONF protocol has 2 different retrieval operations:

- **<get>**: get state data and the running configuration database.
- **<get-config>**: get just the specified configuration database.

Each of these operations accepts a <filter> parameter, which has 2 forms:

- **subtree filter**: retrieve just the subtrees in the database that match the XML subtrees in the filter.
- **XPath filter**: retrieve just the subtrees that match the result node set produced by evaluating the specified XPath expression against the database. This mode cannot be used unless the **:xpath** capability must be advertised by the server.

The **yangcli** program supports 3 different forms of each command:

- **plain**: plain NETCONF operation with user-supplied filter
- **subtree**: XPath path expression or user variable is converted to XML for the <filter> parameter subtree XML.
- **xpath**: XPath path expression or user variable is converted to XML for the <filter> parameter 'select' XML attribute

yangcli Retrieval Commands

command	description	example
get	plain <get> operation	get with-defaults=trim

Yuma Quickstart Guide

command	description	example
get-config	plain <get-config> operation	get-config source=candidate
sget	<get> with a subtree filter	sget /system
sget-config	<get-config> with a subtree filter	sget-config source=running /nacm/rules
xget	<get> with an XPath filter	xget "//interface/counters"
xget-config	<get-config> with an XPath filter	xget-config source=candidate "//interface[name='eth0']"

The retrieval commands return an element named <data> containing the requested XML subtrees.

If any identifier nodes (YANG key leafs) are needed to distinguish the data in the reply, they will be added as needed by the server. In the 'xget' example above, the <name> element for each interface would be returned, even though it was not directly requested by the XPath expression.

4.1.2 DEFAULT VALUE FILTERING

The data will also be filtered according to the defaults handling behavior of the server, unless the <with-defaults> parameter is added to the command. This parameter is only supported if the server advertised the 'with-defaults' capability. If not, the client does not get any indication from the server what type of defaults filtering is being done (if any).

There are 3 types of defaults filtering provided:

- **report-all**: no filtering -- return all nodes even those the server might normally suppress because they are considered to be default values by the server.
- **trim**: return all nodes except skip any leaf nodes that match the schema defined default value
- **explicit**: return all nodes that were set by the client or the server to some value, even if the value happens to be the schema defined default. This is normally the default behavior for the **netconfd** server.

The defaults handling behavior can be changed just for a specific NETCONF session, using the <set-my-session> operation. This is only available on the **netconfd** server.

```
yangcli guest@localhost> set-my-session with-defaults=report-all
RPC OK Reply 12 for session 1:
yangcli guest@localhost>
```

In this example, the 'basic' behavior is changed from 'explicit' to 'report-all', but just for session 1. This setting is temporary, and will not be remembered when the session is terminated. If the <with-defaults> parameter is present, it will be used instead of this value.

4.1.3 SPECIAL RETRIEVAL OPERATIONS

Yuma Quickstart Guide

Any YANG module can add new operations with the 'rpc' statement.

New retrieval operations may also be added which are associated with a protocol capability.

Just like any other data model content, the operator (or application) needs to understand the YANG file definitions, including the description statements, to understand how each custom retrieval operation works.

There are 2 custom retrieval operations supported by **netconfd**:

Special Retrieval Operations

operation	description
get-schema	Retrieve the YANG or YIN source file for one of the modules advertised by the server. This is a standard operation defined in the ietf-netconf-monitoring module.
get-my-session	Retrieve the customizable settings for my session. This is a proprietary operation defined in the yuma-my-session module.

4.2 Notifications

Notifications are used in NETCONF to send server event information to the client application.

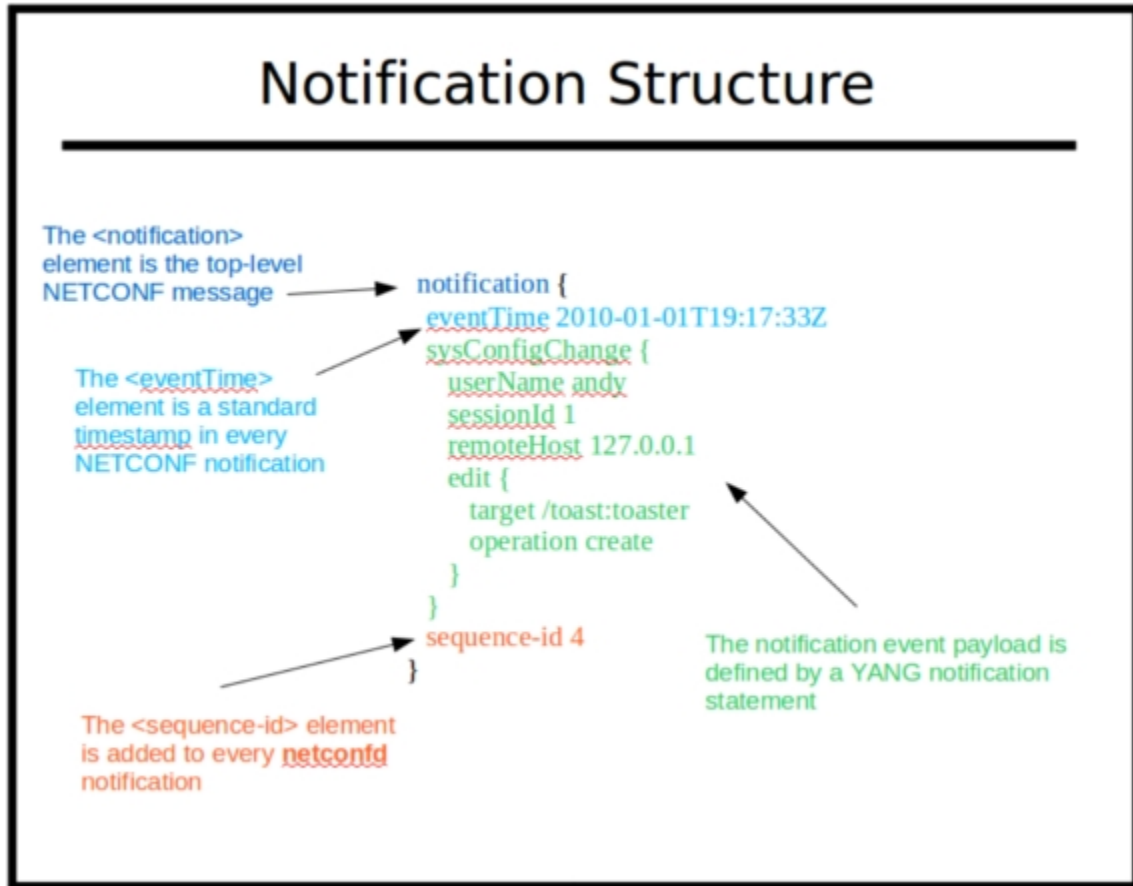
A session must request notifications with the 'create-subscription' command.

Notifications are grouped into 'streams', but only the 'NETCONF' stream is defined at this time.

A notification subscription request specifies the stream name (and perhaps more parameters).

A NETCONF session on the netconfd server will never expire due to inactivity, while a notification subscription is active. This allows notification processing applications to maintain long-lived connections without worrying about a NETCONF timeout. Note that the SSH server may also be configured to drop idle SSH sessions, whether a notification subscription is active or not.

4.2.1 NOTIFICATION CONTENTS

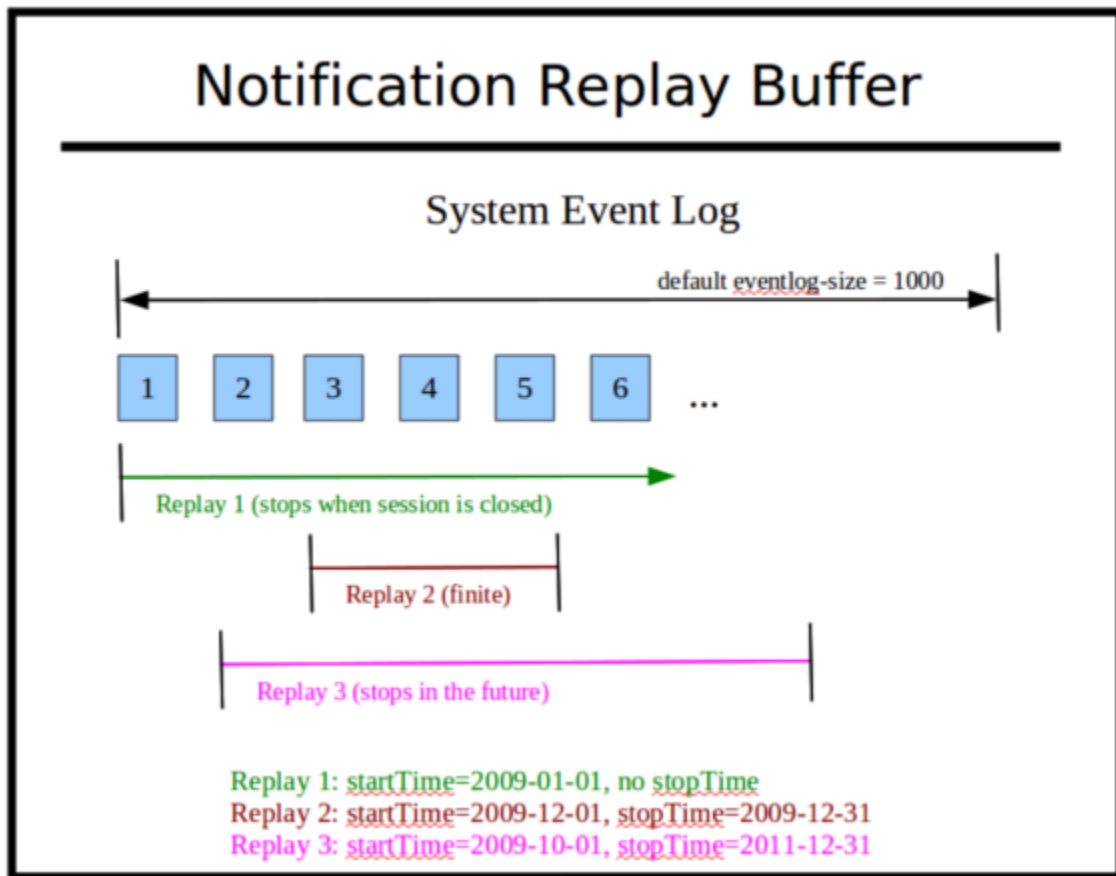


The 'notification' element is sent from the server to the client, if an event occurs, and the client has created a notification subscription.

The child nodes of this element comprise the notification content, and it is divided into 3 sections:

1. **event generation time-stamp**: This standard NETCONF leaf is always the first child element within the notification element.
2. **event payload**: The module-specific event payload is represented as a container with the name of the notification. Any data nodes defined within the YANG notification statement appear (in order) as child nodes of the event type container.
3. **proprietary extensions**: Zero or more vendor-specific elements may appear after the event payload element. For example, the monotonically increasing 'sequence-id' element is added to each notification saved in the **netconfd** event log.

4.2.2 NOTIFICATION REPLAY



The NETCONF server will maintain an ordered buffer of saved notification events, if the `:notification-replay` capability is supported by the server. For the **netconfd** server, this is a configurable feature, set by the **--eventlog-size** parameter.

The **netconfd** default is to save the most recent 1000 notification events.

Only system events are saved and are available for retrieval. The 'replayComplete' and 'subscriptionComplete' events are session-specific events, and are therefore not saved in the replay buffer.

The 'create-subscription' command has 2 parameters to request that stored notifications be delivered to the client session:

- **startTime**: the date (or date-and-time) to compare against the event generation time-stamp. Only notification events that occurred after this time are delivered.
- **stopTime**: the date (or date-and-time) to compare against the event generation time-stamp. Only notification events that occurred before this time are delivered. This parameter can specify a time in the future. When that time has passed, the subscription will be terminated. The stopTime does not cause the server to wait that period of time to generate an event. If the stopTime is in the past, then the subscription will terminate after all the matching event timestamps in the replay buffer have been delivered.

Notifications are delivered in the order they are stored. Each new **netconfd** notification contains a monotonically increasing sequence-id (unsigned integer). This can be used to help determine if any configured notification filters are working as expected.

4.2.3 THE INTERLEAVE CAPABILITY

The **netconfd** server supports the :interleave capability, which means that all commands (except create-subscription) will be accepted by the server. The client should expect <rpc-reply> and <notification> messages. The server will always maintain proper message serialization. These messages will always be sent in their entirety, which may impact applications (e.g., a really long <get> response on the same session will delay notification delivery).

If the NETCONF server does not support the :interleave capability, then it may only allow the <close-session> operation while the notification subscription is active. In this case, a new NETCONF session is required to perform any management operations.

This special mode is only applicable while a notification subscription is active. It is possible for a replay subscription to terminate, without terminating the session as well. In this case, the 'notificationComplete' event will be generated, and the session will return to accepting all possible operations.

4.3 Database Editing

NETCONF supports multiple conceptual configuration databases. Only the 'running' database is actually active. All other databases are scratch-pad databases, or some other special-purpose off-line database.

Every NETCONF server must allow arbitrary partial (and concurrent) editing to its configuration with the <edit-config> operation. Refer to the Yuma Tools User Manual for complete details on this NETCONF operation. The **yangcli** program has simplified editing commands, which are explained below.

The <config> element within an <edit-config> PDU represents the 'root node' (/) in the path expression for each node in the conceptual database. Each top-level YANG object that is supported and configured will be represented as child nodes this root node. The conceptual database can be processed as an XML instance document with multiple top nodes (similar to XSLT rules).

Database editing in NETCONF has several variants, but basically, it follows this simple procedure:

1. Lock the database(s) that will be affected.
2. Use <edit-config> or <copy-config> on the target database to make changes.
3. Activate and save the database edits.
4. Unlock the database(s) that were previously locked.

4.3.1 THE TARGET DATABASE

Usually a NETCONF server supports the <edit-config> operation on only one database, which is either the candidate or the running database. This is called the 'target' database, which corresponds to the <target> parameter in the <edit-config> operation.

If the target database is the candidate configuration, then the <edit-config> operation does not always cause all possible database validation checking to be done by the server. Since the candidate database is just a scratch-pad for (possibly) incremental edits, the server is not required to completely validate its contents. Instead, these 'final validation' tests are only required to be done when the <commit> operation is invoked.

Yuma Quickstart Guide

The **yangcli** program will automatically handle the target database management, based on the server capabilities reported each session, if the 'save' command is used. The manual procedure (<commit> and/or maybe <copy-config> operations) is also supported, but do not mix them within the same editing session.

4.3.2 DATABASE LOCKING

NETCONF supports database locking so a session can have exclusive write access to the configuration. These locks are intended to be short-lived, but there is no actual time limit on a lock. If the session terminates for any reason with any locks, they will be released automatically by the server.

All the databases that are involved in the edit should be locked. This always includes the running database, and the candidate and startup databases, if they are supported by the server.

The yangcli program has 2 special commands to handle all locking:

- **get-locks:** Wait until all database locks have been acquired or the timeout occurs
- **release-locks:** Release any locks that were obtained with get-locks

Refer to the Yuma Tools User Manual for more details on these commands.

4.3.3 NON-VOLATILE STORAGE

The startup configuration is the conceptual database used on the next reboot of the NETCONF server. It is important to know whether the NETCONF server supports the :startup capability or not. If yes, then the operator must explicitly save the running database to non-volatile storage (the startup database), using the <copy-config> operation. If no, then the server will keep the running and startup databases synchronized.

The **yangcli** program has a high-level 'save' command, used after the editing operations, that will automatically issue the correct protocol operations to complete the edit, and save the changes in non-volatile storage.

The startup database is configurable in the **netconfd** server. The **--with-startup** configuration parameter controls whether the startup database will be used or not. The --startup parameter can be used to control the initial load of the running configuration in 3 different ways:

1. **no startup:** skip this step and just use factory defaults
2. **default startup:** look for the default **startup-cfg.xml** file in the configured data path.
3. **specific startup:** use a specified file, either absolute file-spec, or a relative path in the configured data path

Refer to the Yuma Tools User Manual for more details on controlling non-volatile storage.

4.3.4 EDITING COMMANDS

The <edit-config> operation should be used make configuration changes. The <copy-config> operation can also be used, but this is a blunt hammer approach. Although the **netconfd** server will always analyze the edit request and only affect the nodes that actually changed, this is not a requirement in the standard.

The <edit-config> operation allows the operator to have precise control of the server. These database edits are performed by the server using a combination of 3 factors:

1. The nodes that currently exist in the target database.
2. The nodes that exist in the 'source' of the edits (either the inline <config> element or indirectly through the <url> element.

Yuma Quickstart Guide

3. The `<default-operation>` parameter and any XML attributes in the source XML elements (nc:operation attribute and YANG insert operation attributes).

The **yangcli** program provides some high-level commands to automatically handle the complexity of the `<edit-config>` operation. These commands use XPath expressions and a series of interactive prompts (e.g., for the mandatory nodes and key leafs) to fill in the specified data structures, and construct an optimized NETCONF message.

yangcli Editing Commands

command	description
create	Create a new sub-tree, only if it does not already exist
delete	Delete an existing sub-tree, only if it exists
merge	Merge the source sub-tree into the target sub-tree, keeping any existing nodes that are not explicitly contained in the source.
replace	Merge the source sub-tree into the target sub-tree, deleting any existing nodes that are not explicitly contained in the source. This is the mode used for the <code><copy-config></code> operation.
insert	Insert or move a YANG list or leaf-list entry

Refer to the Yuma Tools User Manual for details on these commands.

4.4 Access Control

The **netconfd** server can be configured to give precise access rights to each user (the SSH user name associated with the NETCONF session). Some important points to remember about access control:

- There are 3 types of access -- read, write, and execute.
- If a user does not have read access to some data, then it is silently omitted from the reply.
- The 'access-denied' error is not generated for read requests. It is only generated for write requests to the database, or `<rpc>` operation execution requests.
- An access request results in 1 of 2 outcomes: permit or deny
- The server resolves the access request by searching the access control rules. Either an explicit rule will apply, or the default access rights will be checked if no rule is found.
- The default access rights are configurable, but usually set as follows:
 - read access is permitted
 - write access is denied
 - exec access is permitted
- The **nacm:secure** and **nacm:very-secure** extensions can be used by the YANG module author to override the default access rights, and deny access instead. For example, the `<reboot>` operation is not permitted by default.
- There is a configurable 'superuser' user name. If desired, a specific user name will be considered the 'super user' and all access control will be bypassed for this user. By default, this is the name 'superuser', not 'root', since root login to the SSH server is not recommended.

4.5 Variables

The **yangcli** program supports variables for easier reuse and script-based operations.

There are 2 types of variables:

- **file variables:** the variable name is a file name, and the contents of the variable are stored in this file.
- **internal variables:** the variable name is just an internal identifier, and the contents of the variable are stored in memory

Variables are set with assignment statements. Here are some examples:

```
yangcli guest@localhost> $$backup = get-config source=running
yangcli guest@localhost> $$bad-data = "warn"
yangcli guest@localhost> $itf = "//interface[name='eth0']"
```

Note that in order to assign a string value (e.g., `$$bad-data = "warn"` above), single or double quotes must be used. An unquoted string will be interpreted as a command name, not a simple string value.

Variables are referenced in a similar manner, except the variable is on the right-hand side of the equation. These commands are equivalent in this example:

```
yangcli guest@localhost> @myfile.xml = xget select=$itf
yangcli guest@localhost> @myfile.xml = xget //interface[name='eth0']
```

Complex variable substitution is also supported:

```
yangcli guest@localhost> copy-config source=$$backup
target=candidate
```

Note that **yangcli** will attempt to figure out the structure of the parameter (e.g., 'source' and 'target' above), and adjust the NETCONF operation content. In the example above, since 'source' and 'target' are choices, the real nodes within the cases are examined, and the most appropriate case is selected. The 'source' parameter will contain an in-line `<config>` element with all the child nodes in the **\$\$backup** variable, and the target parameter will contain an empty element named **<candidate>**.

There are several types of internal variables available in the **yangcli** program:

- read-only system variables (\$\$USER)
- read-write system variables (\$\$default-operation)
- global user variables, available at all 'runstack' levels (\$\$backup)

Yuma Quickstart Guide

- local user variables available in the current 'runstack' level only (\$itf)

The command 'show vars' can be used to see the current value of all program variables:

```
yangcli andy@localhost> show vars

No CLI variables

Read-only system variables

    HOME /home/guest
    HOSTNAME
    LANG en_US.UTF-8
    PWD /home/guest
    SHELL /bin/bash
    USER guest
    YUMA_DATAPATH
    YUMA_HOME /home/guest/swdev/yuma/trunk/netconf
    YUMA_MODPATH
    YUMA_RUNPATH

Read-write system variables

    autocomp true
    autoload true
    bad-data check
    default-module
    default-operation none
    display-mode plain
    error-option none
    fixorder true
    log-level info
    optional false
    server
    test-option none
    timeout 30
    user guest
    with-defaults none

No global variables

No local variables

yangcli guest@localhost>
```

4.6 Scripts

Scripts are simply a collection of **yangcli** commands and/or assignment statements that are stored in a text file, instead of typed directly. Scripts can call other scripts (except loops are not allowed), and numbered parameters are available (e.g., --P1='fred' passed as parameter, the \$1 expands to 'fred' inside the script).

The **\$YUMA_RUNPATH** environment variable, or the **--runpath** configuration variable, can be used to set the directory path to look for script files. There is also a default path for finding files, explained in the Yuma Tools User Manual.

Yuma Quickstart Guide

The command '**list scripts**' can be used to show the potential script file available in the run path.

The command '**run foo**' is used to invoke a script named 'foo' (with no file extension).

If a command fails during a script, execution is halted right away and no more commands in the script are executed. If 'get-locks' was used, then any locks obtained will be automatically released. All script runstack levels will be canceled, not just the current script.

Script syntax will be expanded in a future release to provide loops and conditional statements.

5 toaster.yang

The toaster.yang module is included here for reference.

```
module toaster {  
    namespace "http://netconfcentral.com/ns/toaster";  
    prefix "toast";  
    organization  
        "Netconf Central, Inc.";  
    contact  
        "Andy Bierman <andy@netconfcentral.org>";  
    description  
        "YANG version of the TOASTER-MIB.";  
  
    revision 2009-11-20 {  
        description "Toaster module in progress.";  
    }  
  
    identity toast-type {  
        description  
            "Base for all bread types supported by the toaster.  
            New bread types not listed here may be added in the  
            future.";  
    }  
  
    identity white-bread {  
        description  
            "White bread.";  
        base toast:toast-type;  
    }  
  
    identity wheat-bread {  
        description  
            "Wheat bread.";  
        base toast-type;  
    }  
  
    identity wonder-bread {  
        description  
            "Wonder bread.";  
        base toast-type;  
    }  
}
```

Yuma Quickstart Guide

```
identity frozen-waffle {
    description
        "Frozen waffle.";
    base toast-type;
}

identity frozen-bagel {
    description
        "Frozen bagel.";
    base toast-type;
}

identity hash-brown {
    description
        "Hash browned potatoes.";
    base toast-type;
}

typedef DisplayString {
    description
        "YANG version of the SMIV2 DisplayString TEXTUAL-
CONVENTION.";
    reference "RFC 2579, section 2.";
    type string {
        length "0 .. 255";
    }
}

container toaster {
    presence
        "Indicates the toaster service is available";

    description
        "Top-level container for all toaster database objects.";

    leaf toasterManufacturer {
        type DisplayString;
        config false;
        mandatory true;
        description
            "The name of the toaster's manufacturer. For instance,
            Microsoft Toaster.";
    }

    leaf toasterModelNumber {
        type DisplayString;
        config false;
        mandatory true;
        description
            "The name of the toaster's model. For instance,
            Radiant Automatic.";
    }

    leaf toasterStatus {
        type enumeration {
            enum up {
                value 1;
                description
                    "The toaster knob position is up.
                    No toast is being made now.";
            }
            enum down {
                value 2;
            }
        }
    }
}
```


Yuma Quickstart Guide

```
        description
        "The toaster knob position is down.
        Toast is being made now.";
    }
}
config false;
mandatory true;
description
    "This variable indicates the current state of
    the toaster.";
}
}

rpc make-toast {
    description
        "Make some toast.
        The toastDone notification will be sent when
        the toast is finished.
        An 'in-use' error will be returned if toast
        is already being made.
        A 'resource-denied' error will be returned
        if the toaster service is disabled.";
    input {
        leaf toasterDoneness {
            type uint32 {
                range "1 .. 10";
            }
            default 5;
            description
                "This variable controls how well-done is the
                ensuing toast. It should be on a scale of 1 to
                10.
                Toast made at 10 generally is considered unfit
                for human consumption; toast made at 1 is warmed
                lightly.";
        }
        leaf toasterToastType {
            type identityref {
                base toast:toast-type;
            }
            default toast:wheat-bread;
            description
                "This variable informs the toaster of the type of
                material that is being toasted. The toaster
                uses this information, combined with
                toasterDoneness, to compute for how
                long the material must be toasted to achieve
                the required doneness.";
        }
    }
}

rpc cancel-toast {
    description
        "Stop making toast, if any is being made.
        A 'resource-denied' error will be returned
        if the toaster service is disabled.";
}

notification toastDone {
    description
        "Indicates that the toast in progress has completed.";
```

Yuma Quickstart Guide

```
leaf toastStatus {
  description
    "Indicates the final toast status";
  type enumeration {
    enum done {
      description
        "The toast is done.";
    }
    enum cancelled {
      description
        "The toast was cancelled.";
    }
    enum error {
      description
        "The toaster service was disabled or
        the toaster is broken.";
    }
  }
}
}
```

/*****

Original TOASTER-MIB

TOASTER-MIB DEFINITIONS ::= BEGIN

IMPORTS

enterprises

FROM RFC1155-SMI

OBJECT-TYPE

FROM RFC-1212

DisplayString

FROM RFC-1213;

epilogue OBJECT IDENTIFIER ::= {enterprises 12}

toaster OBJECT IDENTIFIER ::= {epilogue 2}

toasterManufacturer OBJECT-TYPE

SYNTAX DisplayString

ACCESS read-only

STATUS mandatory

DESCRIPTION

"The name of the toaster's manufacturer. For instance,

Microsoft Toaster."

::= {toaster 1}

toasterModelNumber OBJECT-TYPE

SYNTAX DisplayString

ACCESS read-only

STATUS mandatory

DESCRIPTION

"The name of the toaster's model. For instance,

Radiant Automatic."

::= {toaster 2}

toasterControl OBJECT-TYPE

SYNTAX INTEGER {up (1), down (2)}

ACCESS read-write

STATUS mandatory

Yuma Quickstart Guide

```
DESCRIPTION
    "This variable controls the current state of the toaster.
    To begin toasting, set it to down (2). To abort toasting
    (perhaps in the event of an emergency), set it to up (2)."
```

::= {toaster 3}

toasterDoneness OBJECT-TYPE
SYNTAX INTEGER (1..10)
ACCESS read-write
STATUS mandatory
DESCRIPTION
 "This variable controls how well-done is the
 ensuing toast. It should be on a scale of 1 to 10.
 Toast made at 10 generally is considered unfit
 for human consumption; toast made at 1 is warmed
 lightly."
 ::= {toaster 4}

toasterToastType OBJECT-TYPE
SYNTAX INTEGER {
 white-bread (1),
 wheat-bread (2),
 wonder-bread (3),
 frozen-waffle (4),
 frozen-bagel (5),
 hash-brown (6),
 other (7)
}
ACCESS read-write
STATUS mandatory
DESCRIPTION
 "This variable informs the toaster of the type of
 material that is being toasted. The toaster
 uses this information, combined with
 toasterToastDoneness, to compute for how
 long the material must be toasted to achieve
 the required doneness."
 ::= {toaster 5}

END
*****/
}