7705 Service Aggregation Router Gen 2

Release 26.10.R1

Basic System Configuration Guide

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Table of contents

List of tables **12**

List of figures **14**

1 Getting started **16**

1.1 About this guide 16

1.2 Platforms and terminology 16

1.3 Conventions 17

1.3.1 Precautionary and information messages 17

1.3.2 Options or substeps in procedures and sequential workflows 17

2 File management **19**

2.1 SR OS file system 19

2.1.1 Storage devices 19

2.1.2 URLs 20

2.1.3 HTTP digest authentication 22

2.1.4 Wildcards and special characters 23

2.2 Text editor 23

2.2.1 Summary of text editor commands 24

2.2.2 Using text editor commands 24

2.3 File management tasks in the classic CLI 31

2.3.1 Displaying directory and file information 32

2.3.2 Modifying file attributes 33

2.3.3 Creating directories 33

2.3.4 Copying files 33

2.3.5 Moving files 35

2.3.6 Deleting files and removing directories 38

2.3.7 Unzipping files 38

2.3.8 Managing storage devices 38

2.3.9 Displaying file checksums 39

2.4 File management tasks in the MD-CLI 40

2.4.1 Displaying directory and file information 41

2.4.2 Modifying file attributes 42

2.4.3 Creating and navigating directories 43

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2.4.4 Copying files....43
2.4.5 Moving files....45
2.4.6 Deleting files and removing directories....48
2.4.7 Unzipping files....49
2.4.8 Managing storage devices....50
2.4.9 Displaying file checksums....51

3 System initialization and boot options....52
3.1 Boot process....52
3.2 Boot Loader....54
3.3 Boot Options File....54
3.3.1 BOF manual mode....54
3.4 Software and configuration....55
3.4.1 Management interface configuration modes....56
3.5 Initial installation and software update....57
3.6 USB recovery boot....57
3.7 Storage card content....58
3.7.1 7705 SAR-10x, 7705 SAR-Hx, 7705 SAR-Mx, and 7705 SAR-1 storage card content....59
3.8 Persistent indexes in classic and mixed configuration mode....60
3.9 BOF and configuration file encryption....61
3.10 System profiles....61
3.11 Configuring the Boot Options File with CLI....62
3.11.1 Basic BOF configuration....62
3.11.2 Common configuration tasks....64
3.11.2.1 Searching for the BOF....64
3.11.2.2 Accessing the CLI....64
3.11.2.3 Console connection....64
3.11.2.4 Configuring BOF encryption....65
3.11.2.5 Configuring the BOF interactive menu password....65
3.11.2.6 Configuring configuration file encryption....65
3.11.3 Autoconfigure....66
3.11.3.1 Autoconfigure restrictions....66
3.11.3.2 DHCP discovery of MAC addresses....66
3.11.3.3 IPv6 DUID....67
3.11.3.4 IPv6 DHCP RAs....67
3.11.4 Service management tasks....68

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3.11.4.1 System management commands in the classic CLI....68
3.11.4.2 System management commands in the MD-CLI....71
3.12 Anti-theft....75
3.12.1 Node behavior when the anti-theft password is set....77
3.12.2 BOF and configuration file behavior....77
3.12.3 Management interface interaction in anti-theft mode....78

4 Debug configuration....80
4.1 Debug configuration in the classic CLI....80
4.1.1 Logging debug events in the classic CLI....80
4.2 Debug configuration in the MD-CLI....81
4.2.1 Logging debug events in the MD-CLI....82
4.3 Debug configuration in mixed and model-driven mode....83

5 Secure boot....85
5.1 Secure Boot chain....85
5.2 Activate Secure Boot....86
5.3 Operational commands and logs....87
5.3.1 Secure Boot state....87
5.3.2 Software update....88
5.3.3 Update Secure Boot variables....88

6 System management....89
6.1 System management commands....89
6.1.1 System information....89
6.1.1.1 Name....89
6.1.1.2 Contact....89
6.1.1.3 Location....89
6.1.1.4 Coordinates....90
6.1.1.5 Naming objects....90
6.1.1.6 Common language location identifier....90
6.1.1.7 DNS security extensions....90
6.1.2 System time....90
6.1.2.1 Time zones....90
6.1.2.2 NTP....93
6.1.2.3 CRON....94

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6.1.2.4 GNSS ... 94
6.2 High Availability ... 95
6.2.1 HA features ... 96
6.2.1.1 Redundancy ... 96
6.2.1.2 Nonstop forwarding ... 98
6.2.1.3 Nonstop Routing ... 98
6.2.1.4 CPIOM switchover ... 99
6.2.2 Synchronization ... 99
6.2.2.1 CPIOM synchronization ... 99
6.3 Network synchronization ... 100
6.3.1 Central synchronization subsystem ... 101
6.3.2 Synchronization Status Messages ... 103
6.3.2.1 E1 signals ... 103
6.3.3 SyncE ... 103
6.3.3.1 Timing reference selection based on QL ... 104
6.3.3.2 Extended QL TLV for ESMC messaging ... 105
6.3.4 Clock source QL definitions ... 105
6.3.5 Advanced G.781 features ... 108
6.3.6 IEEE 1588v2 PTP ... 108
6.3.6.1 PTP clock synchronization ... 116
6.3.6.2 Performance considerations ... 119
6.3.6.3 PTP capabilities ... 120
6.3.6.4 PTP ordinary timeReceiver clock for frequency ... 121
6.3.6.5 PTP ordinary timeTransmitter clock for frequency ... 122
6.3.6.6 PTP boundary clock for frequency and time ... 123
6.3.6.7 PTP timeTransmitter clock for frequency and time distribution ... 124
6.3.6.8 ITU-T G.8275.2 profile and APTS ... 125
6.3.6.9 PTP message encapsulations ... 126
6.3.6.10 PTP time for system time and OAM time ... 127
6.3.6.11 PTP within routing instances ... 127
6.3.6.12 PTSF conditions for G.8275.1 ... 127
6.3.6.13 Profile interworking ... 128
6.3.6.14 Annex J performance monitoring statistics ... 130
6.3.6.15 PTP path trace ... 131
6.4 Differential Clock Recovery ... 131
6.4.1 DCR frequencies ... 132

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6.5 IP hashing as an LSR....133
6.6 Auto-provisioning....133
6.6.1 Auto-provisioning limits....135
6.6.2 Auto-provisioning process....135
6.6.3 Auto-provisioning DHCP rules....135
6.6.4 Auto-provisioning failure....136
6.7 Administrative tasks....136
6.7.1 Saving configurations....137
6.7.2 Specifying post-boot configuration files....137
6.7.3 Network timing....137
6.7.4 Power supplies....137
6.8 System router instances....138
6.9 System configuration process overview....139
6.10 Saving configurations manually....139
6.11 Common configuration tasks....140
6.11.1 System information....140
6.11.1.1 System name....140
6.11.1.2 Contact....140
6.11.1.3 Location....140
6.11.1.4 CLLI code....141
6.11.1.5 GPS coordinates....141
6.11.2 System time elements....141
6.11.2.1 Zone....141
6.11.2.2 Summer (daylight saving) time....141
6.11.2.3 NTP....142
6.11.2.4 SNTP....148
6.11.2.5 CRON....149
6.11.3 ANCP enhancements....150
6.11.4 Configuration backups....150
6.12 System timing....152
6.12.1 Entering edit mode....152
6.12.2 Configuring timing references....152
6.12.3 Using the revert command....152
6.12.4 Committing and discarding changes....153
6.12.5 Forcing a specific reference....154
6.12.6 Configuring system timing to use a GNSS RF port....154

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6.13 Configuring system cooling....154
6.14 Configuring power supply....156
6.15 Configuring multichassis redundancy for LAG....158
6.16 Post-boot configuration extension files....159
6.16.1 Show command output and console messages....159
6.17 Configuring system monitoring thresholds....160
6.17.1 Creating events....161
6.18 Configuring LLDP....162
6.19 Monitoring datapath statistics....163
6.19.1 Virtual FP utilization....163
6.19.2 Buffer pools and congestion status....164
6.19.3 FP input-output statistics....164

7 DHCP persistence....167

8 CPIOM redundancy....168
8.1 File synchronization....168
8.2 Active and standby designations....170
8.3 When the active CPIOM goes offline....170
8.4 OOB management Ethernet port redundancy....171
8.5 Configuration guidelines for synchronization of active and standby CPIOM....172

9 Zero touch provisioning....173
9.1 ZTP overview....173
9.1.1 Network requirements....173
9.1.2 Network support....174
9.2 ZTP process overview....176
9.2.1 Auto-boot process....176
9.2.2 Auto-provisioning process....176
9.3 DHCP support for ZTP....176
9.3.1 DHCP server offer options....177
9.3.1.1 Nokia-specific TLV....177
9.3.2 Supported DHCP client options for ZTP....177
9.3.3 Supported DHCP server options for ZTP....178
9.3.4 DHCP discovery and solicitation....178
9.3.4.1 DHCP discovery (IPv4 and IPv6)....179

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9.3.4.2 DHCP solicitation (IPv6)..... 179
9.3.5 IPv4 and IPv6 DHCP support..... 180
9.3.5.1 IPv4 route installation details..... 180
9.3.5.2 IPv6 DHCP/RA details..... 180
9.3.5.3 ZTP and DHCP timeouts..... 180
9.4 ZTP procedure details..... 181
9.4.1 Node bootup..... 181
9.4.1.1 Reinitiating ZTP during normal node bootup..... 181
9.4.2 BOF..... 181
9.4.2.1 Compact flash support..... 182
9.4.3 Auto-boot process details..... 182
9.4.3.1 Options and option modification..... 182
9.4.3.2 CLI access..... 183
9.4.3.3 Interrupting auto-boot..... 183
9.4.4 Auto-provisioning process..... 183
9.4.4.1 VLAN discovery..... 184
9.4.4.2 Auto-provisioning procedure..... 184
9.4.4.3 Out-of-band management versus in-band management..... 185
9.4.5 Provisioning files..... 186
9.4.5.1 Provisioning file download..... 186
9.4.5.2 Provisioning file resolution using DNS..... 187
9.4.5.3 File download and redundancy..... 187
9.4.5.4 Configuring the ZTP timeout in the provisioning file..... 187
9.4.5.5 Downloading the image file..... 187
9.4.5.6 Example provisioning file..... 188
9.4.5.7 Proxy support..... 190
9.4.6 Day 0 configuration..... 190
9.4.6.1 Day 0 configuration for multi-slot routers..... 191
9.4.6.2 Day 0 symbols..... 191
9.4.6.3 Sample day 0 configuration template..... 194
9.4.7 Logs and events..... 196
9.5 Legacy SZTP (non RFC 8572-compliant)..... 196
9.5.1 Staging the secure environment..... 198
9.5.2 Bootstrapping methods..... 198
9.5.3 Installation site process..... 199
9.5.3.1 Initial conveyed information file..... 200

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9.5.3.2 Onboarding information....202
9.5.3.3 Conveyed information....206
9.6 RFC 8572-compliant SZTP....207
9.6.1 TLS details....209
9.6.2 Bootstrap methods....210
9.6.3 Secure ZTP BOF flag....211
9.6.4 Conveyed, redirect, and onboarding information support....211
9.6.5 Image download rules....212
9.6.6 Configuration script....213
9.6.6.1 Provisioning file format....213
9.6.6.2 Provisioning script format....214
9.6.6.3 Examples of the pre-configuration-script....214
9.6.7 Installation site....216
9.6.8 Non-TPM 2.0 platforms....217
9.6.9 Image download directory....217
9.6.10 Logs....218
9.6.11 NTP and OV certificate date and time validation....218

10 Standards and protocol support....219
10.1 Bidirectional Forwarding Detection (BFD)....219
10.2 Border Gateway Protocol (BGP)....219
10.3 Bridging and management....220
10.4 Certificate management....221
10.5 Ethernet....221
10.6 Ethernet VPN (EVPN)....221
10.7 gRPC Remote Procedure Calls (gRPC)....222
10.8 Intermediate System to Intermediate System (IS-IS)....222
10.9 Internet Protocol (IP) general....223
10.10 Internet Protocol (IP) multicast....224
10.11 Internet Protocol (IP) version 4....225
10.12 Internet Protocol (IP) version 6....225
10.13 Internet Protocol Security (IPsec)....226
10.14 Label Distribution Protocol (LDP)....227
10.15 Multiprotocol Label Switching (MPLS)....228
10.16 Network Address Translation (NAT)....228
10.17 Network Configuration Protocol (NETCONF)....228

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10.18 Open Shortest Path First (OSPF)....228
10.19 Path Computation Element Protocol (PCEP)....229
10.20 Pseudowire (PW)....230
10.21 Quality of Service (QoS)....231
10.22 Remote Authentication Dial In User Service (RADIUS)....231
10.23 Resource Reservation Protocol - Traffic Engineering (RSVP-TE)....231
10.24 Routing Information Protocol (RIP)....231
10.25 Segment Routing (SR)....232
10.26 Simple Network Management Protocol (SNMP)....232
10.27 Storage sanitization....234
10.28 Timing....234
10.29 Two-Way Active Measurement Protocol (TWAMP)....234
10.30 Virtual Private LAN Service (VPLS)....235
10.31 Yet Another Next Generation (YANG)....235

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List of tables

Table 1: Platforms and terminology....16
Table 2: Device names, locations, and support....19
Table 3: URL types and syntax....20
Table 4: Cutting and pasting or deleting text....24
Table 5: Inserting new text....25
Table 6: Moving the cursor within the file....25
Table 7: Moving the cursor around the screen....27
Table 8: Replacing text....28
Table 9: Searching for text or characters....28
Table 10: Manipulating character and line formatting....29
Table 11: Miscellaneous commands....29
Table 12: Line editing commands....30
Table 13: File command local and remote file system support in the classic CLI....31
Table 14: File command local and remote file system support in the MD-CLI....40
Table 15: Console configuration parameter values....65
Table 16: System-defined time zones and UTC offsets....91
Table 17: Revertive, non-revertive timing reference switching operation....102
Table 18: Synchronization message coding and source priorities — SSM received....106
Table 19: Synchronization message coding and source priorities — SSM transmitted....107
Table 20: Local clock parameters when profile is set to ieee1588-2008....112
Table 21: Local clock parameters when profile is set to itu-telecom-freq....112

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Table 22: Local clock settings when profile is set to g8275dot1-2014 113

Table 23: Local Clock Parameters: g8275dot2-2016 115

Table 24: Message rate ranges and defaults 121

Table 25: Mapping between ITU-T G.8275.2 and PTP clock types 126

Table 26: Allowed standard profiles in alternate profile 129

Table 27: Performance monitor record index values 130

Table 28: Supported DHCP client options for ZTP 177

Table 29: Supported DHCP server options for ZTP 178

Table 30: Supported symbols 192

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List of figures

Figure 1: Boot process....53
Figure 2: BOF manual mode....55
Figure 3: Load SR OS configuration....56
Figure 4: Files on storage card — 7705 SAR-10x, 7705 SAR-Hx, 7705 SAR-Mx, and 7705 SAR-1....59
Figure 5: Secure boot chain of trust....86
Figure 6: Conventional network timing architecture (North American nomenclature)....100
Figure 7: CPM clock synchronization reference selection....102
Figure 8: Peer clocks....110
Figure 9: Ethernet multicast ports....111
Figure 10: Messaging sequence between the PTP timeReceiver clock and PTP timeTransmitter clock...116
Figure 11: PTP timeReceiver clock and timeTransmitter clock synchronization timing computation....117
Figure 12: Logical model for using PTP/1588 for network synchronization....118
Figure 13: PTP ordinary timeReceiver clock for frequency....121
Figure 14: Ordinary timeReceiver clock operation....122
Figure 15: PTP timeTransmitter clock....122
Figure 16: Ordinary timeTransmitter clock operation....123
Figure 17: PTP boundary clock for frequency and time....124
Figure 18: DCR on a network....132
Figure 19: Example of a network with no DHCP relay....134
Figure 20: Example of a network with a DHCP relay....134
Figure 21: Example of a network with multiple subnets....134

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Figure 22: System configuration and implementation flow..... 139

Figure 23: Management Ethernet: normal mode..... 171

Figure 24: Management Ethernet: redundancy mode..... 172

Figure 25: Auto-provisioning with all components in the same subnet..... 174

Figure 26: Auto-provisioning with only file and DHCP servers in the same subnet..... 175

Figure 27: Auto-provisioning with all components in different subnets..... 175

Figure 28: SZTP process..... 197

Figure 29: Installation site SZTP process..... 199

Figure 30: SZTP user workflow..... 208

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1 Getting started

1.1 About this guide

This guide describes system concepts and provides configuration explanations and examples to configure SR OS boot option file (BOF), file system, and system management functions.

This guide is organized into functional chapters and provides concepts and descriptions of the implementation flow, as well as Command Line Interface (CLI) syntax and command usage.

Unless otherwise indicated, the topics and commands described in this guide apply only to the 7705 SAR Gen 2 platforms listed in Platforms and terminology.

Command outputs shown in this guide are examples only; actual displays may differ depending on supported functionality and user configuration.

Note: Unless otherwise indicated, CLI commands, contexts, and configuration examples in this guide apply for both the classic CLI and the MD-CLI.

The SR OS CLI trees and command descriptions can be found in the following guides:

- *7705 SAR Gen 2 Classic CLI Command Reference Guide*
- *7705 SAR Gen 2 Clear, Monitor, Show, Tools CLI Command Reference Guide* (for both the MD-CLI and classic CLI)
- *7705 SAR Gen 2 MD-CLI Command Reference Guide*

Note: This guide generically covers Release 26.*x*.R*x* content and may contain some content that will be released in later maintenance loads. See the *SR OS R26.x.Rx Software Release Notes*, part number 3HE 29176 000*x* TQZZA, for information about features supported in each load of the Release 26.*x*.R*x* software. For a list of features and CLI commands that are present in SR OS but not supported on the 7705 SAR Gen 2 platforms, see "SR OS Features not Supported on SAR Gen 2" in the *SR OS R26.x.Rx Software Release Notes*.

1.2 Platforms and terminology

Note:
Unless explicitly noted otherwise, this guide uses the terminology defined in the following table to collectively designate the specified platforms.

Table 1: Platforms and terminology

Platform	Collective platform designation
7705 SAR-10x	7705 SAR Gen 2
7705 SAR-Hx	

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Platform	Collective platform designation
7705 SAR-Mx	
7705 SAR-1	

1.3 Conventions

This section describes the general conventions used in this guide.

1.3.1 Precautionary and information messages

The following information symbols are used in the documentation.

DANGER: Danger warns that the described activity or situation may result in serious personal injury or death. An electric shock hazard could exist. Before you begin work on this equipment, be aware of hazards involving electrical circuitry, be familiar with networking environments, and implement accident prevention procedures.

WARNING: Warning indicates that the described activity or situation may, or will, cause equipment damage, serious performance problems, or loss of data.

Caution: Caution indicates that the described activity or situation may reduce your component or system performance.

Note: Note provides additional operational information.

Tip: Tip provides suggestions for use or best practices.

1.3.2 Options or substeps in procedures and sequential workflows

Options in a procedure or a sequential workflow are indicated by a bulleted list. In the following example, at step 1, the user must perform the described action. At step 2, the user must perform one of the listed options to complete the step.

Example: Options in a procedure

1. User must perform this step.
2. This step offers three options. User must perform one option to complete this step.
   - This is one option.
   - This is another option.
   - This is yet another option.

Substeps in a procedure or a sequential workflow are indicated by letters. In the following example, at step 1, the user must perform the described action. At step 2, the user must perform two substeps (a. and b.) to complete the step.

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Example: Substeps in a procedure

1. User must perform this step.
2. User must perform all substeps to complete this action.
   a. This is one substep.
   b. This is another substep.

Nested substeps within a procedure or a sequential workflow are indicated by roman numerals. In the following example, at step 1, the user must perform the described action. At step 2, the user must perform two substeps (a. and b.) to complete the step. At substep b, the user must perform two additional substeps (i. and ii.) to complete the step.

Example: Nested substeps in a procedure

1. User must perform this step.
2. User must perform all substeps to complete this action.
   a. This is one substep.
   b. User must perform all nested substeps to complete this action.
      i. This is a nested substep.
      ii. This is another nested substep.

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2 File management

This chapter provides information about file system management.

2.1 SR OS file system

The SR OS file system is used to store files used and generated by the system; for example, image files, configuration files, logging files, and accounting files.

The file commands allow you to copy, create, move, and delete files and directories, navigate to a different directory, and display file or directory contents and the image version.

Although some of the storage devices on routers are not actually compact flash devices all storage devices are referred to as compact flash.

2.1.1 Storage devices

On the 7705 SAR Gen 2, each control processor can have up to two storage devices numbered 2 and 3. The names for these devices are:

- cf2:
- cf3:

The preceding device names are relative names; they refer to the devices that are local to the control processor of the current console session. The colon (":") at the end of the name indicates this is a device.

The 7705 SAR-10x, 7705 SAR-Hx, and 7705 SAR-Mx boot from an SD card.

The 7705 SAR-1 boots from an internal embedded MultiMediaCard (eMMC).

The following table describes device names, locations, and support.

Table 2: Device names, locations, and support

7705 SAR Gen 2 platform	Device name and location	
	cf2:	cf3:
7705 SAR-10x	USB port	SD card
7705 SAR-Hx	USB port	SD card
7705 SAR-Mx	USB port	SD card
7705 SAR-1	USB port	eMMC

The user must administratively enable the USB port before it can be used. Use the following command to enable the USB port:

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- **MD-CLI**

```
configure system usb cf2 admin-state enable
```

- **classic CLI**

```
configure system usb cf2 no shutdown
```

Note: On the 7705 SAR-1, only the USB on cf2: is removable.

Note: To prevent corrupting open files in the file system, only remove a storage device that is administratively disabled. SR OS gracefully closes any open files on the device, allowing the storage device to be safely removed.

2.1.2 URLs

The arguments for the SR OS file commands are modeled after standard universal resource locater (URL). A URL refers to a file (a *file-url*) or a directory (a *directory-url*).

SR OS supports operations on both the local file system and on remote files. To categorize the applicability of commands to local and remote file operations, URLs are divided into five types of URLs: **local**, **ftp**, **sftp**, **tftp**, **http**, **https**, and **scp**. The syntax for each of the URL types are listed in Table 3: URL types and syntax.

Table 3: URL types and syntax

URL type	Syntax	Notes
local-url	[*cflash-id*:\]*path*	*cflash-id* is the compact flash device name. Values: **cf2:**, **cf3:**
ftp-url	**ftp://**[*username*[**:***password*]**@**]*host*/*path*	An absolute FTP path from the root of the remote file system. *username* is the FTP username *password* is the FTP user password *host* is the FTP server *path* is the path to the directory or file
	ftp://[*username*[**:***password*]**@**]*host*/**.**/path	A relative FTP path from the user's home directory. Note the period and slash ("**./**") in this syntax compared to the absolute path.
sftp-url	**sftp://**[*username*[**:***password*]**@**]*host*/*path*	An absolute SFTP path from the root of the remote file system. *username* is the SFTP username *password* is the SFTP user password *host* is the SFTP server

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URL type	Syntax	Notes
		path is the path to the directory or file
	sftp://[*username*[**:***password*]**@**]*host***/.**/path	A relative SFTP path from the user's home directory. Note the period and slash ("**./**") in this syntax compared to the absolute path.
tftp-url	**tftp://***host*[*/path*]*/filename*	TFTP is only supported for operations on a *file-url*.
http-url	**http://**[*username[:password]@]host*[*:port*]*/path*	*host* is the HTTP server *port* defaults to 80
https-url	**https://***[username[:password]@]host*[*:port*]*/path*	*host* is the HTTPS server *port* defaults to 443
scp-url	**scp://***username @host*:*path*	*username* is the SSH username *host* is the SSH server *path* is the path to the directory or file

If the host portion of a URL is an IPv6 address, enclose the URL in quotes and the address in square brackets, as shown in the following examples.

Example

- `"ftp://username:password@[2001:db8:3333:4444:5555:6666:7777:8888]/testfile.txt"`
- `"scp://username@[2001:db8:3333:4444:5555:6666:7777:8888]/testfile.txt"`

The system accepts forward slash (/) or backslash (\) characters to delimit directory and/or filenames in URLs. Similarly, the SR OS SCP client application can use either slash or backslash characters, but not all SCP clients treat backslash characters as equivalent to slash characters. In particular, UNIX systems often interprets the backslash character as an escape character. This can cause problems when using an external SCP client application to send files to the SCP server. If the external system treats the backslash like an escape character, the backslash delimiter gets stripped by the parser and is not transmitted to the SCP server.

For example, a destination directory specified as "cf2:\dir1\file1" is transmitted to the SCP server as "cf2:dir1file1" where the backslash escape characters are stripped by the SCP client system before transmission. On systems where the client treats the backslash like an escape character, a double backslash (\\) or the forward slash (/) can typically be used to properly delimit directories and the filename.

When a special character is used in a password, it can cause issues when that password is encoded as part of a URL. To prevent this issue, percent encoding can be used. Percent encoding is a mechanism to encode 8-bit characters that have specific meaning in the context of URLs. The encoding consists of substitution of a percent character (%) followed by the hexadecimal representation of the ASCII value of the replaced character.

Some file manipulation commands such as copying, removing, or moving files, may request access to an HTTP or HTTPS server. If an HTTP or HTTPS server redirects the system to a different URL (from an "HTTP 301" error or similar response), the system prompts the user "y/n" to either repeat the operation with the new URL or terminate it. These file commands can be configured to force the HTTP redirects without prompting or they can be configured to refuse HTTP redirects. If a file command is redirected

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more than eight times, or if it queries an HTTPS URL and gets redirected to an HTTP URL, the command automatically terminates as a security measure.

Use the following command to refuse HTTP redirects:

- **MD-CLI**

```
copy source-url destination-url direct-http
```

- **classic CLI**

```
copy source-url dest-url no-redirect
```

Use the following command to force the HTTP redirects without prompting:

- **MD-CLI**

```
copy source-url destination-url force
```

- **classic CLI**

```
copy source-url dest-url force
```

When connecting to an HTTPS server, the system verifies the server's TLS certificate. For the certificate to pass verification, the system must have a CA profile already configured for the server's Certificate Authority (CA), which specifies up-to-date certificate and CRL files. HTTPS file commands do not use the Online Certificate Status Protocol (OCSP). If the certificate was issued by an intermediate CA, the system must have a CA profile for every CA tracing back to the root CA. If the server's certificate fails verification for any reason, the file command terminates. See the *7705 SAR Gen 2 Multiservice ISA and ESA Guide* for more information about CA profiles.

Use the following CLI command to configure the CA profile:

```
configure system security pki ca-profile
```

An HTTPS **file** command may also include a **client-tls-profile** configuration parameter, referring to a client TLS profile that provides the cipher list, client certificate, and trust anchor the system uses when communicating with the HTTPS server. See the *7705 SAR Gen 2 System Management Guide* for more information about client TLS profiles.

A **file** command that connects to an HTTP or HTTPS server outside the local network may need to use an HTTP proxy. The user may specify a proxy server (which must be an HTTP URL).

2.1.3 HTTP digest authentication

For HTTP or HTTPS **file** commands only, the HTTP digest authentication scheme can be used with the HTTP authentication mechanism as described in RFC 7616 and RFC 2617. The following hash algorithms are supported:

- MD5
- SHA-256
- SHA-512/256

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2.1.4 Wildcards and special characters

SR OS supports the standard wildcard characters. The asterisk (*) can represent zero or more characters in a string of characters, and the question mark (?) can represent any one character and must be enclosed in quotation marks (" ").

Example: MD-CLI

```
[file "cf3:\"]
A:admin@node-2# copy bof.* testdir
11 file(s) copied.

[file "cf3:\"]
A:admin@node-2#
```

Example: classic CLI

```
A:node-2>file cf3:\ # copy bof.* testdir
Copying file cf3:\bof.cfg-1 ... OK
Copying file cf3:\bof.cfg-2 ... OK
Copying file cf3:\bof.cfg-3 ... OK
Copying file cf3:\bof.cfg-4 ... OK
Copying file cf3:\bof.cfg-5 ... OK
Copying file cf3:\bof.cfg-6 ... OK
Copying file cf3:\bof.cfg-7 ... OK
Copying file cf3:\bof.cfg-8 ... OK
Copying file cf3:\bof.cfg-9 ... OK
Copying file cf3:\bof.cfg.1 ... OK
Copying file cf3:\bof.cfg ... OK
11 file(s) copied.
A:node-2>file cf3:\ #
```

2.2 Text editor

The text editor allows the user to edit an ASCII text file. When the user modifies the configuration using a configuration mode, the system validates whether the user is allowed to perform configuration changes. When the text editor is used to edit a configuration file, these validation checks do not occur. For this reason, administrator privileges are required to access the text editor, and the user profile must be modified to allow this access.

Access permission for the directory where the file resides must be granted before a user can open, read, or write a file. If the user does not have permission to access the directory, the operation is denied.

Use the following command to start the text editor:

- **MD-CLI**

  ```
  file edit url
  ```

- **classic CLI**

  ```
  file vi local-url
  ```


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2.2.1 Summary of text editor commands

The text editor operates in the following modes:

- **command mode**

  In this mode, every character entered is a command that causes an action to be taken on the text file. For example, the character “O” typed in command mode causes the text editor to enter insert mode.

- **insert mode**

  In this mode, every character typed is added to the text in the file. Pressing Esc turns off insert mode.

2.2.2 Using text editor commands

Use the commands described in the tables in this section to do the following:

- start and end text editor sessions
- move within a file
- enter new text
- modify, move, and delete existing text
- read from and write to other files

The following table describes the commands to cut, paste, and delete text.

Table 4: Cutting and pasting or deleting text

Text editor command	Description
"	Specify a buffer to be used with any of the commands using buffers. Follow the quotation mark (") character with a letter or a number that corresponds to a buffer.
d	Delete text. The “**dd**” command deletes the current line. A count specifies the number of lines to delete. Deleted text is placed in the buffer specified with the **"** command. If no buffer is specified, the general buffer is used.
D	Delete to the end of the line from the current cursor position.
p	Paste the specified buffer after the current cursor position or line. If no buffer is specified using the **"** command, the general buffer is used.
P	Paste the specified buffer before the current cursor position or line. If no buffer is specified using the **"** command, the general buffer is used.

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Text editor command	Description
x	Delete the character under the cursor. A count specifies the number of characters to delete. The characters after the cursor are deleted.
X	Delete the character before the cursor.
y	Yank text and place the result into a buffer. The "**yy**" command yanks the current line. Entering a number yanks the specified number of lines. The buffer can be specified with the **"** command. If no buffer is specified, the general buffer is used.
Y	Yank the current line into the specified buffer. If no buffer is specified, the general buffer is used.

The following table describes the commands to insert new text.

Table 5: Inserting new text

Text editor command	Description
A	Append text at the end of the current line.
I	Insert text from the beginning of a line.
O	Enter insert mode in a new line above the current cursor position.
a	Enter insert mode and append text after the current cursor position. A preceding count inserts all the text that was inserted the specified number of times.
i	Enter insert mode and insert typed text before the current cursor position. A preceding count inserts all the text that was inserted the specified number of times.
o	Enter insert mode in a new line below the current cursor position.

The following table describes the commands used to move the cursor within the file.

Table 6: Moving the cursor within the file

Text editor command	Description
^B	Scroll backward one page. A count scrolls that many pages.
^D	Scroll forward half a window. A count scrolls that many lines.

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Text editor command	Description
^F	Scroll forward one page. A count scrolls that many pages.
^H	Move the cursor one space to the left. A count moves that many spaces.
^J	Move the cursor down one line in the same column. A count moves that many lines down.
^M	Move to the first character on the next line.
^N	Move the cursor down one line in the same column. A count moves that many lines down.
^P	Move the cursor up one line in the same column. A count moves that many lines up.
^U	Scroll backward half a window. A count scrolls that many lines.
$	Move the cursor to the end of the current line. A count moves to the end of the following lines.
%	Move the cursor to the matching parenthesis or brace.
^	Move the cursor to the first non-whitespace character.
(	Move the cursor to the beginning of a sentence.
)	Move the cursor to the beginning of the next sentence.
{	Move the cursor to the preceding paragraph.
}	Move the cursor to the next paragraph.
|	Move the cursor to the column specified by the count.
+	Move the cursor to the first non-whitespace character in the next line.
-	Move the cursor to the first non-whitespace character in the previous line.
_	Move the cursor to the first non-whitespace character in the current line.
0	Move the cursor to the first column of the current line.
B	Move the cursor back one word, skipping over punctuation.

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Text editor command	Description
E	Move the cursor forward to the end of a word, skipping over punctuation.
G	Go to the line number specified as the count. If no count is specified, go to the end of the file.
H	Move the cursor to the first non-whitespace character at the top of the screen.
L	Move the cursor to the first non-whitespace character at the bottom of the screen.
M	Move the cursor to the first non-whitespace character in the middle of the screen.
W	Move forward to the beginning of a word, skipping over punctuation.
b	Move the cursor back one word. If the cursor is in the middle of a word, move the cursor to the first character of that word.
e	Move the cursor forward one word. If the cursor is in the middle of a word, move the cursor to the last character of that word.
h	Move the cursor one character position to the left.
j	Move the cursor down one line.
k	Move the cursor up one line.
l	Move the cursor one character position to the right.
w	Move the cursor forward one word. If the cursor is in the middle of a word, move the cursor to the first character of the next word.

The following table describes the commands to move the cursor around the screen.

Table 7: Moving the cursor around the screen

Text editor command	Description
^E	Scroll forward one line. A count scrolls that many lines.
^Y	Scroll backward one line. A count scrolls that many lines.
z	Redraw the screen with the following options: • z<return> puts the current line on the top of the screen.

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Text editor command	Description
	• z. puts the current line on the center of the screen. • z- puts the current line on the bottom of the screen. If you specify a count before the **z** command, it changes the current line to the line specified. For example, 16z. puts line 16 on the center of the screen.

The following table describes the commands to replace text.

Table 8: Replacing text

Text editor command	Description
C	Change to the end of the line from the current cursor position.
R	Replace characters on the screen with a set of characters entered, ending with Esc.
S	Change an entire line.
c	The **cc** command changes the current line. A count changes that many lines.
r	Replace one character under the cursor. Specify a count to replace a number of characters.
s	Substitute one character under the cursor, and enter insert mode. Specify a count to substitute a number of characters. A dollar sign ($) is placed at the last character to be substituted.

The following table describes the commands to search for text or characters in the file.

Table 9: Searching for text or characters

Text editor command	Description
,	Repeat the last **f**, **F**, **t** or **T** command in the reverse direction.
/	Search the file forward for the string specified after the forward slash (/).
;	Repeat the last **f**, **F**, **t** or **T** command.
?	Search the file backward for the string specified after the ?.

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Text editor command	Description
F	Search the current line backward for the character specified after the **F** command. If found, move the cursor to the position.
N	Repeat the last search done by forward slash (/) or question mark (?) in the backward direction.
T	Search the current line backward for the character specified after the **T** command, and move to the column after the character, if it is found.
f	Search the current line for the character specified after the **f** command. If found, move the cursor to the position.
n	Repeat the last search done by forward slash (/) or question mark (?) in the forward direction
t	Search the current line for the character specified after the **t** command, and move to the column before the character, if it is found.

The following table describes the commands to manipulate character and line formatting.

Table 10: Manipulating character and line formatting

Text editor command	Description
~	Switch the case of the character under the cursor.
<	Shift the lines up to the left by one shiftwidth. The **<<** command shifts the current line to the left and can be specified with a count.
>	Shift the lines up to the right by one shiftwidth. The **>>** command shifts the current line to the right and can be specified with a count.
J	Join the current line with the next one. A count joins that many lines.

The following table describes miscellaneous commands.

Table 11: Miscellaneous commands

Text editor command	Description
^G	Show the current file name and the status.
^L	Clear and redraw the screen.
^R	Redraw the screen removing false lines.
^[	Cancel a partially formed command (Esc).

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Text editor command	Description
^^	Go back to the last file edited.
&	Repeat the previous **:s** command.
.	Repeat the last command that modified the file.
:	Begin typing a line editing command. The command is executed when the user presses Enter.
@	Type the command stored in the specified buffer.
U	Restore the current line to the previous state before the cursor entered the line.
m	Mark the current position with the character specified after the **m** command.
u	Undo the last change to the file. Redo the change by typing **u** again.
ZZ	Exit the editor, saving if any changes were made.

From the text editor, use the **:** command to enter a line editing command. To modify more than one line using specific commands (such as **:s** and **:w**), the range must be specified before the command. For example, to substitute lines 3 through 15, the command is **:3,15s/from/this/g**.

The following table describes the commonly used line editing commands.

Table 12: Line editing commands

Text editor command	Description
:ab string strings	Abbreviation. If a word is typed in the text editor corresponding to string1, the editor automatically inserts the corresponding words. For example, the abbreviation ":ab vprn Virtual Private Routed Network" inserts the words "Virtual Private Routed Network" whenever the word "vprn" is typed.
:map keys new_seq	Map a key or a sequence of keys to another key or sequence of keys.
:q	Quit the text editor. If changes have been made, the editor issues a warning message.
:q!	Quit the text editor without saving changes.
:s/pattern/to_pattern/options	Substitute the specified pattern with the string in the **to_pattern**. Without options, only the first occurrence of the pattern is substituted. If a g is specified, all occurrences are substituted.
:set [all]	Sets some customizing options. The **:set all** command displays all options.

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Text editor command	Description
:una string	Removes the abbreviation previously defined by **:ab**.
:unm keys	Removes the mapping defined by **:map**.
:vi filename	Starts editing a new file. If changes have not been saved, the editor displays a warning message.
:w	Write contents of the current file.
:w filename	Write the contents of the buffer to the file name specified.
:w >> filename	Append the contents of the buffer to the file name.
:wq	Write the contents of the buffer and quit.

2.3 File management tasks in the classic CLI

The following sections are basic system tasks that can be performed in the classic CLI.

For more information about the supported classic CLI commands, see the *7705 SAR Gen 2 Classic CLI Command Reference Guide*.

When a file system operation is performed that can potentially remove or overwrite a file system entry, a prompt appears to confirm the action. The **force** keyword performs the operation without displaying the confirmation prompt.

All the commands can operate on the local file system with a default of `cf3:`. The following table indicates the commands that also support remote file operations.

Table 13: File command local and remote file system support in the classic CLI

Command	local-url	ftp-url	sftp-url	tftp-url	http-url	https-url
attrib	✓					
cd	✓	✓	✓			
copy	✓	✓	✓	source only	✓	✓
copy (recursive)	✓	✓	✓			
checksum	✓	✓	✓	✓		
delete	✓	✓	✓		✓	✓
dir	✓	✓	✓			
md	✓	✓	✓			
move	✓	✓	✓		✓	✓

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Command	local-url	ftp-url	sftp-url	tftp-url	http-url	https-url
move (recursive)	✓	✓	✓			
rd	✓	✓	✓			
scp	source only					
type	✓	✓	✓	✓	✓	✓
unzip	✓	✓	✓	source only		
version	✓	✓	✓	✓		
vi	✓					

2.3.1 Displaying directory and file information

Use the **dir** command to display a list of files on a file system. The **type** command displays the contents of a file. The **version** command displays the version of an SR OS `.tim` image file.

Example: Display directory and file information

```
A:node-2# file dir
 Volume in drive cf1 on slot A has no label.
Directory of cf1:\
01/01/1980  12:00a                7597 test.cfg
01/01/1980  12:00a                 957 b.
08/19/2001  02:14p              230110 BOOTROM.SYS
01/01/1980  12:00a                 133 NVRAM.DAT
04/03/2003  05:32a                1709 103.ndx
01/28/2003  05:06a                1341 103.cftg.ndx
01/28/2003  05:06a               20754 103.cftg
04/05/2003  02:20a      <DIR>          test
              15 File(s)                338240 bytes.
               3 Dir(s)                1097728 bytes free.
A:node-2# file type example.cfg
File: example.cfg
--------------------------------------------------------------------------------
exit all
config
#--------------------------------------
# Chassis Commands
#--------------------------------------
card 2 card-type faste-tx-32
exit
#--------------------------------------
# Interface Commands
#--------------------------------------
# Physical port configuration
interface faste 2/1
    shutdown
    mode network
exit
interface faste 2/2
    shutdown
exit
```


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```
interface faste 2/3
    shutdown
exit
Press any key to continue (Q to quit)
A:node-2# file version boot.tim
TiMOS-L-24.10.R1
Thu Oct 31 23:49:01 UTC 2024 by builder in /builds/2410B/R1/panos/main/sr
```

2.3.2 Modifying file attributes

The system administrator can change the attribute of a local file or files in a directory. Enter the **attrib** command with no options to display the contents of the directory and the file attributes.

Note: A file with an "R" preceding the filename indicates that the file is read-only.

Example: File configuration output

```
A:node-2>file cf3:\ # attrib
     cf3:\bootlog.txt
     cf3:\bof.cfg
     cf3:\boot.ldr
     cf3:\bootlog_prev.txt
     cf3:\BOF.SAV
A:node-2>file cf3:\ # attrib +r BOF.SAV
A:node-2>file cf3:\ # attrib
     cf3:\bootlog.txt
     cf3:\bof.cfg
     cf3:\boot.ldr
     cf3:\bootlog_prev.txt
R    cf3:\BOF.SAV
```

2.3.3 Creating directories

Use the **md** command to create a new directory in the local file system, one level at a time.

Enter the **cd** command to navigate to different directories.

Example: Creating three levels of directories

```
A:node-2>file cf1:\ # md test1file cf1:\ # cd test1
A:node-2>file cf1:\test1\ # md test2
A:node-2>file cf1:\test1\ # cd test2
A:node-2>file cf1:\test1\test2\ # md test3
A:node-2>file cf1:\test1\test2\ # cd test3
A:node-2>file cf1:\test1\test2\test3 #
```

2.3.4 Copying files

Use the **copy** command to copy files to or from a flash device or an FTP-TFTP server.

The **copy** command supports wildcards.

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The **scp** command copies files between hosts on a network. It uses SSH for data transfer, uses the same authentication, and provides the same security as SSH.

The source file for the **scp** command must be local. The file must reside on the router. The destination file does not need to be local, but it must be in the `user@host:file-name` format.

Example: Image file and network host copy

```
A:node-2>file cf1:\ # copy 104.cfg cf1:\test1\test2\test3\test.cfg
A:node-2>file cf1:\ # scp file1 admin@192.168.x.x:cf1:\file1
A:node-2>file cf1:\ # scp file2 user2@192.168.x.x:/user2/file2
A:node-2>file cf1:\ # scp cf2:/file3 admin@192.168.x.x:cf1:\file3
```

Use the **recursive** keyword to recursively copy files and directories. If files or directories already exist, the operator is prompted to overwrite them. When the **force** keyword is enabled, a positive response to the overwrite prompts is assumed. The operator is not prompted for confirmation and the existing files or directories are overwritten.

Example: Recursive directory copy

```
A:node-2# file dir
Volume in drive cf3 on slot A is SROS VM.

Volume in drive cf3 on slot A is formatted as FAT32

Directory of cf3:\

09/19/2021 06:11p 196 BOF.CFG
09/19/2021 06:11p 0 CONFIG.CFG
09/19/2021 06:11p 101 NVRAM.DAT
09/19/2021 07:22p  SUPPORT/
09/19/2021 06:11p  SYSLINUX/
09/19/2021 06:11p  TIMOS/
09/23/2021 09:03a 27459 bootlog.txt
09/20/2021 09:56a 27326 bootlog_prev.txt
09/23/2021 01:21p 319 nvsys.info
09/21/2021 07:19p  recursive3/
09/23/2021 08:22a  ssh/
7 File(s) 55402 bytes.
6 Dir(s) 612319232 bytes free.

A:node-2# file dir recursive3

Volume in drive cf3 on slot A is SROS VM.

Volume in drive cf3 on slot A is formatted as FAT32

Directory of cf3:\recursive3

09/21/2021 07:18p  ./
09/21/2021 07:18p  ../
09/21/2021 07:19p 7 file1.txt
09/21/2021 07:19p  recursive2/
1 File(s) 7 bytes.
3 Dir(s) 612319232 bytes free.

A:node-2# file copy recursive3 recursive1 recursive
Copying directory cf3:\recursive3
Copying directory cf3:\recursive3\recursive2
Copying file cf3:\recursive3\recursive2\file2.txt ... OK
Copying file cf3:\recursive3\recursive2\file3.txt ... OK
Copying file cf3:\recursive3\file1.txt ... OK
```


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```
2 dir(s) and 3 file(s) copied.
A:sros# file dir

Volume in drive cf3 on slot A is SROS VM.

Volume in drive cf3 on slot A is formatted as FAT32

Directory of cf3:\

09/19/2021 06:11p 196 BOF.CFG
09/19/2021 06:11p 0 CONFIG.CFG
09/19/2021 06:11p 101 NVRAM.DAT
09/19/2021 07:22p  SUPPORT/
09/19/2021 06:11p  SYSLINUX/
09/19/2021 06:11p  TIMOS/
09/23/2021 09:03a 27459 bootlog.txt
09/20/2021 09:56a 27326 bootlog_prev.txt
09/23/2021 01:21p 319 nvsys.info
09/23/2021 02:42p  recursive1/
09/21/2021 07:19p  recursive3/
09/23/2021 08:22a  ssh/
7 File(s) 55402 bytes.
7 Dir(s) 612298752 bytes free.

A:node-2# file dir recursive1

Volume in drive cf3 on slot A is SROS VM.

Volume in drive cf3 on slot A is formatted as FAT32

Directory of cf3:\recursive1

09/23/2021 02:42p  ./
09/23/2021 02:42p  ../
09/23/2021 02:42p 7 file1.txt
09/23/2021 02:42p  recursive2/
1 File(s) 7 bytes.
3 Dir(s) 612298752 bytes free.
```

2.3.5 Moving files

Use the **move** command to move a file or directory from one location to another.

The **move** command supports wildcards, recursively moves files and directories, and overwrites existing content without prompting for confirmation.

Example: Moving files and directories

```
A:node-2>file cf3:\ # dir

Volume in drive cf3 on slot A is TIMOS_VM_CF.

Volume in drive cf3 on slot A is formatted as FAT32

Directory of cf3:\

09/28/2021  11:42a                933 BOF.CFG
09/28/2021  11:42a                166 NVRAM.DAT
09/29/2021  03:51p              12831 bootlog.txt
09/29/2021  03:46p              12828 bootlog_prev.txt
04/16/2014  10:15a                  0 config.cfg
```


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```
09/29/2021  03:51p                 318 nvsys.info
04/16/2014  10:15a      <DIR>          syslinux/
09/29/2021  03:55p               12831 test.txt
09/29/2021  03:54p      <DIR>          test_dir1/
04/16/2014  10:15a      <DIR>          timos/
               7 File(s)                 39907 bytes.
               3 Dir(s)               14452736 bytes free.

A:node-2>file cf3:\ # move test.txt /test_dir1/test_dir2/test_dir3
Moving file cf3:\test.txt ... OK
cf3:\test.txt

A:node-2>file cf3:\ # dir

Volume in drive cf3 on slot A is TIMOS_VM_CF.

Volume in drive cf3 on slot A is formatted as FAT32

Directory of cf3:\

09/28/2021  11:42a                 933 BOF.CFG
09/28/2021  11:42a                 166 NVRAM.DAT
09/29/2021  03:51p               12831 bootlog.txt
09/29/2021  03:46p               12828 bootlog_prev.txt
04/16/2014  10:15a                   0 config.cfg
09/29/2021  03:51p                 318 nvsys.info
04/16/2014  10:15a      <DIR>          syslinux/
09/29/2021  03:54p      <DIR>          test_dir1/
04/16/2014  10:15a      <DIR>          timos/
               6 File(s)                 27076 bytes.
               3 Dir(s)               14452736 bytes free.

A:node-2>file cf3:\ # dir test_dir1/test_dir2/test_dir3

Volume in drive cf3 on slot A is TIMOS_VM_CF.

Volume in drive cf3 on slot A is formatted as FAT32

Directory of cf3:\test_dir1\test_dir2\test_dir3

09/29/2021  03:54p      <DIR>          ./
09/29/2021  03:54p      <DIR>          ../
09/29/2021  03:55p               12831 test.txt
               1 File(s)                 12831 bytes.
               2 Dir(s)               14452736 bytes free.
```

Example: Recursive directory move

```
A:node-2>file cf3:\ # dir

Volume in drive cf3 on slot A is SROS VM.

Volume in drive cf3 on slot A is formatted as FAT32

Directory of cf3:\

09/19/2021 06:11p 196 BOF.CFG
09/19/2021 06:11p 0 CONFIG.CFG
09/19/2021 06:11p 101 NVRAM.DAT
09/19/2021 07:22p  SUPPORT/
09/19/2021 06:11p  SYSLINUX/
09/19/2021 06:11p  TIMOS/
09/23/2021 09:03a 27459 bootlog.txt
```


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```
09/20/2021 09:56a 27326 bootlog_prev.txt
09/23/2021 01:21p 319 nvsys.info
09/23/2021 02:42p  recursive1/
09/23/2021 08:22a  ssh/
7 File(s) 55402 bytes.
7 Dir(s) 612311040 bytes free.

A:node-2>file cf3:\ # dir recursive1

Volume in drive cf3 on slot A is SROS VM.

Volume in drive cf3 on slot A is formatted as FAT32

Directory of cf3:\recursive1

09/23/2021 02:42p  ./
09/23/2021 02:42p  ../
09/23/2021 02:42p 7 file1.txt
09/23/2021 02:42p  recursive2/
1 File(s) 7 bytes.
3 Dir(s) 612311040 bytes free.

A:node-2>file cf3:\ # move recursive1 recursive4
Moving file cf3:\recursive1 ... OK
cf3:\recursive1
A:sros>file cf3:\ # dir

Volume in drive cf3 on slot A is SROS VM.

Volume in drive cf3 on slot A is formatted as FAT32

Directory of cf3:\

09/19/2021 06:11p 196 BOF.CFG
09/19/2021 06:11p 0 CONFIG.CFG
09/19/2021 06:11p 101 NVRAM.DAT
09/19/2021 07:22p  SUPPORT/
09/19/2021 06:11p  SYSLINUX/
09/19/2021 06:11p  TIMOS/
09/23/2021 09:03a 27459 bootlog.txt
09/20/2021 09:56a 27326 bootlog_prev.txt
09/23/2021 01:21p 319 nvsys.info
09/23/2021 02:42p  recursive4/
09/23/2021 08:22a  ssh/
7 File(s) 55402 bytes.
7 Dir(s) 612311040 bytes free.

A:node-2>file cf3:\ # dir recursive4

Volume in drive cf3 on slot A is SROS VM.

Volume in drive cf3 on slot A is formatted as FAT32

Directory of cf3:\recursive4

09/23/2021 02:42p  ./
09/23/2021 02:42p  ../
09/23/2021 02:42p 7 file1.txt
09/23/2021 02:42p  recursive2/
1 File(s) 7 bytes.
3 Dir(s) 612311040 bytes free.
```


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2.3.6 Deleting files and removing directories

Use the **delete** and **rd** commands to delete files and remove directories. Directories can be removed even if they contain files or subdirectories. To remove a directory that contains files and subdirectories, use the **rd rf** command. When files or directories are deleted, they cannot be recovered. The **force** option deletes the file or directory without prompting the user to confirm.

Example: Delete files and remove directories

```
A:node2>file cf1:\test1\ # delete test.cfg
A:node-2>file cf1:\test1\ # delete abc.cfg
A:node-2>file cf1:\test1\test2\ # cd test3
A:node-2>file cf1:\test1\test2\test3\ # cd ..
A:node-2>file cf1:\test1\test2\ # rd test3
A:node-2>file cf1:\test1\test2\ # cd ..
A:node-2>file cf1:\test1\ # rd test2
A:node-2>file cf1:\test1\ # cd ..
A:node-2>file cf1:\ # rd test1
A:node-2>file cf1:\ #
```

2.3.7 Unzipping files

Use the **unzip** command to expand the contents of a ZIP file to the local file system. Any file that is zipped using the store, deflate, or zip64 compression methods can be unzipped. An example is the SR OS software image available from the Nokia customer support portal.

The source ZIP file can be located locally on the installed solid-state storage device, or remotely on an FTP or TFTP server.

The **create-destination** keyword ensures that any non-existent directory structure that is explicitly entered as the destination file URL is created as part of the unzip operation.

Note:

- The destination for the unzipped files and directories must be a locally installed solid-state storage device in the active CPM.
- ZIP filenames, or the filenames of any contained files, must not include special characters.

Example: Unzip command

```
A:node-2# file unzip demo.zip cf3:/mynewfolder/mynewsubfolder create-destination force
Verifying cf3:\demo.zip .. ... OK
Unzipping cf3:\demo.zip to cf3:\mynewfolder\mynewsubfolder\ .. .Processing demodir/
Processing demodir/myfile1.txt
Processing demodir/myfile2.txt
Processing demodir/demosubdir/
Processing demodir/demosubdir/myfile3.txt
Writing...OK
```

2.3.8 Managing storage devices

Use the **repair** command to check a storage device for errors and repair any errors found. The device does not need to be administratively disabled.

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Example: Repair command syntax

```
A:node-2# file repair cf3:
Checking drive cf3: on slot A for errors...
Drive cf31: on slot A is OK.
```

Use the **format** command to format a storage device with a new file system without erasing the data. The device must be administratively disabled first.

Example: Format command syntax

```
A:node-2# file shutdown cf1:
A:node-2# file format cf1:
Formatting Drive cf1: on Slot A ...
Drive cf1: on Slot A is formatted
A:node-2# file no shutdown cf1:
```

Use the **secure-erase** command to secure erase and format a storage device with a new file system using the clear sanitization method to sanitize media as defined in IEEE 2883-2022, *IEEE Standard for Sanitizing Storage*. This action may take several minutes to complete depending on the storage device size, because the data is overwritten in one or more passes. The device must be administratively disabled first.

Example: Secure erase command syntax

```
A:node-2# file shutdown cf1:
A:node-2# file secure-erase cf1:
Are you sure you want to secure erase and format drive cf1: (y/n)?y
Secure erasing drive cf2: on slot A - 100% complete ...
Formatting drive cf1: on slot A ...
Drive cf1: is formatted
Drive cf1: is secure erased
```

Note: New system data may be written to a storage devices after it is administratively enabled. Do not administratively enable a storage device unless it is to be reused.

2.3.9 Displaying file checksums

Use the **checksum** command to display file checksums.

Use the **version** command to check the version of an SR OS `.tim` image file.

Example: Checking the version of an SR OS .tim image file

```
A:node-2# file version cpm.tim
TiMOS-C-20.10.R1
Wed Nov 4 09:18:17 PST 2020 by builder in /builds/c/2010B/R1/panos/main/sros

A:node-2# file version cpm.tim check
TiMOS-C-20.10.R1
Wed Nov 4 09:18:17 PST 2020 by builder in /builds/c/2010B/R1/panos/main/sros
Checking file ... OK
```

Use the **checksum** command to display checksums.

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Example: Output of the checksum operation

The following example shows the output of the checksum operation to compute and display a checksum based on the MD5 and SHA256 algorithms for the `cpm.tim` file on `cf3`.

```
A:node-2# file checksum md5 cmp.tim
Checking file cf3:cpm.tim ...
c65699dc05e6e35a2172eaac80485aa2

A:node-2# file checksum sha256 cpm.tim
Checking file cf3:cpm.tim ...
a1a813a696be04906f9faf1df9db0f90a990ff51cb3383099ade21241203bc1c
```

2.4 File management tasks in the MD-CLI

The following sections describe file management tasks that can be performed in the MD-CLI.

For more information about the supported MD-CLI commands, see the *7705 SAR Gen 2 MD-CLI Command Reference Guide*.

When a file system operation is performed that can potentially remove or overwrite a file system entry, a prompt appears to confirm the action. The **force** keyword performs the operation without displaying the confirmation prompt.

All the commands can operate on the local file system with a default of `cf3:`. The following table lists which commands also support remote file operations.

Table 14: File command local and remote file system support in the MD-CLI

Command	local-url	ftp-url	sftp-url	tftp-url	http-url	https-url
change-directory	✓	✓	✓			
checksum	✓	✓	✓	✓		
copy	✓	✓	✓	source only	✓	✓
copy (recursive)	✓	✓	✓			
list	✓	✓	✓			
make-directory	✓	✓	✓			
move	✓	✓	✓		✓	✓
move (recursive)	✓	✓	✓			
permission	✓					
remove	✓	✓	✓		✓	✓

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Command	local-url	ftp-url	sftp-url	tftp-url	http-url	https-url
remove-directory	✓	✓	✓			
show	✓	✓	✓	✓	✓	✓
unzip	✓	✓	✓	source only		
version	✓	✓	✓	✓		

2.4.1 Displaying directory and file information

Use the **list** command to list the files on a file system, with an option to indicate the list order based on the date, name, or size of the files. The **show** command displays the contents of a specified file or multiple files. The **version** command displays the version of an SR OS `.tim` image file.

Example: Display directory and file information

```
[/]
A:admin@node-2# file list

Volume in drive cf3 on slot A is .

Volume in drive cf3 on slot A is formatted as FAT32

Directory of cf3:\

09/01/2020  11:27p      <DIR>          .ssh/
01/01/1980  12:00a                170 NVRAM.DAT
01/01/1980  12:00a                679 bof.cfg
09/01/2020  11:27p                319 nvsys.info
09/01/2020  11:27p                  1 restcntr.txt
09/02/2020  04:32p      <DIR>          tstdir/
               4 File(s)                  1169 bytes.
               2 Dir(s)                      0 bytes free.

[/]
A:admin@node-2# file list size

Volume in drive cf3 on slot A is .

Volume in drive cf3 on slot A is formatted as FAT32

Directory of cf3:\

09/01/2020  11:27p      <DIR>          .ssh/
09/02/2020  04:32p      <DIR>          tstdir/
09/01/2020  11:27p                  1 restcntr.txt
01/01/1980  12:00a                170 NVRAM.DAT
09/01/2020  11:27p                319 nvsys.info
01/01/1980  12:00a                679 bof.cfg
               4 File(s)                  1169 bytes.
               2 Dir(s)                      0 bytes free.

[/]
A:admin@node-2# file show example.cfg
File: example.cfg
-------------------------------------------------------------------------------
```


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```
configure {
    card 1 {
        mda 1 {
        }
    }
    log {
        filter 1001 {
            entry 10 {
                description "Collect only events of major severity or higher"
                action forward
                match {
                    severity {
                        gte major
                    }
                }
            }
        }
        log-id 99 {
            description "Default System Log"
            source {
                main true
--(more)--(5%)--(lines 1-29/464)--

[/]
A:admin@node-2# file version boot.ldr
TiMOS-L-24.10.R1
Thu Oct 31 23:49:01 UTC 2024 by builder in /builds/2410B/R1/panos/main/sros
```

2.4.2 Modifying file attributes

The system administrator can change the attribute of a local file or files in a directory.

Enter the **permission** command with no options to display the contents of the directory and the file attributes.

A single local file can be specified or the wildcard character (*) can be used to indicate multiple files. If no URL is specified, the command applies to all files in the directory.

A file with an "R" preceding the filename indicates the file is read-only; otherwise, the file is read-write.

Example: Modify file attributes

```
[/]
A:admin@node-2# file permission
            cf3:\NVRAM.DAT
            cf3:\bof.cfg
            cf3:\nvsys.info
            cf3:\restcntr.txt
            cf3:\.ssh
            cf3:\my.txt

[/]
A:admin@node-2# file permission read-only my.txt

[/]
A:admin@node-2# file permission
            cf3:\NVRAM.DAT
            cf3:\bof.cfg
            cf3:\nvsys.info
            cf3:\restcntr.txt
            cf3:\.ssh
```


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```
 R          cf3:\my.txt
```

```
[/]
A:admin@node-2# file permission read-only

[/]
A:admin@node-2# file permission
 R          cf3:\NVRAM.DAT
 R          cf3:\bof.cfg
 R          cf3:\nvsys.info
 R          cf3:\restcntr.txt
 R          cf3:\.ssh
 R          cf3:\my.txt
```

2.4.3 Creating and navigating directories

New directories can be created in the local file system, one level at a time.

Use the **make-directory** command to create a new directory.

The **change-directory** command navigates to different directories.

Example: Create and navigate directories

```
[/]
A:admin@node-2# file

[file "cf3:\"]
A:admin@node-2# make-directory test1

[file "cf3:\"]
A:admin@node-2# change-directory test1

[file "cf3:\test1"]
A:admin@node-2# make-directory test2

[file "cf3:\test1"]
A:admin@node-2# change-directory test2

[file "cf3:\test1\test2"]
A:admin@node-2# make-directory test3

[file "cf3:\test1\test2"]
A:admin@node-2# change-directory test3

[file "cf3:\test1\test2\test3"]
A:admin@node-2# change-directory ..

[file "cf3:\test1\test2"]
A:admin@node-2#
```

2.4.4 Copying files

Use the **copy** command to copy files to or from a flash device, or an FTP, TFTP, or SSH server. The **copy** command supports wildcards.

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Use the **recursive** option to recursively copy files and directories. If files or directories already exist, the user is prompted to overwrite them. Use the **force** option to automatically overwrite the existing files or directories, without being prompted for confirmation.

The following example shows how to copy the `config.cfg` file to the `test_dir1` directory.

Example: Local file copy

```
[/]
A:admin@node-2# file list test_dir1

Volume in drive cf3 on slot A is TIMOS_VM_CF.

Volume in drive cf3 on slot A is formatted as FAT32

Directory of cf3:\test_dir1

09/29/2021  05:07p      <DIR>          ./
09/29/2021  05:07p      <DIR>          ../
               0 File(s)                     0 bytes.
               2 Dir(s)               14458880 bytes free.


[/]
A:admin@node-2# file list

Volume in drive cf3 on slot A is TIMOS_VM_CF.

Volume in drive cf3 on slot A is formatted as FAT32

Directory of cf3:\

09/28/2021  11:43a                931 BOF.CFG
09/28/2021  11:43a                165 NVRAM.DAT
09/28/2021  04:34p              11319 bootlog.txt
09/28/2021  03:50p              11259 bootlog_prev.txt
09/29/2021  05:08p              11319 config.cfg
09/28/2021  04:34p                319 nvsys.info
04/16/2014  10:15a      <DIR>          syslinux/
09/29/2021  05:08p      <DIR>          test_dir1/
04/16/2014  10:15a      <DIR>          timos/
               7 File(s)                  35312 bytes.
               3 Dir(s)               14458880 bytes free.


[/]
A:admin@node-2# file copy config.cfg test_dir1
Copying file cf3:\config.cfg ... OK
1 file copied.

[/]
A:admin@node-2# file list test_dir1

Volume in drive cf3 on slot A is TIMOS_VM_CF.

Volume in drive cf3 on slot A is formatted as FAT32

Directory of cf3:\test_dir1

09/29/2021  05:07p      <DIR>          ./
09/29/2021  05:07p      <DIR>          ../
09/29/2021  05:09p              11319 config.cfg
               1 File(s)                  11319 bytes.
```


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```
               2 Dir(s)                14447104 bytes free.
```

The following example shows how to copy the `config.cfg` file to a file on an SSH server.

Example: File copy to an SSH server

```
[/]
A:admin@node-2# file copy cf3:config.cfg scp://user@10.231.216.68:~/
user@10.231.216.68's password:
config.cfg                                    100%  625     0.6KB/s   00:00
```

The following example shows a recursive move of the `recursive4` directory to `recursive5`.

Example: Recursive directory move

```
[/]
A:admin@node-2# file list

Volume in drive cf3 on slot A is SROS VM.

Volume in drive cf3 on slot A is formatted as FAT32

Directory of cf3:\

09/19/2021 06:11p 196 BOF.CFG
09/19/2021 06:11p 0 CONFIG.CFG
09/19/2021 07:22p SUPPORT/
09/23/2021 09:03a 27459 bootlog.txt
09/20/2021 09:56a 27326 bootlog_prev.txt
09/23/2021 01:21p 319 nvsys.info
09/23/2021 02:42p recursive4/
09/23/2021 08:22a ssh/
7 File(s) 55402 bytes.
7 Dir(s) 612311040 bytes free.

[/]
A:admin@node-2# file copy recursive4 recursive5 recursive
Copying directory cf3:\recursive4
Copying directory cf3:\recursive4\recursive2
Copying file cf3:\recursive4\recursive2\file2.txt ... OK
Copying file cf3:\recursive4\recursive2\file3.txt ... OK
Copying file cf3:\recursive4\file1.txt ... OK
2 dir(s) and 3 file(s) copied.
```

2.4.5 Moving files

Files or directories can be moved from one location to another. The **move** command recursively moves files and directories, and overwrites existing content without prompting for confirmation. The **move** command supports wildcards.

The following example moves the `md-config.cfg` file to the `test_dir1` directory.

Example: Moving files and directories

```
[/file "cf3:\"]
A:admin@node-2# list test_dir1

Volume in drive cf3 on slot A is TIMOS_VM_CF.
```


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```
Volume in drive cf3 on slot A is formatted as FAT32

Directory of cf3:\test_dir1

09/29/2021  05:07p      <DIR>          ./
09/29/2021  05:07p      <DIR>          ../
               0 File(s)                     0 bytes.
               2 Dir(s)               14458880 bytes free.


[/file "cf3:\"]
A:admin@node-2# list

Volume in drive cf3 on slot A is TIMOS_VM_CF.

Volume in drive cf3 on slot A is formatted as FAT32

Directory of cf3:\

09/28/2021  11:43a                931 BOF.CFG
09/28/2021  11:43a                165 NVRAM.DAT
09/28/2021  04:34p              11319 bootlog.txt
09/28/2021  03:50p              11259 bootlog_prev.txt
09/29/2021  05:08p              11319 md-config.cfg
09/28/2021  04:34p                319 nvsys.info
04/16/2014  10:15a      <DIR>          syslinux/
09/29/2021  05:09p      <DIR>          test_dir1/
04/16/2014  10:15a      <DIR>          timos/
               7 File(s)                 35312 bytes.
               3 Dir(s)               14458880 bytes free.


[/file "cf3:\"]
A:admin@node-2# move md-config.cfg test_dir1
Moving file cf3:\md-config.cfg ... OK
cf3:\md-config.cfg

[/file "cf3:\"]
A:admin@node-2# list test_dir1

Volume in drive cf3 on slot A is TIMOS_VM_CF.

Volume in drive cf3 on slot A is formatted as FAT32

Directory of cf3:\test_dir1

09/29/2021  05:07p      <DIR>          ./
09/29/2021  05:07p      <DIR>          ../
09/29/2021  05:08p              11319 md-config.cfg
               1 File(s)                 11319 bytes.
               2 Dir(s)               14458880 bytes free.


[/file "cf3:\"]
A:admin@node-2# list

Volume in drive cf3 on slot A is TIMOS_VM_CF.

Volume in drive cf3 on slot A is formatted as FAT32

Directory of cf3:\

09/28/2021  11:43a                931 BOF.CFG
09/28/2021  11:43a                165 NVRAM.DAT
```


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```
09/28/2021  04:34p               11319 bootlog.txt
09/28/2021  03:50p               11259 bootlog_prev.txt
09/28/2021  04:34p                 319 nvsys.info
04/16/2014  10:15a      <DIR>          syslinux/
10/01/2021  04:17p      <DIR>          test_dir1/
04/16/2014  10:15a      <DIR>          timos/
               6 File(s)                 23993 bytes.
               3 Dir(s)               14458880 bytes free.
```

The following example shows a recursive move of the recursive1 directory to recursive3.

Example: Recursive directory move

```
[/file "cf3:\"]
A:admin@node-2# list

Volume in drive cf3 on slot A is SROS VM.

Volume in drive cf3 on slot A is formatted as FAT32

Directory of cf3:\

09/19/2021 06:11p 196 BOF.CFG
09/19/2021 06:11p 0 CONFIG.CFG
09/19/2021 07:22p SUPPORT/
09/20/2021 09:56a 27326 bootlog.txt
09/20/2021 02:55p 319 nvsys.info
09/21/2021 07:19p recursive1/
09/20/2021 09:55a ssh/
6 File(s) 27943 bytes.
6 Dir(s) 612347904 bytes free.

[/file "cf3:\"]
A:admin@node-2# list recursive1

Volume in drive cf3 on slot A is SROS VM.

Volume in drive cf3 on slot A is formatted as FAT32

Directory of cf3:\recursive1
09/21/2021 07:18p ./
09/21/2021 07:18p ../
09/21/2021 07:19p 7 file1.txt
09/21/2021 07:19p recursive2/
1 File(s) 7 bytes.
3 Dir(s) 612347904 bytes free.

[/file "cf3:\"]
A:admin@node-2# list recursive1/recursive2

Volume in drive cf3 on slot A is SROS VM.

Volume in drive cf3 on slot A is formatted as FAT32

Directory of cf3:\recursive1\recursive2

09/21/2021 07:19p ./
09/21/2021 07:19p ../
09/21/2021 07:19p 7 file2.txt
09/21/2021 07:19p 7 file3.txt
2 File(s) 14 bytes.
2 Dir(s) 612347904 bytes free.
```


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```
[/file "cf3:\"]
A:admin@sros# move recursive1 recursive3
Moving file cf3:\recursive1 ... OK
cf3:\recursive1

[/file "cf3:\"]
A:admin@node-2# list

Volume in drive cf3 on slot A is SROS VM.

Volume in drive cf3 on slot A is formatted as FAT32

Directory of cf3:\

09/19/2021 06:11p 196 BOF.CFG
09/19/2021 06:11p 0 CONFIG.CFG
09/19/2021 06:11p 101 NVRAM.DAT
09/19/2021 07:22p SUPPORT/
09/19/2021 06:11p SYSLINUX/
09/19/2021 06:11p TIMOS/
09/20/2021 09:56a 27326 bootlog.txt
09/20/2021 02:55p 319 nvsys.info
09/21/2021 07:19p recursive3/
09/20/2021 09:55a ssh/
6 File(s) 27943 bytes.
6 Dir(s) 612347904 bytes free.

[/file "cf3:\"]
A:admin@node-2# list recursive3

Volume in drive cf3 on slot A is SROS VM.

Volume in drive cf3 on slot A is formatted as FAT32

Directory of cf3:\recursive3

09/21/2021 07:18p ./
09/21/2021 07:18p ../
09/21/2021 07:19p 7 file1.txt
09/21/2021 07:19p recursive2/
1 File(s) 7 bytes.
3 Dir(s) 612347904 bytes free.
```

2.4.6 Deleting files and removing directories

Use the **remove** and **remove-directory** commands to delete files and remove directories. Directories can be removed even if they contain files or subdirectories.

Example: Removing directories

```
[file "cf3:\test1\test2"]
A:admin@node-2# list

Volume in drive cf3 on slot A is TIMOS_VM_CF.

Volume in drive cf3 on slot A is formatted as FAT32

Directory of cf3:\test1\test2

09/01/2020  08:13p      <DIR>          ./
09/01/2020  08:13p      <DIR>          ../
```


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```
09/04/2020  06:36p                 874 bof.cfg
04/28/2020  03:15p               11401 md-config.cfg
09/04/2020  06:43p      <DIR>          test3/
               2 File(s)                 12275 bytes.
               3 Dir(s)               10641920 bytes free.

[file "cf3:\test1\test2"]
A:admin@node-2# list test3

Volume in drive cf3 on slot A is TIMOS_VM_CF.

Volume in drive cf3 on slot A is formatted as FAT32

Directory of cf3:\test1\test2\test3

09/01/2020  08:13p      <DIR>          ./
09/01/2020  08:13p      <DIR>          ../
09/04/2020  06:43p               11788 conf3.cfg
09/04/2020  04:24p                6645 mybof.cfg
               2 File(s)                 18433 bytes.
               2 Dir(s)               10641920 bytes free.

[file "cf3:\test1\test2"]
A:admin@node-2# remove-directory test3 ?

 remove-directory
 force                 - Force removal without prompting
 recursive             - Remove directory and its content recursively

[file "cf3:\test1\test2"]
A:admin@node-2# remove-directory test3 recursive
Deleting all subdirectories and files in specified directory. y/n ?y
Deleting file cf3:\test1\test2\test3\mybof.cfg ... OK
Deleting file cf3:\test1\test2\test3\conf3.cfg ... OK
Deleting directory cf3:\test1\test2\test3 ... OK

[file "cf3:\test1\test2"]
A:admin@node-2# list

Volume in drive cf3 on slot A is TIMOS_VM_CF.

Volume in drive cf3 on slot A is formatted as FAT32

Directory of cf3:\test1\test2

09/01/2020  08:13p      <DIR>          ./
09/01/2020  08:13p      <DIR>          ../
09/04/2020  06:36p                 874 bof.cfg
04/28/2020  03:15p               11401 md-config.cfg
               2 File(s)                 12275 bytes.
               2 Dir(s)               10661376 bytes free.
```

2.4.7 Unzipping files

Use the **unzip** command to expand the contents of a ZIP file to the local file system. Any file zipped using the store, deflate, or zip64 compression methods can be unzipped. An example is the SR OS software image available from the Nokia customer support portal.

The source ZIP file location can be a locally installed solid-state storage device or a remote FTP or TFTP server.

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The **create-destination** keyword ensures that any non-existent directory structure that is explicitly entered as the destination file URL is created as part of the unzip operation. This parameter is required to create new directories.

Note:

- The destination for the unzipped files and directories must be a locally installed solid-state storage device in the active CPM.
- ZIP filenames, or the filenames of any contained files, must not include special characters.

Example: Unzipping a file

```
[/]
A:admin@node-2# file unzip demo.zip cf3:/mynewfolder/mynewsubfolder create-
destination  force
Verifying cf3:\demo.zip .. ... OK
Unzipping cf3:\demo.zip to cf3:\mynewfolder\mynewsubfolder\ .. .Processing demodir/
Processing demodir/myfile1.txt
Processing demodir/myfile2.txt
Processing demodir/demosubdir/
Processing demodir/demosubdir/myfile3.txt
Writing...OK
```

2.4.8 Managing storage devices

Use the **repair** command to check a storage device for errors and repair any errors found. The device does not need to be administratively disabled.

Example: Repair command syntax

```
[/]
A:admin@node-2# file repair cf3:
Checking drive cf3: on slot A for errors...
Drive cf3: on slot A is OK.
```

Use the **format** command to format a storage device with a new file system without erasing the data. The device must be administratively disabled first.

Example: Format command syntax

```
[/]
A:admin@node-2# file disable cflash-id cf1:

[/]
A:admin@node-2# file format cf1:
Formatting Drive cf1: on Slot A ...
Drive cf1: on Slot A is formatted

[/]
A:admin@node-2# file enable cflash-id cf1:
```

Use the **secure-erase** command to secure erase and format a storage device with a new file system using the clear sanitization method to sanitize media as defined in IEEE 2883-2022, *IEEE Standard for Sanitizing Storage*. This action may take several minutes to complete depending on the storage device size, because the data is overwritten in one or more passes. The device must be administratively disabled first.

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Example: Secure erase command syntax

```
[/]
A:admin@node-2# file disable cflash-id cf1:

[/]
A:admin@node-2# file secure-erase cf1:
Are you sure you want to secure erase and format drive cf1: (y/n)?y
Secure erasing drive cf2: on slot A - 100% complete ...
Formatting drive cf1: on slot A ...
Drive cf1: is formatted
Drive cf1: is secure erased
```

Note: New system data may be written to a storage devices after it is administratively enabled. Do not administratively enable a storage device unless it is to be reused.

2.4.9 Displaying file checksums

Use the **checksum** command to display file checksums.

Example: Check a `.tim` image file checksum

The following example shows the output of the operation to check an SR OS `.tim` image file checksum.

```
[/]
A:admin@node-2# file checksum image cpm.tim
TiMOS-C-20.2.R1
Sat Feb 29 10:39:32 PST 2020 by builder in /builds/c/202B/R1/panos/main/sros
Checking file ... OK
```

Example: Output of the checksum operation

The following example shows the output of the checksum operation to compute and display a checksum based on the MD5 and SHA256 algorithms for the `cpm.tim` file on `cf3`.

```
[/]
A:admin@node-2# file checksum md5 cpm.tim
Checking file cf3:cpm.tim
c65699dc05e6e35a2172eaac80485aa2

[/]
A:admin@node-2# file checksum sha256 cpm.tim
Checking file cf3:cpm.tim
a1a813a696be04906f9faf1df9db0f90a990ff51cb3383099ade21241203bc1c
```


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3 System initialization and boot options

This section describes the system initialization and boot option process.

3.1 Boot process

The router startup process begins after a reset or power cycle with the firmware initializing the hardware before executing the Boot Loader images. The Boot Loader then executes the Boot Options File (BOF) to load the SR OS software image and configuration. The BOF file contains system initialization commands including the software image and configuration locations.

SR OS Boot Loader, software images, and configuration files are stored in storage media cards referred to as CF in the system. See Storage devices for more information about the type of storage supported for each platform.

The following diagram shows the system boot process from the firmware up to the SR OS image and configuration file.

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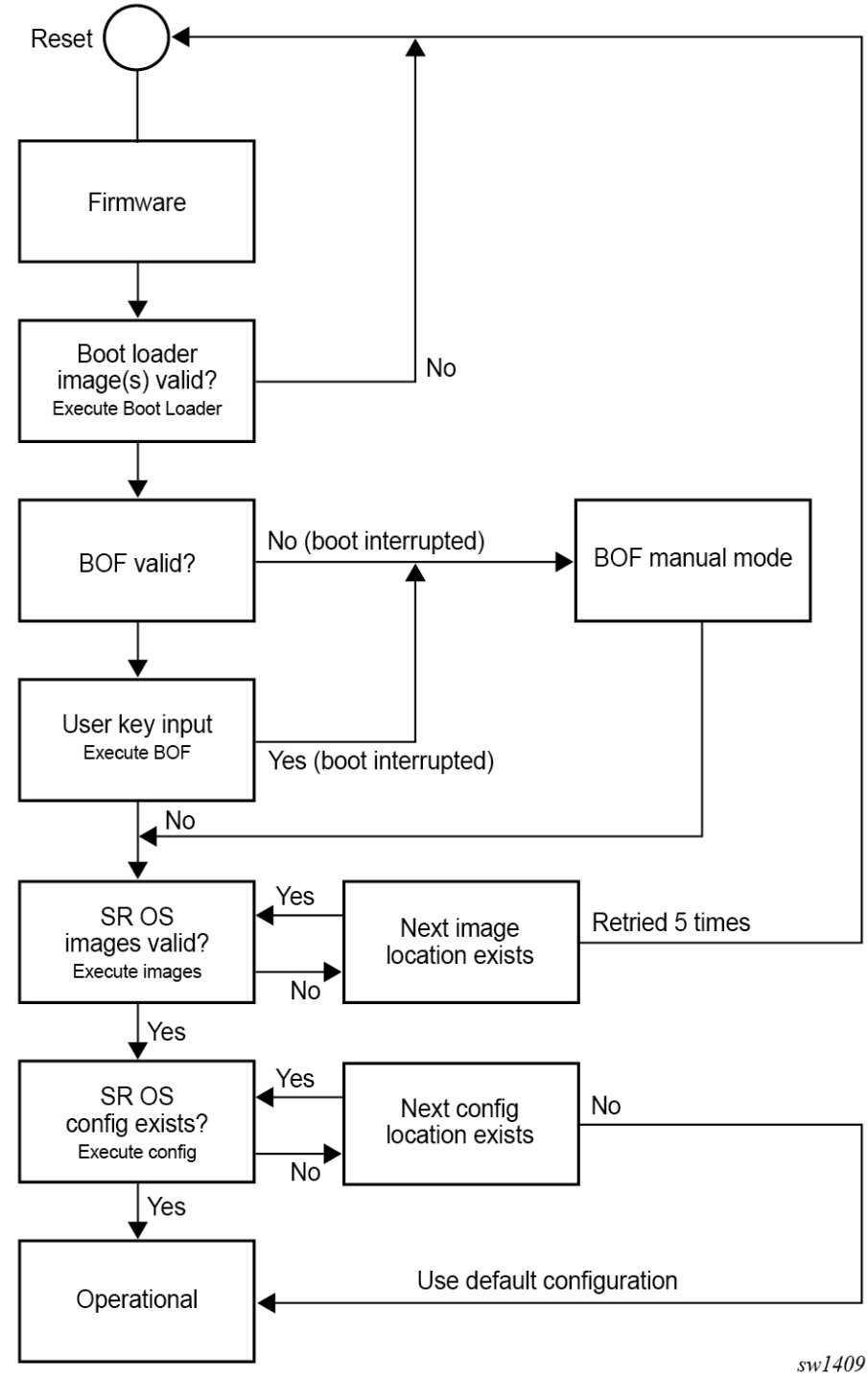
Figure 1: Boot process



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3.2 Boot Loader

The Boot Loader executes the initialization parameters from the BOF to load the software images and configuration file.

The Boot Loader phase can be manually interrupted even if the BOF is present by pressing any key on the console connected to the console port. This is done by typing **sros** and pressing the **Enter** key within 30 seconds to enter the BOF Manual Mode. This mode allows the configuration of the BOF system initialization commands manually and overwrites the existing BOF file if present.

Different Boot Loader images are used depending on the CPM or CPIOM control module:

- 7705 SAR-10x, 7705 SAR-Hx, 7705 SAR-Mx, 7705 SAR-1
  - `bootaa64.efi` is the original Boot Loader image located in `/EFI/B00T`
  - `bootaa64.efi` executes the other images in `/EFI/B00T/aarch64` before executing the BOF file and loading SR OS TiMOS software images and configuration

3.3 Boot Options File

The BOF file (`bof.cfg`) must be located at the root of the cf3: card directory and contains various system initialization commands including:

- management Ethernet port (speed, duplex, IP address, static routes)
- console port speed
- software image locations
- configuration file locations
- BOF and configuration file encryption settings
- BOF password
- system profile
- wait time
- Zero Touch Provisioning
- licenses
- persistency

3.3.1 BOF manual mode

The system enters the BOF manual mode if the BOF is not present on cf3:\ or if the user interrupts the Boot Loader phase and requires access to the console port for configuration.

After the manual BOF configuration is completed and saved, a `bof.cfg` file with the new configured command options is created on cf3:\ and used for subsequent reboots. The Boot Loader image then processes the new BOF command options to boot the system.

This process is described in the following diagram.

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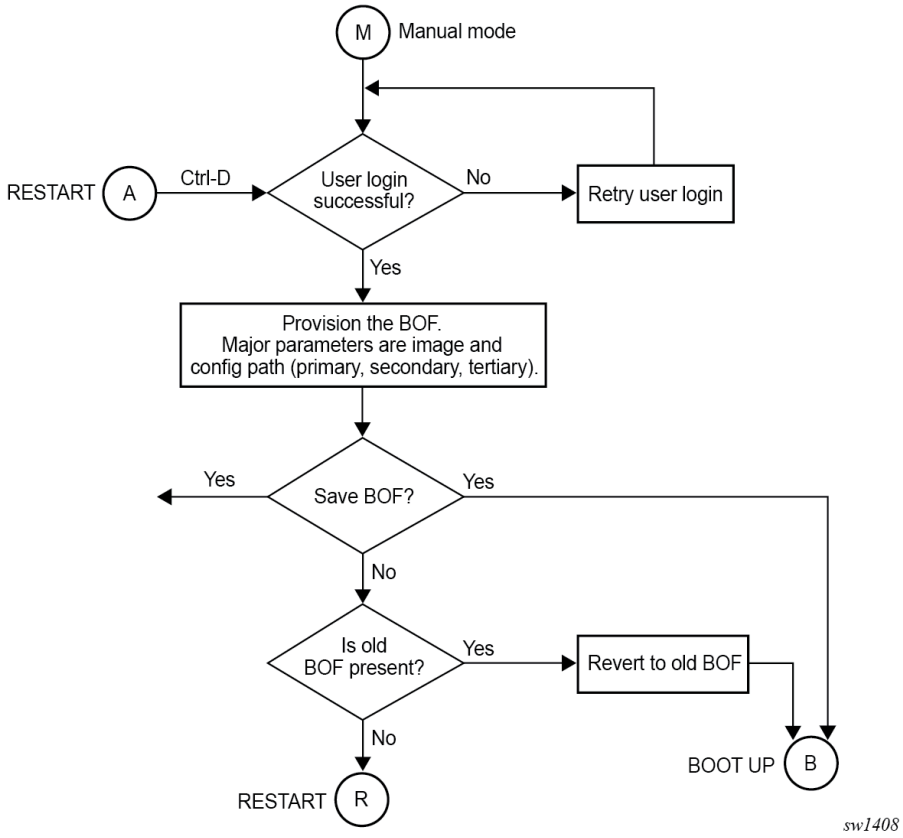
Figure 2: BOF manual mode



3.4 Software and configuration

The software image and configuration file location are configured in the BOF.

Up to three locations, local or remote, can be configured for the software image and configuration file defined as primary image, secondary image, tertiary image, primary config, secondary config and tertiary config in the BOF.

Before loading the configuration, the software first attempts to read the license file if one has been included in the BOF. If a license file is found, it is activated. If there are any issues with the activation, a log event is raised, and the startup processing continues with the reading of the configuration file.

The following usage guidelines apply:

- The primary, secondary, and tertiary image locations must have the same version of software. If the secondary or tertiary image is configured with an older software image, this may result in a failure to load the configuration file as the file may contain commands only applicable to the more recent release.
- Similarly, the secondary and tertiary configuration files, if used, should be saved with the same version of software as the software executed on boot as it can result in a failure to load the configuration file otherwise.

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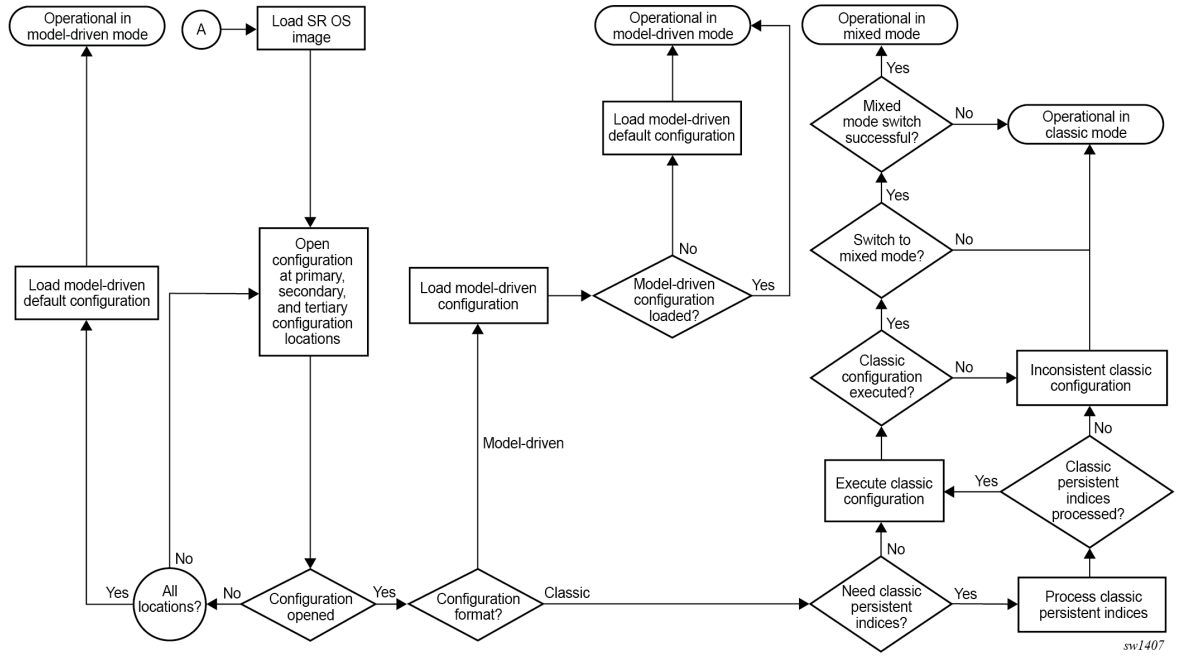
- In the model-driven configuration mode, with incremental saved configuration files enabled, the primary configuration location supports complete and incremental saved configuration files. The secondary and tertiary configuration locations support complete saved configuration files. The user must ensure that complete saved configuration files are stored at both locations.

The following diagram provides additional details on the boot process differences between classic and MD-CLI configuration file processing.

Figure 3: Load SR OS configuration



3.4.1 Management interface configuration modes

The system can operate in different management interface configuration modes, which affect the CLI and network management protocols that can be used to configure the system. When the system boots and loads the configuration file, the configuration mode is set as follows:

- The default configuration mode is **model-driven** and a model-driven configuration file format is loaded. The value of **configure system management-interface configuration-mode** in the configuration file must not be **classic** or **mixed**.
- If the configuration file has **exit all** as the first executable line, the configuration mode is set to **classic** and a classic configuration file format is loaded. Lines beginning with a number sign character (#) are ignored.
  - The configuration mode may be changed to **mixed** if the value of **configure system management-interface configuration-mode** is **mixed** in the configuration file.
  - The value of **configure system management-interface configuration-mode** in the configuration file must not be **model-driven**.

See "Management interface configuration modes" in the *7705 SAR Gen 2 System Management Guide* for more information.

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3.5 Initial installation and software update

SR OS is preinstalled on 7705 SAR Gen 2 systems from Nokia. The user is not required to perform initial software installation.

The 7705 SAR Gen 2 boot files are released by Nokia in a cflash package. When upgrading or changing software, the boot files must be placed in the root of cf3:\. The BOF primary location must be configured to to the location of the boot files.

3.6 USB recovery boot

Prerequisites

- USB drive installed in cf:2\ containing the cflash package from Nokia that includes the boot files for the desired SR OS software release. The cflash package must be extracted and placed in the root of the USB drive. The files are preconfigured by Nokia to use the correct boot settings and should not be modified for the recovery procedure.

WARNING: The USB recovery procedure erases the contents of the eMMC or SD card. Nokia recommends creating a backup of the eMMC or SD card contents, if possible, to prevent data loss.

About this task

The 7705 SAR Gen 2 supports a boot recovery procedure using the USB drive installed on cf2:\. This procedure should be used only if the eMMC or SD card on cf3:\ becomes corrupt and the system fails to boot.

Perform the following steps to recover the eMMC or SD card to a bootable state.

Procedure

Step 1. Power on the system.

Step 2. On the boot screen, press the Up arrow key to enter the Recovery menu when the screen displays the following message: `Autoboot in # seconds`.

Example

```
Booting /MemoryMapped(0xa0000000, 0x199000)

Boot rom version is v72
Nokia 7xxx Boot ROM. Copyright 2020-2025 Nokia
All rights reserved. All use is subject to applicable license agreements.
X-0.0.18017 on Sat Feb 1 02:15:28 UTC 2025 by builder

INFO: Board type 0x24 [xxxxx_r3]
Autoboot in 3 seconds
```

Step 3. In the Recovery Menu, enter `1` to select the `Recover using USB(cf2)` option.

Example

```
------------------------------
Recovery Menu:
```


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```
-----------------------------
1. Recover using USB(cf2)
2. Exit

Enter valid recovery drive option: 1
```

Step 4. Enter Y to confirm the recovery process.

Example

eMMC

```
-----------------------------
Recovery Menu:
-----------------------------
1. Recover using USB(cf2)
2. Exit

Enter valid recovery drive option: 1

[WARNING]: eMMC(cf3) will be erased during recovery. Ensure to have a backup before
 proceeding.
Continue to recover eMMC(cf3) using USB(cf2) - y/ [N] ? y
```

Example

SD card

```
-----------------------------
Recovery Menu:
-----------------------------
1. Recover using USB(cf2)
2. Exit

Enter valid recovery drive option: 1

[WARNING]: SDCard(cf3) will be erased during recovery. Ensure to have a backup before
 proceeding.
Continue to recover SDCard(cf3) using USB(cf2) - y/[N] ? y
```

Expected outcome

Upon user confirmation in step 4, the system reformats the eMMC or SD card using the files from the USB drive, then initiates the boot process.

3.7 Storage card content

SR OS software downloaded from the Nokia support website includes boot and operating system images for all platforms. This section describes the required storage media card directory and filenames on a per-platform basis to clarify which files and directory apply to which platform.

On the 7705 SAR-10x, 7705 SAR-Hx, and 7705 SAR-Mx, the primary copy of SR OS is located on the SD card on cf3:\.

On the 7705 SAR-1, the primary copy of the SR OS software is located on the eMMC on cf3:\.

Configurations and executable images can be stored in any storage media supported by the platform while the boot loader images, and boot option file must be installed in the cf3:\ storage device.

See the Storage devices section for the list of storage media names, locations, and support.

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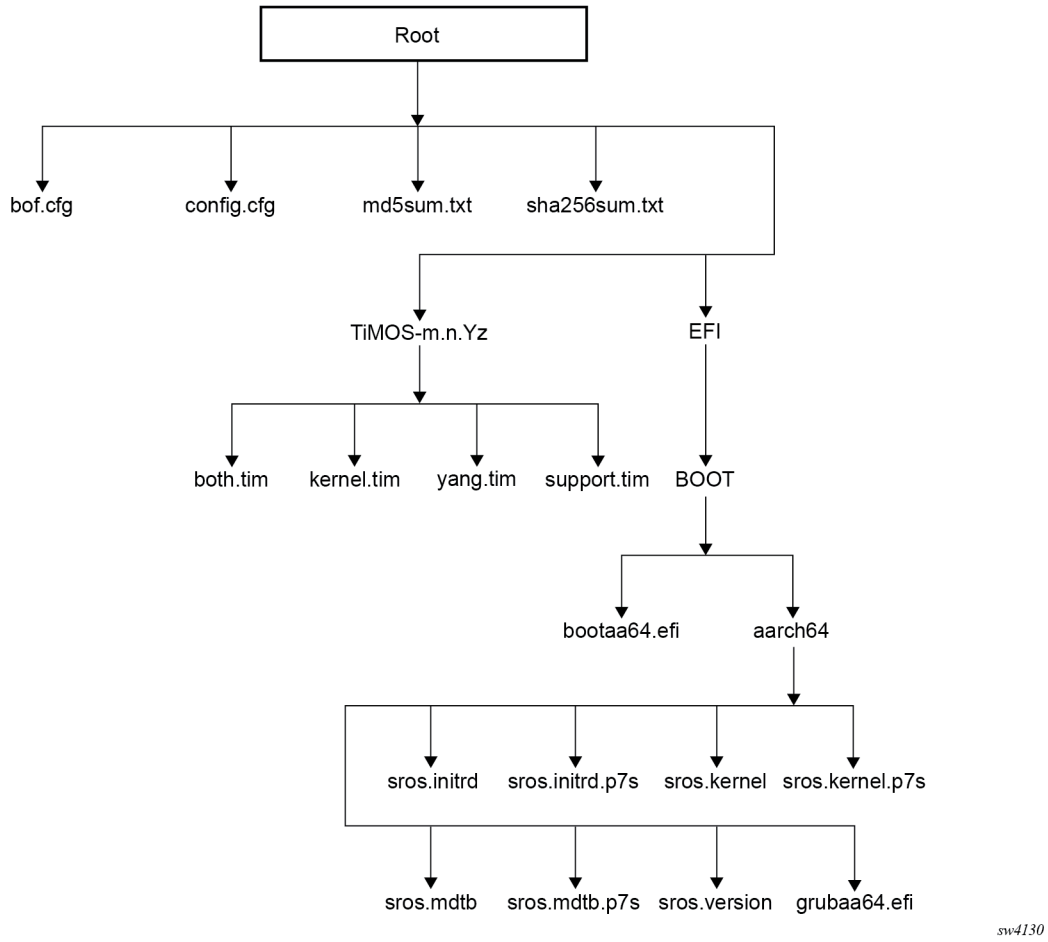
3.7.1 7705 SAR-10x, 7705 SAR-Hx, 7705 SAR-Mx, and 7705 SAR-1 storage card content

When installing a new storage media card into the system for the first time, ensure that the media card contains only the software files shipped by Nokia.

The following figure shows the required storage media card directory structure and filenames.

Figure 4: Files on storage card — 7705 SAR-10x, 7705 SAR-Hx, 7705 SAR-Mx, and 7705 SAR-1



The following files are present on the storage media card:

- `bof.cfg` – boot option file
- `config.cfg` – default configuration file
- `md5sum.txt` – MD5 checksum file
- `sha256sum.txt` – SHA256 checksum file
- TiMOS-m.n.Yz:

  m – signifies a major release number

  n – signifies a minor release number

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Y: A signifies an alpha release

B – signifies a beta release

M – signifies a maintenance release

R – signifies a released software

z – signifies a version number

- `both.tim` – CPM and IOM image file
- `kernel.tim` – host operating system
- `support.tim` – required data for SR OS `.tim` files
- `yang.tim` – YANG model library

The following files and folder structure under `/EFI` should only be included if the system is booted with a new storage media card installed for the first time:

- EFI:
  - BOOT:
    - `bootaa64.efi` – EFI file; Boot Loader
    - aarch64
      - `sros.mdtb` - device tree blob
      - `sros.initrd` – OS installer file; installer rootfs
      - `sros.kernel` – OS installer file; installer kernel
      - `sros.version` – OS installer file; installer version
      - `grubaa64.efi` – EFI file; GRUB boot loader
      - `sros.kernel.p7s` - OS installer file; installer kernel digital signature
      - `sros.initrd.p7s` - OS installer file; installer rootfs digital signature
      - `sros.mdtb.p7s` - device tree blob digital signature

3.8 Persistent indexes in classic and mixed configuration mode

The BOF **persist** command option specifies whether the system should preserve system indexes when the configuration is saved. During a subsequent boot, the index file is read along with the configuration file. As a result, a number of system indexes are preserved between reboots, including the SNMP interface index, LSP IDs, path IDs, and so on. If persistence is not required and the configuration file is successfully processed, the system becomes operational. If persist is required, a matching `config.ndx` file must be successfully processed before the system can become operational. Configuration and index files must have the same filename prefix such as `config.cfg` and `config.ndx` and are created at the same time when an **admin save** command is executed. Note that the persistence option must be enabled to deploy a Network Management System (NMS) using SNMP. The default is off.

Note: System indexes in model-driven configuration mode are always persistent.

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3.9 BOF and configuration file encryption

In cases where the platform is not installed in a physically secure location, the user can encrypt the BOF and the configuration file to halt or hinder interpretation of the file content.

By default, the BOF and configuration files are not encrypted. When encryption is enabled for either file and a change is saved , the original file is moved to *filename*.1 and the encrypted file becomes the new *filename*.cfg.

Caution: The first time a file is encrypted and the original file is moved to *filename*.1, the *filename*.1 file is unencrypted. Delete the unencrypted file to maintain node security.

When the BOF is encrypted on the Compact Flash, the BOF interactive menu can be used during node startup to access the file and modify BOF fields. To prevent unauthorized modification of the BOF using the BOF interactive menu, configure a password using the following command:

- **MD-CLI**

```
bof configuration password
```

- **classic CLI**

```
bof password
```

The BOF interactive menu is accessible only when the configured password is entered. If the correct password is not entered in 30 seconds, the node reboots.

See Configuring BOF encryption for information about configuring BOF encryption. See Configuring the BOF interactive menu password for information about configuring the BOF interactive menu password. See Configuring configuration file encryption for information about configuring configuration file encryption.

3.10 System profiles

System profiles provide flexibility when using line cards by supporting different system capabilities. The system profile is defined in the BOF and is used by the system when it is next rebooted.

The following system profiles are supported on 7705 SAR Gen 2 platforms:

- **profile none**

  This profile represents the existing system capabilities. This profile is indicated by the omission of the profile parameter in the BOF.

- **profile A**

  This profile is intended for generic deployment scenarios, IP forwarding and MPLS switching use-cases.

- **profile B**

  This profile is intended for applications requiring high packet manipulation and processing (for example, NAT and IPsec).

Note: The 7705 SAR-10x supports system profile A only.

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Use the following command to configure the profile:

- **MD-CLI**

```
bof system profile
```

- **classic CLI**

```
bof system-profile
```

When changing between system profiles, it is mandatory to remove all configuration commands for features that are not supported in the target system profile before rebooting the system, otherwise the reboot fails at the unsupported configuration command on startup.

On the 7705 SAR Gen 2, the following conditions apply about the profile parameter:

- The default system profile is **none** when the parameter is omitted.
- The parameter can be configured to either **profile-a** or **profile-b**.
- If the parameter is configured to an invalid value, it is ignored and profile **none** is used by the system.

Use the following command to display the BOF system profile:

- **MD-CLI**

```
admin show configuration bof | match profile
```

- **classic CLI**

```
show bof | match system-profile
```

The BOF system profile used by the system when it booted can be seen in the boot messages (using the **show boot-messages** command), which display the BOF read when rebooting.

Use the following command to display the system profile that is in use on the system.

```
show chassis | match "System Profile"
```

3.11 Configuring the Boot Options File with CLI

This section provides information about configuring BOF parameters with CLI.

3.11.1 Basic BOF configuration

The parameters which specify the location of the image filename that the router tries to boot from and the configuration file are in the BOF.

The most basic BOF configuration should include the following:

- primary address
- primary image location
- primary configuration location

The following is an example of a basic BOF configuration.

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Example: MD-CLI

```
[]
A:admin@node-2# admin show configuration bof
# TiMOS-B-22.2.R1 both/x86_64 Nokia 7705 SAR Copyright (c) 2000-2022 Nokia.
# All rights reserved. All use subject to applicable license agreements.
# Built on Sat Feb 26 15:31:00 PST 2022 by builder in /builds/c/222B/R1/panos/main/sros
# Configuration format version 22.2 revision 0

# Generated 2022-03-07T17:08:41.4+00:00 by admin from Console

bof {
    configuration {
        primary-location "cf3:\config.cfg"
    }
    console {
        speed 115200
    }
    dns {
        domain "example.com"
        primary-server 10.251.72.68
        secondary-server 10.251.10.29
    }
    image {
        primary-location "cf3:\timos\"
    }
    li {
        local-save false
        separate false
    }
    license {
        primary-location "cf3:\license.txt"
    }
    port "management" {
        autonegotiate true
    }
    router "management" {
        interface "management" {
            cpm active {
                ipv4 {
                    ip-address 192.168.189.52
                    prefix-length 24
                }
            }
            cpm standby {
            }
        }
        static-routes {
            route 192.168.0.0/16 {
                next-hop 192.168.189.1
            }
            route 172.16.0.0/16 {
                next-hop 192.168.189.1
            }

        }
    }
    system {
        fips-140 false
        persistent-indices true
    }
}
```


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```
# Finished 2022-03-07T17:09:40.4+00:00
```

Example: classic CLI

```
A:node-2# show bof
===============================================================================
BOF (Memory)
===============================================================================
    primary-image    ftp://*:*@192.168.15.1/./images/
    primary-config   ftp://*:*@192.168.15.1/./images/dut-a.cfg
    address          192.168.189.53/16 active
    address          192.168.189.54/16 standby
    static-route     192.0.2.0/24 next-hop 192.0.2.254
    static-route     192.168.0.0/16 next-hop 192.0.2.254
    static-route     192.168.10.10/16 next-hop 192.0.2.254
    autonegotiate
    duplex           full
    speed            100
    wait             3
    persist          off
    console-speed    115200
===============================================================================
```

3.11.2 Common configuration tasks

This sections describes basic system tasks that must be performed to configure BOF.

For more information about hardware installation and initial router connections, see the specific hardware installation guide.

3.11.2.1 Searching for the BOF

The BOF should be on the same drive (`cf3:`) as the bootstrap image file. If the system cannot load or cannot find the BOF, the system checks whether the boot sequence was manually interrupted.

3.11.2.2 Accessing the CLI

To access the CLI to configure the software for the first time, perform the following steps:

- When the power to the chassis is turned on, the SR OS software automatically begins the boot sequence.
- When the boot loader and BOF image and configuration files are successfully located, establish a router connection (console session).

3.11.2.3 Console connection

To establish a console connection, you need the following:

- a ASCII terminal or a PC running terminal emulation software set to the parameters shown in the following table
- a standard serial cable connector for connecting to an RS232 port (provides an RJ-45 connector)

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Table 15: Console configuration parameter values

Parameter	Value
Baud rate	115200
Data bits	8
Parity	None
Stop bits	1
Flow control	None

3.11.2.4 Configuring BOF encryption

The BOF contents can be encrypted using AES-256.

Use the following command to enable BOF encryption:

- **MD-CLI**

```
bof configuration encrypt
```

- **classic CLI**

```
bof encrypt
```

3.11.2.5 Configuring the BOF interactive menu password

Access to the BOF interactive menu can be controlled using a password.

Use the following command to configure a BOF interactive menu password:

- **MD-CLI**

```
bof configuration password
```

- **classic CLI**

```
bof password
```

3.11.2.6 Configuring configuration file encryption

The configuration file contents can be encrypted using AES-256.

Use the following command to configure a configuration file encryption key:

- **MD-CLI**

```
bof configuration encryption-key
```


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- **classic CLI**

```
bof encryption-key
```

Caution: The **admin save** command must be executed after changing configuration file encryption keys to ensure that a complete saved configuration file is saved with the new encryption key. After changing the encryption key, previously saved configuration files are no longer readable or loadable with the following command:

- **MD-CLI**

```
rollback
```

- **classic CLI**

```
admin rollback
```

Caution: Previously saved unencrypted configuration files, including incremental saved configuration files, are not automatically removed and must be removed manually.

3.11.3 Autoconfigure

When autoconfigure is enabled, the router performs a DHCP discovery or solicit (IPv6) to get the IP address of the out-of-band (OOB) management port.

The OOB management port can support a DHCP client for IPv4, IPv6, or dual stack. For dual stack, both IPv4 and IPv6 DHCP are configured. When the offer for either of the address families arrives, the management port is configured with the IP address in the offer. Eventually, both offers arrive and the management port is configured with both address families.

When a DHCP client is configured using autoconfigure, all image and license files should be placed and loaded from the CF. The configuration file could be loaded from the network, but Nokia recommends that the config file be on the CF as well. The configuration file is not loaded until the DHCP client offer is received and programmed successfully for the management port IP address, or the DHCP client timeout is expired.

3.11.3.1 Autoconfigure restrictions

When autoconfigure is enabled, a static IP address or static route cannot be configured in the BOF.

Similarly, a DNS server cannot be configured in the BOF, and only the DNS server provided by the DHCP offer can be used to resolve URLs.

The option 15 DNS domain name is not supported. The user can configure the DNS domain in the BOF so that the domain is not blocked when autoconfigure is used. Otherwise, the user must use the absolute URL with the hostname and domain included.

3.11.3.2 DHCP discovery of MAC addresses

When autoconfigure is used on redundant CPM chassis, the DHCP discovery uses the chassis MAC address. Only the active CPM performs a DHCP discovery and not the inactive CPM. When the offer

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arrives, the node uses that IP and the chassis MAC as addresses for management. Consequently, the inactive CPM is not reachable by the network, because it has no separate IP address. On activity switch, the inactive CPM inherits the active IP and chassis MAC.

For non-redundant CPMs, the management port MAC is used.

Note: The router must be rebooted when enabling autoconfigure for the first time to ensure that the CPM card uses the chassis MAC address.

3.11.3.3 IPv6 DUID

The SR OS supports type 2 DUID (link local), which is set to the chassis serial number. Type 3 (enterprise) is set to the chassis MAC address. Type 1 is not supported.

For type 2 DUID, the SR OS sends the Nokia Enterprise ID as the second byte of the DUID, followed by the chassis serial number. The first byte is the DUID type code. The chassis serial number starts with capital ASCII letters, which ensures that the serial number is unique as an application ID in the SR OS IPv6 DHCP application domain.

DUID type codes are as follows:

- DHCP6C_DUID_ENT_ID__IPSEC_IPV4ADDR - 1
- DHCP6C_DUID_ENT_ID__IPSEC_ASN1DN - 2
- DHCP6C_DUID_ENT_ID__IPSEC_FQDN - 3
- DHCP6C_DUID_ENT_ID__IPSEC_USER_FQDN - 4
- DHCP6C_DUID_ENT_ID__IPSEC_IPV6ADDR - 5
- DHCP6C_DUID_ENT_ID__IPSEC_ASN1GN - 6
- DHCP6C_DUID_ENT_ID__IPSEC_KEYID - 7
- DHCP6C_DUID_ENT_ID__WLAN_GW - 8
- DHCP6C_DUID_ENT_ID__AUTOBOOT - 9
- DHCP6C_DUID_ENT_ID__ZTP_BOF_AUTOP - Capital letters in ASCII

3.11.3.4 IPv6 DHCP RAs

An IPv6 DHCP offer does not have an IP prefix within the offer, unlike an IPv4 DHCP offer. The IPv6 prefix is usually obtained from the IPv6 Route Advertisement (RA) arriving from the upstream router. For ZTP, the SR OS is a host and assigns a /128 prefix to the IPv6 address obtained from the DHCP offer. In addition, the SR OS supports the installation of IPv6 default and static routes from upstream routers using the IPv6 RA. Multiple upstream routers can respond to a route solicitation with their own RA. The SR OS installs all the routes advertised by the RA. If the same route is advertised by multiple upstream routers (next hops), the SR OS installs the route with the highest preference. The SR OS does not support ECMP when the same route is advertised from multiple next hops by multiple RAs.

To ensure that all the RAs are obtained before the auto-provisioning process is started for IPv6, the SR OS follows the RFC 4861 recommendation that the host (in this case, the SR OS) send a minimum of three route solicitations. This is to ensure that if a route solicitation is lost, at least one of the three would reach the upstream routers. Each route solicitation is followed by a 4 s timeout. If the first route solicitation is sent at T0, the second is sent at T0+4 s and the third is sent at T0+8 s. The upstream routers must respond to

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the route solicitation within 0.5 s. This means that the SR OS has all of the RAs and the routes within 8.5 s of the first route solicitation. Therefore, the SR OS waits for a maximum of 9 s to receive all RAs.

If the DHCPv6 timeout is less than 9 s, the DHCPv6 timeout is honored even for the RA wait time. If the node has received a single RA and DHCP offer, the process is considered a success. However, it is possible that not all the RAs have arrived on the node because the node has waited less than 9 s.

3.11.4 Service management tasks

This section describes the service management tasks and the system administration commands.

3.11.4.1 System management commands in the classic CLI

For more information about the supported classic CLI commands, see the *7705 SAR Gen 2 Classic CLI Command Reference Guide*.

Use the following administrative commands to perform management tasks.

```
admin display-config
admin reboot
admin save
```

3.11.4.1.1 Viewing the current configuration

Use the following command to display the current configuration. The **detail** option displays all default values. The **index** option applies to the classic CLI and displays only the persistent indexes.

```
admin display-config
```

Use the following command to display context-level information.

```
info detail
```

The following example shows a configuration file for the 7705 SAR Gen 2.

Example

```
# TiMOS-B-25.3.R1.I8049 both/x86_64 Nokia 7705 SAR Gen 2 Copyright (c) 2000-2025 Nokia.
# All rights reserved. All use subject to applicable license agreements.
# Built on Mon Mar 3 02:15:04 UTC 2025 by builder in /builds/00/I8049/panos/main/srux
# Configuration format version 25.3 revision 0

# Generated Fri Mar 14 22:33:00 2025 UTC

exit all
configure
#--------------------------------------------------
echo "System Configuration"
#--------------------------------------------------
    system
        name "7705-1"
        config-backup 5
        boot-good-exec "ftp://test.*.*.*/./images/env.cfg"
        switchover-exec "ftp://test.*.*.*/./images/env.cfg"
```


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```
        management-interface
            cli
                md-cli
                    no auto-config-save
                exit
            exit
            yang-modules
                no nokia-combined-modules
                nokia-submodules
            exit
        exit
        netconf
            no auto-config-save
        exit
        time
            ntp
                no shutdown
            exit
            sntp
                shutdown
            exit
            zone UTC
        exit
    exit
...
#--------------------------------------------------
echo "System Configuration Mode Configuration"
#--------------------------------------------------
    system
        management-interface
            configuration-mode mixed
        exit
    exit

exit all

# Finished Fri Mar 14 22:33:04 2025 UTC
```

3.11.4.1.2 Modifying and saving a configuration

If you modify a configuration file, the changes remain in effect only during the current power cycle unless a **save** command is executed. Changes are lost if the system is powered down or the router is rebooted without saving:

- Specify the file URL location to save the running configuration. If a destination is not specified, the files are saved to the location where the files were found for that boot sequence. The same configuration can be saved with different filenames to the same location or to different locations.
- The **detail** option adds the default parameters to the saved configuration.
- The **index** option forces a save of the index file.
- Changing the active and standby addresses without reboot standby CPM may cause a boot-env sync to fail.

Example: Saving the BOF configuration

```
A:node-2# bof save
Writing configuration to cf3:/bof.cfg ... OK
Completed.
```


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Example: Saving the system configuration

```
A:node-2# admin save
Writing configuration to cf3:/config.cfg
Saving configuration ... OK
Completed.
```

Note: If the **persist** option is enabled and the **admin save** command is executed with an FTP path used as the file URL, two FTP sessions simultaneously open to the FTP server. The FTP server must be configured to allow multiple sessions from the same login; otherwise, the configuration and index files will not be saved correctly.

3.11.4.1.3 Deleting BOF parameters

You can delete specific BOF parameters. The changes remain in effect only during the current power cycle unless a **save** command is executed. Changes are lost if the system is powered down or the router is rebooted without saving.

Deleting a BOF address entry is not allowed from a remote session.

Use the **no** form of following commands to remove and save BOF configuration parameters.

```
bof address <ip-prefix/ip-prefix-length> [<cpm>]
bof autonegotiate
bof console-speed <baud-rate>
bof dns-domain <dns-name>
bof duplex <duplex>
bof ip-mtu <octets>
bof li-local-save
bof li-separate
bof license-file <file-url>
bof persist {on|off}
bof primary-config <file-url>
bof primary-dns <ip-address>
bof primary-image <file-url>
bof secondary-config <file-url>
bof secondary-dns <ip-address>
bof secondary-image <file-url>
bof speed <speed>
bof static-route <ip-prefix/ip-prefix-length> next-hop <ip-address>
bof system-base-mac <mac-address>
bof system-profile <profile>
bof tertiary-config <file-url>
bof tertiary-dns <ip-address>
bof tertiary-image <file-url>
bof wait <seconds>
```

Example: Saving BOF configuration parameters

```
A:node-2# bof save
Writing configuration to cf3:/bof.cfg ... OK
Completed.
```


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3.11.4.1.4 Saving a configuration to a different filename

Save the current configuration with a unique filename to have additional backup copies and to edit parameters with a text editor. You can save your current configuration to an ASCII file.

The following example shows saving a configuration to a different location.

Example: Using the admin save command

```
A:node-2>admin save cf3:\testABC.cfg
Writing configuration to cf3:\testABC.cfg
Saving configuration ... OK
Completed.
```

3.11.4.1.5 Rebooting

When an **admin**>**reboot** command is issued, routers with redundant CPM are rebooted as well as the XMAs, XCMs, and IOMs. Changes are lost unless the configuration is saved. Use the **admin**>**save** *file-url* command to save the current configuration. If no command line options are specified, the user is prompted to confirm the reboot operation.

The following example shows a reboot.

Example

```
A:node-2>admin# reboot
Are you sure you want to reboot (y/n)? y
```

3.11.4.1.6 Setting the MTU value for the management port

You can configure the MTU for IP packets transmitted out the interface of the management router instance associated with the management port. The command applies to the SR OS, however, it does not necessarily apply during the boot loader processing.

The operational MTU for the port is set to the lesser of the values configured with the **ip-mtu** command and the management port MTU. For example, with the port MTU fixed at 1514 bytes and an Ethernet header size of 14 bytes, the MTU of the management port is 1500 bytes (the default operational IP MTU).

If the interface supports IPv6 packets, the command value must be set to 1280 or higher, in accordance with RFC 2460, *Internet Protocol, Version 6 (IPv6) Specification*. Use the following command to configure the MTU for IP packets transmitted out the interface of the management router instance.

```
bof ip-mtu
```

3.11.4.2 System management commands in the MD-CLI

For more information about the supported MD-CLI commands, see the *7705 SAR Gen 2 MD-CLI Command Reference Guide*.

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Use the following administrative commands to perform management tasks.

```
admin show configuration
admin reboot
admin save
```

3.11.4.2.1 Viewing the current configuration

The **admin show configuration** command displays the current configuration for a specified configuration region (the default region is **configure**). The **booted** and **cflash-id** options are valid only for the **bof** configuration region.

Example: Detailed show output of BOF configuration file

The following example shows a BOF configuration file with the **detail** option to display all default and unconfigured values and the **units** option to show units where applicable.

```
A:admin@node-2# admin show configuration bof units detail
# TiMOS-B-22.10.R1 both/x86_64 Nokia 7705 SAR Copyright (c) 2000-2022 Nokia.
# All rights reserved. All use subject to applicable license agreements.
# Built on Sun Oct 30 14:49:55 PDT 2022 by builder in /builds/c/2210B/R1/panos/main/sros
# Configuration format version 22.10 revision 0
# Generated 2023-01-12T16:57:57.6-05:00 by admin from Console

bof {
    configuration {
        primary-location "cf3:\config.cfg"
     ## secondary-location
     ## tertiary-location
    }
    console {
        speed 115200 bps
        wait-time 3 seconds
    }
    dns {
     ## domain
     ## primary-server
     ## secondary-server
     ## tertiary-server
    }
    image {
        primary-location "cf3:\timos\"
     ## secondary-location
     ## tertiary-location
    }
    li {
        local-save false
        separate false
    }
    license {
        primary-location "cf3:\license.txt"
    }
    port "management" {
        autonegotiate true
        duplex full
        speed 100 megabps
    }
    router "management" {
        interface "management" {
         ## ip-mtu
```


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```
            cpm active {
                ipv4 {
                    ip-address 192.168.189.52
                    prefix-length 24
                }
             ## ipv6
            }
            cpm standby {
             ## ipv4
             ## ipv6
            }
        }
        static-routes {
            route 192.168.0.0/16 {
                next-hop 192.168.189.1
            }
            route 172.16.0.0/16 {
                next-hop 192.168.189.1
            }
        }
    }
    system {
     ## base-mac-address
        fips-140 false
     ## gateway-role
        persistent-indices true
     ## profile
    }
}
# Finished 2023-01-12T16:57:57.6-05:00
```

3.11.4.2.2 Modifying BOF parameters

BOF parameters can be modified via a BOF session in exclusive, private, or read-only configuration mode in the MD-CLI. The same configuration management commands that are available in the configure region are available in the bof region.

Note: Changing the active and standby addresses without rebooting the standby CPM may cause synchronization with the **boot-env** option to fail.
Deleting a BOF address entry is not allowed from a remote session.

Example

```
[/]
A:admin@node-2# bof exclusive
INFO: CLI #2060: Entering exclusive configuration mode
INFO: CLI #2061: Uncommitted changes are discarded on configuration mode exit

[ex:/bof]
A:admin@node-2# ?

 configuration         + Enter the configuration context
 console               + Enter the console context
 dns                   + Enter the dns context
 image                 + Enter the image context
 li                    + Enter the li context
 license               + Enter the license context
 port                  + Enter the port list instance
 router                + Enter the router list instance
```


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```
 system                + Enter the system context
```

See the *7705 SAR Gen 2 MD-CLI Command Reference Guide* and the *7705 SAR Gen 2 MD-CLI User Guide* for more information.

3.11.4.2.3 Saving a configuration

Configuration changes are lost if the system is powered down or the router is rebooted before the changes are saved. If the URL location to save the running configuration is not specified, the files are saved to the location where the files were found for the boot sequence. The same configuration can be saved with different filenames to the same location or to different locations.

Changing the active and standby addresses without rebooting the standby CPM may cause synchronization with the **boot-env** option to fail.

The following command saves the running configuration for the configure region. If no URL is specified, the configuration is saved to the `config.cfg` file.

```
admin save
```

Example: Configuration save output

```
[admin]
A:admin@node-2# save
Writing configuration to cf3:\config.cfg
Saving configuration OK
Completed.
```

The BOF configuration is saved to `cf3:\bof.cfg` with every **commit** command.

Example

The BOF configuration can be manually saved to a backup file on a server or to a different location, as shown in the following example.

```
[]
A:admin@node-2# admin save bof ftp://10.9.236.68/backup/node-2/bof.cfg
Writing configuration to ftp://10.9.236.68/backup/node-2/bof.cfg OK
Completed.
```

Example

The following example saves the BOF configuration to a file, named `testbof.cfg` on `cf3:`.

```
[]
A:admin@node-2# admin save bof testbof.cfg
Writing configuration to cf3:\testbof.cfg OK
Completed.
```

Note: The BOF configuration file is saved in classic CLI format.

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3.11.4.2.4 Rebooting

When a **reboot** command is issued, routers with redundant CPM are rebooted as well as the XMAs, XCMs, and IOMs. If the **now** option is not specified, the user is prompted to confirm the reboot operation.

3.11.4.2.5 Setting the MTU value for the management port

The following command configures the MTU for IP packets transmitted out the interface of the management router instance associated with the management port.

```
bof router "management" interface "management" ip-mtu
```

The command applies to the SR OS but does not necessarily apply during the boot loader processing.

The operational MTU for the port is set to the lesser of the values configured with the **ip-mtu** command and the management port MTU. For example, with the port MTU fixed at 1514 bytes and an Ethernet header size of 14 bytes, the MTU of the management port is 1500 bytes (the default operational IP MTU).

If the interface supports IPv6 packets, the command value must be set to 1280 or higher, in accordance with RFC 2460 *Internet Protocol, Version 6 (IPv6) Specification*.

Example

```
[ex:bof]
A:admin@node-2# router "management" interface "management" ip-mtu ?

 ip-mtu <number>
 <number> - <512..9786> - bytes

    Interface IP MTU

    Note: The new value of this element takes effect when the candidate is
    committed.
```

3.12 Anti-theft

To discourage theft, the 7705 SAR Gen 2 includes an anti-theft feature that prevents the 7705 SAR Gen 2 from being redeployed in other networks when it is powered down and removed from the original network. This feature also ensures that the router cannot be deployed in any network other than the intended network.

Before activating the anti-theft feature, the user must configure the OS security password. The password length must be between 12 and 32 characters, and must not contain any non-printable characters, spaces, or double quotes (").

Use the following command to configure the OS security password.

```
admin system security os-security set-password
```

Users can reconfigure the OS security password using the **set-password** command. When prompted, the user must enter the **current-password** followed by the **new-password**. Use the **activate-password**

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command to activate the newly entered password. The system immediately reboots and encrypts the BOF and configuration files with the new password.

Note:

- Nokia recommends using a random password generator to ensure a strong and secure password.
- After the OS security password is configured, the router reboots to save the password.
- The anti-theft feature does not need to be deactivated to reconfigure the OS security password.

After the OS security password is set, the anti-theft feature can be enabled on a per-CPM basis. When anti-theft is enabled, after a router reboot, the router blocks the CLI configuration until the administrative user logs on to the router and enters the OS security password to unlock anti-theft. If the entered OS security password is incorrect, the CLI configuration remains blocked.

Use the following command to activate the anti-theft feature for a CPM.

```
admin system security os-security anti-theft activate
```

When prompted, the user must enter their OS security password to enable the anti-theft feature. For each incorrect password attempt, the initial unsuccessful authentication wait period is doubled. This wait period is common for all users. Entering the correct password resets the wait period to the initial value for all users.

Example: Enable anti-theft (MD-CLI)

```
[/admin system security os-security]
A:admin@node-2# set-password
New password:
Re-enter new password:

A:admin@node-2# admin system security os-security anti-theft activate card "A"
force password
```

Example: Enable anti-theft (classic CLI)

```
*A:node-2>admin>system>security>os-security#
set-password
New password:
Re-enter new password:

A:node-2>admin>system>security>os-security>anti-theft#
activate card "A"
Current password:
```

When the anti-theft feature is enabled and the router reboots, all CLI configuration is blocked for the CPM after booting up, until the user unlocks the OS. Use the following command to unlock the OS.

```
admin system security os-security anti-theft unlock
```

When prompted, the user must enter the OS security password to unlock the router. For each incorrect password attempt, the initial unsuccessful authentication wait period is doubled. This wait period is common for all users. When the correct password is entered, the router resumes normal operation and allows configuration.

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Use the following command to disable the anti-theft feature. When prompted, the user must enter the OS security password to disable anti-theft.

```
admin system security os-security anti-theft deactivate
```

Use the following command to remove the OS security password.

```
admin system security os-security remove-password
```

3.12.1 Node behavior when the anti-theft password is set

If it reboots when in the anti-theft mode, the node performs the following actions in the listed order upon booting up:

1. The node can be accessed using the console connection at this point. Remote connections using SSH/ Telnet, SFTP/SCP, SNMP, NETCONF, and so on, are not possible until after the BOF and configuration are successfully loaded.
2. The node loads the configuration only if the BOF and the configuration file is decrypted successfully.

   The configuration file is loaded, and a remote connection is allowed for management and entering the OS security password to put the router into a normal mode of operation.

   It is assumed that the current configuration file is not useful to the organization that stole the router.
3. After connecting to the node, configuration using any management interface is not allowed.

   Example: Anti-theft node error

   ```
   *A:node-2#ssh admin@192.168.239.179
   KANVMPLM6 -  Dut-B
   admin@192.168.239.179's password:
   *A:node-2# configure
   ERROR: “MINOR: MGMT_CORE #2XXX: Operation not permitted – OS lockdown activated – enter OS
    security password”
   ```
4. The user can enter the OS security password after the reboot by using interactive management sessions, the corresponding NETCONF YANG, and so on.
5. After the OS security password is set, the node starts normal operation and allows configuration.

3.12.2 BOF and configuration file behavior

When the anti-theft feature is enabled, the BOF and configure files are saved in an encrypted format, and the router reboots. The router loads the configuration only if the BOF and configuration files are successfully decrypted.

If there is a failure in decryption and execution of the BOF, the router reboots. If the configuration file is not decrypted correctly, the router does not load the configuration file. This ensures that the router does not accept any configuration files that are loaded from unknown sources.

BOF and configuration files can be decrypted and stored as a single backup file. They are not saved as the active configuration or BOF, and do not overwrite the existing encrypted files.

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All encrypted configuration files can be saved as backup configuration in cleartext using the **cleartext** option in the following command.

```
admin save
```

All encrypted BOF files can be saved as cleartext using the **cleartext** option in the following command:

- **MD-CLI**

  ```
  admin save bof
  ```

- **classic CLI**

  ```
  bof save
  ```

When anti-theft is enabled on the system and the **cleartext** option is used to save in cleartext, the user must enter the anti-theft OS security password or the BOF encryption key to perform the save operation.

Note: The **bof save cleartext** command does not require a password when **bof encryption** is enabled.

If the BOF and configuration files are already in cleartext and are saved using the **cleartext** option, there is no effect on the **admin save** command.

Note: When anti-theft is enabled, Nokia recommends transferring the files and then deleting the cleartext copies as soon as possible to prevent insecure file leakage.

3.12.3 Management interface interaction in anti-theft mode

In the anti-theft mode, the **configure** and **bof** branches are blocked in both the classic CLI and MD-CLI after a reboot of the router. The branches become available again only if the OS security password is entered.

The following branches are allowed for debugging the router in the anti-theft mode:

- **show**
- **tools**
- **debug**
- **clear**

Commands in the **admin** branch, with the following exceptions, can be used in the anti-theft mode:

MD-CLI

```
admin clear security lockout all
admin clear security lockout user
global-commands rollback
admin show configuration
admin system security hash-control custom-hash key
admin system security system-pasword admin-password
admin system security pki import type
admin system security pki crl-update ca-profile
admin save clear-text
admin system security os-security
admin system management-interface commit confirmed
```


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classic CLI

```
admin clear lockout all
admin clear lockout user
admin rollback
admin display-config
admin system security hash-control custom-hash key
admin system security system-pasword admin-password
admin system security system-password dynsvc-password
admin certificate import type
admin certificate crl-update ca
admin save clear-text
admin system security os-security
```

The SCP, SFTP, and FTP are accessible in anti-theft mode. Actions such as removing and copying files are allowed.

Note: Deleting the **configure** or **bof** branches will cause encryption or authentication failure, and the router will not boot up.

The **exec** command is only allowed for non-configuration command contexts (for example, **show**, **tools**, **debug**, **clear**). Any configuration command in the script is blocked. The router stops executing the script as soon as it encounters a configuration command in the script. The configuration commands are blocked until the following command is executed.

```
admin system security os-security anti-theft unlock
```


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4 Debug configuration

The **debug** configuration commands enable detailed debugging information for various protocols.

4.1 Debug configuration in the classic CLI

The **debug** commands in the classic CLI are available by entering the **debug** configuration context.

Debugging configuration is not persistent across CPM switchovers or router reboots. The **show debug** command displays debugging information.

Example: Show debug information

```
A:node-2# show debug
debug
    system
    netconf info
    exit
exit
```

The **admin debug-save** command saves the debugging configuration to `config.dbg` at the BOF **primary-config** location if a URL is not specified.

Example: Save debug configuration

```
A:node-2# admin debug-save
Writing configuration to cf3:\config.dbg
Saving configuration OK
Completed.
```

For a description of individual **debug** commands, see the *7705 SAR Gen 2 Classic CLI Command Reference Guide*.

4.1.1 Logging debug events in the classic CLI

The following is an example configuration for debug events that are stored in destination CLI log identifier 7. The log entries wrap at 50 entries (the configured value of **cli**).

Example: Configuration for stored debug events

```
A:node-2>config>log# log-id 7
A:node-2>config>log>log-id$ from debug-trace
A:node-2>config>log>log-id$ to cli 50
A:node-2>config>log>log-id$ info
----------------------------------------------
            from debug-trace
            to cli 50
            no shutdown
----------------------------------------------
```


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After the log is configured, execute the following **tools** command in the CLI session that is intended to display output of the debug events. See the *7705 SAR Gen 2 Clear, Monitor, Show, Tools CLI Command Reference Guide* for more information about the **tools** command.

Example: Subscribe to debug log output to the CLI session

```
A:node-2# tools perform log subscribe-to log-id 7
```

Debug events can be displayed using the **show log** command and cleared using the **clear log** command.

Example: Unsubscribe from debug log output to the CLI session

```
A:node-2# show log log-id 7
===============================================================================
Event Log 7 log-name 7
===============================================================================
Description : (Not Specified)
Log contents  [size=50   next event=2  (not wrapped)]

---snip---

A:node-2# clear log log-id 7
```

The following is an example of terminating the output of the logs to the CLI session using the **unsubscribe-from** command.

Example: Unsubscribe from debug log output to the CLI session

```
A:node-2# tools perform log unsubscribe-from log-id 7
```

4.2 Debug configuration in the MD-CLI

The **debug** commands in the MD-CLI are available in an exclusive, private, or read-only session using the explicit or implicit configuration mode. The same configuration management commands that are available in the configure region are available in the debug region.

Debugging configuration is not persistent across router reboots. Use the following command to display debugging information.

```
admin show configuration debug
```

The command displays debugging information and supports all configuration display formats, datastores, and output formats that are supported for other regions.

Example: Display debug information

```
[/]
A:admin@node-2# admin show configuration debug
# TiMOS-B-22.2.R1 both/x86_64 Nokia 7750 SR Copyright (c) 2000-2022 Nokia.
# All rights reserved. All use subject to applicable license agreements.
# Built on Sat Feb 26 15:31:00 PST 2022 by builder in /builds/c/222B/R1/panos/main/sros
# Configuration format version 22.2 revision 0

# Generated 2022-03-07T16:51:54.1+00:00 by admin from Console

debug {
```


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```
    system {
        management-interface {
            netconf info
        }
    }
}

# Finished 2022-03-07T16:51:54.1+00:00
```

The **admin save debug** command saves the debugging configuration to `debug.cfg` at the following location if a URL is not specified.

```
bof configuration primary-location
```

Example: Save debug configuration

```
[/]
A:admin@node-2# admin save debug
Writing configuration to cf3:\debug.cfg
Saving configuration OK
Completed.
```

For descriptions of individual **debug** commands, see the *7705 SAR Gen 2 MD-CLI Command Reference Guide*.

4.2.1 Logging debug events in the MD-CLI

Example: Configuring a CLI log for debug events

The following is an example of a configuration for debug events that are stored in destination CLI log identifier 7. The log entries wrap at 50 entries (the configured value of **max-entries**).

```
*(ex)[configure log]
A:admin@node-2# log-id 7

*(ex)[configure log log-id "7"]
A:admin@node-2# source debug

*(ex)[configure log log-id "7"]
A:admin@node-2# destination cli max-entries 50

*(ex)[configure log log-id "7"]
A:admin@node-2# info
    source {
        debug true
    }
    destination {
        cli {
            max-entries 50
        }
    }
```

Example: Subscribing to a CLI log

After the **commit** command is issued to include the log in the running configuration, the following **tools** command can be executed in the CLI session that is intended to display output of the debug

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events. See the *7705 SAR Gen 2 Clear, Monitor, Show, Tools CLI Command Reference Guide* for more information about the **tools** command.

```
[/]
A:admin@node-2# tools perform log subscribe-to log-id 7
```

Example: Displaying and clearing debug events

Debug events can be displayed using the **show log** command and cleared using the **clear log** command.

```
[/]
A:admin@node-2# show log log-id 7
===============================================================================
Event Log 7 log-name 7
===============================================================================
Description : (Not Specified)
Log contents  [size=50   next event=2  (not wrapped)]

...

[/]
A:admin@node-2# clear log log-id 7
```

4.3 Debug configuration in mixed and model-driven mode

When debugging is configured in mixed or model-driven management mode, the following usage guidelines apply.

If the commands are available in the MD-CLI, the MD-CLI commands must be used to configure debugging:

- The classic CLI cannot be used.
- Debug configuration commands entered in the MD-CLI are only displayed in the MD-CLI **info** and in the following command output.

  ```
  admin show configuration debug
  ```

- Debug configuration entered in the MD-CLI can be saved to `debug.cfg` or a file URL with the **admin save debug** command.
- Debug configuration commands entered in the MD-CLI are not displayed in the classic CLI **show debug** output.

Note: References must be configured with the MD-CLI names, not the classic CLI IDs. For example, the MD-CLI VPRN service name, not the classic CLI VPRN service ID.

If the commands are not available in the MD-CLI, the classic CLI must be used to configure debugging:

- The MD-CLI cannot be used.
- Debug configuration commands entered in the classic CLI are only displayed in the classic CLI **show debug** output.

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- Debug configuration entered in the classic CLI can be saved to `config.dbg` or a file URL with the **admin debug-save** command.
- Debug configuration commands entered in the classic CLI are not displayed in the MD-CLI **info** or in the following command output.

```
admin show configuration debug
```

The user must manually remove the classic and model-driven debug configuration before changing the management interface configuration mode from model-driven to mixed mode. The system automatically removes the classic and model-driven debug configuration during all other mode switches.

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5 Secure boot

SR OS Secure Boot ensures the system executes only trusted software that originates from Nokia IP Routing.

At every boot of the control card, each step in the boot process verifies the digital signature of the next software element to boot for integrity and authenticity up to the SR OS operating system images. This boot sequence forms the Secure Boot chain of trust.

Software image signatures use RSA-4096 keys and SHA-384 hashes.

The Secure Boot chain is rooted in the platform CPM firmware, which is based on UEFI specifications. As such, Nokia Platform Key, Key Exchange Key, and allowed and disallowed databases are provisioned when the user activates Secure Boot to perform the required signature verification.

Firmware updates are also digitally signed and verified using the same process. The existing firmware verifies the signature at boot time, before the firmware update can proceed.

5.1 Secure Boot chain

The following figures displays the Secure Boot chain of trust for SR OS platforms.

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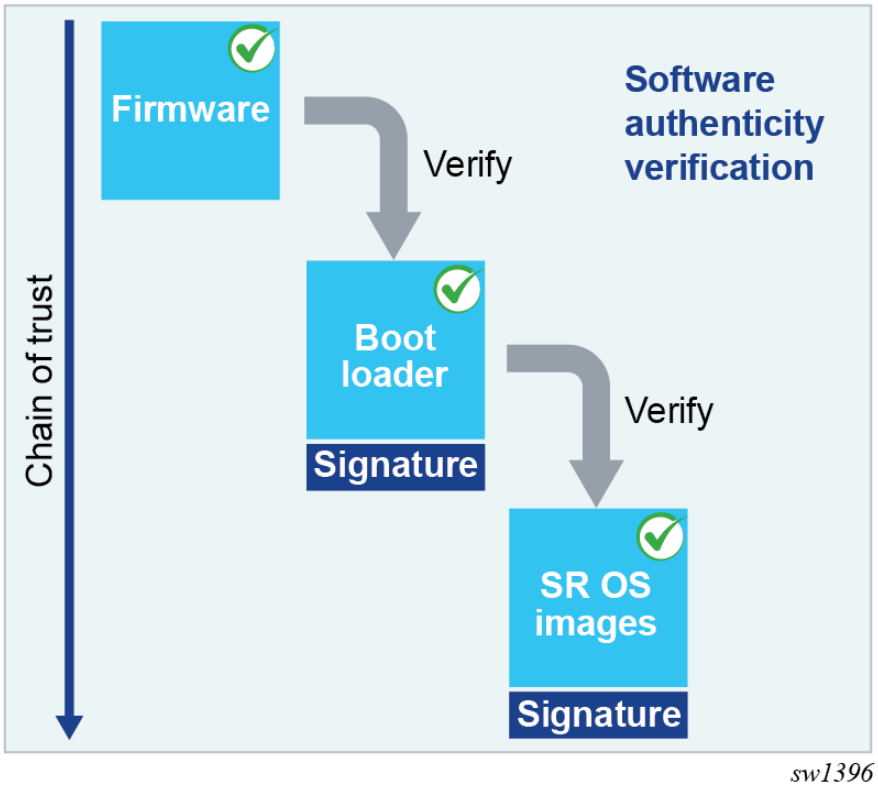
Figure 5: Secure boot chain of trust



5.2 Activate Secure Boot

Note: This section does not apply to systems with Secure Boot enabled by default.

Secure Boot is enabled, per CPM card, by providing the card slot, card serial number, and confirmation code.

Use the following command to activate Secure Boot:

- **MD-CLI**

```
admin system security secure-boot activate card A
admin system security secure-boot activate confirmation-code secure-boot-permanent
admin system security secure-boot activate serial-number NS123456789
```

- **classic CLI**

```
admin system security secure-boot activate card "A" serial-number NS123456789 confirmation-
code secure-boot-permanent
```

The following example shows the warning messages and a prompt for proceeding with Secure Boot activation.

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Example

```
WARNING: CLI This operation will permanently activate secure boot on card A and cannot be
 reversed.
WARNING: CLI After activation, the system will only accept digitally signed software and
 will not boot using un-signed software.
WARNING: CLI This operation will immediately reset card A.
WARNING: CLI Configuration and/or Boot options may have changed since the last save.
Are you sure you want to continue (y/n)?
```

The system requires the card serial number and Secure Boot confirmation code to prevent unintentionally activating Secure Boot in the network. The confirmation code is *secure-boot-permanent*.

The Secure Boot **activate** command verifies that the BOF primary image uses the same software release as the currently running software and automatically reboots the designated CPM card if the software release matches. Otherwise, an error is generated in the CLI.

Note: The system also verifies the boot.ldr version against the running software version on applicable platforms. These verifications ensure that the entire boot chain up to the primary image supports Secure Boot before activating Secure Boot and rebooting the CPM.

WARNING: After Secure Boot is activated on a CPM, the capability is permanently enabled and cannot be disabled. The CPM permanently refuses to execute unsigned software for security reasons. As a result, a user cannot downgrade to a software release published before the release that introduced Secure Boot for a specific platform.

5.3 Operational commands and logs

This section describes the following:

- Secure Boot state
- software update process
- update Secure Boot variables

5.3.1 Secure Boot state

Use the following command to display Secure Boot state information, including the Secure Boot status and UEFI variables status per CPM.

```
show card A detail
```

Output example

```
Hardware Data
    Secure boot status            : enabled
    UEFI variables status         : ok
```

where

- Secure Boot status — indicates if Secure Boot is enabled or disabled
- UEFI variables status — indicates if Secure Boot variables need updating

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At each boot, the system records in the security log whether Secure Boot is enabled or disabled for each CPM. The following is an example of such a log message.

```
24 2023/05/17 06:09:03.140 EDT MAJOR: SECURITY #2241 Base Card A
"CPM A has booted with a secure-boot status of enabled"
```

Use the following command to obtain Secure Boot UEFI variables for each CPM card:

- **MD-CLI**

  ```
  perform system security secure-boot show uefi-variables card
  ```

- **classic CLI**

  ```
  tools dump system security secure-boot uefi-vars card
  ```

The command displays the following x509 certificates and SHA-256 hash UEFI variables:

- Platform Key (PK)
- Key Exchange Key (KEK)
- Allowed Database (DB)
- Disallowed Database (DBx)

5.3.2 Software update

After enabling Secure Boot, and before upgrading to a new software release, the user must verify that the new software image is properly signed. The additional verification is required on systems with Secure Boot enabled because the system only boots Nokia-signed software images and does not boot unsigned or improperly signed images.

Use the following command to validate the signature of the TiMOS *.tim images contained in the **software-image** *url* location referenced in the command. This verification includes `cpm.tim`, `iom.tim`, `support.tim`, `both.tim`, `kernel.tim`, as well as the `boot.ldr` if present in the CF3 directory.

```
admin system security secure-boot validate software-image url
```

5.3.3 Update Secure Boot variables

Use the following commands to configure Secure Boot UEFI key updates and revocation.

```
admin system security secure-boot update-key
admin system security secure-boot revoke-key
```


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6 System management

This chapter provides information about configuring basic system management parameters.

6.1 System management commands

System management commands allow you to configure basic system management functions, such as the system name, contact, router location and coordinates, as well as time zones, Network Time Protocol (NTP), Simple Network Time Protocol (SNTP) synchronization, Precision Time Protocol (PTP), and CRON.

6.1.1 System information

This section describes the system information components.

6.1.1.1 Name

You can configure a name for the system device. The name is used in the prompt string. Only one system name can be configured. If multiple system names are configured the last one encountered overwrites the previous entry. Use the following command to configure the system name.

```
configure system name
```

6.1.1.2 Contact

Use the **contact** command to specify the name of a system administrator, IT staff member, or other administrative entity.

Use the following command to configure the contact.

```
configure system contact
```

6.1.1.3 Location

Use the **location** command to specify the location of the device. For example, enter the city, building address, floor, room number, and so on, where the router is located.

Use the following command to configure the location.

```
configure system location
```


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6.1.1.4 Coordinates

You can optionally configure the GPS location of the device. If the string contains special characters (#, $, spaces, and so on), the entire string must be enclosed within double quotes. Use the following command to configure the system coordinates.

```
configure system coordinates
```

6.1.1.5 Naming objects

Avoid configuring named objects with a name that starts with "_tmnx_" and with "_" in general.

6.1.1.6 Common language location identifier

A Common Language Location Identifier (CLLI) for the device is an 11-character standardized code string that uniquely identifies the geographic location of places and specific functional categories of equipment unique to the telecommunications industry. The CLLI code is stored in the Nokia Chassis MIB tmnxChassisCLLICode object.

The CLLI code can be any ASCII printable text string of up to 11 characters.

6.1.1.7 DNS security extensions

DNS Security (DNSSEC) Extensions are now implemented in the SR OS, allowing operators to configure DNS behavior of the router to evaluate whether the Authenticated Data bit was set in the response received from the recursive name server and to trust the response, or ignore it.

6.1.2 System time

Routers are equipped with a real-time system clock for timekeeping purposes. When set, the system clock always operates on Coordinated Universal Time (UTC), but the software has options for local time translation as well as system clock synchronization.

6.1.2.1 Time zones

Setting a time zone in SR OS allows for times to be displayed in the local time rather instead of UTC. SR OS has both user-defined and system-defined time zones.

A user-defined time zone has a user-assigned name of up to four printable ASCII characters in length and is unique from the system-defined time zones. For user-defined time zones, the offset from UTC is configured as well as any summer time adjustment for the time zone.

SR OS includes multiple commands to control the presentation of times in either UTC or local time zone format. For a CLI session, the environment variable time-display may be set to indicate UTC or local time zone. This setting only affects time strings shown during that specific CLI session. A global setting of the

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following command can be used to control time strings for objects with larger scope than a single CLI session.

```
configure system time prefer-local-time
```

Time strings include the following:

- log filenames and log header information
- times in rollback information
- times in rollback and configuration files header information
- times related to CRON scripts
- times related to CRON scripts
- times in the event handler system
- times in NETCONF and gRPC date-and-time leafs

A separate control per log file controls the format of the time strings on the event recorded into the logs (separate from the log filename and header information). Use the following command to set these time strings.

```
configure log log-id time-format
```

The SR OS system-defined time zones are listed in the following table, which includes both time zones with and without daylight saving (summer) time adjustment.

Table 16: System-defined time zones and UTC offsets

Acronym	Time zone name	UTC offset
Europe:		
GMT	Greenwich Mean Time	UTC
BST	British Summer Time	UTC +1
IST	Irish Summer Time	UTC +1*
WET	Western Europe Time	UTC
WEST	Western Europe Summer Time	UTC +1
CET	Central Europe Time	UTC +1
CEST	Central Europe Summer Time	UTC +2
EET	Eastern Europe Time	UTC +2
EEST	Eastern Europe Summer Time	UTC +3
MSK	Moscow Time	UTC +3
MSD	Moscow Summer Time	UTC +4
US and Canada:		

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Acronym	Time zone name	UTC offset
AST	Atlantic Standard Time	UTC -4
ADT	Atlantic Daylight Time	UTC -3
EST	Eastern Standard Time	UTC -5
EDT	Eastern Daylight Saving Time	UTC -4
ET	Eastern Time	Either as EST or EDT, depending on place and time of year
CST	Central Standard Time	UTC -6
CDT	Central Daylight Saving Time	UTC -5
CT	Central Time	Either as CST or CDT, depending on place and time of year
MST	Mountain Standard Time	UTC -7
MDT	Mountain Daylight Saving Time	UTC -6
MT	Mountain Time	Either as MST or MDT, depending on place and time of year
PST	Pacific Standard Time	UTC -8
PDT	Pacific Daylight Saving Time	UTC -7
PT	Pacific Time	Either as PST or PDT, depending on place and time of year
HST	Hawaiian Standard Time	UTC -10
AKST	Alaska Standard Time	UTC -9
AKDT	Alaska Standard Daylight Saving Time	UTC -8
Australia and New Zealand:		
AWST	Western Standard Time (for example, Perth)	UTC +8 hours
ACST	Central Standard Time (for example, Darwin)	UTC +9.5 hours
AEST	Eastern Standard/Summer Time (for example, Canberra)	UTC +10 hours
NZT	New Zealand Standard Time	UTC +12 hours
NZDT	New Zealand Daylight Saving Time	UTC +13 hours

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6.1.2.2 NTP

NTP is the Network Time Protocol defined in RFC 1305, *Network Time Protocol (Version 3) Specification, Implementation and Analysis* and RFC 5905, *Network Time Protocol Version 4: Protocol and Algorithms Specification*. It allows for the participating network nodes to keep time more accurately and more importantly they can maintain time in a more synchronized fashion between all participating network nodes.

SR OS uses an NTP process based on a reference build provided by the Network Time Foundation. Nokia strongly recommends that the users review RFC 8633, *Network Time Protocol Best Current Practices*, when they plan to use NTP with the router. The RFC section "Using Enough Time Sources" indicates that using only two time sources (NTP servers) can introduce instability if they provide conflicting information. To maintain accurate time, Nokia recommends configuring three or more NTP servers.

NTP uses stratum levels to define the number of hops from a reference clock. The reference clock is considered to be a stratum-0 device that is assumed to be accurate with little or no delay. Stratum-0 servers cannot be used in a network. However, they can be directly connected to devices that operate as stratum-1 servers. A stratum-1 server is an NTP server with a directly-connected device that provides Coordinated Universal Time (UTC), such as a GPS or atomic clock.

The higher stratum levels are separated from the stratum-1 server over a network path, therefore, a stratum-2 server receives its time over a network link from a stratum-1 server. A stratum-3 server receives its time over a network link from a stratum-2 server.

SR OS routers normally operate as a stratum-2 or higher device. The router relies on an external stratum-1 server to source accurate time into the network. However, SR OS also allows for the use of the local PTP recovered time to be sourced into NTP. In this latter case, the local PTP source appears as a stratum-0 server and SR OS advertises itself as a stratum-1 server. Activation of the PTP source into NTP may impact the network NTP topology because the SR OS router is promoted to stratum-1.

SR OS router runs a single NTP clock which then operates NTP message exchanges with external NTP clocks. Exchanges can be made with external NTP clients, servers, and peers. These exchanges can be through the base, management, or VPRN routing instances.

NTP operates associations between clocks as either client or server, symmetric active and symmetric passive, or broadcast modes. These modes of operation are applied according to which elements are configured on the router. To run server mode, the operator must enable NTP server mode for the base and each needed VPRN routing instance. To run client mode, the operator must configure external servers. If both the local router and remote router are configured with each other as peers, then the router operates in symmetric active mode. If only one side of the association has peering configured, then the modes are symmetric passive. To operate using broadcast mode, interfaces must be configured to transmit as broadcast servers or receive as broadcast clients.

NTP server operation for both unicast and broadcast communication within a VPRN is configured within the VPRN (see "NTP Within a VPRN Service" in the *7705 SAR Gen 2 Layer 3 Services Guide: IES and VPRN*).

The following NTP elements are supported:

- **server mode**

  In this mode, the node advertises the ability to act as a clock source for other network elements. The node, by default, transmits NTP packets in NTP version 4 mode.

- **authentication keys**

  Authentication keys implement increased security support in carrier and other networks. Both DES and MD5 authentication are supported, as well as multiple keys.

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- **operation in symmetric active mode**

  This capability requires that NTP be synchronized with a specific node that is considered more trustworthy or accurate than other nodes carrying NTP in the system. This mode requires that a specific peer is set.

- **server and peer addressing using IPv6**

  Both external servers and external peers may be defined using IPv6 or IPv4 addresses. Other features (such as multicast, broadcast) use IPv4 addressing only.

- **broadcast or multicast modes**

  When operating in these modes, the node receives or sends using either a multicast (default 224.0.1.1) or a broadcast address. Multicast is supported only on the CPM MGMT port.

- **alert when NTP server is not available**

  When none of the configured servers are reachable on the node, the system reverts to manual timekeeping and issues a critical alarm. When a server becomes available, a trap is issued indicating that standard operation has resumed.

- **NTP and SNTP**

  If both NTP and SNTP are enabled on the node, then SNTP transitions to an operationally down state. If NTP is removed from the configuration or shut down, then SNTP resumes an operationally up state.

- **gradual clock adjustment**

  As several applications (such as Service Assurance Agent (SAA)) can use the clock, and if determined that a major (128 ms or more) adjustment needs to be performed, the adjustment is performed by programmatically stepping the clock. If a minor (less than 128 ms) adjustment must be performed, then the adjustment is performed by either speeding up or slowing down the clock.

- To avoid the generation of too many events/trap the NTP module rates limit the generation of events/traps to three per second. At that point a single trap is generated that indicates that event/trap squashing is taking place.

6.1.2.3 CRON

The CRON feature supports periodic and date and time-based scheduling in SR OS. CRON can be used, for example, to schedule Service Assurance Agent (SAA) functions. CRON functionality includes the ability to specify scripts that need to be run, when they are scheduled, including one-time only functionality (one-shot), interval and calendar functions. Scheduled reboots, peer turn ups, service assurance agent tests and more can all be scheduled with CRON, as well as OAM events, such as connectivity checks, or troubleshooting runs.

CRON supports the schedule element. The schedule function configures the type of schedule to run, including one-time only (one-shot), periodic, or calendar-based runs. All runs are determined by month, day of month or weekday, hour, minute, and interval (seconds).

6.1.2.4 GNSS

The 7705 SAR-10x, 7705 SAR-Hx, and 7705 SAR-Mx support frequency synchronization using a Layer 1 interface, such as Synchronous Ethernet (SyncE), and ToD synchronization using protocols such as NTP or PTP. In cases where these methods are not possible or where accuracy cannot be ensured for the

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service, you can deploy a GNSS receiver as a synchronous timing source. GNSS data is used to provide network-independent frequency and ToD synchronization.

GNSS receivers on the 7705 SAR-10x, 7705 SAR-Hx, and 7705 SAR-Mx support GPS and Galileo reference using an integrated GNSS RF port.

A 7705 SAR Gen 2 chassis equipped with a GNSS receiver and an attached GNSS antenna can be configured to receive frequency traceable to Stratum-1 (PRC/PRS). The GNSS receiver provides a synchronization clock to the SSU in the router with the corresponding QL for SSM. This frequency is distributed to the rest of the router from the SSU as configured with the following commands:

- **MD-CLI**

```
configure system central-frequency-clock ref-order
configure system central-frequency-clock ql-selection
```

- **classic CLI**

```
configure system sync-if-timing ref-order
configure system sync-if-timing ql-selection
```

The GNSS reference is qualified only when the GNSS receiver is in a position hold state and has successfully recovered the frequency. A PTP timeTransmitter or boundary clock can also use this frequency reference with PTP peers.

If GNSS signal loss or jamming causes timing information to become unavailable, the GNSS receiver automatically prevents the output of clock or synchronization data to the system. In this case, the system can revert to alternate timing sources.With Assisted Partial Timing Support (APTS), the system can perform a seamless switch when reverting to a backup PTP session; see GNSS failure with APTS.

6.1.2.4.1 GNSS failure with APTS

When the G.8275.2 profile is used for GNSS-enabled 7705 SAR Gen 2 platforms, the APTS capability frequently measures and stores the delay offset between the GNSS time and a backup PTP session time. If a GNSS failure occurs, the backup PTP session automatically becomes the selected reference for time and frequency, and the stored delay offset value is added to or subtracted from the backup PTP session time to keep time and phase for the router as accurate as possible.

When GNSS has recovered and is stable, the system automatically switches back to GNSS for the time and frequency reference, and backup PTP monitoring and delay measurement resumes.

6.2 High Availability

This section describes the High Availability (HA) features that service providers can use to diminish vulnerability at the network or service provider edge and alleviate the effects of a lengthy outage on IP/MPLS networks.

HA is an important feature in service provider routing systems because the demand from enterprise and residential communities has led to unprecedented growth of IP and MPLS based services and applications in service provider networks. Downtime can be very costly, and, in addition to lost revenue, customer information and business-critical communications can be lost. Availability is the combination of continuous uptime over long periods (Mean Time Between Failures (MTBF)) and the speed at which failover or recovery occurs (Mean Time To Repair (MTTR)).

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The advantage of HA routing is evident at the network or service provider edge, where thousands of connections are hosted and rerouting options around a failed piece of equipment are often limited. As service providers converge mission-critical services, such as teleprotection, real-time voice (VoIP), video, and VPN applications over their IP networks, the requirements for HA become much more stringent compared to the requirements for best-effort data.

The requirements are further raised with mission-critical networks hosting various signaling and circuit emulation services that operate with tight synchronization between nodes, as well synchronization as a service and other similar services, all collapsed on a single node. Similarly, Fixed Mobile Convergence (FMC) allows fixed networks such as DSLAM or GPON OLT, and other subscriber aggregation nodes, Layer 2 and Layer 3 business services, and mobile anyhaul to all be integrated on a single router. Network and service availability become critical aspects when offering advanced IP and MPLS services, which dictate that the IP/MPLS routers that are used to construct the foundations of these networks must be resilient to component and software outages.

For high availability configuration information, see File synchronization.

6.2.1 HA features

This section describes HA features for devices.

6.2.1.1 Redundancy

The redundancy features enable the duplication of data elements to maintain service continuation in case of outages or component failure.

6.2.1.1.1 Software redundancy

Software outages are challenging even when baseline hardware redundancy is in place. A balance should be maintained when providing HA routing, otherwise router problems typically propagate not only throughout the service provider network, but also externally to other connected networks possibly belonging to other service providers. This could affect customers on a broad scale. Currently supports several software availability features are supported that contribute to the percentage of time that a router is available to process and forward traffic.

All routing protocols specify minimum time intervals in which the peer device must receive an acknowledgment before it disconnects the session:

- OSPF default session timeout is approximately 40 seconds. The timeout intervals are configurable.
- BGP default session timeout is approximately 120 seconds. The timeout intervals are configurable.

Therefore, the router software must recover faster than the specified time interval to maintain up time.

6.2.1.1.2 Configuration redundancy

Features configured on the active CPIOM are also applied on the standby CPIOM. If the active device fails, these features are brought up on the standby device when it becomes active.

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6.2.1.1.2.1 7705 SAR-10x redundancy

The 7705 SAR-10x chassis has two CPIOM slots (slots A and B). CPIOMs combine the functionality of CPMs and IOMs.

The 7705 SAR-10x supports control plane HA when equipped with dual CPIOMs, which ensures a seamless control plane activity switch from active to the newly active CPIOM, which was previously on standby. All control plane protocols, including, but not limited to, IGP (OSPF, IS-IS) BGP, BFD, MPLS (LDP, RSVP-TE), Segment Routing, and SNMP are protected against active control plane failures. In a graceful restart scenario, the control plane on a standby module is initialized upon detection of a failure and cannot recover from IGP or BGP topology changes during initialization. Unlike graceful restart, in the 7705 SAR-10x control plane HA implementation, the standby control plane is always ready to assume the active role without the loss of routing information or the routing information state.

Close synchronization of status between the active and the protecting (standby) control plane is implemented to ensure that both control planes have exactly the same topology and routing information at all times. The continuous synchronization between control planes precludes the need to synchronize the state of information during failures. When a CPIOM fails or is shut down, the remaining CPIOM can take over the control plane for the whole node.

The 7705 SAR-10x also supports forwarding plane HA when equipped with dual CPIOMs. The IOM handles packet processing, forwarding, and switching capabilities. In the case of a failure of the active CPIOM, all the packet processing, forwarding, and switching functions are handled by the standby CPIOM. The IOM configuration and various lookup tables are kept up to date on the standby CPIOM to ensure fast switchover from the active CPIOM to the standby CPIOM. The change of ownership for packet processing, forwarding, and switching functions provides protection and redundancy.

The 7705 SAR-10x supports CPIOM redundancy with the above control plane and IOM capabilities such that only one CPIOM is active at a time. In a 7705 SAR-10x equipped with dual CPIOMs, the standby CPIOM is closely synchronized with the active CPIOM and is ready to assume the active role during any failure. CPIOM activity switching is transparent to the MDAs, and all datapath ports remain up and operational during an activity switch.

6.2.1.1.3 Component redundancy

Note: In the 7705 SAR Gen 2 CLI, the power management modules, called Power Supply Units (PSUs), are also known as power equalization and control modules (PEQs); both terms are used interchangeably in these guides.

The component redundancy of 7705 SAR-10x platforms is critical to reduce MTTR for the system, and primarily consists of the features described in the following sections.

6.2.1.1.3.1 Power redundancy

The 7705 SAR-10x platform supports component redundancy of the power supply feeds. The use of up to four power supply feeds for 2+2 power redundancy is supported. A power feed can fail without impacting traffic when a redundant power feed configuration is in use.

See the *7705 SAR-10x Chassis Installation Guide* for information about power redundancy for the 7705 SAR-10x.

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6.2.1.1.4 Service redundancy

All service-related statistics are kept during a switchover. Services, SDPs, and SAPs remain up with a minimum loss of forwarded traffic during a CPIOM switchover.

6.2.1.1.5 Accounting configuration redundancy

When there is a switchover and the standby CPIOM becomes active, the accounting servers are checked, and if they are administratively up and capable of coming online (media present, and others), the standby is brought online and new accounting files are created. Users must manually copy the previous accounting records from the failed CPIOM.

6.2.1.2 Nonstop forwarding

In a control plane failure or a forced switchover event, the router continues to forward packets using the existing stale forwarding information. Nonstop forwarding requires clean control plane and data plane separation.

Nonstop forwarding is used to notify peer routers to continue forwarding and receiving packets, even if the route processor (control plane) is not working or is in a switch-over state. Nonstop forwarding requires clean control plane and data plane separation and usually the forwarding information is distributed to the line cards. This method of availability has both advantages and disadvantages. Nonstop forwarding continues to forward packets using the existing stale forwarding information during a failure. This may cause routing loops and black holes, and also requires that surrounding routers adhere to separate extension standards for each protocol. Every router vendor must support protocol extensions for interoperability.

6.2.1.2.1 Nonstop forwarding without Nonstop Routing

A graceful restart-based solution is used to notify peer routers to continue forwarding and receiving packets, even if the route processor (control plane) is not working or is in a switchover state. Nonstop forwarding requires clean control plane and data plane separation and usually the forwarding information is distributed to the line cards.

This method of availability has both advantages and disadvantages. Nonstop forwarding continues to forward packets using the existing stale forwarding information during a failure. This may cause routing loops and black holes, and requires that surrounding routers adhere to separate extension standards for each protocol. Every router vendor must support protocol extensions for interoperability.

6.2.1.3 Nonstop Routing

With Nonstop Routing (NSR) on the 7705 SAR-10x, routing neighbors are unaware of a routing process fault. If a fault occurs, a reliable and deterministic activity switch to the inactive control complex occurs such that routing topology and the reach ability are not affected, even in the presence of routing updates. NSR achieves HA through parallelization by maintaining up-to-date routing state information, at all times, on the standby route processor. This capability is achieved independently of protocols or protocol extensions, providing a more robust solution than graceful restart protocols between network routers.

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The NSR implementation on 7705 SAR-10x routers supports all routing protocols. NSR makes it possible to keep the existing sessions (such as BGP, LDP, and OSPF) during a CPIOM switchover, including support for MPLS signaling protocols. Peers do not see any change.

Protocol extensions are not required. There are no interoperability issues and there is no need to define protocol extensions for every protocol. Unlike nonstop forwarding and graceful restart, the forwarding information in NSR is always up to date, which eliminates possible black holes or forwarding loops.

Traditionally, addressing HA issues have been patched through nonstop forwarding solutions. With the implementation of NSR, these limitations are overcome by delivering an intelligent near-hitless failover solution. This enables a carrier-class foundation for transparent networks, required to support business IP services backed by stringent SLAs. This level of HA poses a major issue for conventional routers whose architectural design limits or prevents them from implementing NSR.

6.2.1.4 CPIOM switchover

During a switchover, system control and routing protocol execution are transferred from the active CPIOM to the standby CPIOM.

An automatic switchover may occur under the following conditions:

- a fault condition that causes the active CPIOM to crash or reboot
- the active CPIOM is declared down (not responding)
- online removal of the active CPIOM

To trigger a manual switchover, use the following command to force a switchover from an active CPIOM to a standby.

```
admin redundancy force-switchover
```

Use the following commands to configure a batch file that executes after failover:

```
configure redundancy switchover-exec
```

Note: During a CPIOM activity switch, both control plane (CPM) and forwarding (IOM) operations are switched simultaneously.

6.2.2 Synchronization

Synchronization between the CPIOMs includes the following:

- configuration and boot-env synchronization (File synchronization)
- CPIOM synchronization

6.2.2.1 CPIOM synchronization

When a new standby CPIOM is inserted into the system, it synchronizes with the active CPIOM after a successful boot process.

When the standby CPIOM is rebooted, it synchronizes with the active CPIOM after a successful boot process.

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When configuration or state changes occur, an incremental synchronization is conducted from the active CPIOM to the standby CPIOM.

If the synchronization fails, the standby CPIOM does not reboot automatically. The following command displays synchronization output information.

```
show redundancy synchronization
```

If the active and standby CPIOMs are not synchronized, users can manually synchronize the standby CPIOM by issuing the following command on the active or the standby CPIOM.

```
admin reboot standby
```

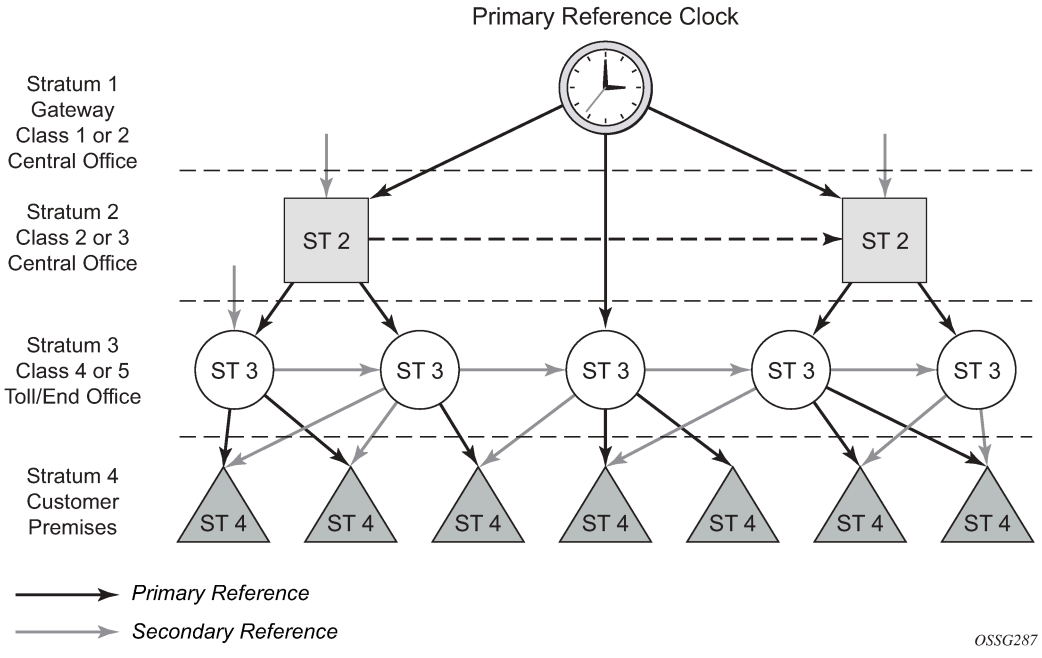
6.3 Network synchronization

This section describes network synchronization capabilities available on 7705 SAR Gen 2 platforms. These capabilities involve multiple approaches to network timing; namely SyncE, Adaptive clocking, and a Precision Time Protocol (PTP) IEEE 1588v2. These features address barriers to entry by:

- providing the synchronization quality required by the mobile space, such as radio operations and circuit emulation services (CES) transport
- augmenting and potentially replacing the existing timing infrastructure, and delivering high-quality network timing for frequency and time-sensitive wireline applications

The network time architecture in the following figure shows how network synchronization is commonly distributed in a hierarchical PTP topology at the physical layer.

Figure 6: Conventional network timing architecture (North American nomenclature)



The architecture shown in the preceding figure provides the following benefits:

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- limits the need for high-quality clocks at each network element and only requires reliable and accurate replication of the input to remain traceable to its reference
- uses reliable physical media to provide transport of the timing signal. It does not consume any bandwidth and requires limited additional processing

The synchronization network is designed so a clock always receives timing from a clock of equal or higher stratum level or quality level (QL). This ensures that if an upstream clock has a fault condition (for example, loses its reference and enters a holdover or free-run state) and begins to drift in frequency, the downstream clock is able to follow it. For greater reliability and robustness, most offices and nodes have at least two synchronization references that can be selected in priority order (such as primary and secondary).

Further levels of resiliency can be provided by designing a capability in the node clock that operates within prescribed network performance specifications in the absence of any reference for a specified period. A clock operating in this mode is said to hold the last known state over (or holdover) until the reference lock is once again achieved. Each level in the timing hierarchy is associated with minimum levels of network performance.

Each synchronization capable port can be independently configured to transmit data using the node reference timing or loop timing.

Specifically for SyncE, transmitting a reference clock through a chain of Ethernet equipment requires that all equipment supports SyncE. A single piece of non-SyncE equipment breaks the chain. Although Ethernet frames still get through, the recovered line timing is not traceable to an acceptable stratum source and downstream devices should not use it.

6.3.1 Central synchronization subsystem

The timing subsystem for platforms has a central clock located on the CPM (motherboard). The timing subsystem performs many duties of the network element clock as defined by Telcordia (GR-1244-CORE) and ITU-T G.781.

The system can select from up to four timing inputs to train the local oscillator. The priority order of these references must be specified. This is a simple ordered list of inputs: {ref1, ref2, ptp, gnss}. The CPM clock output has the ability to drive the clocking for all line cards in the system. The routers support selection of the node reference using QL indications. The following figure shows this selection process.

Note: Not all signals are available on all platforms.

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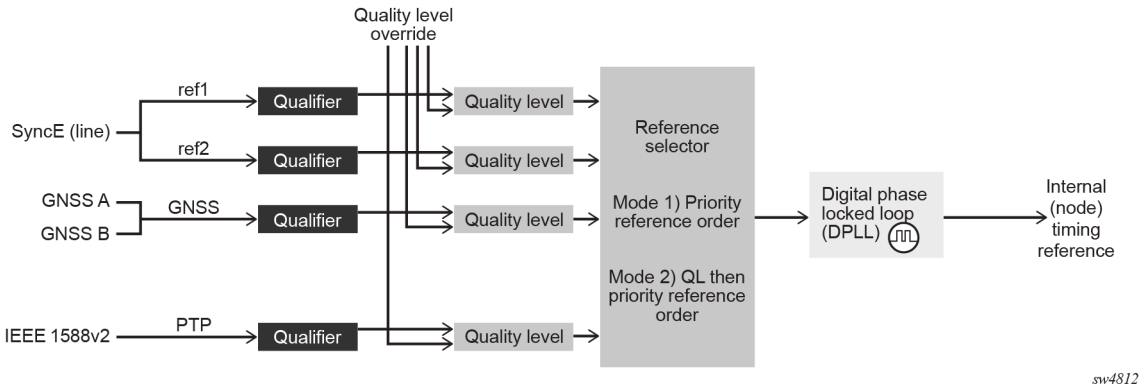
Figure 7: CPM clock synchronization reference selection



The recovered clock can derive its timing from any of the following:

- SyncE ports
- GNSS RF ports
- IEEE 1588v2 timeReceiver port (PTP)

When QL selection mode is disabled, the reversion setting controls when the central clock can reselect a previously failed reference.

The following table lists the selection operation for two references in both revertive and non-revertive modes:

Table 17: Revertive, non-revertive timing reference switching operation

Status of reference A	Status of reference B	Active reference non-revertive case	Active reference revertive case
OK	OK	A	A
Failed	OK	B	B
OK	OK	B	A
OK	Failed	A	A
OK	OK	A	A
Failed	Failed	holdover	holdover
OK	Failed	A	A
Failed	Failed	holdover	holdover
Failed	OK	B	B
Failed	Failed	holdover	holdover
OK	OK	A or B	A

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6.3.2 Synchronization Status Messages

Synchronization Status Messages (SSMs) allow the synchronization distribution network to determine the QL of the clock sourcing a specific synchronization trail. This allows a network element (NE) to select the best of multiple input synchronization trails. SSMs have been defined for various transport protocols, including T1/E1 and SyncE, for interaction with office clocks (such as BITS or SSUs) and embedded NE clocks.

SSMs allow equipment to autonomously provision and reconfigure (by reference switching) their synchronization references, while helping to avoid the creation of timing loops. These messages are particularly useful to allow synchronization reconfigurations when timing is distributed in both directions around a ring.

The following sections provide details about the SSM message functionality for different signal types. These functions apply to all platforms that support the signal type.

6.3.2.1 E1 signals

E1 signals can indicate the QL of the source generating the timing information using the SSM as specified in Recommendation G.704.

One of the Sa4 to Sa8 bits (the actual Sa bit is for user selection) is allocated for SSMs. To prevent ambiguities in pattern recognition, it is necessary to align the first bit (San1) with frame 1 of a G.704 E1 multi-frame.

A San bit is one of a 4-bit nibble, San1 to San4. San1 is the most significant bit; San4 is the least significant bit.

The message set in San1 to San4 is a copy of the set defined in SDH bits 5 to 8 of byte S1.

6.3.3 SyncE

Traditionally, Ethernet-based networks employ the physical layer transmitter clock to be derived from an inexpensive +/-100ppm crystal oscillator and the receiver locks onto it. There is no need for long term frequency stability because the data is packetized and can be buffered. For the same reason there is no need for consistency between the frequencies of different links. However, you can derive the physical layer transmitter clock from a high quality frequency reference by replacing the crystal with a frequency source traceable to a primary reference clock. This would not affect the operation of any of the Ethernet layers, for which this change would be transparent. The receiver at the far end of the link would lock onto the physical layer clock of the received signal, and therefore gain access to a highly accurate and stable frequency reference. Then, in a manner analogous to conventional hierarchical network synchronization, this receiver could lock the transmission clock of its other ports to this frequency reference and a fully time synchronous network could be established.

The advantage of using SyncE compared with methods that rely on sending timing information in packets over an unclocked physical layer, is that it is not influenced by impairments introduced by the higher levels of the networking technology (packet loss, packet delay variation). Hence, the frequency accuracy and stability may be expected to exceed those of networks with unsynchronized physical layers.

SyncE allows users to gracefully integrate existing systems and future deployments into conventional industry-standard synchronization hierarchy. The concept behind SyncE is analogous to SONET/SDH system timing capabilities. It allows the user to select any (optical) Ethernet port as a candidate timing

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reference. The recovered timing from this port is then used to time the system (for example, the CPM locks to this configured reference selection). The user then could ensure that any of system output would be locked to a stable traceable frequency source.

Fixed copper Ethernet ports in the 1000BASE-T mode of operation depend on the 802.3 link timing for the SyncE functionality, in accordance with recommendations in ITU-T G.8262. The 802.3 link timing states must align with the wanted direction of SyncE timing flow. When a fixed copper Ethernet port is specified as an input reference for the node or when it is removed as an input reference for the node, an 802.3 link auto-negotiation is triggered to ensure the link timing aligns properly.

The SSM of SyncE uses an Ethernet OAM PDU that uses the slow protocol subtype. For a complete description of the format and processing, see ITU-T G.8264.

6.3.3.1 Timing reference selection based on QL

For a SyncE interface that supports Ethernet Synchronization Message Channel (ESMC), a timing input or PTP clock class provides a QL value to indicate the source of timing of the far-end transmitter. These values provide input to the selection process on the nodal timing subsystem. This selection process determines which input to use to generate the signal on the SSM egress ports and the reference to use to synchronize the nodal clock, as follows:

- For the two reference inputs (ref1 and ref2), if the interface configuration supports the reception of a QL over SSM or ESMC, the QL value is associated with the timing derived from that input.
- For the two reference inputs, if the interface configuration is T1 with SF framing, the quality level associated with the input is QL-UNKNOWN.
- For the two reference inputs, if they are SyncE ports and the ESMC is disabled, the QL value associated with that input is QL-UNKNOWN.
- For the two reference inputs, if the interface configuration supports the reception of a QL over SSM (and not ESMC), and no SSM value has been received, the QL value associated with the input is QL-STU.
- For the two reference inputs, if the interface configuration supports the reception of a QL over SSM or ESMC, but the QL value received over the interface is not valid for the type of interface, the QL value associated with that input is QL-INVALID.
- For the two reference inputs, if they are external synchronization ports, the QL value associated with the input is QL-UNKNOWN.
- For the two reference inputs, if they are SyncE ports and the ESMC is enabled, but no valid ESMC Information PDU has been received within the previous 5 s, the QL value associated with that input is QL-FAILED.
- For GNSS reference input, the QL is PRS if a frequency is successfully recovered; otherwise, the QL is QL-FAILED.
- If the user has configured an override for the QL associated with an input, the node displays both the received and override QL value for the input. If no value has been received, the associated value is displayed instead.

After the QL values have been associated with the system timing inputs, the two reference inputs and the external input timing ports are processed by the system timing module to select a source for the SSU. This selection process is as follows.

- Before an input can be used as a potential timing source, it must be enabled using the following command:

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– **MD-CLI**

```
configure system central-frequency-clock ql-selection
```

– **classic CLI**

```
configure system sync-if-timing ql-selection
```

If the **ql-selection** command option is disabled, the priority order of the inputs for the Synchronous Equipment Timing Generator (SETG) is the priority order configured under the following command:

– **MD-CLI**

```
configure system central-frequency-clock ref-order
```

– **classic CLI**

```
configure system sync-if-timing ref-order
```

- If the **ql-selection** command is enabled, the priority of the inputs is calculated using the associated QL value of the input and the priority order configured under the **ref-order** command. The inputs are ordered by the internal relative QL based on their associated QL values. If two or more inputs have the same quality level value, they are placed in order based on where they appear in the **ref-order** priority. The priority order for the SETG is based on both the reference inputs and the external synchronization input ports.
- After a prioritized list of inputs is calculated, the SETG and the external synchronization output ports are configured to use the inputs in their respective orders.
- After the SETG and external synchronization output ports priority lists are programmed, the highest-qualified priority input is used. To be qualified, the signal is monitored to ensure that it has the expected format and a frequency that is within the pull-in range of the SETG.

6.3.3.2 Extended QL TLV for ESMC messaging

SR OS supports the extended QL TLV of the ESMC message as defined in ITU-T G.8264. This TLV allows the communication of newer QL values and some synchronization trail information up to the current clock. The newly added QL values include:

- QL_ePRTC
- QL_PRTC
- QL_PRC
- QL_eEEC

6.3.4 Clock source QL definitions

The following clock source QLs have been identified for tracking network timing flow. These levels make up all the defined network deployment options described in Recommendation G.803 and G.781. The Option I network is developed on the original European SDH model. The Option II network is developed on the North American SONET model.

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In addition to the QL values received over the SSM of an interface, the standards also define additional codes for internal use. These include the following:

- QL INVx is generated internally by the system if and when an unallocated SSM value is received, where x represents the binary value of this SSM. All independent values are assigned as the single value of QL-INVALID.
- QL FAILED is generated internally by the system if and when the terminated network synchronization distribution trail is in the signal fail state.

Additionally, QL-UNKNOWN is an internal QL used to differentiate from a received QL-STU code. For the purposes of QL selection, it is considered equivalent.

The following table lists the synchronization message coding and source priorities for SSM received.

Table 18: Synchronization message coding and source priorities — SSM received

SSM value received on port				**Internal relative QL**
SDH interface or SyncE interface in SDH mode	**SONET interface or SyncE interface in SONET mode**	**E1 interface**	**T1 interface (ESF)**	
0010 (prc)	0001 (prs)	0010 (prc)	00000100 11111111 (prs)	1. Best quality
	0000 (stu)		00001000 11111111 (stu)	2.
	0111 (st2)		00001100 11111111 (ST2)	3.
0100 (ssua)	0100 (tnc)	0100 (ssua)	01111000 11111111 (TNC)	4.
	1101 (st3e)		01111100 11111111 (ST3E)	5.
1000 (ssub)		1000 (ssub)		6.
	1010 (st3/eec2)		00010000 11111111 (ST3)	7.
1011 (sec/eec1)		1011 (sec)		8. Lowest quality qualified in QL-enabled mode
	1100 (smc)		00100010 11111111 (smc)	9.
			00101000 11111111 (st4)	10.
	1110 (pno)		01000000 11111111 (pno)	11.

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SSM value received on port				Internal relative QL
SDH interface or SyncE interface in SDH mode	SONET interface or SyncE interface in SONET mode	E1 interface	T1 interface (ESF)	
1111 (dnu)	1111 (dus)	1111 (dnu)	00110000 11111111 (dus)	12.
Any other	Any other	Any other	N/A	13. QL_INVALID
				14. QL-FAILED
				15. QL-UNC

The following table lists the synchronization message coding and source priorities for SSM transmitted.

Table 19: Synchronization message coding and source priorities — SSM transmitted

Internal relative QL	SSM values transmitted by interface of type			
	SDH interface or SyncE interface in SDH mode	SONET interface or SyncE interface in SONET mode	E1 interface	T1 interface (ESF)
1. Best quality	0010 (prc)	0001 (PRS)	0010 (prc)	00000100 11111111 (PRS)
2.	0100 (ssua)	0000 (stu)	0100 (ssua)	00001000 11111111 (stu)
3.	0100 (ssua)	0111 (st2)	0100 (ssua)	00001100 11111111 (st2)
4.	0100 (ssua)	0100 (tnc)	0100 (ssua)	01111000 11111111 (tnc)
5.	1000 (ssub)	1101 (st3e)	1000 (ssub)	01111100 11111111 (st3e)
6.	1000 (ssub)	1010 (st3/eec2)	1000 (ssub)	00010000 11111111 (st3)
7.	1011 (sec/eec1)	1010 (st3/eec2)	1011 (sec)	00010000 11111111 (st3)
8. Lowest quality qualified in QL-enabled mode	1011 (sec/ eec1)	1100 (smc)	1011 (sec)	00100010 11111111 (smc)
9.	1111 (dnu)	1100 (smc)	1111 (dnu)	00100010 11111111 (smc)

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Internal relative QL	SSM values transmitted by interface of type			
	SDH interface or SyncE interface in SDH mode	SONET interface or SyncE interface in SONET mode	E1 interface	T1 interface (ESF)
10.	1111 (dnu)	1111 (dus)	1111 (dnu)	00101000 11111111 (st4)
11.	1111 (dnu)	1110 (pno)	1111 (dnu)	01000000 11111111 (pno)
12.	1111 (dnu)	1111 (dus)	1111 (dnu)	00110000 11111111 (dus)
13. QL_INVALID	1111 (dnu)	1111 (dus)	1111 (dnu)	00110000 11111111 (dus)
14. QL-FAILED	1111 (dnu)	1111 (dus)	1111 (dnu)	00110000 11111111 (dus)
15. QL-UNC	1011 (sec/eec1)	1010 (st3/eec2)	1011 (sec)	00010000 11111111 (st3)

Note: When the internal QL is in the 9 through 14 range, the output codes shown in the preceding table appear only if QL selection is disabled. If QL selection is enabled, all internal states are changed to internal state 15 (Holdover) and the generated SSM value reflects the holdover quality of the internal clock.

6.3.5 Advanced G.781 features

The central clock of the node supports several advanced features of the ITU-T G.781 standard. These include the specification of minimum acceptable QL values for the input references and the specification of a Wait To Restore timer for input references. These features allow for more options in the management of the synchronization topology.

6.3.6 IEEE 1588v2 PTP

Note: The IEEE 1588 Working Group has introduced the terms timeTransmitter and timeReceiver as alternatives to the former master/slave terminology. This document has been updated with these new terms.

PTP is a timing-over-packet protocol defined in the IEEE 1588v2 standard 1588 PTP 2008.

PTP may be deployed as an alternative timing-over-packet option to Adaptive Clock Recovery (ACR). PTP provides the capability to synchronize network elements to a Stratum-1 clock or primary reference clock (PRC) traceable frequency source over a network that may or may not be PTP-aware. PTP has several advantages over ACR. It is a standards-based protocol, has lower bandwidth requirements, can transport both frequency and time, and can potentially provide better performance.

Support is provided for an ordinary clock in timeReceiver or timeTransmitter mode or a boundary clock. When configured as an ordinary clock timeTransmitter, PTP can only be used for the distribution of a

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frequency reference, not a time reference. The boundary clock and ordinary clock timeReceiver can be used for both frequency and time distribution.

The ordinary clock timeTransmitter, ordinary clock timeReceiver, and boundary clock communicate with neighboring IEEE 1588v2 clocks. These neighbor clocks can be ordinary clock timeTransmitters, ordinary clock timeReceivers, or boundary clocks. The communication can be based on either unicast IPv4/IPv6 sessions transported through IP interfaces or multicast Ethernet transported through Ethernet ports.

Note: The source address used for the originating IPv6 PTP messages must have an IPv6 address defined using the following commands:

- **MD-CLI**

```
configure system security source-address ipv6 address
configure service vprn source-address ipv6 address
```

- **classic CLI**

```
configure system security source-address application6
configure service vprn source-address application6
```

For the unicast IP sessions, the external clocks are labeled "peers". There are two types of peers: configured and discovered. An ordinary clock timeReceiver or a boundary clock should have configured peers for each PTP neighbor clock from which it may accept synchronization information. The router initiates unicast sessions with all configured peers. An ordinary clock timeTransmitter or boundary clock accepts unicast session requests from external peers. If the peer is not a configured peer, then it is considered a discovered peer. An ordinary clock timeTransmitter or boundary clock can deliver synchronization information toward discovered peers. The following figure shows the relationship of various neighbor clocks using unicast IP sessions to communicate with a 7705 SAR Gen 2 configured as a boundary clock with two configured peers.

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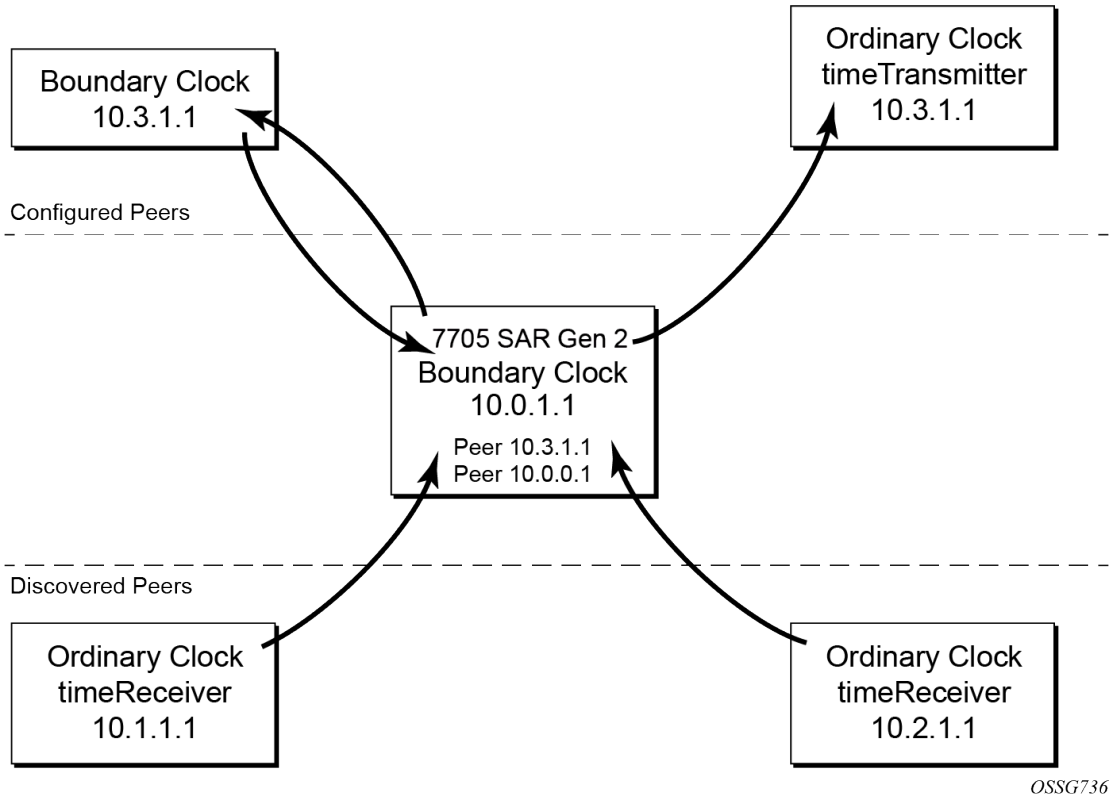
Figure 8: Peer clocks



For multicast Ethernet operation, the router listens for and transmits PTP messages using the configured multicast MAC address. Neighbor clocks are discovered via the reception of messages through an enabled Ethernet port. An ordinary clock timeTransmitter, ordinary clock timeReceiver, and a boundary clock support more than one neighbor PTP clock connecting into a single port. This may be encountered with the deployment of an Ethernet multicast LAN segment between the local clock and the neighbor PTP ports using an end-to-end transparent clock or an Ethernet switch. The Ethernet switch is not recommended because of the introduction of PDV and potential performance degradation, but it can be used if appropriate to the application.

Figure 9: Ethernet multicast ports shows the relationship of various neighbor clocks using multicast Ethernet sessions to a 7705 SAR Gen 2 configured as a boundary clock. The 7705 SAR Gen 2 has three ports configured for multicast Ethernet communications. Port 1/2/1 of the 7705 SAR Gen 2 shows a connection where two neighbor clocks connect to one port of the 7705 SAR Gen 2 through an end-to-end transparent clock.

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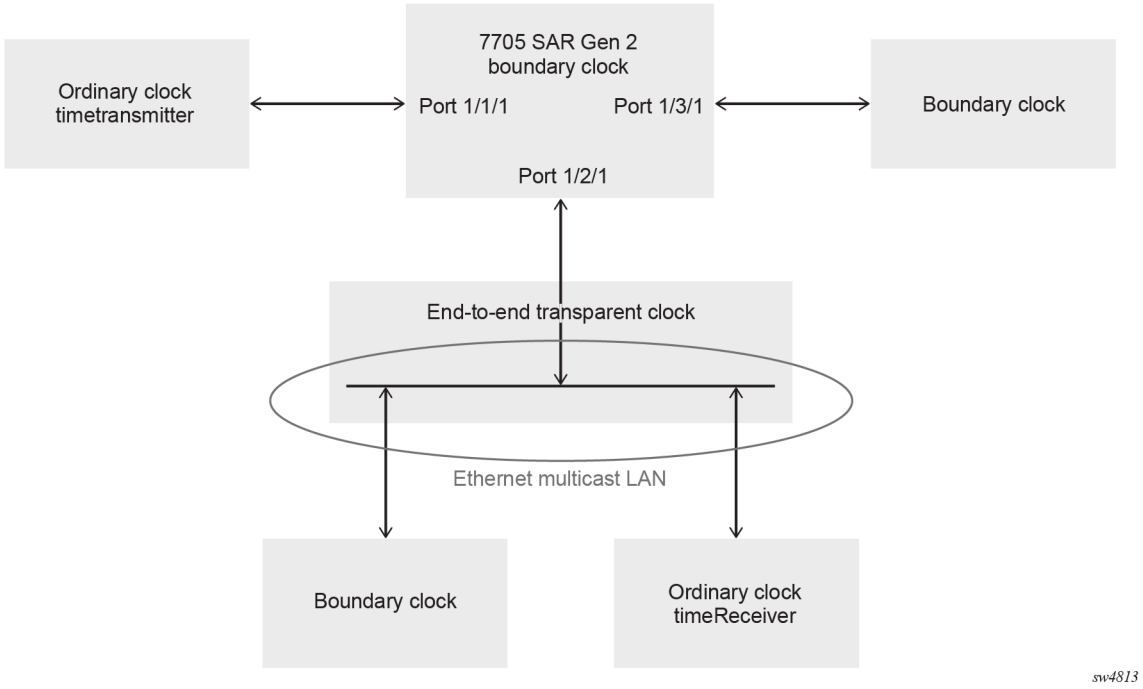
Figure 9: Ethernet multicast ports



The ordinary clock timeTransmitter, ordinary clock timeReceiver, and boundary clock allow PTP operation over both unicast IPv4/IPv6 and multicast Ethernet at the same time.

The IEEE 1588v2 standard includes the concept of PTP profiles. These profiles are defined by industry groups or standards bodies that define how IEEE 1588v2 should be used for a specific application.

The following profiles are supported on the 7705 SAR Gen 2:

- IEEE 1588v2 (ieee1588-2008)
- G.8265.1 (g8265dot1-2010)
- G.8275.1 (g8275dot1-2014)
- IEC 61850-9-3 (iec-61850-9-3-2016)
- C37.238 (c37dot238-2017)
- G.8275.2 (g8275dot2-2016)

When an ordinary clock timeReceiver or a boundary clock receives Announce messages from one or more configured peers or multicast neighbors, it executes a Best TimeTransmitter Clock Algorithm (BTCA) to determine the state of communication between itself and the peers. The system uses the BTCA to create a hierarchical topology allowing the flow of synchronization information from the best source (the grandmaster clock) out through the network to all boundary and timeReceiver clocks. Each profile has a dedicated BTCA.

If the **profile** setting for the clock is **ieee1588-2008**, **iec-61850-9-3-2016**, or **c37dot238-2017**, the precedence order for the BTCA is as follows:

1. priority1
2. clockClass

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3. clockAccuracy
4. PTP variance (offsetScaledLogVariance)
5. priority2
6. clockIdentity
7. stepsRemoved from the grandmaster

The ordinary clock timeTransmitter, ordinary clock timeReceiver, and boundary clock set their local parameters as listed in the following table.

Table 20: Local clock parameters when profile is set to ieee1588-2008

Parameter	Value
clockIdentity	Chassis MAC address following the guidelines of 7.5.2.2.2 of IEEE 1588
clockClass	6 — local clock is configured using a time reference from a GNSS receiver 7 — local clock is in holdover after losing time reference from the local GNSS receiver for no more than ten minutes 13 — local clock configured as ordinary clock time Transmitter and is locked to an external reference 14 — local clock configured as ordinary clock time Transmitter and in holdover after having been locked to an external source 248 — local clock configured as ordinary clock time Transmitter and is in free run or the router is configured as a boundary clock 255 — local clock configured as ordinary clock timeReceiver
clockAccuracy	FE — unknown 21 — when using a time reference from a GNSS receiver
offsetScaledLogVariance	FFFF — not computed

If the **profile** setting for the clock is **g8265dot1-2010**, the precedence order for the best timeTransmitter selection algorithm is:

1. clockClass
2. priority

The ordinary clock timeTransmitter, ordinary clock timeReceiver, and boundary clock use local settings as listed in the following table.

Table 21: Local clock parameters when profile is set to itu-telecom-freq

Parameter	Value
clockClass	80-110 — value corresponding to the QL out of the central clock as per Table 1/G.8265.1

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Parameter	Value
	255 — the clock is configured as ordinary clock timeReceiver
domain number	0 to 255 — configured domain value must be within this range when the G.8265.1 profile is used, and is 4 by default

The **g8265dot1-2010** profile is for use in an environment with only ordinary clock timeTransmitters and timeReceivers for frequency distribution.

If the **profile** setting for the clock is **g8275dot1-2014**, the precedence order for the best timeTransmitter selection algorithm is very similar to that used with the default profile. It ignores **priority1**, includes a **localPriority**, and includes the ability to force a port to never enter timeReceiver state (**timeTransmitter-only**).

Note: The **g8275dot1-2014** keyword is the CLI name of the profile. SR OS complies with the latest published version of the ITU-T G.8275.1 recommendation; the year in the keyword does not indicate the edition of the recommendation that is supported.

The precedence is as follows:

1. clockClass
2. clockAccuracy
3. PTP variance (offsetScaledLogVariance)
4. priority2
5. localPriority
6. clockIdentity (See Note)
7. stepsRemoved from the grandmaster

Note:
This step is typically skipped when comparing two clocks with advertised clock class of less than 128, which is the case for most grandmaster clocks.

The ordinary clock timeTransmitter, ordinary clock timeReceiver, and boundary clock use local settings listed in the following table.

Table 22: Local clock settings when profile is set to g8275dot1-2014

Parameter	Value
clockIdentity	Chassis MAC address following the guidelines of 7.5.2.2.2 of IEEE 1588
clockClass	165 — local clock configured to a boundary clock and the boundary clock was previously locked to a grandmaster with a clock class of 6 248 — local clock configured as boundary clock 255 — local clock configured as ordinary clock timeReceiver
clockAccuracy	FE — unknown

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Parameter	Value
offsetScaledLogVariance	FFFF — not computed
clockMode	freerun acquiring locked holdover within specification holdover out of specification
sdoId	0
profileIdentifier	The profile identifier assigned to the latest published version of the ITU-T G.8275.1 recommendation

The clock mode indicates the synchronization state of the local clock. The router reports both the current clock mode and the time that has elapsed since the clock entered that mode, which allows it to track the holdover performance of the clock. The values of the fields in the transmitted Announce messages follow the clock mode.

The **numberPorts** value in the defaultDS data set reports the number of PTP ports and peers on the local clock. If the node supports GNSS and is configured as a boundary clock, GNSS ports are also counted. Otherwise, GNSS inputs are not considered PTP ports are not counted.

The router transmits and accepts PTP messages that use either an IEEE 1588-2019 or an IEEE 1588-2008 message header. The majorSdoId and minorSdoId fields are set to 0 and the minorVersionPTP field is set to 1.

If the **profile** setting for the clock is **g8275dot2-2016**, the precedence order for the best master selection algorithm is very similar to that used with the **g8275dot1-2014** profile. It ignores the **priority1** parameter, includes a **localPriority** parameter, and includes the ability to force a port to never enter slave state (**master-only**). The precedence is as follows:

- clockClass
- clockAccuracy
- PTP variance (offsetScaledLogVariance)
- priority2
- localPriority
- clockIdentity
- stepsRemoved from the grandmaster

Note: If the two clocks being compared have a clockClass of less than 128, the comparison of the clockIdentity is skipped. Skipping the comparison of the clockIdentity is the normal case because the vast majority of clocks used as grandmasters advertise a clockClass of less than 128.

The following table describes the local parameter settings when the **profile** setting for the clock is **g8275dot2-2016**.

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Table 23: Local Clock Parameters: g8275dot2-2016

Parameter	Value and Description
clockIdentity	Chassis MAC address following the guidelines of 7.5.2.2.2 of IEEE 1588
clockClass	6 — local clock is using a time reference from a GNSS receiver 165 — local clock is configured as a boundary clock in holdover; the boundary clock was previously locked to a grandmaster clock with a clock class of 6 248 — local clock is configured as a grandmaster clock or boundary clock in free-run mode 255 — local clock is configured as an ordinary clock slave
clockAccuracy	0xFE — unknown 0x21 — when using a time reference from a GNSS receiver
offsetScaledLogVariance	0xFFFF — not computed 0x4e5d (1.8E-15) — when using a time reference from a GNSS receiver

There is a limit on the number of external PTP clocks to which the ordinary clock timeReceiver or boundary clock requests unicast service (number of configured peers). There is also a limit to the number of external PTP clocks to which the ordinary clock timeTransmitter or boundary clock grants unicast service (number of discovered peers). An association where the boundary clock has a symmetric relationship with another boundary clock (in other words, they both have the other as a configured peer) consumes a request and a grant unicast service in each router.

The number of configured Ethernet ports is not restricted.

There are limits to the maximum transmitted and received event message rates supported in the router. Each unicast IP service established consumes a portion of one of the unicast message limits. When either limit is reached, the device sends a grant response with zero in the duration field to refuse additional unicast service requests.

See the scaling guide for the appropriate release for the specific unicast message limits related to PTP.

Multicast messages are not considered when validating the unicast message limit. When multicast messaging on Ethernet ports is enabled, the PTP load must be monitored to ensure usage capabilities are not exceeded. If the capacity usage reaches 100%, the PTP software process on the router is at its limit of transmitting and receiving PTP packets.

Several commands are available for use to monitor PTP load:

- Use the following command to identify the load of the PTP software process.

```
show system cpu
```

- Use the following command to display aggregate packet rates.

```
show system ptp statistics
```

Because the volume of PTP messages received over the Ethernet ports is unpredictable, use the statistics commands to identify the source of the message load..

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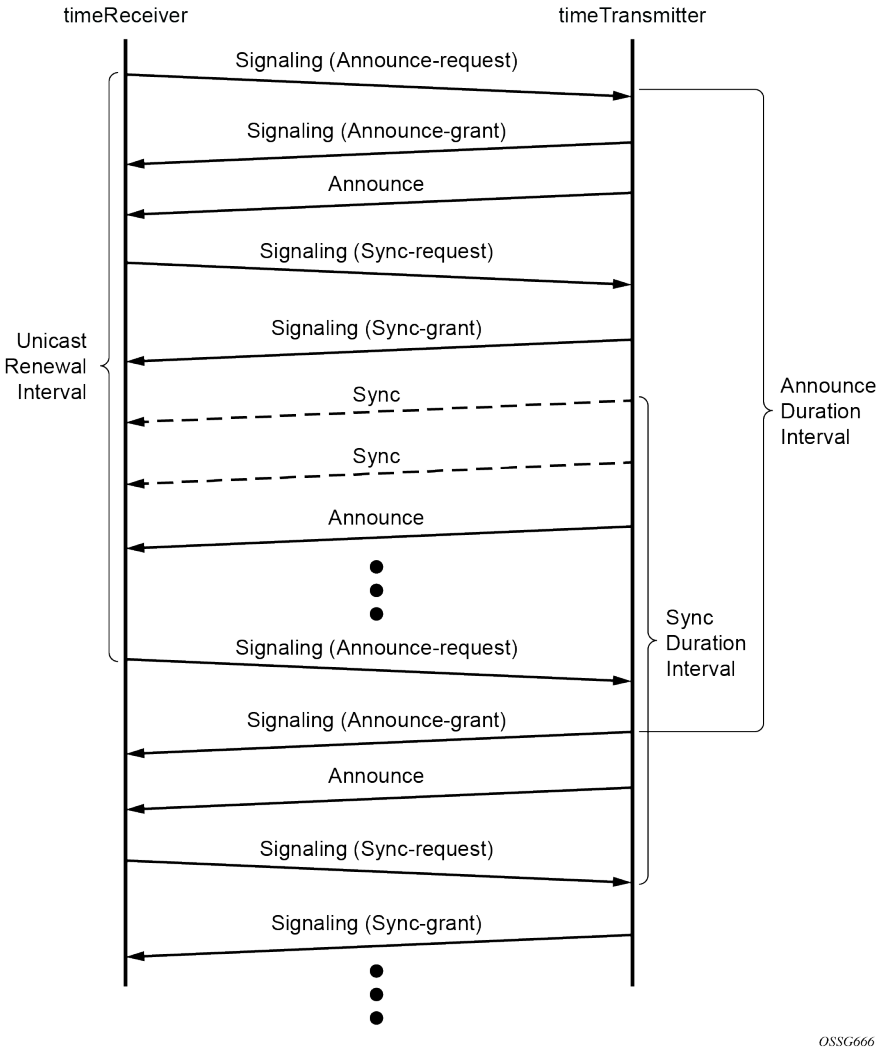
Use the following commands to display received packet rates.

```
show system ptp port
show system ptp port detail
```

Figure 10: Messaging sequence between the PTP timeReceiver clock and PTP timeTransmitter clock shows the unicast negotiation procedure performed between a timeReceiver and a peer clock that is selected to be the timeTransmitter clock. The timeReceiver clock requests Announce messages from all peer clocks but only request Sync and Delay_Resp messages from the clock selected to be the timeTransmitter clock.

Figure 10: Messaging sequence between the PTP timeReceiver clock and PTP timeTransmitter clock



6.3.6.1 PTP clock synchronization

The IEEE 1588v2 standard synchronizes the frequency and time from a timeTransmitter clock to one or more timeReceiver clocks over a packet stream. This packet-based synchronization standard defines

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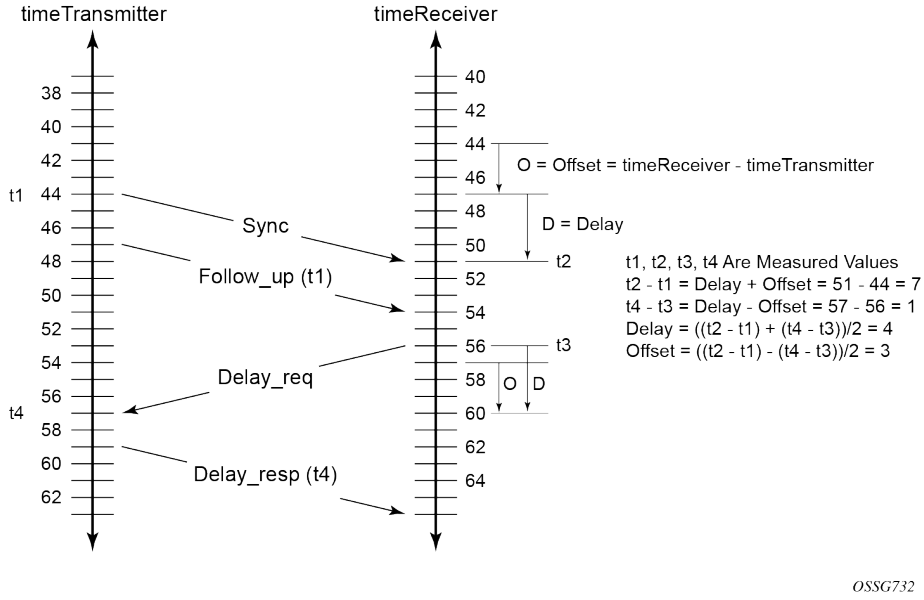
transport to use UDP/IP with unicast or Ethernet with multicast. See PTP capabilities for information about supported PTP encapsulation types.

As part of the basic synchronization timing computation, a number of event messages are defined for synchronization messaging between the PTP timeReceiver port and PTP timeTransmitter port. A one-step or two-step synchronization operation can be used, with the two-step operation requiring a follow-up message after each synchronization message. Ordinary clock timeTransmitter and boundary clock timeTransmitter ports use one-step operation; ordinary clock timeReceiver and boundary clock timeReceiver ports can accept messages from either one-step or two-step operation timeTransmitter ports.

The IEEE 1588v2 standard includes a mechanism to control the topology for synchronization distribution. The Best TimeTransmitter Clock Algorithm (BTCA) defines the states for the PTP ports on a clock. One port is set to the timeReceiver state and the other ports are set to the timeTransmitter (or passive) state. Ports in the timeReceiver state recover synchronization delivered by an external PTP clock, and ports in the timeTransmitter state transmit synchronization to external PTP clocks.

The following figure shows the basic synchronization timing computation between the PTP timeReceiver clock and PTP best timeTransmitter. This figure illustrates the offset of the timeReceiver clock referenced to the best timeTransmitter signal during startup.

Figure 11: PTP timeReceiver clock and timeTransmitter clock synchronization timing computation



When using IEEE 1588v2 for distribution of a frequency reference, the timeReceiver calculates a message delay from the timeTransmitter to the timeReceiver based on the timestamps exchanged. A sequence of these calculated delays contain information of the relative frequencies of the timeTransmitter clock and timeReceiver clock but has a noise component related to the PDV experienced across the network. The timeReceiver must filter the PDV effects to extract the relative frequency data, then adjust the timeReceiver frequency to align with the timeTransmitter frequency.

When using IEEE 1588v2 for distribution of time, the 7705 SAR-Hx and 7705 SAR-Mx use the four timestamps exchanged using the IEEE 1588v2 messages to determine the offset between the router time base and the external timeTransmitter clock time base. The router determines the offset adjustment and then in between these adjustments, the router maintains the progression of time using the frequency from the central clock of the router. This allows time to be maintained using a SyncE input source even if the

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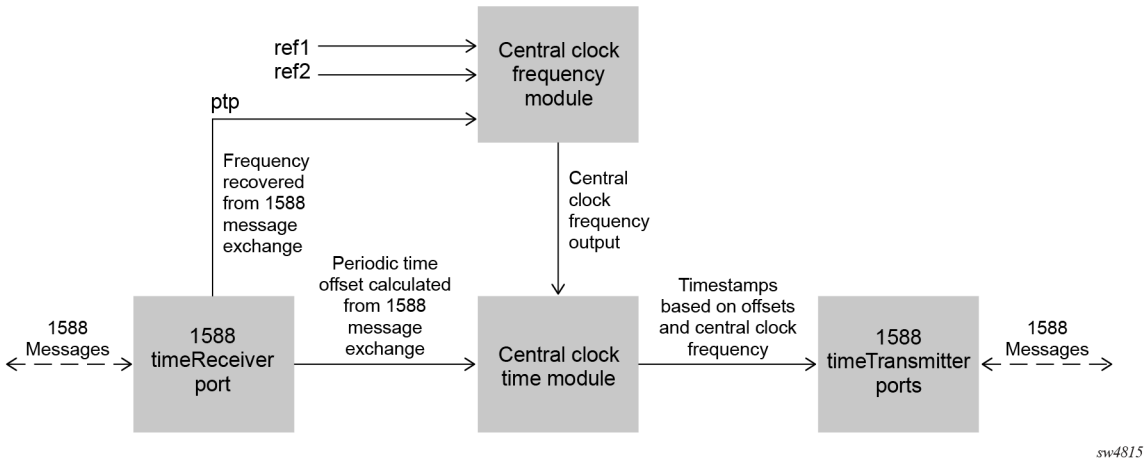
IEEE 1588v2 communications fail. When using IEEE 1588v2 for time distribution, the central clock should at a minimum have a system timing input reference enabled.

The following figure shows a logical model for using PTP/1588 for network synchronization.

Figure 12: Logical model for using PTP/1588 for network synchronization



6.3.6.1.1 Synchronization uncertainty

The PTP protocol uses the BTCA to build the network topology from a PTP grandmaster, through one or more boundary clocks, and into timeReceiver clocks. This mechanism relies on the grandmaster information contained in the Announce messages sent between these clocks. While the BTCA is designed to create the topology quickly and without any timing loops, it does not account for the time it takes for each clock to synchronize its local time with that of its newly selected parent clock.

To address this, the IEEE and ITU-T adds the synchronizationUncertain bit to the header of Announce message. A grandmaster or boundary clock sets this bit to true when it is calibrating. In addition, if this bit is set to true in the Announce messages from its parent clock, the boundary clock always transmits this bit as true. This allows the topology to settle quickly, but also provides an indication to the final timeReceiver clocks as to when they can trust the time being delivered by the network.

The optional synchronizationUncertain bit (flagField octet 1, bit 6) defined in the G.8275.1, G.8275.2, and IEEE 1588 specifications in Announce messages indicates the synchronization uncertainty of the PTP clock to the user and downstream clocks. A synchronizationUncertain bit value of 1 indicates a SyncUncertain TRUE state, meaning the local clock is still in the transient phase and attempting to achieve stability. A synchronizationUncertain bit value of 0 indicates a SyncUncertain FALSE state, meaning the local clock has reached the steady state phase.

Transition to the SyncUncertain FALSE state occurs when all of the following conditions are true for a number of consecutive, stable PTP time update windows:

- the parent PTP clock is in a SyncUncertain FALSE state
- PTP time recovery is locked
- the grandmaster PTP clock is Clock Class 6 or 7
- the central frequency clock is locked, and the QL of the frequency is QL-PRC/QL-PRS

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- PTP frequency recovery is locked if PTP is used for frequency and the profile is G.8275.2 or IEEE 1588v2

The transition back to the SyncUncertain TRUE state occurs if any of the preceding conditions are not met, even momentarily, and the stable PTP time update window count resets to 0.

In some deployments, other PTP clocks in the network may not support the synchronizationUncertain bit. If the upstream clocks do not support synchronizationUncertain, the synchronizationUncertain bit is 0, indicating a SyncUncertain FALSE state, regardless of the actual state of the local clock. If the downstream clocks do not support synchronizationUncertain, it may be desirable to stop transmitting Announce messages while the local clock is in the SyncUncertain TRUE state. Use the following command to stop this transmission:

- **MD-CLI**

```
configure system ptp tx-while-sync-uncertain false
```

- **classic CLI**

```
configure system ptp no tx-while-sync-uncertain
```

If this command is used to stop the transmission of Announce messages while the local clock is in the SyncUncertain TRUE state, unicast negotiation grant requests are not granted and current grants are canceled.

6.3.6.2 Performance considerations

Although IEEE 1588v2 can be used on a network that is not PTP-aware, the use of PTP-aware network elements (boundary clocks) within the packet-switched network improves synchronization performance by reducing the impact of PDV between the grandmaster clock and the timeReceiver clock. When IEEE 1588v2 is used to distribute high-accuracy time, such as for mobile base station phase requirements, the network architecture requires the deployment of PTP awareness in every device between the grandmaster clock and the mobile base station timeReceiver.

In addition, performance is also improved by the removal of any PDV caused by internal queuing within the boundary clock or timeReceiver clock. This is accomplished with hardware that is capable of detecting and time stamping the IEEE 1588v2 packets at the Ethernet interface. This capability is referred to as port-based timestamping.

6.3.6.2.1 Port-based timestamping of PTP messages

To meet the stringent performance requirements of PTP mobile network applications, the 1588 packets must be timestamped at the ingress and egress ports. This requires the use of 1588 port-based timestamping on the ports handling the PTP messages. This avoids any possible PDV that may be introduced between the port and the CPM. The ability to timestamp in the interface hardware is provided on a subset of the MDA assemblies of the routers.

When configuring the **ptp-hw-assist** command for PTP over IP, a loopback address must be used for PTP to ensure these message are timestamped at the port, even after the routing topology changes. To configure the loopback address, use one of the following commands:

- **MD-CLI**

```
configure system security source-address ipv4 ptp address
```


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```
configure system security source-address ipv6 ptp address
```

- **classic CLI**

```
configure system security source-address application ptp
configure system security source-address application6 ptp
```

Enabling the **ptp-hw-assist** command option within a Layer 3 interface is only supported if one of the following conditions is met:

- all physical ports contained in the interface support PBT for PTP over UDP/IPv4
- all physical ports contained in the interface support PBT for PTP over UDP/IPv6 and a loopback IPv6 address is configured for PTP using the following commands:
  - **MD-CLI**

```
configure system security source-address ipv6 ptp address address
configure service vprn source-address ipv6 ptp address address
```

  - **classic CLI**

```
configure system security source-address application6 ptp ip-int-name | ip-address
configure service vprn source-address application6 ptp ip-int-name | ip-address
```

While the **ptp-hw-assist** feature supports port timestamping for a single router interface per physical port, the **ptp-timestamping** port-level configuration feature supports port timestamping for multiple router interfaces per physical port. The **ptp-timestamping** feature applies port timestamping to PTP messages using UDP/IPv4 or UDP/IPv6 transport. The destination IP addresses specified under the port-level **ptp-timestamping** feature should be configured as one of the source addresses defined for PTP use.

The **ptp-timestamping** feature enables the local PTP clock to use PTP over IP over multiple router interfaces per physical port. This feature can also be used for router interfaces across different router instances that have the same local PTP IP address.

When using the **ptp-timestamping** feature, all received messages that match the characteristics (PTP protocol, UDP over IP with the configured address, PTP event message) must be delivered to the PTP process of the node.

Caution: If PTP traffic on the port within a VLAN is forwarded across the node and does not reach the PTP process of the node, the traffic may become corrupted. To avoid corruption, this traffic should be moved to a different physical port.

6.3.6.3 PTP capabilities

To exchange PTP messages between the router and an external 1588 clock, a unicast session must be established for each PTP message type using the unicast negotiation procedures. The router allows the configuration of the message rate to be requested from external 1588 clocks. The router also supports a range of message rates that it grants to requests received from the external 1588 clocks. The IEEE 1588 standard allows the grantor port to respond with a shorter duration than what was in the request. The router can accept such a grant and uses that duration. The router issues a renegotiation before the duration expires.

The following table describes the ranges for both the rates that the 7705 SAR-10x, 7705 SAR-Hx, and 7705 SAR-Mx can request and grant.

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Table 24: Message rate ranges and defaults

Message type	Rates requested		Rates granted	
	Minimum	Maximum	Minimum	Maximum
Announce	1 packet every 16 seconds	8 packets per second	1 packet every 16 seconds	8 packets per second
Sync	1 packet per second	64 packet per second	1 packet per second	128 packet per second
Delay_Resp	1 packet per second	64 packets per second	1 packet per second	128 packets per second
(Duration)	300	300	1	1000

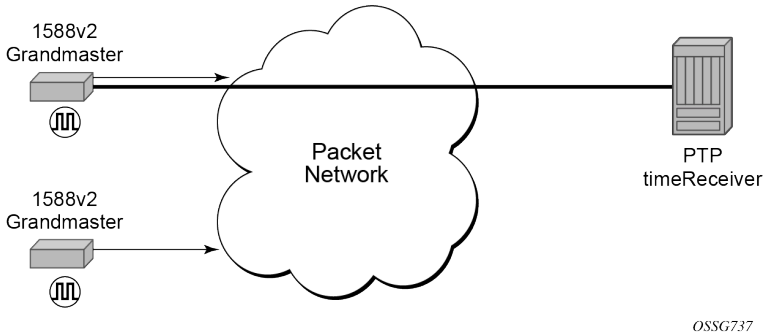
State and statistics data for each PTP peer are available to assist in detecting failures or unusual situations.

6.3.6.4 PTP ordinary timeReceiver clock for frequency

Traditionally, only clock frequency is required to ensure smooth transmission in a synchronous network. The PTP ordinary clock with timeReceiver capability on the router provides another option to reference a Stratum-1 traceable clock across a packet-switched network. The recovered clock can be referenced by the internal SSU and distributed to all slots and ports.

The following figure shows a PTP ordinary timeReceiver clock network configuration.

Figure 13: PTP ordinary timeReceiver clock for frequency



The PTP timeReceiver capability is implemented on the CPM. The IEEE 1588v2 messages can ingress and egress the router on any line interface. The following figure shows the operation of an ordinary PTP clock in timeReceiver mode.

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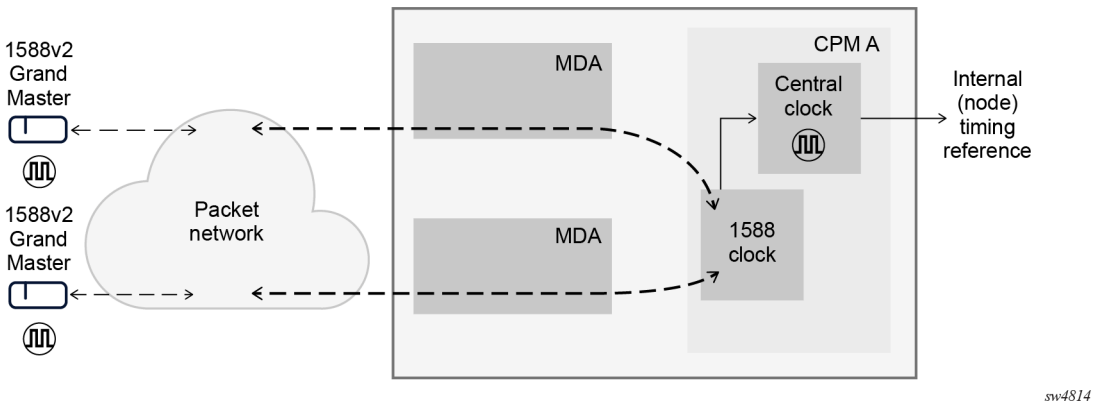
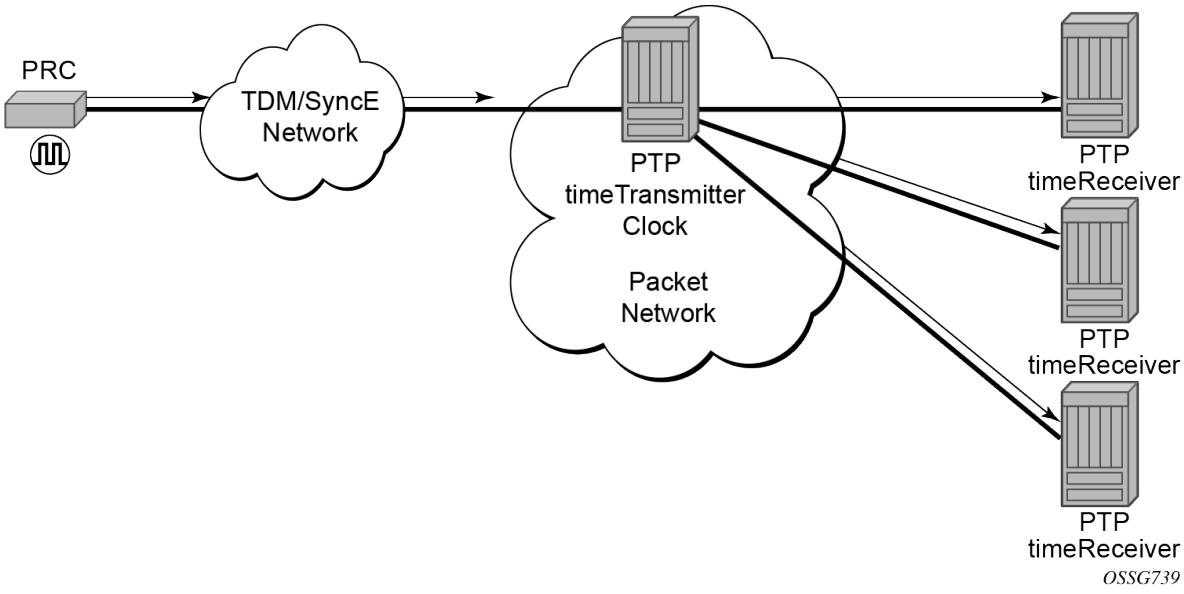
Figure 14: Ordinary timeReceiver clock operation



6.3.6.5 PTP ordinary timeTransmitter clock for frequency

The router supports the PTP ordinary clock in timeTransmitter mode. Normally, an IEEE 1588v2 grandmaster is used to support many timeReceivers and boundary clocks in the network. In cases where only a small number of timeReceivers and boundary clocks exist and only frequency is required, a PTP integrated timeTransmitter clock can greatly reduce hardware and management costs to implement PTP across the network. It also provides an opportunity to achieve better performance by placing a timeTransmitter clock closer to the edge of the network, as close to the timeReceiver clocks as possible. The following figure shows a PTP timeTransmitter clock network configuration.

Figure 15: PTP timeTransmitter clock



All packets are routed to their destination via the best route as determined in the route table, as shown in the following figure. It does not matter which ports are used to ingress and egress these packets (unless port based time stamping is enabled for higher performance).

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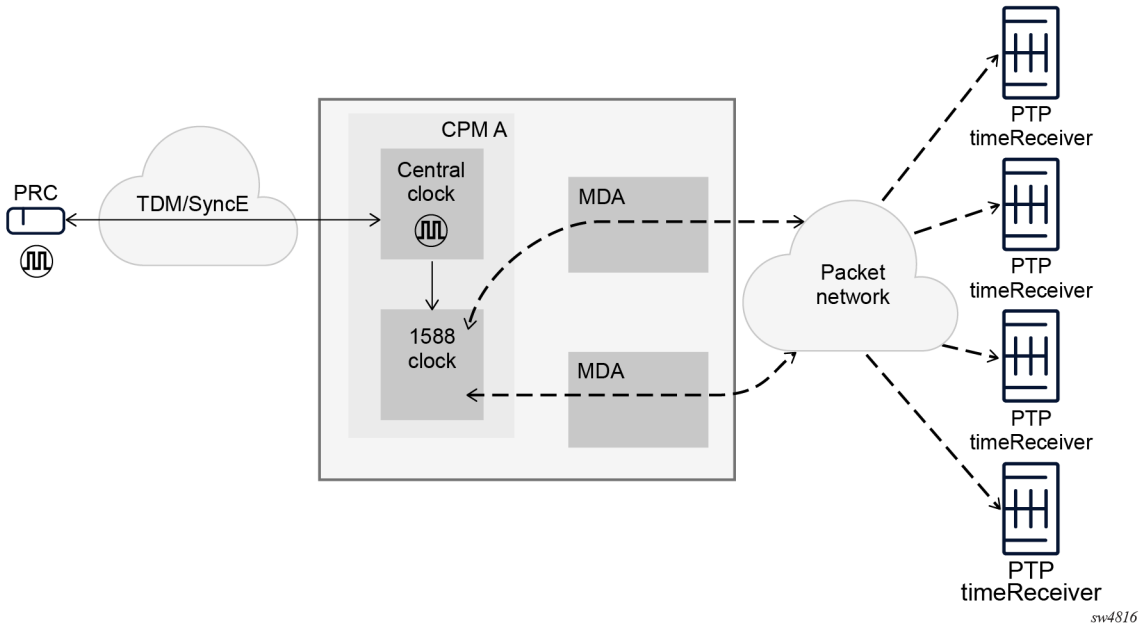
Figure 16: Ordinary timeTransmitter clock operation



6.3.6.6 PTP boundary clock for frequency and time

The router supports boundary clock PTP devices in both timeTransmitter and timeReceiver states.

IEEE 1588v2 can function across a packet network that is not PTP-aware. However, the performance may be unsatisfactory and unpredictable. PDV across the packet network varies with the number of hops, link speeds, utilization rates, and the inherent behavior of the routers. By using routers with boundary clock functionality in the path between the grandmaster clock and the timeReceiver clock, one long path over many hops is split into multiple shorter segments, allowing better PDV control and improved timeReceiver performance. This allows PTP to function as a valid timing option in more network deployments, allowing better scalability and increased robustness in specific topologies, such as rings.

Boundary clocks can simultaneously function as a PTP timeReceiver of an upstream grandmaster (ordinary clock) or boundary clock, and as a PTP timeTransmitter of downstream timeReceivers (ordinary clock) and boundary clocks, as shown in the following figure.

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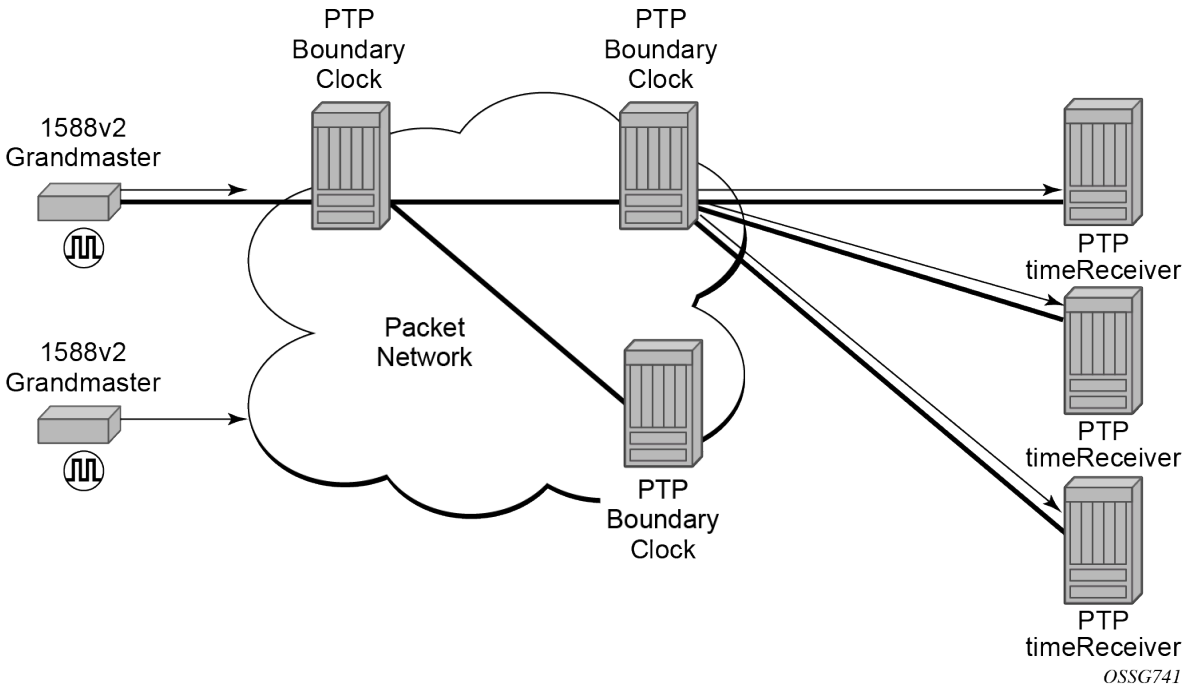
Figure 17: PTP boundary clock for frequency and time



Nokia strongly recommends using port-based timestamping in every network element between the grandmaster and the end timeReceiver application to achieve time accuracies of one microsecond required by mobile applications.

The router always uses the frequency output of the central frequency clock to maintain the timebase within the router. When using the G.8275.1 profile, it is mandatory to have the central frequency clock configured to use a Layer 1 frequency source, such as a SyncE port. For other profiles, Nokia recommends using a Layer 1 frequency source. If a Layer 1 frequency source is unavailable, enable PTP as a source for the central frequency clock to have frequency for timestamping traceable to a high accuracy source.

When a router with an enabled GNSS port is configured with boundary clock functionality, the boundary clock acts as a grandmaster clock. The timeReceiver function stops and the timeTransmitter ports use frequency and time recovered from the GNSS port.

6.3.6.7 PTP timeTransmitter clock for frequency and time distribution

PTP timeTransmitter clock capability for frequency and time distribution is implemented on the7705 SAR-Hx and 7705 SAR-Mx.

GNSS must be the active system timing and frequency reference for routers that are used as a grandmaster clock. The PTP timeTransmitter clock can be used for frequency and time distribution. See Configuring system timing to use a GNSS RF port for information about configuring the router to use GNSS as a system timing reference.

Use the following commands to configure the router as a grandmaster clock:

- **MD-CLI**

```
configure system ptp profile ieee1588-2008
```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```
configure system ptp clock-type master-only
configure system ptp admin-state enable
```

- **classic CLI**

```
configure system ptp profile ieee1588-2008
configure system ptp clock-type ordinary master
configure system ptp no shutdown
```

6.3.6.8 ITU-T G.8275.2 profile and APTS

The 7705 SAR-10x, 7705 SAR-Hx, and 7705 SAR-Mx support Recommendation ITU-T G.8275.2, which, similar to Recommendation ITU-T G.8275.1, specifies the architecture that allows the distribution of time and phasing. Recommendation ITU-T G.8275.1 supports full-timing from the network and Recommendation ITU-T G.8275.2 supports partial-timing (PTS) and APTS.

When the router is configured to use the G.8275.1 or G.8275.2 profile, it uses an alternate BTCA for best timeTransmitter clock selection. This BTCA includes a PTP dataset comparison that is defined in IEEE 1588-2008, but with the following differences:

- the **priority1** value is removed from the dataset comparison
- the **master-only** value must be considered
- multiple active grandmaster clocks are allowed; therefore, the BTCA selects the nearest clock of equal quality
- a port-level **local-priority** attribute value is used to select a timeReceiver port if two ports receive an Announce message. This attribute is used as a tiebreaker in the dataset comparison algorithm if all other previous attributes of the datasets being compared are equal.
- the **local-priority** value is considered for the default dataset

When the clock is configured as a boundary clock, the GNSS is treated as a virtual PTP port into the BTCA. On systems with redundant GNSS, the preference in the BTCA shall be the local GNSS followed by the standby GNSS. The GNSS receiver shall only be considered into the BTCA if it is in locked state. Also in these systems, when one of the GNSS is selected as the parent clock, there may still be a PTP port running frequency and time recovery from a remote PTP timeTransmitter port as a backup. The ptp statistics reflect this backup session.

When the PTP clock is configured to use the G.8275.2 profile without GNSS configured, the clock operates using PTS. When the PTP clock is configured to use the G.8275.2 profile and the internal GNSS is configured and operationally up, GNSS is the preferred reference by default and is selected as the source of time for PTP. For extra resilience, APTS can be deployed by configuring a PTP backup over a network with PTP support to a remote grandmaster clock.

When the clock is configured as a boundary clock, the GNSS is treated as a virtual PTP port into the BTCA. On systems with redundant GNSS, the preference in the BTCA is the local GNSS followed by the standby GNSS. The GNSS receiver is considered into the BTCA when it is in locked state. Also in these systems, when one of the GNSS is selected as the parent clock, there may still be a PTP port running frequency and time recovery from a remote PTP timeTransmitter port as a backup. The PTP statistics reflect this backup session.

During normal operation, the local GNSS source is the reference for time and frequency. If the GNSS source fails, the PTP backup is automatically used to keep the clocks synchronized and stable. The delay offset value, which is calculated while the GNSS source was up, is applied to the PTP backup to keep

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time and phase as accurate as possible. See GNSS failure with APTS for more information about APTS functionality during a GNSS failure.

The following table describes the mapping between ITU-T G.8275.2 and PTP clock types. T-BC-A and T-TSC-A clocks are applicable to APTS.

Table 25: Mapping between ITU-T G.8275.2 and PTP clock types

Clock type from ITU-T G.8275.2	Description	Clock type from IEEE 1588
T-GM	timeTransmitter ordinary clock (clock with a single PTP port; cannot be a timeReceiver from another PTP clock)	Ordinary clock
	timeTransmitter boundary clock (clock with multiple PTP ports; cannot be a timeReceiver from another PTP clock)	Boundary clock[1]
T-BC-P (partial)	Boundary clock (may become a grandmaster clock, or may be a timeReceiver from another PTP clock)	Boundary clock
T-BC-A (assisted partial)	Boundary clock assisted by a local time reference that is used as a primary source of time (may become a grandmaster clock, or may be a time Receiver to another PTP clock)	Boundary clock[2]
T-TSC-P (partial)	Always timeReceiver; single-port ordinary clock	Ordinary clock
	PTP clock at the end of the PTP synchronization chain; multiple port clock	Boundary clock[1]
T-TSC-A (assisted partial)	Always timeReceiver; single-port ordinary clock assisted by a local time reference that is used as a primary source of time	Ordinary clock[2]
	PTP clock at the end of the PTP synchronization chain; multiple-port clock assisted by a local time reference that is used as a primary source of time	Boundary clock[1, 2]

6.3.6.9 PTP message encapsulations

For physical ports located on an MDA on the 7705 SAR-10x, 7705 SAR-Hx, and 7705 SAR-Mx, PTP messages are supported in the following encapsulations:

- PTP within raw Ethernet (no VLAN header)
- PTP within UDP/IPv4 or UDP/IPv6 within raw Ethernet (no VLAN header)

No other encapsulations are supported.

1 As defined by IEEE 1588, a clock with multiple PTP ports is a boundary clock.

2 Examples of a local time reference include PRTC or a GNSS-based time source.

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6.3.6.10 PTP time for system time and OAM time

PTP has the potential to provide much more accurate time into the router than can be obtained with NTP. This PTP recovered time can be made available for system time and OAM packet timestamping to improve the accuracy of logged events and OAM delay measurements. To activate PTP as the source for these internal time bases, allocate PTP as a local server into NTP. This allows the NTP time recovery to use PTP as a time source and then distribute it to system time and the OAM process within the router. This activation also affects the operation of the NTP server within the SR OS. The PTP server appears as an NTP stratum 0 server. Consequently the SR OS advertises itself as an NTP Stratum 1 server to external peers and clients. This activation may impact the NTP topology.

6.3.6.11 PTP within routing instances

PTP is supported over direct Ethernet encapsulation (that is, PTP ports) and UDP/IP encapsulation (that is, PTP peers). PTP ports operate below the routing plane. They can be used on appropriate ports irrespective of any type of router interface also on the port. PTP peers operate at the routing plane and have restrictions based on and across the following router instances.

Transmission and reception of PTP messages using PTP peers is supported in the following contexts:

- Network interface in the Base routing instance (**configure router interface**)
- IES interface (**configure service ies interface**)
- VPRN interface (**configure service vprn interface**)

Transmission and reception of PTP messages using PTP peers is not supported in the following contexts:

- IES spoke SDP interface (**configure service ies spoke-sdp interface**)
- VPRN spoke SDP interface (**configure service vprn spoke-sdp interface**)
- VPRN transport tunnel (**configure service vprn auto-bind-tunnel** or **configure service vprn spoke-sdp**)
- Any interface of the management router instance
- Any interface of the vpls-management router instance
- Any interface of a user created CPM router instance

It is important to note that there is only one PTP clock within the router. All PTP ports and PTP peers communicate into one clock instance. Only one router instance may have PTP peers configured, which means that only that router instance (or PTP port) can run the timeReceiver functionality and recover time from an external PTP clock. All other router instances only support the dynamic PTP peers. The PTP process in the router only includes outward server time toward the dynamic PTP peers. The dynamic PTP peers are shared across all router instances. If controlling the number of dynamic peers that can be consumed by a routing instance is required, the user must configure it specifically for that routing instance.

6.3.6.12 PTSF conditions for G.8275.1

The PTP clock in the router monitors the Sync, Follow_Up (if present), and Delay_Resp messages received from external neighbor ports. If a high variation is detected in the network path between the external neighbor port and the local port, that neighbor port is considered unusable (PTSF-unusable as defined in the ITU-T G.8275.1 recommendation). When a neighbor is unusable, all Announce messages from that neighbor are discarded on reception and excluded from the BTCA. If the neighbor is the parent

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clock to the local clock, the local clock must either select a new parent clock or go into holdover. In addition, any neighbor clock marked as unusable cannot act as the parent to the local PTP clock until underlying condition is investigated and resolved, and the unusable state is cleared.

Use the commands in the following context to enable monitoring for the PTSF-unusable condition.

```
configure system ptp ptsf monitor-ptsf-unusable
```

The unusable state is cleared when PTP, PTSF-unusable monitoring, or the local PTP port is administratively disabled, the PTP port is deleted, or the external neighbor port stops sending messages to the node. It can also be cleared by using the appropriate **clear** command.

The PTP clock also monitors whether the timing messages that it expects from an external neighbor port continue to arrive. If those messages stop arriving, the neighbor port is considered to have experienced loss of timing messages (PTSF-LOTM, defined as PTSF-lossOfTimingMessages in the ITU-T G.8275.1 recommendation).

Use the **sync-receipt-timeout** and **delay-resp-receipt-timeout** commands in the following contexts to configure the number of intervals after receiving Sync and Delay_Resp messages to declare a neighbor as PTSF-LOTM.

- **MD-CLI**

  ```
  configure system ptp router peer
  configure system ptp port
  ```

- **classic CLI**

  ```
  configure service vprn ptp peer
  configure system ptp peer
  configure system ptp port
  ```

Expiry of either timeout sets the read-only PTSF-LOTM state for the affected PTP port or peer. A port or peer in the PTSF-LOTM state is excluded from the BTCA in the same way as a neighbor that is marked unusable, as previously described.

Upon receiving the expected messages from the neighbor again, the system clears the PTSF-LOTM state and restarts the corresponding receipt timeout. The state is also cleared when PTP or the local PTP port is administratively disabled, when the PTP port or configured peer is deleted, or when the corresponding receipt timeout command is disabled.

6.3.6.13 Profile interworking

There is one PTP clock within an SR OS system. The clock runs a BTCA and can set a port into timeReceiver state to recover frequency, time, or both. The recovery process is controlled by the rules of a primary profile. The SR OS also allows frequency, time, or both to be distributed outward from the clock using PTP messages that conform to the rules of an alternate profile. The primary profile and alternate profiles include a command option to configure the standard profile that defines these rules. The following guidelines apply to profile interworking on the 7705 SAR-10x, 7705 SAR-Hx, and 7705 SAR-Mx:

- Alternate profiles can only be configured if the primary profile is using standard profile **g8275dot1-2014** or **g8275dot2-2016**.
- Alternate profiles can use standard profiles **g8265dot1-2010**, **ieee1588-2008**, **g8275dot1-2014**, **g8275dot2-2016**, **iec-61850-9-3-2016**, or **c37dot238-2017**.

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- The primary profile and an alternate profile can use the same standard profile.
- Multiple alternate profiles can also use the same standard profile.

Note: The last two cases described in the preceding list may be useful if external clocks require different domain numbers or announce message rates.

Alternate profiles are associated with PTP ports and peers. Alternate profile associations are configured for PTP ports and learned by PTP peers. PTP peer alternate profiles are learned by matching the domain number of received unicast messaging with the domain of the configured alternate profile. Configured peers always use the primary profile.

Caution: When a PTP port is configured, the **log-delay-interval** and **log-sync-interval** commands are automatically configured based on the primary PTP profile that is configured. When an alternate profile is assigned to the PTP port, these values do not change. The user must configure the **log-delay-interval** and **log-sync-interval** to align with the requirements of the attached equipment.
Additionally, if the **log-delay-interval** and **log-sync-interval** commands are not changed from their default values, the values change if the primary profile changes. This behavior may result in an unexpected message rate if the default values are retained.

The following table lists the profile interworking between the primary and alternate profiles depending on the standard profile used as the primary on the 7705 SAR-10x, 7705 SAR-Hx, and 7705 SAR-Mx.

Table 26: Allowed standard profiles in alternate profile

Standard profile used in primary profile	Standard profile allowed in alternate profile
g8275dot1-2014	g8265dot1-2010 ieee1588-2008 g8275dot1-2014 g8275dot2-2016 iec-61850-9-3-2016 c37dot238-2017
g8275dot2-2016	g8265dot1-2010 ieee1588-2008 g8275dot1-2014 g8275dot2-2016 iec-61850-9-3-2016 c37dot238-2017
g8265dot1-2010 ieee1588-2008 iec-61850-9-3-2016 c37dot238-2017	Not allowed

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6.3.6.14 Annex J performance monitoring statistics

Support is provided for the collection of performance monitoring statistics for the time recovery algorithm based on Annex J/IEEE1588-2019. The following table describes the record index values.

Table 27: Performance monitor record index values

Record index value	Record shown
0	current 15-minute interval
1-96	15-minute interval within the last 24 hours
97	current 24-hour interval
98	previous 24-hour interval
501	current minute interval
502-516	one-minute interval within the last 15 minutes

Each record includes the average, minimum, maximum, and standard deviation for the following statistics:

- offset-from-master
- mean-path-delay
- timeTransmitter-to-timeReceiverDelay (master-to-slave-delay)
- timeReceiver-to-timeTransmitter delay (slave-to-master-delay)

These performance statistics are available in the following scenarios:

- local active timeReceiver port to remote PTP parent
- local active GNSS to backup PTP port
- local active timeReceiver port to other selected local PTP ports

In the local active timeReceiver port to remote PTP parent scenario, the local active timeReceiver port and the remote parent timeTransmitter port are compared. In a system where the PTP has stabilized, the offset-from-master tends toward 0. A high value indicates that the PTP path has high packet delay variation or high asymmetry.

In the local active GNSS to backup PTP port scenario, when a platform includes a GNSS receiver that is being used as a PTP time source with G.8275.1 or G.8275.2 as the PTP profile, the PTP clock runs a PTP timeReceiver port with an external timeTransmitter port, if one is available. If the PTP clock runs a PTP timeReceiver port, the Annex J statistics are computed as a comparison between the timeReceiver computed time and the GNSS time. Computing the Annex J statistics this way can provide a good indication for PTP performance should the GNSS lose lock and the node switches to use PTP input as its source of time.

In the local active timeReceiver port to other selected local PTP ports scenario, the local active timeReceiver port and another timeReceiver port in the router are compared. Up to four timeReceiver ports can be monitored simultaneously. In this case, these timeReceiver port are designated to be monitored by configuring the PTP port (or PTP peer) to be a monitorReceiver. At the remote end of these monitored PTP ports, the timeTransmitter port can be configured to be monitorSender so that the monitor process can proceed correctly, no matter the PTP state of the port.

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6.3.6.15 PTP path trace

SR OS supports PTP path trace of IEEE1588-2019 clause 16.2. This feature records and displays the chain of PTP clocks from the local clock up to the grandmaster clock.

A node-level configuration option allows the user to include or exclude the PATH_TRACE TLV. If this feature is enabled and the Announce message received from the parent clock does not include the TLV, the SR OS boundary clock creates the TLV with the local clock identity and includes that TLV in the Announce message transmitted by the node.

SR OS supports a maximum length chain of 40 clocks in the PATH_TRACE TLV. If this number is exceeded, SR OS includes only the closest 40 clock identifiers in the transmitted PATH_TRACE TLV.

6.4 Differential Clock Recovery

Differential Clock Recovery (DCR) maintains the service clock across the packet network for a circuit emulated service. DCR is only supported on the 8-port T1/E1 ASAP Adapter card.

Use the following command to enable DCR on a DS1 or E1 port.

```
configure port tdm ds1 clock-source differential
configure port tdm e1 clock-source differential
```

DCR is not supported on DS1 or E1 channels that have CAS signaling enabled.

DCR is mutually exclusive with Asymmetric Delay Control (ADC) and Active Multipath (AMP); if DCR is enabled on a port, ADC and AMP cannot also be enabled on the same port.

A port with DCR enabled cannot be used as a system sync reference.

DCR uses channel group 1 for timing recovery. If a T1 or E1 port is channelized, all TDM PWs that share the port use the timing recovered from channel group 1.

To enable DCR, the network must have a common clock between the routers performing the TDM-to-packet interworking function or between the two terminating SAPs. The common clock can come from two PRC-traceable clocks or one clock that is made available to both ends, such as the transmitted clock of a SONET/SDH or synchronous Ethernet port.

In each direction, the service clock is compared to the common clock and the difference is encoded into the RTP header in the TDM PW overhead. At the other end of the network, the original service clock is reproduced by comparing the common clock to the frequency difference in the RTP header. The following figure shows an example of a network using DCR.

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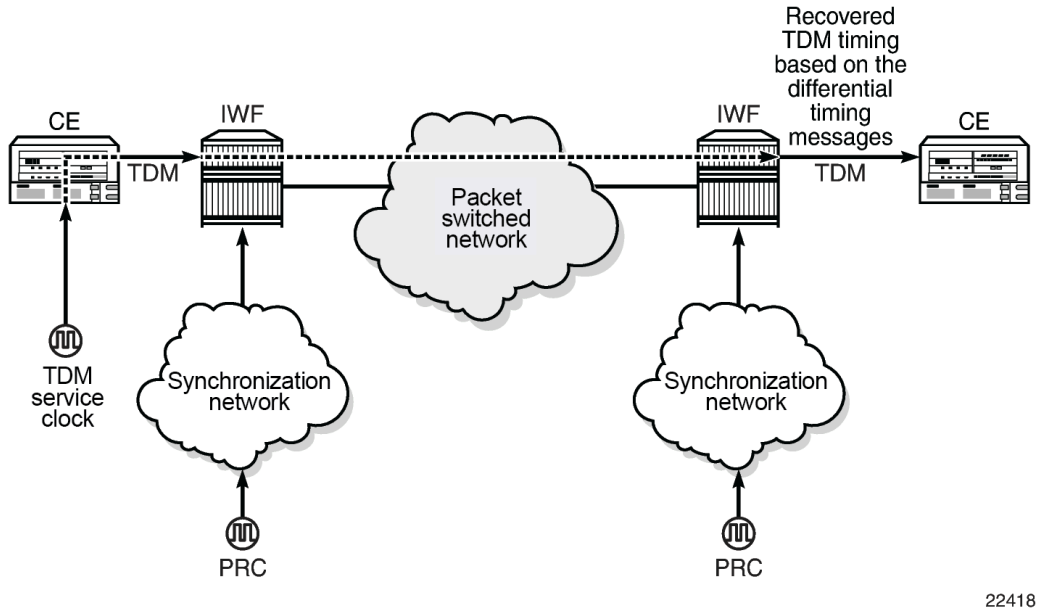
Figure 18: DCR on a network



RTP headers are disabled by default and must be enabled for all circuit emulation services that require DCR. RTP must be enabled for the TDM PW that uses channel group 1. All channel groups on the same DS1 or E1 channel must be configured for the same mode of operation.

To achieve the best DCR performance, use a Layer 1 network synchronization method to ensure the common clock has the best stability. If a timing-over-packet technique is used to transfer the common clock, the number and type of nodes, the traffic profile, and the temperature variations affect DCR synchronization performance. Nokia also recommends a packet rate of at least 200 pps (up to 4000 pps is supported). Packet rates lower than 200 pps may affect system performance.

6.4.1 DCR frequencies

Each DS1 or E1 circuit configured with DCR executes its own clock recovery from the packet stream. This allows each circuit to have an independent frequency.

The 8-port T1/E1 ASAP Adapter card supports a timestamp frequency of 77.76 MHz and 19.44 MHz. The default timestamp frequency is 77.76 MHz.

The timestamp frequency is configured at the adapter card level and used by all DCR ports or channels on the supporting platforms and cards. Both ends of a TDM PW using DCR must be running the same frequency. If a network contains different types of equipment using DCR, select a common frequency that is supported by all equipment.

Use the following command to configure the timestamp frequency.

```
configure card mda timestamp-freq
```

DCR complies with published jitter and wander specifications (G.823, G.824, and G.8261) for traffic interfaces under typical network conditions and for synchronous interfaces under specified packet network delay, loss, and delay variance (jitter) conditions

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6.5 IP hashing as an LSR

It is now possible to include IP header in the hash routine at an LSR for the purpose of spraying labeled-IPv4 and labeled-IPv6 packets over multiple equal cost paths in ECMP in an LDP LSP and over multiple links of a LAG group in all types of LSPs.

A couple of configurable options are supported. The first option is referred to as the Label-IP Hash option and is designated in the CLI as **lbl-ip**. When enabled, the hash algorithm parses down the label stack and after it hits the bottom of the stack, it checks the next nibble. If the nibble value is four or six then it assumes it is an IPv4 or IPv6 packet. The result of the hash of the label stack, along with the incoming port and system IP address, is fed into another hash along with source and destination address fields in the IP packet's header. The second option is referred to as IP-only hash and is enabled in CLI using **ip-only**. It operates the same way as the Label-IP Hash method except the hash is performed exclusively on the source and destination address fields in the IP packet header. This method supports both IPv4 and IPv6 payload.

By default, MPLS packet hashing at an LSR is based on the whole label stack, along with the incoming port and system IP address. This method is referred to as the Label-Only Hash option and is enabled by entering **lbl-only**.

Use the following context to configure **lbl-only**, **lbl-ip**, and **ip-only** on a system-wide basis or override them on a per-IP-interface basis.

```
configure system load-balancing lsr-load-balancing
```

6.6 Auto-provisioning

Auto-provisioning is used to provision a node using an external DHCP server and file server. It is used to obtain a configuration file and an image file from an external server using an in-band mechanism. Auto-provisioning is not compatible with an out-of-band management port.

Before using auto-provisioning, the SR OS must be booted up and running the application image. In addition, it needs to have some minimum configuration before the auto-provision script is executed by the operator.

After the auto-provision application is triggered using a tools command, SR OS checks all operationally up ports without IP addresses and send DHCP discovery to these interfaces. The DHCP server needs to be configured with Option 67 and the user must provide the SR OS with the URL of a file server and the corresponding directory for the image.

Figure 19: Example of a network with no DHCP relay to Figure 21: Example of a network with multiple subnets describe scenarios in which auto-provisioning are used.

In Figure 19: Example of a network with no DHCP relay, there is no DHCP relay and all IP addresses are assigned from a single pool.

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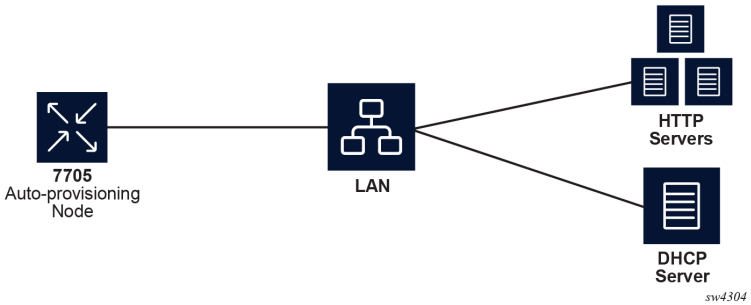
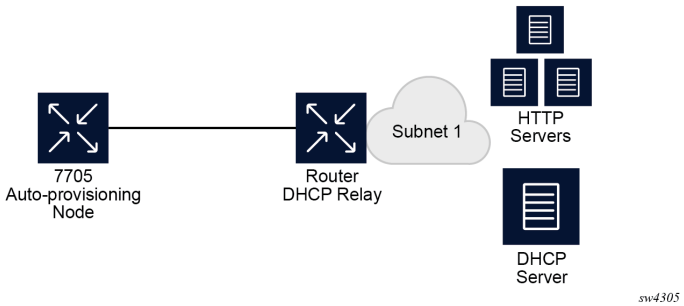
Figure 19: Example of a network with no DHCP relay



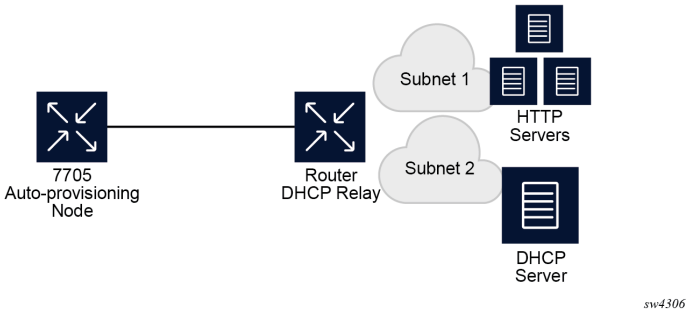
In Figure 20: Example of a network with a DHCP relay, there is a DHCP relay which injects the Option 82 as a gateway address. The DHCP server is assigned the IP address from the pool dictated by the gateway address option 82. The DHCP server and HTTP server are in the same subnet. The DHCP offer has option 3 "router" which is used for a default gateway creation on the 7705 SAR Gen 2.

Figure 20: Example of a network with a DHCP relay



In Figure 21: Example of a network with multiple subnets, all components are in different subnets. The DHCP relay adds Option 82 to the DHCP request as the gateway address which is used for pool selection. The DHCP server must add option 3 configured with the gateway address of the HTTP server.

Figure 21: Example of a network with multiple subnets



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6.6.1 Auto-provisioning limits

The following are some configuration limits for auto-provisioning:

- A maximum of 12 Layer 3 interfaces are supported for auto-provisioning.
- Only IPv4 auto-provisioning is supported.
- It is highly recommended to only have a basic card, MDA, port, and interface configuration as described in this document and no additional static routes or IGP or BGP protocols when performing auto-provisioning because auto-provisioning installs default static routes that may be affected by any extra routing configuration.
- A maximum of 255 characters is supported for the remote URL (200 character maximum for the filepath, the rest for the main URL consisting of the protocol, login credentials, and host IP). A maximum of 200 characters is supported for the local URL. The local file or folder name must not exceed 99 characters.
- The maximum number of file pairs for each image/config record is 10.

6.6.2 Auto-provisioning process

In this process, the node detects operational ports, attempts to discover its IP address, and downloads the relevant files for provisioning.

1. The node sends a DHCP discovery request to the DHCP server using the out-of-band management port. If DHCP discovery is unsuccessful, the node reattempts it using the in-band management ports.
2. After DHCP discovery is successful, the DHCP server returns an IPv4 or IPv6 FTP or HTTP URL of a file server from which the node can retrieve provisioning information.
3. The node downloads the provisioning information and performs the auto-provisioning according to the specifications in the files.
4. After the node is successfully provisioned, it automatically reboots and becomes operationally up.

See Provisioning files for more information about the auto-provisioning process.

The SR OS can also initiate the auto-provisioning process using a **tools** command.

6.6.3 Auto-provisioning DHCP rules

The following are the DHCP rules in the auto-provisioning stage:

1. First, auto-provisioning walks through the interfaces with a configured port, where the port is in operational status up, one by one.
2. It sends a DHCP request to the first configured interface with a port up and no IP address configured.
   - If, on this interface, multiple DHCP offers arrives, only the first offer is sent to the auto-provisioning task and the other offers are ignored. This could occur if the node is on a LAN and multiple DHCP servers are connected to the interface.
   - The DHCP client has an exponential retry mechanism. If the DHCP offer does not arrive from the server, the client resends a DHCP request at 2, 4, 8, 32 and 64 s, with 64 s being the maximum timeout, If the 64 s timeout interval is reached, the DHCP client keeps retrying every 64 s. The

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user can configure a timeout value. If no DHCP offer has arrived by this timeout value, the auto-provisioning process moves to the next interface.

- If the DHCP offer arrives on the port and the DHCP client task does not acknowledge the DHCP offer, for any reason, it disables the DHCP client and remove the IP from the port.
- If the DHCP offer arrives on the port and the DHCP client acknowledges the offer, it sends the information to auto-provisioning. If auto-provisioning does not like the offer, because there is no Option 67, Option 67 is malformed, or for any other reason listed in Auto-provisioning failure, the auto-provisioning process deconfigures the DHCP client and the DHCP client sends a DHCP release, and unassigns the IP address.
- In case of failure, more information is displayed by the auto-provisioning process and the process moves to the next port that is up and does not have an IP address.

3. If auto-provisioning is successful using the offer and its option, the provisioning file download starts though the protocol dictated by Option 67.

The **auto-provisioning** command is CLI blocking. All information about the auto-provisioning process is displayed on the CLI and logged.

6.6.4 Auto-provisioning failure

Auto-provisioning fails for the following reasons:

- There is no Option 67.
- The Option 67 format is not acceptable to auto-provisioning.
- The format is a URL or DNS is not supported. There is a failure in the download provisioning file or the server is not reachable.
- There is failure in the download of the image or config file using the provisioning file information, for example, the server is not available, the wrong directory is listed, or the wrong credentials are given.
- The image or config fails to copy to the compact flash.
- The image or config fails to sync to the inactive CPM.
- The BOF does not point to the compact flash, for example, it is pointing to the network.

If the auto-provisioning procedure on this interface fails, then auto-provisioning does the following:

1. Displays information about the blocked CLI and in the log, describing the failure in detail.
2. Updates the DHCP task so the DHCP task can take the appropriate actions to release the IP address on the interface. This is done by sending a DHCP release for the DHCP ack received from the server.
3. Goes to the next interface with port up and no IP address.

Note: If no other interface with port up is found, the auto-provisioning task stops and a failure error is displayed on the CLI and in the log.

6.7 Administrative tasks

This section contains information to perform administrative tasks.

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6.7.1 Saving configurations

Whenever configuration changes are made, the modified configuration must be saved so they are not lost when the system is rebooted.

Configuration files are saved by executing explicit command syntax which includes the file URL location to save the configuration file as well as options to save both default and non-default configuration parameters. Boot option file (BOF) parameters specify where the system should search for configuration and image files as well as other operational parameters during system initialization.

For more information about boot option files, see the Boot Options section.

6.7.2 Specifying post-boot configuration files

Two post-boot configuration extension files are supported and are triggered when either a successful or failed boot configuration file is processed. The **boot-bad-exec** and **boot-good-exec** commands specify URLs for the CLI scripts to be run following the completion of the bootup configuration. A URL must be specified or no action is taken.

For example, after a configuration file is successfully loaded, the specified URL can contain a nearly identical configuration file with specific commands enabled or disabled, or particular parameters specified and according to the script which loads that file.

6.7.3 Network timing

In Time Domain Multiplexed (TDM)-based networks (for example, SONET or SDH circuit- switched networks), the concept of network timing is used to prevent over-run or under-run issues where circuits are groomed (rebundled) and switched. Hardware exists in each node that takes a common clock derived from an internal oscillator, a specific receive interface, or special BITS interface and provides it to each synchronous interface in the system. Usually, each synchronous interface is allowed to choose between using the chassis-provided clock or the clocking recovered from the received signal on the interface. The clocking is used to drive the transmit side of the interface. The appropriate configuration at each node which defines how interface clocking is handled must be considered when designing a network that has a centralized timing source so each interface is operating in a synchronous manner.

The effect of timing on a network is dependent on the nature of the type of traffic carried on the network. With bit-wise synchronous traffic (traditional circuit-based voice or video), non-synchronous transmissions cause a loss of information in the streams affecting performance. With packet-based traffic, the applications expect and handle jitter and latency inherent to packet-based networks. When a packet-based network is used to carry voice or video traffic, the applications use data compression and elasticity buffering to compensate for jitter and latency. The network itself relies on appropriate Quality of Service (QoS) definitions and network provisioning to further minimize the jitter and latency the application may experience.

6.7.4 Power supplies

SR OS supports a **power-supply** command to configure the type and number of power supplies present in the chassis. The operational status of a power source is always displayed by the LEDs on the Control Processor/Switch Fabric Module (CP/SFM) front panel, but the power supply information must be explicitly

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configured in order for a power supply alarm to be generated if a power source becomes operationally disabled.

6.8 System router instances

SR OS supports multiple Layer 3 router instances. These instances have their own IP addressing spaces and configuration options. Router instances are isolated from each other.

The following are the different types of router instances in SR OS:

- **Base**

  All SR OS routers have the Base router instance: the system created default router instance used to forward user IP traffic among router line card ports. Router interfaces (that is, network interfaces configured under **configure router** [**Base**]) and IES services and interfaces exist in the Base router instance. The Base router instance is identified in SNMP as vRtrType = baseRouter (1) and has a vRtrID of 1.

- **VPRN instances**

  Another type of router instance is the set of operator configured VPRN services. Each VPRN service has a unique router instance. For more information about VPRN services and their associated router instances, see the *7705 SAR Gen 2 Layer 3 Services Guide: IES and VPRN*. VPRN router instances are identified in SNMP as vRtrType = vprn (2), and the vRtrID is dynamically allocated.

- **Special system router instances**

  SR OS routers also support the following special router instances:

  – **management**

    The management router instance is a system created router instance that is used for management of the router. The management router instance is bound to CPM/CCM ports A/1 and B/1. This is a CPM router instance which cannot be renamed or deleted by an operator. The management router instance is identified in SNMP as vRtrType = vr(3), and the vRtrID is 4095.

  – **vpls-management**

    The vpls-management router instance is used for management of VPLS services. It is identified in SNMP as vRtrType = vr(3), and the vRtrID is 4094.

  – **User created CPM router instances**

    User created CPM router instances are user defined router instances that are mainly used with Ethernet ports on the CPM/CCM cards: CPM router instances only use CPM/CCM Ethernet ports as interfaces. CPM router instances have a user-defined name and are the only types of non-VPRN router instances that can be created by the user. User created CPM router instances are identified in SNMP as vRtrType = vr(3), and the vRtrID is dynamically allocated.

Some management protocols can use either the base routing instance (in-band) or the management routing instance (out-of-band). A listing of these protocols can be found in the CPM Filter: Protocols and Ports section of the *7705 SAR Gen 2 System Management Guide*. Unless otherwise stated in the detailed description of the protocol, when the server or client for the protocol is reachable via the management routing instance, those protocol messages use the management interface for the protocol communication.

If BOF is set up with autoconfiguration and the DHCP server provides a general default route such as 0.0.0.0/0, with some protocols (like PCEP, TACACS+, RADIUS, and LDAP), Authentication, Authorization, Accounting (AAA) always prefers OOB over in-band connectivity. This is because these protocols prefer to

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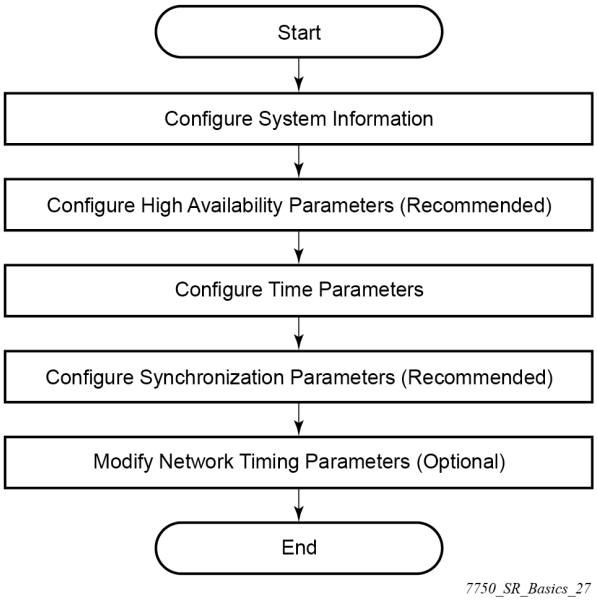
use the OOB management port first. If a matching route is not found, in-band is attempted. The static route provided by DHCP must be properly set to ensure the correct route preference is made by these protocols.

6.9 System configuration process overview

The following figure shows the process for basic system provisioning.

Figure 22: System configuration and implementation flow



6.10 Saving configurations manually

Whenever configuration changes are made, the modified configuration must be saved so the changes are persistent when the system is rebooted. The system uses the configuration and image files, as well as other operational parameters necessary for system initialization, according to the locations specified in the boot option file (BOF) parameters. For more information about BOFs, see the System initialization and boot options chapter of this manual.

Configuration files can be manually saved in two ways with the **admin save** command:

- When a location is specified as a parameter after the command, the system saves the configuration to the file URL that is entered.
- When a location is not specified, the system saves the configuration to the current BOF primary configuration location. If the primary configuration location (path or filename) has changed since the last boot, the new configuration location is used.

If the save attempt fails to the primary location, the system does not try to save the file to the secondary or tertiary configuration locations unless the path and filename are explicitly specified with the **admin save** command.

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The classic CLI provides additional options for saving the configuration that are not needed in the MD-CLI. See the specific command descriptions in the *7705 SAR Gen 2 Classic CLI Command Reference Guide* for more information.

6.11 Common configuration tasks

This section provides an overview of the CLI commands used to configure system parameters:

- System information
- System time elements

6.11.1 System information

This section describes the basic system information commands that configure the system name of the router, contact information, location (such as an address, floor, room number, and so on), CLLI code, and global positioning system (GPS) coordinates.

6.11.1.1 System name

The device's system name is used in the prompt string. Only one system name can be configured; if multiple system names are configured, the last one overwrites the previous entry.

Use the following command to configure the system name.

```
configure system name
```

6.11.1.2 Contact

Use the **contact** command to specify the name of a system administrator, IT staff member, or other administrative entity.

Use the following command to configure the contact.

```
configure system contact
```

6.11.1.3 Location

Use the **location** command to specify the location of the device. For example, enter the city, building address, floor, room number, and so on, where the router is located.

Use the following command to configure the location.

```
configure system location
```


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6.11.1.4 CLLI code

The Common Language Location Code (CLLI code) is an 11-character standardized geographic identifier that is used to uniquely identify the geographic location of a router.

Use the following command to configure the CLLI code.

```
configure system clli-code
```

6.11.1.5 GPS coordinates

Use the optional **coordinates** command to specify the GPS location of the device. If the string contains special characters (#, $, spaces, and so on), the entire string must be enclosed within double quotes.

Use the following command to configure the coordinates.

```
configure system coordinates
```

6.11.2 System time elements

The system clock maintains time according to Coordinated Universal Time (UTC). Configure the time zone and summer time (daylight saving time) command options to correctly display time according to the local time zone.

6.11.2.1 Zone

The **zone** command sets the time zone and time zone UTC offset for the router. SR OS supports system-defined and user-defined time zones. The system-defined time zones and offsets are listed in Table 16: System-defined time zones and UTC offsets.

Use the following command to set the time zone and time zone UTC offset.

```
configure system time zone
```

6.11.2.2 Summer (daylight saving) time

Configure the start and end dates and offset for summer (daylight saving) time to override system defaults or for user-defined time zones. When configured, the time will be adjusted by changing to the configured offset when summer time starts and returning to the configured offset when summer time ends.

Use commands in the following context to configure the start day, end day, and offset of the summer.

```
configure system time dst-zone
```

If the time zone configured is listed in Table 16: System-defined time zones and UTC offsets, the start and end command options and offset do not need to be configured with this command unless there is a need to override the system defaults. The command will return an error if the start and end dates and times are not

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available either in Table 16: System-defined time zones and UTC offsets or entered as optional command options in this command.

6.11.2.3 NTP

NTP is the Network Time Protocol defined in RFC 1305, *Network Time Protocol (Version 3) Specification, Implementation and Analysis* and RFC 5905, *Network Time Protocol Version 4: Protocol and Algorithms Specification*. It allows for the participating network nodes to keep time more accurately and more importantly they can maintain time in a more synchronized fashion between all participating network nodes.

SR OS uses an NTP process based on a reference build provided by the Network Time Foundation. Nokia strongly recommends that the users review RFC 8633, *Network Time Protocol Best Current Practices*, when they plan to use NTP with the router. The RFC section "Using Enough Time Sources" indicates that using only two time sources (NTP servers) can introduce instability if they provide conflicting information. To maintain accurate time, Nokia recommends configuring three or more NTP servers.

NTP uses stratum levels to define the number of hops from a reference clock. The reference clock is considered to be a stratum-0 device that is assumed to be accurate with little or no delay. Stratum-0 servers cannot be used in a network. However, they can be directly connected to devices that operate as stratum-1 servers. A stratum-1 server is an NTP server with a directly-connected device that provides Coordinated Universal Time (UTC), such as a GPS or atomic clock.

The higher stratum levels are separated from the stratum-1 server over a network path, therefore, a stratum-2 server receives its time over a network link from a stratum-1 server. A stratum-3 server receives its time over a network link from a stratum-2 server.

SR OS routers normally operate as a stratum-2 or higher device. The router relies on an external stratum-1 server to source accurate time into the network. However, SR OS also allows for the use of the local PTP recovered time to be sourced into NTP. In this latter case, the local PTP source appears as a stratum-0 server and SR OS advertises itself as a stratum-1 server. Activation of the PTP source into NTP may impact the network NTP topology because the SR OS router is promoted to stratum-1.

SR OS router runs a single NTP clock which then operates NTP message exchanges with external NTP clocks. Exchanges can be made with external NTP clients, servers, and peers. These exchanges can be through the base, management, or VPRN routing instances.

NTP operates associations between clocks as either client or server, symmetric active and symmetric passive, or broadcast modes. These modes of operation are applied according to which elements are configured on the router. To run server mode, the operator must enable NTP server mode for the base and each needed VPRN routing instance. To run client mode, the operator must configure external servers. If both the local router and remote router are configured with each other as peers, then the router operates in symmetric active mode. If only one side of the association has peering configured, then the modes are symmetric passive. To operate using broadcast mode, interfaces must be configured to transmit as broadcast servers or receive as broadcast clients.

NTP server operation for both unicast and broadcast communication within a VPRN is configured within the VPRN (see "NTP Within a VPRN Service" in the *7705 SAR Gen 2 Layer 3 Services Guide: IES and VPRN*).

The following NTP elements are supported:

- **server mode**

  In this mode, the node advertises the ability to act as a clock source for other network elements. The node, by default, transmits NTP packets in NTP version 4 mode.

- **authentication keys**

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Authentication keys implement increased security support in carrier and other networks. Both DES and MD5 authentication are supported, as well as multiple keys.

- **operation in symmetric active mode**

  This capability requires that NTP be synchronized with a specific node that is considered more trustworthy or accurate than other nodes carrying NTP in the system. This mode requires that a specific peer is set.

- **server and peer addressing using IPv6**

  Both external servers and external peers may be defined using IPv6 or IPv4 addresses. Other features (such as multicast, broadcast) use IPv4 addressing only.

- **broadcast or multicast modes**

  When operating in these modes, the node receives or sends using either a multicast (default 224.0.1.1) or a broadcast address. Multicast is supported only on the CPM MGMT port.

- **alert when NTP server is not available**

  When none of the configured servers are reachable on the node, the system reverts to manual timekeeping and issues a critical alarm. When a server becomes available, a trap is issued indicating that standard operation has resumed.

- **NTP and SNTP**

  If both NTP and SNTP are enabled on the node, then SNTP transitions to an operationally down state. If NTP is removed from the configuration or shut down, then SNTP resumes an operationally up state.

- **gradual clock adjustment**

  As several applications (such as Service Assurance Agent (SAA)) can use the clock, and if determined that a major (128 ms or more) adjustment needs to be performed, the adjustment is performed by programmatically stepping the clock. If a minor (less than 128 ms) adjustment must be performed, then the adjustment is performed by either speeding up or slowing down the clock.

- To avoid the generation of too many events/trap the NTP module rates limit the generation of events/traps to three per second. At that point a single trap is generated that indicates that event/trap squashing is taking place.

6.11.2.3.1 Authentication-check

NTP supports an authentication mechanism to provide some security and access control to servers and clients. The authentication check feature provides the option to skip the rejection of NTP PDUs that do not match the authentication key or authentication type requirements.

The default behavior when authentication is configured is to reject all NTP PDUs that have a mismatch in either the authentication key ID, type, or key.

When authentication check is configured, NTP PDUs are authenticated on receipt. However, mismatches cause a counter to be increased, one counter for key ID, one for type, and one for key value mismatches.

Use commands in the following context to enable authentication check.

```
configure system time ntp authentication-check
```

Example: MD-CLI

```
[ex:/configure system time ntp]
```


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```
A:admin@node-2# info
    admin-state enable
    authentication-check true
```

Example: classic CLI

```
A:node-2>config>system>time>ntp# info
----------------------------------------------
                authentication-check
                no shutdown
----------------------------------------------
```

6.11.2.3.2 Authentication-key

The **authentication-key** command configures an authentication key ID, key type, and key used to authenticate NTP PDUs sent to and received from other network elements participating in the NTP. For authentication to work, the authentication key ID, authentication type, and authentication key value must match.

Example: MD-CLI

```
[ex:/configure system time ntp]
A:admin@node-2# info
    admin-state enable
    authentication-key 1 {
        key "OAwgNUlbzgI hash2"
        type des
    }
```

Example: classic CLI

```
A:node-2>config>system>time>ntp# info
----------------------------------------------
                shutdown
                authentication-key 1 key "OAwgNUlbzgI" hash2 type des
----------------------------------------------
```

6.11.2.3.3 Broadcast

The **broadcast** command is used to transmit broadcast packets on a given interface. Interfaces in the base routing context or the management interface may be specified. Due the relative ease of spoofing of broadcast messages, it is strongly recommended to use authentication with broadcast mode. The messages are transmitted using a destination address that is the NTP Broadcast address. The following example enables NTP and configures the broadcast interface.

Example: MD-CLI

```
[ex:/configure system time ntp]
A:admin@node-2# info
    admin-state enable
    broadcast "Base" interface-name "int11" {
        version 4
        ttl 127
    }
```


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Example: classic CLI

```
A:node-2>config>system>time>ntp# info
----------------------------------------------
                broadcast interface int11 version 4 ttl 127
                no shutdown
----------------------------------------------
```

6.11.2.3.4 Broadcastclient

The **broadcastclient** command enables listening to NTP broadcast messages on the specified interface. Interfaces in the base routing context or the management interface may be specified. Due the relative ease of spoofing of broadcast messages, it is strongly recommended to use authentication with broadcast mode. The messages must have a destination address of the NTP Broadcast address. The following example enables NTP and configures the broadcast client.

Example: MD-CLI

```
[ex:/configure system time ntp]
A:admin@node-2# info
    admin-state enable
    broadcast-client "Base" interface-name "int11" {
    }
```

Example: classic CLI

```
A:node-2>config>system>time>ntp# info
----------------------------------------------
                broadcastclient interface int11
                no shutdown
----------------------------------------------
```

6.11.2.3.5 Multicast

When configuring NTP the node can be configured to transmit or receive multicast packets on the CPM MGMT port. Broadcast and multicast messages can easily be spoofed; therefore, authentication is strongly recommended. Multicast is used to configure the transmission of NTP multicast messages. When transmitting multicast NTP messages the default address of 224.0.1.1 is used. The following example enables NTP and multicast.

Example: MD-CLI

```
[ex:/configure system time ntp]
A:admin@node-2# info
    admin-state enable
    multicast {
    }
```

Example: classic CLI

```
A:node-2>config>system>time>ntp# info
----------------------------------------------
                multicast
                no shutdown
```


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```
-----------------------------------------------
```

6.11.2.3.6 Multicastclient

The **multicastclient** command is used to configure an address to receive multicast NTP messages on the CPM MGMT port. Broadcast and multicast messages can easily be spoofed, therefore, authentication is strongly recommended. If multicastclient is not configured, all NTP multicast traffic is ignored. The following example enables NTP and configures the address to receive multicast NTP messages.

Example: MD-CLI

```
[ex:/configure system time ntp]
A:admin@node-2# info
    admin-state enable
    multicast-client {
        authenticate true
    }
```

Example: classic CLI

```
A:node-2>config>system>time>ntp# info
-----------------------------------------------
                multicastclient
                no shutdown
-----------------------------------------------
```

6.11.2.3.7 NTP-server

The **ntp-server** command configures the node to assume the role of an NTP server. Unless the **server** command is used, this node will function as an NTP client only and will not distribute the time to downstream network elements. If the **authenticate** command option is specified, the NTP server requires client packets to be authenticated.

The following is an example of a configuration output of NTP enabled with the **ntp-server** command configured.

Example: MD-CLI

```
[ex:/configure system time ntp]
A:admin@node-2# info
    admin-state enable
    ntp-server {
        authenticate true
    }
```

Example: classic CLI

```
A:node-2>config>system>time>ntp# info
-----------------------------------------------
        no shutdown
        ntp-server
-----------------------------------------------
```


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6.11.2.3.8 Peer

Configuration of an NTP peer configures symmetric active mode for the configured peer. Although any system can be configured to peer with any other NTP node, Nokia recommends configuring authentication and to configure known time servers as their peers. Administratively disable this command to remove the configured peer.

Use commands in the following context to configure symmetric active mode.

```
configure system time ntp peer
```

Example: MD-CLI

```
[ex:/configure system time ntp]
A:admin@node-2# info
    admin-state enable
    peer 192.168.1.1 router-instance "Base" {
        key-id 1
    }
```

Example: classic CLI

```
A:node-2>config>system>time>ntp# info
----------------------------------------------
            no shutdown
            peer 192.168.1.1 key-id 1
----------------------------------------------
```

6.11.2.3.9 Server

The **server** command is used when the node should operate in client mode with the NTP server specified in the address field. Up to ten NTP servers can be configured. The following example enables NTP and configures the server.

Example: MD-CLI

```
[ex:/configure system time ntp]
A:admin@node-2# info
    admin-state enable
    server 192.168.1.1 router-instance "Base" {
        key-id 1
    }
```

Example: classic CLI

```
A:node-2>config>system>time>ntp# info
----------------------------------------------
               no shutdown
               server 192.168.1.1 key 1
----------------------------------------------
```


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6.11.2.4 SNTP

SNTP is a compact, client-only version of NTP. SNTP can only receive the time from SNTP/NTP servers; it cannot be used to provide time services to other systems. SNTP can be configured in either broadcast or unicast client mode.

SNTP time elements include the Broadcast-client and Server-address.

Use the commands in the following context to configure the SNTP.

```
configure system time sntp
```

6.11.2.4.1 Broadcast-client

Use the following command to enable listening at the global device level to SNTP broadcast messages on interfaces with broadcast client configured:

- **MD-CLI**

```
configure system time sntp sntp-state broadcast
```

- **classic CLI**

```
configure system time sntp broadcast-client
```

The following example shows SNTP enabled with the broadcast client.

Example: MD-CLI

```
[ex:/configure system time sntp]
A:admin@node-2# info
    admin-state enable
    sntp-state broadcast
```

Example: classic CLI

```
A:node-2>config>system>time>sntp# info
------------------------------------------------
                broadcast-client
                no shutdown
------------------------------------------------
```

6.11.2.4.2 Server-address

Use the following command to configure an SNTP server for SNTP unicast client mode:

- **MD-CLI**

```
configure system time sntp server
```


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- **classic CLI**

```
configure system time sntp server-address
```

The following is an example of a configuration output of SNTP enabled with the **server-address** command configured.

Example: MD-CLI

```
[ex:/configure system time sntp]
A:admin@node-2# info
    admin-state enable
    server 10.10.0.94 {
        version 1
        prefer true
        interval 100
    }
```

Example: classic CLI

```
A:node-2>config>system>time>sntp# info
----------------------------------------------
                server-address 10.10.0.94 version 1 preferred interval 100
                no shutdown
----------------------------------------------
```

6.11.2.5 CRON

The CRON feature supports periodic and date and time-based scheduling in SR OS. CRON can be used, for example, to schedule Service Assurance Agent (SAA) functions. CRON functionality includes the ability to specify scripts that need to be run, when they are scheduled, including one-time only functionality (one-shot), interval and calendar functions. Scheduled reboots, peer turn ups, service assurance agent tests and more can all be scheduled with CRON, as well as OAM events, such as connectivity checks, or troubleshooting runs.

CRON supports the schedule element. The schedule function configures the type of schedule to run, including one-time only (one-shot), periodic, or calendar-based runs. All runs are determined by month, day of month or weekday, hour, minute, and interval (seconds).

6.11.2.5.1 Schedule

The **schedule** command configures the type of schedule to run, including one-time only (oneshot), periodic, or calendar-based runs. All runs are determined by month, day of the month or weekday, hour, minute, and interval (seconds). If the **end-time** and **interval** command options are both configured, whichever condition is reached first is applied.

The following is an example of a configuration output that schedules a script named "test" to run every 15 minutes on the 17th of each month and every Friday until noon on July 17, 2007.

Example: MD-CLI

```
[ex:/configure system cron]
A:admin@node-2# info
    schedule "test" owner "TiMOS CLI" {
```


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```
        day-of-month [17]
        minute [0 15 30 45]
        weekday [friday]
        end-time {
            date-and-time 2007-07-17T12:00:00.0+00:00
        }
    }
```

Example: classic CLI

```
*A:node-2>config>system>cron# info
----------------------------------------------
        schedule "test"
            shutdown
            day-of-month 17
            minute 0 15 30 45
            weekday friday
            end-time 2007/07/17 12:00
        exit
----------------------------------------------
```

6.11.3 ANCP enhancements

Persistency is available for subscriber ANCP attributes and is stored on the on-board compact flash card. ANCP data stays persistent during an ISSU as well as node reboots. During recovery, ANCP attributes are first restored fully from the persistence file, and incoming ANCP sessions are temporarily on hold. Afterwards, new ANCP data can overwrite any existing values. This new data is then stored into the compact flash in preparation for the next event.

6.11.4 Configuration backups

You can specify the maximum number of configuration and classic CLI index backups stored in the configuration primary location.

For example, the maximum number of backups is set to 5 and the configuration file is called `xyz.cfg`. When the configuration is saved, the most recent file is renamed with a .1 extension. Each subsequent file increments the numeric extension until the maximum count is reached. The oldest file (5) is deleted as more recent files are saved.

- `config.cfg`
- `config.cfg.1`
- `config.cfg.2`
- `config.cfg.3`
- `config.cfg.4`
- `config.cfg.5`

Each persistent index file is updated at the same time as the associated configuration file. When the index file is updated, the save is performed to `config.cfg` and the classic CLI index file is created as `config.ndx`. Synchronization between the active and standby SF/CPMSF/CPM is performed for all configurations and their associated persistent index files.

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Use the following commands to specify the maximum number of backup versions of the configuration and index files kept in the primary location:

- **MD-CLI**

```
configure system management-interface configuration-save configuration-backups
```

- **classic CLI**

```
configure system config-backup
```

The following example shows the command usage to set the maximum number of backup versions of the configuration and index files kept in the primary location to 7.

Example: MD-CLI

```
[ex:/configure]
A:admin@node-2# system management-interface configuration-save configuration-backups 7
```

Example: classic CLI

```
A:node-2# system config-backup 7
```

Example: Configuration backup configuration output (MD-CLI)

```
[ex:/configure system]
A:admin@node-2# info
    contact "Fred Information Technology"
    name "node-2"
    location "Bldg.1-floor 2-Room 201"
    coordinates "N 45 58 23, W 34 56 12"
    clli-code "abcdefg1234"
...
 management-interface {
        configuration-save {
            configuration-backups 7
        }
...
```

Example: Configuration backup configuration output (classic CLI)

```
A:node-2>config>system>time# info
#------------------------------------------
echo "System Configuration"
#------------------------------------------
        name "node-2"
        contact "Fred Information Technology"
        location "Bldg.1-floor 2-Room 201"
        clli-code "abcdefg1234"
        coordinates "N 45 58 23, W 34 56 12"
        config-backup 7
...
-------------------------------------------------
```


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6.12 System timing

When network timing is required for synchronous interfaces in the router, a timing subsystem provides a clock to all synchronous interfaces within the system.

This section describes the commands used to configure and control the timing subsystem.

6.12.1 Entering edit mode

Note: This applies to the classic CLI.

Use the following command to enter the edit mode and edit timing references.

```
configure system sync-if-timing begin
```

Example

The following is an example of an error message that is displayed if you try to modify **sync-if-timing** parameters without entering the **begin** keyword.

```
A:node-2>config>system>sync-if-timing>ref1# source-port 2/1/1
MINOR: CLI The sync-if-
timing must be in edit mode by calling begin before any changes can be made.
MINOR: CLI Unable to set source port for ref1 to 2/1/1.
A:node-2>config>system>sync-if-timing>ref1#
```

Note: Use the **commit** command to save the changes made in a session or the **abort** command to discard them.

6.12.2 Configuring timing references

Use commands in the following context to configure timing reference settings:

- **MD-CLI**

  ```
  configure system central-frequency-clock
  ```

- **classic CLI**

  ```
  configure system sync-if-timing
  ```

The source port specified for **ref1** and **ref2** is dependent on the router model type and chassis slot.

6.12.3 Using the revert command

The revert function allows the clock to revert to a higher-priority reference if the current reference goes offline or becomes unstable.

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When mode is non-revertive, a failed clock source is not selected again. If a node enters holdover because the references are in a previously failed state, the revertive switching mode enables the node to select one of the previously failed references, instead of going into holdover.

If revertive switching is enabled, the highest-priority valid timing reference is used. If a reference with a higher priority becomes valid, a switchover to that reference is initiated. If a failure on the current reference occurs, the next highest reference takes over. Use the following command to enable revertive mode:

- **MD-CLI**

```
configure system central-frequency-clock revert true
```

- **classic CLI**

```
configure system sync-if-timing revert
```

If non-revertive switching is enabled, the active reference always remains selected while it is valid, even if a higher priority reference becomes available. If the active reference becomes invalid, a reference switchover to a valid reference with the highest priority is initiated. The failed reference is eligible for selection when it becomes operational. Use the following command to enable non-revertive mode:

- **MD-CLI**

```
configure system central-frequency-clock revert false
```

- **classic CLI**

```
configure system sync-if-timing no revert
```

6.12.4 Committing and discarding changes

Use the following command to save changes made to the timing references during a session. Modifications are not persistent across system boots unless this command is used.

- **MD-CLI**

```
configure system central-frequency-clock commit
```

- **classic CLI**

```
configure system sync-if-timing commit
```

Use the following command to discard changes that have been made to the timing references during a session:

- **MD-CLI**

```
configure system central-frequency-clock discard
```

- **classic CLI**

```
configure system sync-if-timing abort
```


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6.12.5 Forcing a specific reference

Note: This applies to the classic CLI.

The **debug sync-if-timing force-reference** command should only be used to test and debug problems. Network synchronization problems may appear if network elements are left with this manual override setting. When the system timing reference input has been forced, it may be cleared using the **no force-reference** command.

Force the CPM clock to use a specific input reference using the **force-reference** command.

When the command is executed, the CPM clock on the active CPM immediately switches its input reference to that specified by the command. If the specified input is not available (shutdown), or in a disqualified state, the CPM clock shall use the next qualified input reference based on the selection rules.

On a CPM activity switch, the **force** command is cleared and normal reference selection is determined.

6.12.6 Configuring system timing to use a GNSS RF port

Use the following command to configure a GNSS RF port as a system timing reference:

- **MD-CLI**

```
configure system central-frequency-clock gnss admin-state enable
```

- **classic CLI**

```
configure system sync-if-timing gnss no shutdown
```

Example: Timing reference configuration (MD-CLI)

```
[ex:/configure system central-frequency-clock]
A:admin@node-2# info
    gnss {
        admin-state enable
    }
```

Example: Timing reference configuration (classic CLI)

```
A:node-2>config>system>sync-if-timing# info
----------------------------------------------
            gnss
               no shutdown
            exit
----------------------------------------------
```

6.13 Configuring system cooling

The 7705 SAR-10x chassis supports using passive or active cooling during operation. Passive cooling is the default mode and requires no configuration. The user can install and provision an optional fan module to use active cooling.

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See the *7705 SAR-10x Chassis Installation Guide* for more information about installing the fan module on the chassis.

Use the following command to provision a fan module and enable active cooling:

- **MD-CLI**

```
configure chassis fan fan-module-type
```

- **classic CLI**

```
configure system fan-module fan-module-type
```

The fan module and accompanying fan filter can be installed in a front-to-back or right-to-left airflow arrangement. The user must provision the **fan-module-type** to match the airflow direction of the installed components.

The 7705 SAR-10x system fan algorithm automatically controls the fan speeds of the fan module; fan speeds are not user-configurable.

If the provisioned fan module experiences a partial or complete failure, or cannot be detected, the system raises the corresponding alarms in the **show system alarms** output. The 7705 SAR-10x does not automatically revert to the passive cooling mode in the event of a fan module failure. The user must deprovision the fan module to switch the 7705 SAR-10x to passive cooling.

Use the following command to display fan module information.

```
show chassis environment
```

Output example

```
A:node-2>config>system>fan-module# show chassis environment
===============================================================================
Chassis 1 Detail
===============================================================================
Environment Information

  Number of fan trays               : 1

  Fan tray number                   : 1
    Fan module assigned type        : fan-sar-10x-f
    Fan module equipped type        : fan-sar-10x-f
    Speed                           : 20 %
    Airflow direction               : frontToBack
    Status                          : up
...
===============================================================================
```

Output example

The following output shows an alarm raised in the event of a mismatch between the provisioned and installed **fan-module-type**.

```
A:node-2>show>system# alarms
===============================================================================
Alarms [Critical:1 Major:0 Minor:0 Warning:0 Total:1]
===============================================================================
Index      Date/Time              Severity  Alarm      Resource
   Details
-------------------------------------------------------------------------------
```


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```
1          2026/10/01 16:43:44.50  CRITICAL  7-6026-1   Chassis 1 Fan 1
   Fan Chassis 1 Fan 1: fan tray module type mismatch
===============================================================================
```

6.14 Configuring power supply

The 7705 SAR Gen 2 supports component redundancy for the power supply feeds, as follows:

- **7705 SAR-1, 7705 SAR-Hx, 7705 SAR-Mx**
  The use of up to two power supply feeds for 1+1 power redundancy is supported.
- **7705 SAR-10x**
  The use of up to four power supply feeds for 2+2 power redundancy is supported.

A power feed can fail without impacting traffic when a redundant power feed configuration is in use.

The following outputs show the chassis power supply information on 7705 SAR Gen 2 platforms.

Example: Power supply information on 7705 SAR-1

```
A:node-2 show chassis power-supply
===============================================================================
Chassis 1 Detail
===============================================================================
Power Supply Information
  Number of power supplies          : 2

  Power supply number               : 1
    Power supply type               : ac single
    Status                          : up
    AC power                        : within range
    DC power                        : within range

  Power supply number               : 2
    Power supply type               : ac single
    Status                          : up
    AC power                        : within range
    DC power                        : within range
===============================================================================
```

Example: Power supply information on 7705 SAR-Hx or 7705 SAR-Mx

```
A:node:2# show chassis power-supply
===============================================================================
Chassis 1 Detail
===============================================================================
Power Supply Information
  Number of power supplies          : 2

  Power supply number               : 1
    Power supply type               : ac single
    Power supply model              : peq
    Status                          : up
    AC power                        : within range
    DC power                        : within range
    Over temp                       : within range
    Hardware Data
      Part number                   : 3HE20432AARA01
      CLEI code                     : INPSAJ6FAA
      Serial number                 : NS2531XI371
```


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```
      Manufacture date              : 08042025
      Manufacturing deviations      : (Not Specified)
      Manufacturing assembly number :
      Administrative state          : up
      Operational state             : up
      Time of last boot             : N/A
      Current alarm state           : alarm cleared

  Power supply number               : 2
    Power supply type               : ac single
    Power supply model              : peq
    Status                          : up
    AC power                        : within range
    DC power                        : within range
    Over temp                       : within range
    Hardware Data
      Part number                   : 3HE20432AARA01
      CLEI code                     : INPSAJ6FAA
      Serial number                 : NS2535XL610
      Manufacture date              : 09172025
      Manufacturing deviations      : (Not Specified)
      Manufacturing assembly number :
      Administrative state          : up
      Operational state             : up
      Time of last boot             : N/A
      Current alarm state           : alarm cleared
===============================================================================
```

Example: Power supply information on 7705 SAR-10x

```
A:node:2# show chassis power-supply
===============================================================================
Chassis 1 Detail
===============================================================================
Power Supply Information
  Number of power supplies          : 4

  Power supply number               : 1
    Power supply type               : ac single
    Power supply model              : peq
    Status                          : up
    AC power                        : within range
    DC power                        : within range
    Over temp                       : within range
    Hardware Data
      Part number                   : 3HE20432AARA01
      CLEI code                     : INPSAJ6FAA
      Serial number                 : NS2605X4351
      Manufacture date              : 02072026
      Manufacturing deviations      : (Not Specified)
      Manufacturing assembly number :
      Administrative state          : up
      Operational state             : up
      Time of last boot             : N/A
      Current alarm state           : alarm cleared

  Power supply number               : 2
    Power supply type               : ac single
    Power supply model              : peq
    Status                          : up
    AC power                        : within range
    DC power                        : within range
    Over temp                       : within range
```


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```
    Hardware Data
      Part number                   : 3HE20432AARA01
      CLEI code                     : INPSAJ6FAA
      Serial number                 : NS2605X4620
      Manufacture date              : 02072026
      Manufacturing deviations      : (Not Specified)
      Manufacturing assembly number :
      Administrative state          : up
      Operational state             : up
      Time of last boot             : N/A
      Current alarm state           : alarm cleared

  Power supply number               : 3
    Power supply type               : ac single
    Power supply model              : peq
    Status                          : up
    AC power                        : within range
    DC power                        : within range
    Over temp                       : within range
    Hardware Data
      Part number                   : 3HE20432AARA01
      CLEI code                     : INPSAJ6FAA
      Serial number                 : NS2605X4356
      Manufacture date              : 02072026
      Manufacturing deviations      : (Not Specified)
      Manufacturing assembly number :
      Administrative state          : up
      Operational state             : up
      Time of last boot             : N/A
      Current alarm state           : alarm cleared

  Power supply number               : 4
    Power supply type               : ac single
    Power supply model              : peq
    Status                          : up
    AC power                        : within range
    DC power                        : within range
    Over temp                       : within range
    Hardware Data
      Part number                   : 3HE20432AARA01
      CLEI code                     : INPSAJ6FAA
      Serial number                 : NS2535XL610
      Manufacture date              : 09172025
      Manufacturing deviations      : (Not Specified)
      Manufacturing assembly number :
      Administrative state          : up
      Operational state             : up
      Time of last boot             : N/A
      Current alarm state           : alarm cleared
===============================================================================
```

6.15 Configuring multichassis redundancy for LAG

When configuring the associated LAG ID, the LAG must be in access mode and LACP must be enabled. The following example configures multichassis redundancy features.

Example: MD-CLI

```
[ex:/configure redundancy multi-chassis]
A:admin@node-2# info
```


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```
    peer 10.10.10.2 {
        admin-state enable
        description "Mc-Lag peer 10.10.10.2"
        mc-lag {
            admin-state enable
            lag "lag-1" {
                lacp-key 32666
                system-id 00:00:00:33:33:33
                system-priority 32888
            }
        }
    }
```

Example: classic CLI

```
A:node-2>config>redundancy>multi-chassis# info
----------------------------------------------
        peer 10.10.10.2 create
            description "Mc-Lag peer 10.10.10.2"
            mc-lag
                no shutdown
            exit
            no shutdown
        exit
----------------------------------------------
```

6.16 Post-boot configuration extension files

Two post-boot configuration extension files are supported and are triggered when either a successful or failed boot configuration file is processed. The commands specify URLs for the CLI scripts to be run following the completion of the startup configuration. A URL must be specified or no action is taken. The commands are persistent between router reboots and are included in the configuration saves.

Use the following commands to specify the CLI scripts that are run following the completion of the boot-up configuration.

```
configure system boot-bad-exec
configure system boot-good-exec
```

6.16.1 Show command output and console messages

Use the following command to show the current value of the bad and good exec URLs and indicate whether a post-boot configuration extension file was executed when the system was booted.

```
show system information
```

If an extension file was executed, the command also indicates whether it completed successfully.

The following example shows the show output for the 7705 SAR-1.

Output example: Show system information output for the 7705 SAR-1

```
===============================================================================
System Information
```


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```
===============================================================================
System Name            : node-2
System Type            : 7705 SAR-1
...
BOF Source             : cf3:
Image Source           : primary
Config Source          : N/A
Last Booted Config File: N/A
Last Boot Cfg Version  : N/A
Last Boot Config Header: N/A
Last Boot Index Version: N/A
Last Boot Index Header : N/A
Last Saved Config      : ftp://test:test@192.168.xx.xxx/./images/dut-bg.cfg
Time Last Saved        : 2025/03/27 20:12:15
Changes Since Last Save: No
User Last Modified     : admin
Max Cfg/BOF Backup Rev : 5
Cfg-OK Script          : ftp://test:test@192.168.xx.xxx/./images/env.cfg
Cfg-OK Script Status   : success
Cfg-Fail Script        : N/A
Cfg-Fail Script Status : not used
...
===============================================================================
```

When executing a post-boot configuration extension file, status messages are displayed on the console before the “Login” prompt.

The following example shows a failed bootup configuration that caused a boot-bad-exec file containing another error to be executed.

Example: Failed start-up configuration error message

```
Attempting to exec configuration file:
’ftp://test:test@192.168.xx.xxx/./12.cfg’ ...
System Configuration
Log Configuration
MAJOR: CLI #1009 An error occurred while processing a CLI command -
File ftp://test:test@192.168.xx.xxx/./12.cfg, Line 195: Command "log" failed.
CRITICAL: CLI #1002 An error occurred while processing the configuration file.
The system configuration is missing or incomplete.
MAJOR: CLI #1008 The SNMP daemon is disabled.
If desired, enable SNMP with the ’config>system>snmp no shutdown’ command.
Attempting to exec configuration failure extension file:
’ftp://test:test@192.168.xx.xxx/./fail.cfg’ ...
Config fail extension
Enabling SNMP daemon
MAJOR: CLI #1009 An error occurred while processing a CLI command -
File ftp://test:test@192.168.xx.xxx/./fail.cfg, Line 5: Command "abc log" failed.
TiMOS-B-x.0.Rx both/hops ALCATEL Copyright (c) 2000-20011 Alcatel-Lucent.
All rights reserved. All use subject to applicable license agreements.
Built on Thu Nov 207 19:19:11 PST 2008 by builder in /rel5x.0/b1/Rx/panos/main


Login:
```

6.17 Configuring system monitoring thresholds

This section provides information about configuring system monitoring thresholds.

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6.17.1 Creating events

The **event** command controls the generation and notification of threshold crossing events configured with the **alarm** and **hc-alarm** (high capacity) commands. When a threshold crossing event is triggered, the **rmon event** configuration optionally specifies whether an entry in the alarm table is created to record the occurrence of the event. It can also specify whether an SNMP trap be generated for the event. There are two notifications for threshold crossing events: a rising alarm and a falling alarm.

Creating an event entry in the alarm table does not create a corresponding entry in the event logs. However, when the event is set to trap, the generation of a rising alarm or falling alarm notification creates an entry in the event logs and that is distributed to whatever log destinations are configured: console, session, memory, file, syslog, or SNMP trap destination. The log message includes a rising or falling threshold crossing event indicator, the sample type (absolute or delta), the sampled value, the threshold value, the RMON alarm ID, the associated RMON event ID, and the sampled SNMP object identifier.

The **alarm** command configures an entry in the RMON-MIB::alarmTable. The **hc-alarm** command configures an entry in the HC-ALARM-MI:: hcAlarmTable. These commands control the monitoring and triggering of threshold crossing events. For notification or logging of a threshold crossing event to occur, there must be at least one associated **rmon event** configured.

The agent periodically takes statistical sample values from the MIB OID specified for monitoring and compares them to thresholds that have been configured. The **alarm** and **hc-alarm** commands configure the MIB OID to be monitored, the polling period (interval), sampling type (absolute or delta value), and rising and falling threshold parameters. If a sample has crossed a threshold value, the associated event is generated.

Preconfigured CLI threshold commands are available. Preconfigured commands hide some of the complexities of configuring RMON alarm and event commands and perform the same function. The preconfigured commands do not require the user to know the SNMP object identifier to be sampled. The preconfigured threshold configurations include memory warnings and alarms and compact flash usage warnings and alarms.

Example: MD-CLI

```
[ex:/configure system thresholds]
A:admin@node-2# info
    cflash-cap-warn-percent "cf1-B:" {
        rising-threshold 100
        falling-threshold 50
        interval 240
        startup-alarm either
    }
    kb-memory-use-alarm {
        rising-threshold 50000000
        falling-threshold 45999999
        interval 500
        startup-alarm either
    }
    rmon {
        event 5 {
            description "alarm testing"
            owner "Timos CLI"
        }
    }
```


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Example: classic CLI

```
A:node-2>config>system>thresholds# info
----------------------------------------------
            rmon
                event 5 description "alarm testing" owner "Timos CLI"
            exit
            cflash-cap-warn cf1-B: rising-threshold 2000000 falling-threshold
1999900 interval 240 trap
            memory-use-alarm rising-threshold 50000000 falling-threshold
45999999 interval 500
----------------------------------------------
```

6.18 Configuring LLDP

Use the commands in the following context to configure LLDP.

```
configure system lldp
```

Example: LLDP default configuration (MD-CLI)

```
[ex:/configure system lldp]
A:admin@node-2# info detail
 ## apply-groups
 ## apply-groups-exclude
    admin-state enable
    tx-credit-max 5
    message-fast-tx 1
    message-fast-tx-init 4
    tx-interval 30
    tx-hold-multiplier 4
    reinit-delay 2
    notification-interval 5
```

Example: LLDP default configuration (classic CLI)

```
A:node-2>config>system>lldp# info detail
----------------------------------------------
             no tx-interval
             no tx-hold-multiplier
             no reinit-delay
             no notification-interval
             no tx-credit-max
             no message-fast-tx
             no message-fast-tx-init
             no shutdown
----------------------------------------------
```

Example: LLDP port configuration (MD-CLI)

```
[ex:/configure port 1/1/1 ethernet lldp]
A:admin@node-2# info
    dest-mac nearest-bridge {
        receive true
        transmit true
        tx-tlvs {
            port-desc true
```


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```
            sys-cap true
        }
        tx-mgmt-address system {
            admin-state enable
        }
    }
```

Example: LLDP port configuration (classic CLI)

```
A:node-2>config>port>ethernet>lldp# info
----------------------------------------------
       dest-mac nearest-bridge
              admin-status tx-rx
              tx-tlvs port-desc sys-cap
              tx-mgmt-address system
       exit
----------------------------------------------
```

Example: Global system LLDP configuration (MD-CLI)

```
[ex:/configure system lldp]
A:admin@node-2# info
    tx-interval 10
    tx-hold-multiplier 2
    reinit-delay 5
    notification-interval 10
```

Example: Global system LLDP configuration (classic CLI)

```
A:node-2>config>system>lldp# info
----------------------------------------------
        tx-interval 10
        tx-hold-multiplier 2
        reinit-delay 5
        notification-interval 10
----------------------------------------------
```

6.19 Monitoring datapath statistics

This section provides information about monitoring datapath statistics on the 7705 SAR Gen 2.

6.19.1 Virtual FP utilization

The 7705 SAR Gen 2 allocates CPU cores to different system tasks based on the active system profile. See System profiles for more information about system profiles.

Use the following command to display the virtual FP utilization for each task.

```
show card virtual fp
```

Output example: Virtual FP utilization on profile A

```
===============================================================================
Card 1 Virtual Forwarding Plane Statistics
```


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```
===============================================================================
Task                    vCPUs           Average         Maximum
                                        Utilization     Utilization
-------------------------------------------------------------------------------
NIC                     2               0.00 %          0.00 %
Worker                  8               0.04 %          0.04 %
Scheduler               1               0.00 %          0.00 %
BufferMgr               1               8.06 %          8.06 %
===============================================================================
```

6.19.2 Buffer pools and congestion status

Use the following command to display buffer pool utilization and congestion status.

```
tools dump system congestion-status card
```

Output example: Buffer pool utilization and congestion status

```
===============================================================================
System congestion status
===============================================================================
Settings
Packet size                                     : jumbo
Early discard                                   : disabled

Packet pool
Average free buffers (%)                        : 96
Current free buffers                            : 410436 / 411395

Congestion status
Current                                         : not-congested
Last second                                     : not-congested
Last minute                                     : not-congested
Last 5 minutes                                  : not-congested
Last 30 minutes                                 : not-congested
===============================================================================
```

6.19.3 FP input-output statistics

The 7705 SAR Gen 2 supports displaying FP input-output statistics at the port, MDA, or card level. In the MD-CLI, **state** commands also provide the ability to display counters for individual statistics.

In the MD-CLI, use the commands in the following contexts to display individual statistics counters.

```
state port fp input-output statistics
state mda fp input-output statistics
state card fp input-output statistics
```

Use the commands in the following contexts to display aggregated FP statistics.

```
tools dump port fp input-output statistics
tools dump mda fp input-output statistics
tools dump card fp input-output statistics
```


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In the **port** context, the commands display per-port FP statistics. The commands are supported on all embedded Ethernet ports. For per-port statistics, the router supports displaying either the cumulative statistics since the last system reboot, or the statistics accumulated since they were last cleared using the **clear port fp input-output statistics** command. The latter is useful for debugging purposes.

In the **mda** context, the commands display the aggregated FP statistics of all ports on the specified MDA. These commands are supported for all MDAs. Unlike with ports, the aggregated MDA FP statistics cannot be cleared directly. However, using the **clear port** command to clear the information on a specific MDA (for example, 1/1) also clears the FP utilization statistics for that MDA.

In the **card** context, the commands display the aggregated statistics of all ports for all MDAs on the card. These statistics cannot be cleared.

The following output shows the **state** FP statistics counters available for monitoring at the card level.

Output example: state card fp input-output statistics

```
[/state card 1 fp 1 input-output statistics cumulative]
A:admin@node-2# tree
+-- traffic-class-0-policer-count-green
+-- traffic-class-0-policer-count-red
+-- traffic-class-0-policer-count-rered
+-- traffic-class-0-policer-count-reyellow
+-- traffic-class-0-policer-count-yellow
+-- traffic-class-1-policer-count-green
+-- traffic-class-1-policer-count-red
+-- traffic-class-1-policer-count-rered
+-- traffic-class-1-policer-count-reyellow
+-- traffic-class-1-policer-count-yellow
+-- traffic-class-2-policer-count-green
+-- traffic-class-2-policer-count-red
+-- traffic-class-2-policer-count-rered
+-- traffic-class-2-policer-count-reyellow
+-- traffic-class-2-policer-count-yellow
+-- traffic-class-3-policer-count-green
+-- traffic-class-3-policer-count-red
+-- traffic-class-3-policer-count-rered
+-- traffic-class-3-policer-count-reyellow
+-- traffic-class-3-policer-count-yellow
+-- traffic-class-4-policer-count-green
+-- traffic-class-4-policer-count-red
+-- traffic-class-4-policer-count-rered
+-- traffic-class-4-policer-count-reyellow
+-- traffic-class-4-policer-count-yellow
+-- traffic-class-5-policer-count-green
+-- traffic-class-5-policer-count-red
+-- traffic-class-5-policer-count-rered
+-- traffic-class-5-policer-count-reyellow
+-- traffic-class-5-policer-count-yellow
+-- traffic-class-6-policer-count-green
+-- traffic-class-6-policer-count-red
+-- traffic-class-6-policer-count-rered
+-- traffic-class-6-policer-count-reyellow
+-- traffic-class-6-policer-count-yellow
+-- traffic-class-7-policer-count-green
+-- traffic-class-7-policer-count-red
+-- traffic-class-7-policer-count-rered
+-- traffic-class-7-policer-count-reyellow
+-- traffic-class-7-policer-count-yellow
```

The following output is an example of FP statistics information at the card level.

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Example: tools dump card fp input-output statistics

```
A:node-2>tools>dump>card>fp>input-output# statistics cumulative

Forwarding Path Statistics for Card 1:


    Traffic Class 0 Policer Count Red          :                0
    Traffic Class 0 Policer Count Yellow       :                0
    Traffic Class 0 Policer Count Green        :                0
    Traffic Class 0 Policer Count Re-Red       :                0
    Traffic Class 0 Policer Count Re-Yellow    :                0
    Traffic Class 1 Policer Count Red          :                0
    Traffic Class 1 Policer Count Yellow       :                0
    Traffic Class 1 Policer Count Green        :                0
    Traffic Class 1 Policer Count Re-Red       :                0
    Traffic Class 1 Policer Count Re-Yellow    :                0
    Traffic Class 2 Policer Count Red          :                0
    Traffic Class 2 Policer Count Yellow       :                0
    Traffic Class 2 Policer Count Green        :                0
    Traffic Class 2 Policer Count Re-Red       :                0
    Traffic Class 2 Policer Count Re-Yellow    :                0
    Traffic Class 3 Policer Count Red          :                0
    Traffic Class 3 Policer Count Yellow       :                0
    Traffic Class 3 Policer Count Green        :                0
    Traffic Class 3 Policer Count Re-Red       :                0
    Traffic Class 3 Policer Count Re-Yellow    :                0
    Traffic Class 4 Policer Count Red          :                0
    Traffic Class 4 Policer Count Yellow       :                0
    Traffic Class 4 Policer Count Green        :                0
    Traffic Class 4 Policer Count Re-Red       :                0
    Traffic Class 4 Policer Count Re-Yellow    :                0
    Traffic Class 5 Policer Count Red          :                0
    Traffic Class 5 Policer Count Yellow       :                0
    Traffic Class 5 Policer Count Green        :                0
    Traffic Class 5 Policer Count Re-Red       :                0
    Traffic Class 5 Policer Count Re-Yellow    :                0
    Traffic Class 6 Policer Count Red          :                0
    Traffic Class 6 Policer Count Yellow       :                0
    Traffic Class 6 Policer Count Green        :                0
    Traffic Class 6 Policer Count Re-Red       :                0
    Traffic Class 6 Policer Count Re-Yellow    :                0
    Traffic Class 7 Policer Count Red          :                0
    Traffic Class 7 Policer Count Yellow       :                0
    Traffic Class 7 Policer Count Green        :                0
    Traffic Class 7 Policer Count Re-Red       :                0
    Traffic Class 7 Policer Count Re-Yellow    :                0
```


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7 DHCP persistence

The DHCP persistence feature on the 7705 SAR Gen 2 retains information learned through DHCP snooping across reboots. This information can include data such as the IP address, MAC binding information, lease length information, and ingress SAP information (required for VPLS snooping to identify the ingress interface). This information is referred to as the DHCP lease-state information.

When a DHCP message is snooped, the system performs the following steps to make the data persistent. For systems with only one CPM, only step 1 applies; for those with dual CPMs, all steps apply.

1. When a DHCP ACK is received from a DHCP server, the entry information is written to the active CPM compact flash. If writing is successful, the ACK is forwarded to the DHCP client. If persistency fails completely (for example, because of a bad compact flash), a trap is generated indicating that persistency can no longer be guaranteed.

   If the complete persistency system fails, the DHCP ACKs are still forwarded to the DHCP clients. DHCP ACKs may get dropped and not forwarded to the DHCP clients only during small persistency interruptions, or in overload conditions of the compact flash.

2. DHCP message information is sent to the standby CPM, where the DHCP information is also logged on the compact flash. If persistency fails on the standby CPM, a trap is generated.

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8 CPIOM redundancy

This chapter provides information about configuring CPIOM redundancy.

8.1 File synchronization

The 7705 SAR-10x uses a 1:1 redundancy scheme. CPIOM redundancy requires file synchronization between the active and standby CPIOM compact flash drives so that they maintain identical system files to prevent inconsistencies in the event of a CPIOM failure.

If synchronization fails, alarms and log messages that indicate the type of error that caused the failure of the synchronization operation are generated. When the error condition ceases to exist, the alarm is cleared.

Only files stored on the router are synchronized. If a configuration file or image is stored in a location other than on a local compact flash, the file is not synchronized (for example, storing a configuration file on an FTP server).

Two types of synchronization are supported:

- **automatic**

  Automatic synchronization is set to **config** by default on systems with CPIOM redundancy. You can configure automatic synchronization for all files required for the boot process, or you can configure it for only the configuration files. Use the following command to configure which type of automatic synchronization to perform.

  ```
  configure redundancy synchronize
  ```

  When automatic synchronization is set to **config**, the following files are synchronized if they have been modified:

  – the configuration files (`config.cfg`) and their backups in the primary, secondary, and tertiary configuration locations

  – the model-driven commit history and incremental saved configuration files in the `.commit-history` directory when the system is in model-driven configuration mode

  – the persistent index file (`config.ndx`) and its backups when the system is in classic or mixed configuration mode

  – SSH key files in the `.ssh` directory

  – the password history file (`passwd/history`)

  When automatic synchronization is set to **boot-env**, the following files are synchronized if they have been modified and are applicable to the platform:

  – the configuration files (`config.cfg`) and their backups in the primary, secondary, and tertiary configuration locations

  – the BOF configuration file (`bof.cfg`) and its backups

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- the model-driven commit history and incremental saved configuration files in the .commit-history directory when the system is in model-driven configuration mode
- the persistent index file (`config.ndx`) and its backups when the system is in classic or mixed configuration mode
- the boot loader file (`boot.ldr`)
- all SR OS image (`.tim`) files in the primary, secondary, and tertiary image locations
- signature (`.txt`) files (for example, `sha256sum.txt`)
- the nvsys file (`nvsys.info`)
- SSH key files in the `.ssh` directory
- the password history file (`passwd/history`)
- classic CLI rollback files (`.rb`) and their backups
- the license file (`licence.txt`) in the license location

BOF configuration file (`bof.cfg`) and file synchronization also occurs when the following BOF parameter values are changed:

- the configuration files (`config.cfg`) and their backups in the primary, secondary, and tertiary configuration locations
- all image (`.tim`) files in the primary, secondary, and tertiary image locations
- the license file (`licence.txt`) in the license location

Configuration file (`config.cfg`) synchronization also occurs when the configuration is committed in model-driven interfaces if the **auto-config-save** command is enabled, or is saved with the **admin save** command.

The debug configuration file (`debug.cfg`) and its backups are not synchronized, because the debug configuration is not automatically loaded after a CPIOM switchover. These files must be manually copied to standby CPIOM using the following command, if needed:

```
file copy
```

- **manual**

  You can manually synchronize all files required for the boot process, the configuration files, or PKI certificate files in the **system-pki** directory. Manual synchronization synchronizes all files regardless whether or not they have been modified, which takes a significantly longer time than automatic synchronization. Use the following commands to perform manual synchronization.

  ```
  admin redundancy synchronize
  ```

Note:

- See "Configuration rollback" in the *7705 SAR Gen 2 Classic CLI Command Reference Guide* for more information about classic CLI configuration rollback file synchronization.
- See the **configure redundancy cert-sync** command in the *7705 SAR Gen 2 Classic CLI Command Reference Guide* and *7705 SAR Gen 2 MD-CLI Command Reference Guide* for more information about PKI certificate synchronization.

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8.2 Active and standby designations

Typically, the first CPIOM card installed in a redundant 7705 SAR-10x chassis assumes the role as active, regardless of whether it is inserted in Slot A or B. The next CPIOM installed in the same chassis then assumes the role as standby. If two CPIOMs are inserted simultaneously (or almost simultaneously) and are booting at the same time, preference is given to the CPIOM installed in Slot A.

If only one CPIOM is installed in a redundant router device, it becomes the active CPIOM regardless of the slot it is installed in.

To visually determine the active and standby designations, the Status LED on the faceplate is lit green (steady) to indicate the active designation. The Status LED on the second CPIOM faceplate is lit green (slow blink) to indicate the standby designation.

Use the following command to display information about the card status.

```
show card
```

Output example: show card

The following example output shows that the CPIOM installed in Slot A is acting as the active CPIOM, and the CPIOM installed in Slot B is acting as the standby.

```
===============================================================================
Card Summary
===============================================================================
Slot      Provisioned Type                        Admin Operational   Comments
              Equipped Type (if different)        State State
-------------------------------------------------------------------------------
1         iom-sar-x                               up    up
2         iom-sar-x                               up    provisioned
A         cpiom-sar-x                             up    up/active
B         cpiom-sar-x                             up    down/standby
===============================================================================
```

Example: Console message

The following is an example console message which displays when a CPIOM boots in Slot B, sees an active CPIOM in Slot A, and becomes the standby CPIOM.

```
...
Slot A contains the Active CPM
```

8.3 When the active CPIOM goes offline

When an active CPIOM goes offline (because of reboot, removal, or failure), the standby CPIOM takes control without rebooting or initializing. It is assumed that the CPIOMs are synchronized; therefore, there is no delay in control plane operability.

Note: Datapath operation for CPIOMs is briefly interrupted during a CPIOM switchover.

When the CPIOM that went offline boots and comes back online, it comes online as the standby CPIOM.

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Example: Output displayed when the standby CPIOM comes online

```
Active CPM in Slot A has stopped
Slot B is now active CPM


Attempting to exec configuration file:
'cf3:/config.cfg' ...

...

Executed 49,588 lines in 8.0 seconds from file cf3:\config.cfg
```

8.4 OOB management Ethernet port redundancy

SR OS provides a resilient out-of-band (OOB) management Ethernet redundancy mode for system management.

Use the following command to enable OOB management Ethernet port redundancy.

```
configure redundancy mgmt-ethernet
```

When the management Ethernet port is down on the active CPIOM, the OOB Ethernet redundancy feature allows the active CPIOM to use the management Ethernet port of the standby CPIOM, as shown in the following figures.

Figure 23: Management Ethernet: normal mode

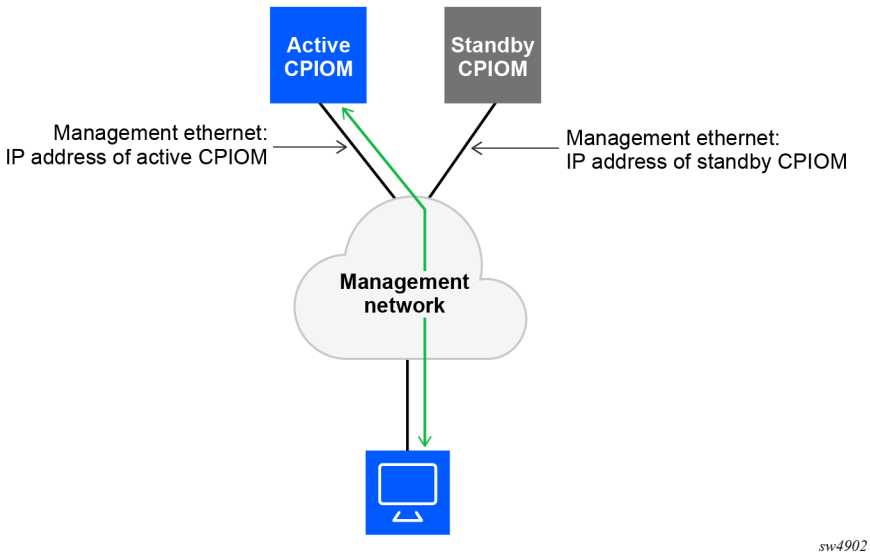

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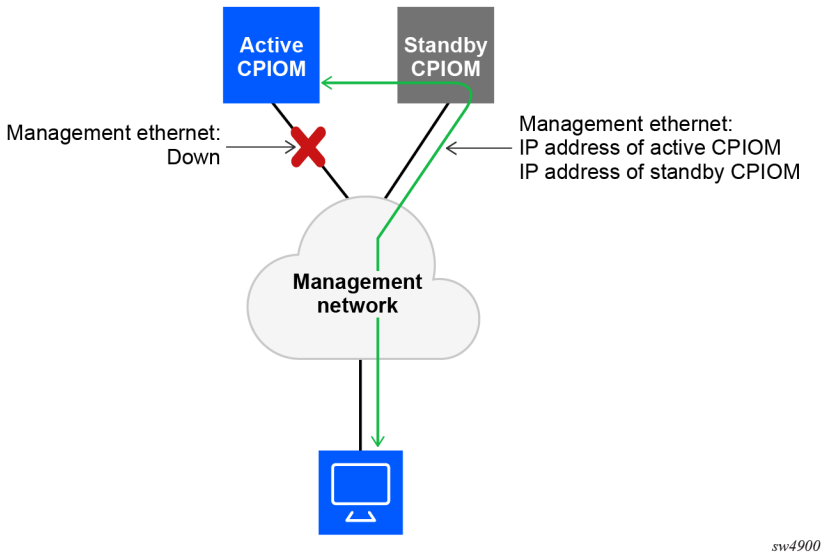
Figure 24: Management Ethernet: redundancy mode



8.5 Configuration guidelines for synchronization of active and standby CPIOM

The following configuration guidelines apply for synchronization of active and standby CPIOM:

- The active CPIOM and standby CPIOM should boot from the same drives. For example, if active is booted from `cf3:/`, standby must use `cf3:/` to start up. Even though it is possible to make the CPIOM operational by booting them using any drive on active and standby, Nokia recommends using the same drives for booting the system.
- The user should ensure that a valid bootstrap image file (`boot.ldr`) and BOF (`bof.cfg`) exist in the `cf3:/` drive of both active and standby CPIOM cards. The user should verify that `bof.cfg` resides at the same drive as the `boot.ldr.` Only booting from `cf3:/` is supported.
- The TiMOS application image (both.tim) and the configuration file can reside in any location (local or remote), but the locations in the BOF should be configured identically on both active and standby CPIOM for primary, secondary, or tertiary locations.
- Boot environment synchronization must be executed before config synchronization.
- Synchronization can only occur locally between compact flash drives `cf2:Active` to `cf2:Standby` and `cf3:Active` to `cf3:Standby`. Synchronization across different drives is not supported.
- If the active and standby are not synchronized for some reason, the user can manually synchronize and then reboot the standby CPIOM by executing the following commands.

```
admin redundancy synchronize boot-env
```

```
admin reboot standby
```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9 Zero touch provisioning

Traditional deployment of new nodes in a network is a multi-step process in which the user connects to the hardware to provision global and local configuration options. ZTP automatically configures the node by obtaining the required information from the network and automatically provisioning the node with minimal manual intervention and configuration. When nodes that support ZTP are installed in the rack, connected to the network, and powered on, the nodes are auto-provisioned.

Note: To support ZTP, make sure the new nodes are purchased with the **auto-boot** flag enabled in the factory-loaded BOF.

9.1 ZTP overview

ZTP is used to automatically install and provision new nodes in the field. For out-of-band management, the nodes can be installed and powered up with network connectivity on the management (Mgmt) port. For in-band management, the first two connectors on the first two slots can be used for ZTP.

Note: For breakout connectors, only the first breakout port on the first two connectors can be used for ZTP.

After network connectivity is established, the ZTP process starts automatically. The node sends a DHCP discovery request to the DHCP server using a ZTP-capable port and the DHCP server returns an IPv4/IPv6 FTP or HTTP URL from which the provisioning information can be retrieved. The provisioning information is in a file called the provisioning file, which contains the URL of the image, config, and other files to be downloaded. After downloading these files and successfully provisioning, the node automatically reboots and comes back up in normal mode.

Secure ZTP (SZTP), which is an extension of ZTP, is also supported. See Legacy SZTP (non RFC 8572-compliant) for information about SZTP.

Note: ZTP and SZTP support TLS 1.2 and TLS 1.3 for HTTPS.

9.1.1 Network requirements

ZTP requires the following network components:

- **DHCP server (IPv4 or IPv6)**

  The DHCP server supports assignment of IP addresses through DHCP requests and offers.

- **file server**

  The FTP or HTTP file server is used for staging and transfer of RPMs, configurations, images, and scripts.

- **DHCP relay**

  A DHCP relay is required if the servers are across a Layer 3 network.

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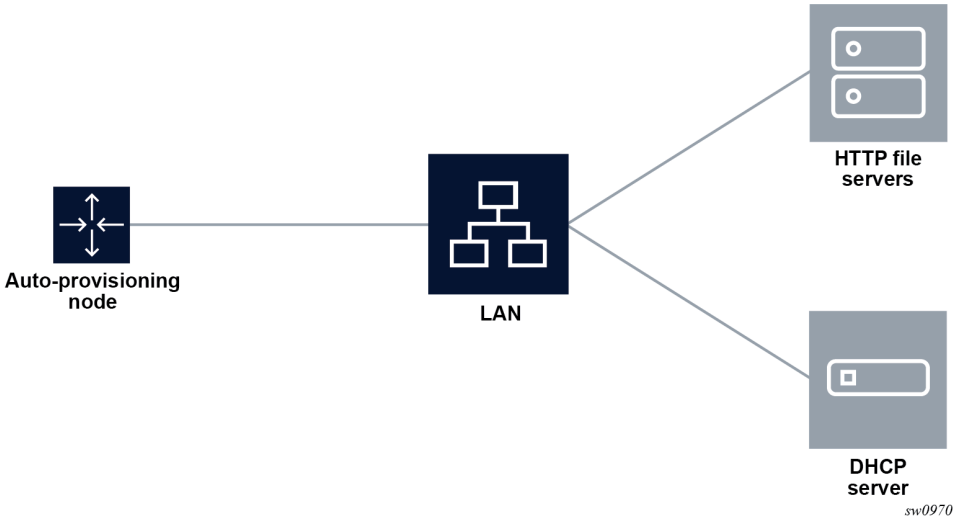
9.1.2 Network support

ZTP operates in the following network environments:

- **node, file servers, and DHCP server in the same subnet**

  The following figure shows the scenario where all components are in a Layer 2 broadcast domain. There is no DHCP relay and all IP addresses are assigned from a single pool.

  Figure 25: Auto-provisioning with all components in the same subnet



- **file servers and DHCP server in the same subnet, separate from the nodes**

  The following figure shows the scenario where only the file servers and DHCP server are in the same subnet. The DHCP relay is used to fill option 82 as the gateway address. The gateway address is used to find the appropriate pool in the DHCP server to assign the correct subnet IP address to the system.

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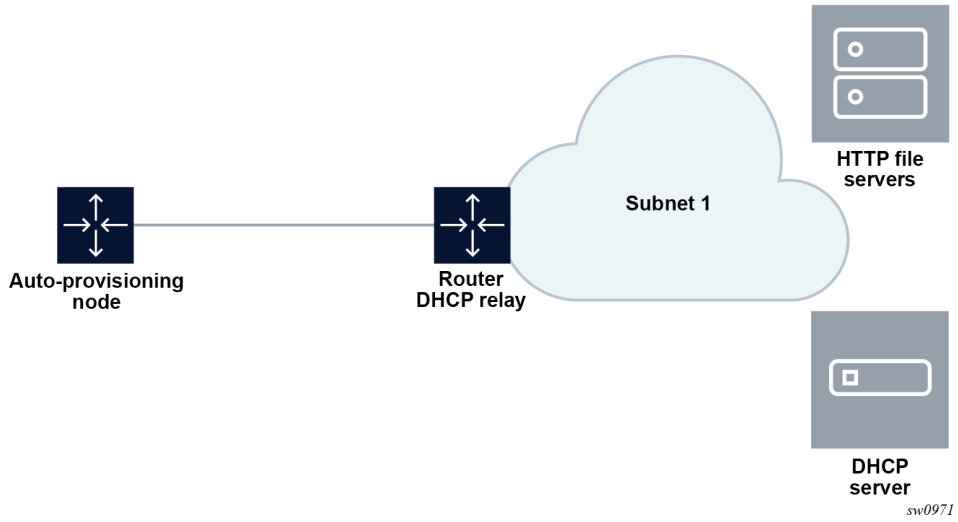
Figure 26: Auto-provisioning with only file and DHCP servers in the same subnet

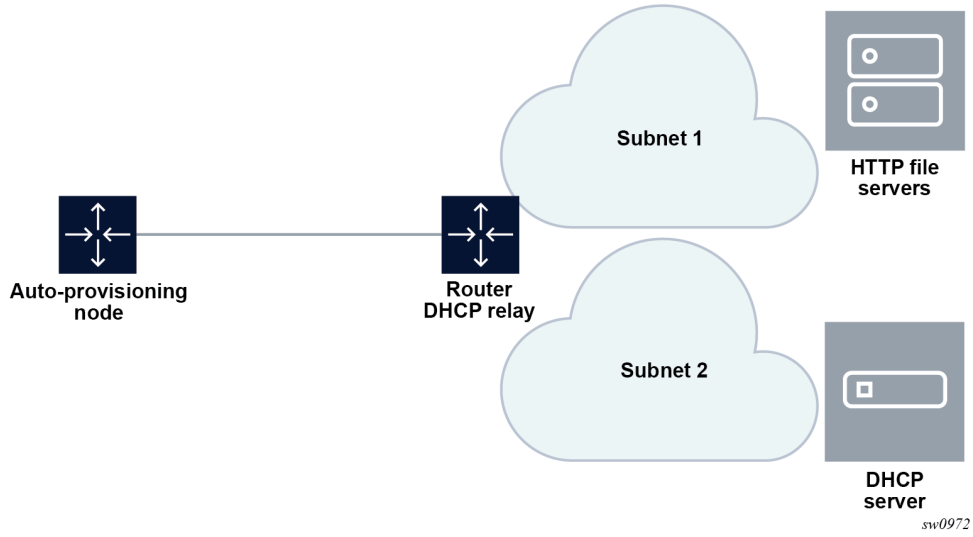


DHCP allows the Option 3 router to define the default gateway. If multiple addresses are provided using Option 3, the first address is used for the default gateway.

- **node, file servers, and DHCP server in different subnets**

  The following figure shows the scenario where all components are in different subnets. The DHCP relay adds the option 82 gateway address to the DHCP request, and the DHCP server adds the option 3 with the gateway address of the file server.

  Figure 27: Auto-provisioning with all components in different subnets



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9.2 ZTP process overview

ZTP consists of the following processes:

- Auto-boot process
- Auto-provisioning process

9.2.1 Auto-boot process

In this process, the node discovers and provisions the chassis and installed cards.

1. The node is first connected to the network and powered on.
2. The out-of-band management port is checked for link connectivity. If a link is not found, the system checks the in-band management ports for a link.
3. The first two card or MDA slots are auto-provisioned based on the installed card types. See ZTP overview for information about the specific card or MDA slots that are used.
4. The auto-boot process switches control to the auto-provisioning process.

See Auto-boot process details for more information about the auto-boot process.

9.2.2 Auto-provisioning process

In this process, the node detects operational ports, attempts to discover its IP address, and downloads the relevant files for provisioning.

1. The node sends a DHCP discovery request to the DHCP server using the out-of-band management port. If DHCP discovery is unsuccessful, the node reattempts it using the in-band management ports.
2. After DHCP discovery is successful, the DHCP server returns an IPv4 or IPv6 FTP or HTTP URL of a file server from which the node can retrieve provisioning information.
3. The node downloads the provisioning information and performs the auto-provisioning according to the specifications in the files.
4. After the node is successfully provisioned, it automatically reboots and becomes operationally up.

See Provisioning files for more information about the auto-provisioning process.

The SR OS can also initiate the auto-provisioning process using a **tools** command.

9.3 DHCP support for ZTP

This section provides information about DHCP messages, DHCP clients, and DHCP servers that are supported by ZTP.

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9.3.1 DHCP server offer options

Options 66, 67, and 43 are supported for indicating the location of the provisioning file. If both Options 66 and 67 are present in the DHCP offer, they take precedence over Option 43.

Option 66 contains the server URL or IP address, and Option 67 contains the URL of the provisioning file location.

Options 66 and 67 are meant for use by PXE TFTP, but are also used for HTTP and FTP. If an offer arrives with Options 66 and 67, Option 66 should resolve the server IP address and Option 67 should resolve the file location. Option 66 can be omitted by the provider, in which case Option 67 is used for both the server IP address and provider file URL. If an offer arrives with Option 67 only, it should resolve both the server IP address and file URL.

The auto-provisioning process distinguishes the host part of the URL and can resolve it using DHCP DNS.

9.3.1.1 Nokia-specific TLV

The Nokia-specific TLV is NOKIA-DCTOR-AUTOCONFIG. The location of the BOF for each system to use is configured in the optional **autoboot** file parameter, which is a standard Option 43 value initialized at the beginning of the process. The BOF location is sent in Option 43 as part of the DHCP offer and Ack messages from the DHCP server to the system. The system uses the location specified in Option 43 to initiate an FTP download of the BOF.

9.3.2 Supported DHCP client options for ZTP

The following table lists the supported DHCP client options for ZTP.

Table 28: Supported DHCP client options for ZTP

Options	DHCP IPv4 option	IPv4 comments	DHCP IPv6 option	IPv6 comments
Lease time	Option 51	Always infinite	—	—
Requested option list	Option 55	—	—	—
Client ID	Option 61	Default is chassis serial ID	Option 1 (DUID)	Type 2 — vendor-assigned unique ID (default with chassis serial ID) Type 3 — link-layer address
User class	Option 77	"*platform*;timos-*release*;ztp”	Option 15	"*platform*;timos-*release*;ztp”
Class ID	Option 60	"NOKIA: Fmt ChassisType Strings”	—	—

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9.3.3 Supported DHCP server options for ZTP

The following table lists the supported DHCP server options for ZTP.

Table 29: Supported DHCP server options for ZTP

Options	DHCP IPv4 option	IPv4 comments	DHCP IPv6 option	IPv6 comments
Subnet mask	Option 1	—	—	—
Router	Option 3	Default gateway	—	—
DNS server	Option 6	DNS server	Option 23	DNS server
Lease time	Option 51	Must be infinite	—	—
Server address	Option 54	Identifies the DHCP server	—	—
Classless static route	Option 121	Used to install static routes	—	—
NTP server[3]	Option 42	—	Option 56	—
TFTP server name	Option 66	Server IP address	—	—
Bootfile name	Option 67	URL of the file This option can be used without Option 66, in which case it contains the server name and the URL	Option 59	Server name and URL of the file
Vendor-specific options (See Nokia-specific TLV)	Option 43	Nokia proprietary file location; can be used instead of Options 66 or 67, but Options 66 and 67 take precedence over Option 43	Option 17	Nokia proprietary file location; can be used instead of Option 59, but Option 59 takes precedence over Option 17

9.3.4 DHCP discovery and solicitation

IPv4 DHCP discovery and IPv6 DHCP solicitation are supported.

[3] When the node is running in ZTP mode, the date and time are set by NTP. This information is required for HTTPs certificate verification, and to record date and time stamps in events and logs.

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IPv4 DHCP discovery messages and IPv6 DHCP solicitation messages are sent from out-of-band and in-band management ports with active links. The first valid DHCP offer for the address family that arrives on the node is used.

In the BOF, the **auto-boot** option can be configured to send out IPv4, IPv6, or both IPv4 and IPv6 DHCP requests.

9.3.4.1 DHCP discovery (IPv4 and IPv6)

This section describes DHCP discovery options.

9.3.4.1.1 DHCP discovery Options 61 and 77

SR OS supports both Option 61 (client ID) and Option 77 (user class) DHCP discovery options.

Option 61 is used for DHCP server pool selection. Option 61 provides the client ID; the serial ID of the chassis with a type of 0 is used by default. This option is configurable using commands in the **bof auto-boot** context.

Option 77 provides the user class, describing what the device is and other information, such as the OS version. This option is set automatically, but can be removed using the BOF configuration. For example, the user can delete **include-user-class** in the BOF auto-boot configuration to avoid sending Option 77.

For ZTP, the DHCP discovery message should be sent with Option 77; the following information is automatically configured:

platform;timos-*release*;ztp

For auto-provisioning, Option 77 should use the following information:

platform;timos-*release*;AP

9.3.4.1.2 DHCP discovery Option 1 DUID (IPv6)

By default, the node uses RFC 3315 DUID Type 2 vendor-assigned unique IDs. The value for *enterprise-id* is 6527 and the identifier is the chassis serial number.

Note: The system uses the chassis serial number for ZTP pool selection and auto-provisioning.

The option to use Type 3 is configured in the BOF. For MAC, the chassis MAC address is configured in a string format.

Type 1 is not supported.

9.3.4.2 DHCP solicitation (IPv6)

Unlike IPv4 DHCP offers, which contain the prefix and default route, IPv6 DHCP offers only contain the IP address assignment. The IPv6 route advertisement (RA) provides the default router and the prefix is set to /128 for the IP address supplied by the DHCP server.

For further information about RA support, see IPv6 DHCP/RA details. For further information about DHCP server offers, see DHCP server offer options.

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9.3.5 IPv4 and IPv6 DHCP support

The ZTP process supports the use of IPv4 and IPv6 DHCP clients to obtain the provisioning file.

For ZTP processes, the node transmits both IPv4 and IPv6 discovery and solicitation messages. If offers arrive from both IPv4 and IPv6 servers, both offers are cached and the first offer received is processed. If the first offer does not fulfill the ZTP requirements and is rejected, the second offer is processed and accepted or rejected. If both offers received on an interface are rejected, ZTP goes to the next interface.

The provisioning file only allows file transfer in the address family of the DHCP offer that is used. If the offer is IPv4, the provisioning files are downloaded using IPv4. If the offer is IPv6, the provisioning files are downloaded using IPv6.

9.3.5.1 IPv4 route installation details

Option 3 (default route) and Option 121 (classless static route) are supported for IPv4 DHCP.

For identical routes with different next hops, only the first route is installed and the second route is kept as a backup route. ECMP is not supported.

There is no route limit for Option 121.

9.3.5.2 IPv6 DHCP/RA details

IPv6 DHCP offers do not contain an IP prefix. The IPv6 prefix is usually obtained from the IPv6 RA arriving from the upstream router. Because the SR OS router is the host for the ZTP process, the system assigns a /128 prefix to the IPv6 address obtained from the DHCP offer.

SR OS supports the use of an IPv6 RA to install IPv6 default and static routes from upstream routers. The system installs all the routes advertised using the RA. If the same route has been advertised from multiple upstream routers (next hops), the system installs the route with the highest preference. SR OS does not support ECMP if the same route is advertised from multiple next hops by multiple RAs.

In accordance with RFC 4861 recommendations, SR OS ensures that all RAs are obtained before the auto-provisioning process is started for IPv6. RFC 4861 recommends that the host (in this case, the SR OS router) send a minimum of three route solicitations to increase the likelihood of at least one route solicitation being received by the upstream routers. Each route solicitation is followed by a 4-second timeout, so the third route solicitation is sent 8 seconds after the first. The upstream routers must respond within 0.5 seconds. As a result, the SR OS router receives all RAs and routes within 8.5 seconds of the first route solicitation, and waits a maximum of 9 seconds to receive all RAs; ZTP always waits 20 seconds to receive all RAs, however, only the first RA received is used.

9.3.5.3 ZTP and DHCP timeouts

The ZTP timeout is user-configurable with a default value of 30 minutes. See Options and option modification and Configuring the ZTP timeout in the provisioning file for more information. After each ZTP timeout, the node reboots and reattempts the ZTP process. If the ZTP timeout interval expires while the node is executing a DHCP offer or downloading files, the node does not reboot. The DHCP offer is executed until it succeeds or fails, at which point the node reboots. If the offer is successful, the node comes up in normal operation mode.

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The DHCP timeout interval is 20 seconds. If a DHCP offer is not received within the DHCP timeout interval, the auto-provisioning process is reattempted using the next valid interface.

9.4 ZTP procedure details

This section describes ZTP procedures including node bootup, BOF, auto-provisioning, logs, and events.

9.4.1 Node bootup

After the node is powered up, the BOF is examined for the **auto-boot** flag status. If the **auto-boot** flag is set in the `bof.cfg` file, the node goes into ZTP mode. If the **auto-boot** flag is not set in the `bof.cfg` file, the node continues booting normally.

If it is in ZTP mode, the node provisions all hardware necessary for the ZTP process. This includes the fabric, the first two card slots, and the MDAs for the first two card slots. The node then checks for links on the management (Mgmt) port and valid Ethernet ports.

Note: A `bof.cfg` file with the **auto-boot** flag enabled can be shipped as an orderable part with the applicable software license. The **auto-boot** flag can also be set using the **bof auto-boot** command.

For more information about the BOF, see BOF.

9.4.1.1 Reinitiating ZTP during normal node bootup

ZTP can be reinitiated any time by setting the **auto-boot** flag and configuring the flag options in the BOF. After the auto-boot flag is set, any reboot forces the node into ZTP mode, including DHCP discovery, and downloading and reprocessing the provisioning file. The old BOF is kept in the storage medium until the ZTP process is successful, then the old BOF information is overwritten. If an unsuccessful ZTP process is interrupted and the **auto-boot** flag is removed, the node boots using the old BOF.

9.4.2 BOF

Two versions of each supported 7705 SAR Gen 2 platform software license are currently available: one for non-ZTP bootup, and one for ZTP bootup. Software packages for ZTP bootup contain a `bof.cfg` file with the **auto-boot** flag set, which causes the node to automatically boot up in ZTP mode and execute ZTP processes.

The **auto-boot** flag contains the following information:

- **client ID**

  The client ID is sent to the DHCP server to identify the chassis or node and to find a pool for the DHCP offer. If no client ID is configured, the chassis serial number is sent.

  This option is used for both IPv4 client ID and IPv6 DUID Type 2.

- **port (port:vlan)**

  The port is used to send DHCP discovery; the port number must be configured manually in the BOF.

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For more information about the BOF, see System initialization and boot options.

9.4.2.1 Compact flash support

The BOF itself does not support loading from the network using HTTP or HTTPS.

9.4.3 Auto-boot process details

This section describes the ZTP auto-boot process.

9.4.3.1 Options and option modification

By default, the auto-boot process scans all ZTP-enabled ports to find a port with an operational link. The scanned ports include:

- out-of-band management port (Mgmt port)
- Ethernet ports on the first two card or MDA slots (used for in-band management)

Note: For breakout connectors, only the first breakout port in the connector can be used for ZTP.

ZTP attempts to discover the node IP via DHCP and identifies the node using DHCP client ID Option 61 (IPv4) or Option 1 (IPv6). The client ID uses the chassis serial number by default. The chassis serial number is visible on the shipping box of the chassis.

Table 28: Supported DHCP client options for ZTP lists the default DHCP client options for ZTP. Some client options can be manually configured in the BOF using the **bof auto-boot** command.

The optional **auto-boot** configuration options are as follows:

- **management port**

  Specify that ZTP should only be performed using the out-of-band management port (Mgmt port).

- **in-band VLAN**

  Specify ZTP should only be performed using Ethernet ports on the first two card or MDA slots. The VLAN ID can be used to specify an in-band VLAN to use for the auto-boot process.

- **IPv4, IPv6**

  Specify that IPv4 discovery, IPv6 discovery, or both, should be performed. If both are specified, the system dual-stacks.

- **client identifier**

  Identify the node to the DHCP server and find a pool for DHCP offers. This information is sent using Option 61 (IPv4) or Option 1 (IPv6). If the **client-identifier** options are not configured, the chassis serial number is sent by default. This option is used for both IPv4 client ID and IPv6 DUID Type 2.

- **include user class**

  Specify to include Option 77.

- **timeout**

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Specify in minutes the timeout for the ZTP process to be executed successfully before the node is rebooted and ZTP is retried because of an unsuccessful ZTP completion. The default ZTP timeout is 30 minutes.

See Configuring the ZTP timeout in the provisioning file for information about how to configure the ZTP timeout in a ZTP provisioning file.

The **auto-boot** options can be modified using the **bof auto-boot** command, or by interrupting the bootup process and manually modifying the `bof.cfg` file.

Caution: Manually modifying the `bof.cfg` file is not recommended. When modifying **auto-boot** options using CLI, all required options must be explicitly configured because the default cases are no longer used. When modifying the `bof.cfg` file manually, the format must be correct.

9.4.3.2 CLI access

The auto-boot process is executed in the background and does not block the CLI. The user can enter CLI commands while the auto-boot process runs in the background. A warning message is displayed to notify the user that the auto-boot process is being executed. Any configurations performed using the CLI may be lost when the node reboots following successful auto-boot and auto-provisioning processes. After the node has finished booting and if the **auto-boot** flag is set in the BOF, the node displays the login prompt.

The user can access the CLI using a console and can change and save the BOF configuration; as such, the user can remove or modify the **auto-boot** option in the BOF.

9.4.3.3 Interrupting auto-boot

The auto-boot process can be interrupted using the **tools perform auto-boot terminate** command. After the auto-boot process is terminated, use the **bof auto-boot** command to modify the **auto-boot** flag.

Note: The **auto-boot** flag can also be modified without interrupting the auto-boot process.

9.4.4 Auto-provisioning process

In this process, the node detects operational ports, attempts to discover its IP address, and downloads the relevant files for provisioning.

1. The node sends a DHCP discovery request to the DHCP server using the out-of-band management port. If DHCP discovery is unsuccessful, the node reattempts it using the in-band management ports.
2. After DHCP discovery is successful, the DHCP server returns an IPv4 or IPv6 FTP or HTTP URL of a file server from which the node can retrieve provisioning information.
3. The node downloads the provisioning information and performs the auto-provisioning according to the specifications in the files.
4. After the node is successfully provisioned, it automatically reboots and becomes operationally up.

See Provisioning files for more information about the auto-provisioning process.

The SR OS can also initiate the auto-provisioning process using a **tools** command.

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9.4.4.1 VLAN discovery

Note: VLAN discovery is not supported on the 7705 SAR Gen 2. The information is included in this chapter for reference only.

The node can perform VLAN discovery if it is shipped in ZTP mode. VLAN discovery is supported only for the in-band management port. It is not supported for the out-of-band management ports.

After the node is installed and powered up:

1. ZTP is attempted on the null (untagged) port first, including the out-of-band management port, and then on all in-band management ports with operational links.
   a. SR OS scans each port with an operational link and sends IPv4 DHCP discovery messages.
   b. SR OS waits for the DHCP offer within the DHCP timeout.
2. The first VLAN with a valid offer that includes the IPv4 DHCP Options 66 and 67, or Option 67 or 43, or IPv6 DHCP Option 59 or 17 is selected as the working VLAN and the ZTP process is executed on this VLAN.

   Note: If there is no offer or the offer does not have the relevant or correct options, SR OS floods the network with DHCP discovery messages on all remaining non-reserved VLANs (1 to 4094).

3. When a VLAN is discovered, the ZTP process is executed on the respective VLAN as described in the following sections.

   Note: If there is no offer on any VLAN or the offer does not have the relevant or correct options, the node starts over from step 1.

9.4.4.1.1 VLAN discovery option

By default, the auto-boot flag in the `bof.cfg` file has the VLAN discovery option enabled. The option can be disabled manually in the `bof.cfg` file or implicitly from the CLI BOF menu, using the command **bof auto-boot inband**. When the VLAN discovery option is disabled, the node executes the ZTP process using the untagged method only.

9.4.4.2 Auto-provisioning procedure

After the node enters ZTP mode, the auto-discovery process is executed to provision the necessary hardware for node discovery.

The following are the operational steps of the auto-discovery process.

1. DHCP is used to discover the IP address of the node.
2. Options 66 and 67, or Option 43 is used to find and download the provisioning file.

   The provisioning file includes the location of necessary files, such as configuration information, system image, and licenses, along with the DNS needed to resolve these location URLs. The file also includes BOF information required to boot the node into operational mode.

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3. The provisioning file is executed to download the named files to the node.
4. After all files are successfully downloaded, the node is rebooted and the **auto-boot** flag is cleared from the BOF.

After the node reboots, it comes up in normal operational mode.

The node can be put back into ZTP mode by editing the BOF to include the **auto-boot** flag and saving the BOF. Doing this causes the node to enter ZTP mode after it is rebooted.

Use one of the following methods to run the auto-provisioning process.

- **automatic execution**

  The auto-boot process automatically executes the auto-provisioning process if the **auto-boot** flag is set in the BOF.

- **manual execution**

  The auto-provisioning process can be executed manually using the following command.

  ```
  tools perform system auto-node-provisioning
  ```

  If the auto-provisioning process is executed manually, only interfaces without IP addresses are considered part of the discovery mechanism. Additionally, while the process is running, it attempts to discover DHCP servers using all card or MDA slots and ports with Layer 3 interfaces that do not have IP addresses.

Note: Using the following command while the auto-boot process is running is not allowed.

```
tools perform system auto-node-provisioning
```

9.4.4.3 Out-of-band management versus in-band management

The auto-provisioning process can use the out-of-band management port (Mgmt port), or in-band management on Ethernet ports.

The node attempts the auto-provisioning process using any port with an operational link, starting with the out-of-band management port. If the node cannot be discovered using the out-of-band management port, either because the port is down or the port is not receiving a DHCP offer from the DHCP server, the process is reattempted using Ethernet ports. If the node cannot be discovered using the Ethernet ports, the process is reattempted using the out-of-band management port and the cycle repeats.

The following operational guidelines apply to in-band and out-of-band management ports:

- Out-of-band management and in-band management support untagged frames.
- Out-of-band management does not support dot1q (VLAN tags).
- In-band management supports dot1q interfaces if the VLAN is correctly configured in the BOF.
- In-band ports support VLAN discovery for IPv4 by default, if not disabled in the BOF.

If out-of-band management is used, no card or MDA provisioning is necessary and the auto-provisioning process executes as soon as an active link is detected on the Mgmt port.

To use out-of-band management exclusively, use the following command:

```
bof auto-boot management-port
```


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To use in-band management exclusively, use the following command:

```
bof auto-boot inband vlan
```

9.4.4.3.1 Supported in-band management ports

See ZTP overview for information about which ports support in-band management for ZTP.

9.4.5 Provisioning files

Provisioning files are created by the operator based on requirements and the locations of the necessary files. A provisioning file contains the locations and URLs of critical files such as the system image, configuration files, and necessary licenses, and can also contain DNS server information used to resolve these locations.

A provisioning file consists of two main parts:

- **locations of files**

  Contains locations of the following file types:

  – system image

  – configuration files

  – licenses

  These items can be downloaded using HTTP, HTTPS, or FTP; DNS server information can also be included.

  Note: If classic configuration mode is required when booting with ZTP, configuration files must have **exit all** as the first executable line.

- **BOF information**

  Contains BOF information to be loaded on the node after the ZTP processes are completed; the BOF section of the file must be formatted correctly.

  Caution: Ensure that the **auto-boot** flag is not set on the BOF that will be downloaded by the auto-provisioning process; failure to do so will cause the node to go back into ZTP mode after it reboots.

  The provisioning file can be executed using the following command to re-download the named files:

```
tools perform system auto-node-provisioning file
```

9.4.5.1 Provisioning file download

The provisioning file location is discovered using DHCP offer Options 66 and 67 or Option 43, and is downloaded using HTTP or FTP.

The provisioning file URL can be resolved using DNS, in which case the IP addresses for up to three DNS servers should be present in the DHCP offer using Option 6 (IPv4) or Option 23 (IPv6). The DHCP DNS is

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only used for resolving the provisioning file URL, and not for resolving the URLs of the files named within the provisioning file.

ZTP does not support Option 15 domain names; the URL of the provisioning file should be in "*host*/*domain*" format, or a simple IP address should be used.

9.4.5.2 Provisioning file resolution using DNS

If the downloaded provisioning file includes a DNS IP in the DNS section of the file, the URLs of the files in the provisioning file must be resolved using this DNS server or the DNS server listed in the DHCP offer.

Up to three DNS addresses (primary, secondary, tertiary) can be listed in the DNS sections of the provisioning file. If all three DNS addresses are listed, they are attempted in the listing order to resolve the file URLs.

9.4.5.3 File download and redundancy

Up to three locations can be set for each file type, using the primary-url, secondary-url, and tertiary-url fields. The auto-provisioning process attempts to download all files using the primary-url information for each file. If this attempt is unsuccessful, the process reattempts using the secondary-url information for each file. If this attempt is not successful, the process reattempts using the tertiary-url information.

A ZTP operation is considered successful when all files named in the provisioning file are downloaded. If all file locations are attempted and all named files are not successfully downloaded, the auto-provisioning process fails and ZTP reattempts the provisioning process using the next valid interface.

9.4.5.4 Configuring the ZTP timeout in the provisioning file

The ZTP timeout is the total time allowed for the ZTP process to execute successfully. If the ZTP process fails to run successfully within the ZTP timeout duration, the node is rebooted and the ZTP process is retried. The default timeout is 30 minutes.

See Options and option modification for information about how to configure the ZTP timeout using CLI commands.

ZTP timeout information can be included in the provisioning file to configure a value different from the default. For a provisioning file example, see Example provisioning file.

Example

The following example shows how the timeout is added to the provisioning file to change the default value.

```
set {
  timeout hours 1
  timeout minutes 30
}
```

9.4.5.5 Downloading the image file

The image file can be downloaded in the following ways:

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- Extract the images from the OLCS CFLASH file and explicitly list them in the provisioning file. Each of the .tim files is validated and the version of the software is checked. The hash-value must be explicitly listed.

```
download {
  image "$(BOOT-PATH)/both.tim" {
    primary-url "$(FILESERVER)/both.tim"
      verification {
          hash-algorithm sha256
          hash-value "53473e2727caf55f3a38fa466622af2147762e26a8587e9248240a572cdee849"
      }

  }
  ……..
}
```

- Zip the image files and perform a single image download. ZTP can extract the images and verify the .tim file and software version. An additional file can also be listed for all files to be verified using sha256 or md5.

```
download {
  image "$(BOOT-PATH)/images.zip" {
      primary-url "$(FILESERVER)/images.zip"
      unzip
      verification {
          hash-algorithm sha256
          hash-value "53473e2727caf55f3a38fa466622af2147762e26a8587e9248240a572cdee849"
      }
  }
  # SHA-256 Checksum Files - File of a list of SHAR256 checksum values and file names (must
 be absolute)
  sha256 "$(BOOT-PATH)/somefile.txt" {
      primary-url "$(FILESERVER)/sha256-checksums.txt"
      verification {
          hash-algorithm sha256
          hash-value "53473e2727caf55f3a38fa466622af2147762e26a8587e9248240a572cdee849"
      }
  }
}
```

9.4.5.6 Example provisioning file

This section provides examples of provisioning file information.

Example: Provisioning file information

```
set {
  hours 1
  minutes 30
}
dns {
      primary 192.0.2.1
      secondary 192.0.2.2
      tertiary 192.0.2.3
      domain sample.domain.com
}
download {
  image "cf3:/both.tim" {
    primary-url "http://192.168.40.140:81/both.tim"
```


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```
    secondary-url "http://192.168.40.140:81/both.tim"
    tertiary-url "http://192.168.40.140:81/both.tim"
  }
  image "cf3:/support.tim" {
    primary-url "http://192.168.40.140:81/support.tim"
    secondary-url "http://192.168.40.140:81/support.tim"
    tertiary-url "http://192.168.40.140:81/support.tim"
  }
  config "cf3:/config.cfg" {
    primary-url "ftp://ftpserv:name@192.168.194.50/./images/dut-a.cfg"
    secondary-url "http://192.168.41.140:81/dut-a.cfg"
    tertiary-url "http://192.168.42.140:81/dut-a.cfg"
  }
  file "cf3:/license.txt" {
    primary-url "ftp://ftpserv:name@192.168.194.50/./images/provision_example.cfg"
    secondary-url "http://192.168.41.140:81/dut-a.cfg"
    tertiary-url "http://192.168.42.140:81/dut-a.cfg"
  }
}
bof {
  primary-image cf3:/both.tim
  primary-config cf3:/config.tim
  address 192.168.100.1 active
  autonegotiate
  duplex full
  speed 100
  wait 3
  persist off
  console-speed 115200
}
```

For an HTTPS URL, the trust anchor needs to be referenced in the provisioning file. The trust anchor name references the entry in the `import trust-anchor` section of the file.

In the following example, the trust anchor name is TRUST_ANCHOR.

Example: Trust anchor for HTTPS URL in provisioning file

```
import {
    client {
        cert "cf3:/client.crt" {
            format pem
            primary-url http://10.10.10.67:81/client.crt
        }
        key "cf3:/client.key" {
            format pem
            primary-url http://10.10.10.67:81/client.key
        }
    }
    trust-anchor TRUST_ANCHOR{
        cert "cf3:/ca.crt" {
            format pem
            primary-url ftp://user-name:password@10.10.10.66//user-name/logs/
fileserver-4/ca.crt
        }
        crl "cf3:/ca.crl" {
            format der
            primary-url ftp://user-name:password@10.10.10.66//user-name/logs/
fileserver-4/ca.crl
        }
    }
}
<snip>
```


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```
    download {
      config "cf3:/ztp/ztp_dut-a.cfg" {
        primary-url "https://10.10.10.64:81/ztp_node-2.cfg"
        primary-trust-anchor "TRUST_ANCHOR"
  }
```

9.4.5.7 Proxy support

HTTP and HTTPS can connect to public servers using a proxy. The proxy is in URL format and the URL must be resolved using the provisioning file DNS.

The proxy can include a username and password. Proxy Auto-Configuration (PAC) is not supported.

Proxy information formatting is as follows:

http://*user@hostname*:*file-path*

https://*user@hostname*:*file-path*

proxy http://*ip-or-url user@hostname*:*port*

The HTTP (or HTTPS) proxy support information is included in **file** commands and in the ZTP provisioning file. The following example shows HTTP proxy information in the provisioning file.

Example

```
image "cf3:/both.tim" {
    primary-url "http://200.150.40.140:81/both.tim"
    secondary-url "http://200.150.40.140:81/both.tim"
    tertiary-url "http://200.150.40.140:81/both.tim"
    primary-proxy http://132.2.3.1:8080
    secondary-proxy http://133.3.4.1:8080
  }
```

9.4.6 Day 0 configuration

To improve initial router functionality and reuse information discovered by ZTP in the configuration file, the user can include an optional day 0 configuration template within the provisioning file. This day 0 configuration template can obtain configuration details for specific modules that can be used to provision the node and establish node connectivity. Predefined symbols are used to add parameters discovered by ZTP, such as the port and VLAN, to the configuration template.

Any supported configuration can be included in the day 0 configuration template, including configuration of port types and services. However, Nokia recommends that day 0 configuration details should be kept to the minimum necessary to ensure that basic network connectivity is available for the ZTP process to run and complete.

Caution: Before using the configuration, verify the configuration details in the day 0 template and check for syntax, context, and other errors. The ZTP process does not verify the configuration details before implementing them.

When the provisioning file is received through the ZTP process, the day 0 configuration template section of the provisioning file is converted to a configuration file, as specified by the **`Write`** `cf3:/`*`configuration-file-name`*`.cfg` entry within the template. The BOF section of the provisioning file

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must specify the configuration file generated from the day 0 configuration template using the `primary-config cf3:/configuration-file-name.cfg` entry.

Some unknown elements within the day 0 configuration template can be entered as symbols, which are then converted to discovered information as the node is provisioned; see Day 0 symbols.

See Sample day 0 configuration template for a configuration example, including the day 0 configuration template and associated BOF section of the provisioning file.

9.4.6.1 Day 0 configuration for multi-slot routers

On multi-slot routers, the discovered IOMs, MDAs, IMMs, and fabric (that is, the discovered hardware) are part of the day 0 configuration. ZTP automatically adds the CLI configuration to the correct location in the day 0 configuration in the provisioning file.

This process ensures that the nodes for different sites are populated with the correct hardware, regardless of what physical hardware is used for a specific site.

The day 0 configuration process for multi-slot routers is as follows:

1. The provider creates a day 0 configuration template with the required services and interfaces.
2. ZTP provisions the IOMs, MDAs, IMMs, and fabric.
3. ZTP discovers the port and VLAN on which the DHCP server is connected.
4. ZTP adds the discovered and provisioned hardware to the day 0 configuration in the provisioning file
5. ZTP uses the day 0 configuration in provisioning file to create an initial configuration file and saves it to the specified location on the node.

   The BOF section of the provisioning file must specify the configuration file generated from the day 0 configuration.
6. After rebooting, the node boots up using the day 0 configuration file.

9.4.6.2 Day 0 symbols

Use symbols to generalize and reuse a single provisioning file across multiple ZTP deployments and for value substitutions and conditions in the day 0 configuration template of the provisioning files. The same symbol can appear as many times as required and can be used for both conditional statements and substitutions.

9.4.6.2.1 Symbol use for substitution

A day 0 configuration template can include symbols that are replaced with discovered information when the day 0 configuration is implemented. Symbols for substitution must be entered using the format `$(<symbol-name>)`. The following example shows a supported use case of a symbol for substitution.

Example

```
card $(ztp.bootstrap.slot)
    card-type $(ztp.bootstrap.card-type)
        mda $(ztp.bootstrap.mda)
            mda-type $(ztp.bootstrap.mda-type)
    exit
```


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```
exit
```

9.4.6.2.2 Symbol use for conditions

A day 0 configuration template can include symbols that are replaced with discovered information when the day 0 configuration is implemented. Symbols for conditions must be entered using the format @(<*symbol-name*>) at the beginning of a line. If the condition is not met (that is, the symbol does not exist), the rest of the line is skipped and not written into the day 0 configuration file on the compact flash. The following example shows a supported use case of a symbol for conditions.

Example

```
@(ztp.uplink.connector)    port (ztp.uplink.connector)
@(ztp.uplink.connector)    connector
@(ztp.uplink.connector)    breakout $(ztp.uplink.breakout)
@(ztp.uplink.connector)    exit
@(ztp.uplink.connector)    exit
```

9.4.6.2.3 Supported symbols

The following table describes the supported symbols for a day 0 configuration template.

Table 30: Supported symbols

Symbol name	Description	Example value	Conditional	Discovered
sys.platform	Platform name	"7705"	No. Always available.	Configured for the system and is exposed at system boot-up
sys.type	Chassis type	"SAR-1"	No. Always available.	Configured for the system and is exposed at system bootup
sys.serial-number	Serial number of the chassis	“NS1234567”	No. Always available.	Configured for the system and is exposed at system bootup
sys.mac-address	Base chassis MAC of chassis	“01:01:01:01:01:01”	No. Always available.	Configured for the system and is exposed at system bootup
ztp.bootstrap.uplink	Full uplink used for bootstrap (including VLAN). Intended to be used as interface port binding	“1/1/1” “1/1/1:1000” “A/1”	No. Always available.	Discovered at VLAN discover or ZTP discovery time

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Symbol name	Description	Example value	Conditional	Discovered
	in the day 0 configuration.			
ztp.bootstrap.uplink.card-type	Card-type of uplink slot used for bootstrap	“xcm-1s”	Yes. Available when uplink is inband.	Discovered at VLAN discover or ZTP discovery time
ztp.bootstrap.uplink.slot	Slot of uplink used for bootstrap	“1”	Yes. Available when uplink is inband.	Discovered at VLAN discover or ZTP discovery time
ztp.uplink.xiom	Xiom identifier of uplink used for bootstrap	“x1”	Yes. Available when uplink is inband and has an xiom.	Discovered at VLAN discover or ZTP discovery time
ztp.uplink.xiom-type	Xiom-type of xiom used for bootstrap	lom2-se-6.0t”	Yes. Available when uplink is inband and has an xiom.	Discovered at VLAN discover or ZTP discovery time
ztp.uplink.mda	The MDA number of the MDA used for bootstrap (This will either be the MDA under card or MDA under xiom if uplink has xiom)	“1”	Yes. Available when uplink is inband.	Discovered at VLAN discover or ZTP discovery time
ztp.uplink.mda-type	The MDA number of the MDA used for bootstrap (This will either be the MDA under card or MDA under xiom if uplink has xiom)	“m4-sfp”	Yes. Available when uplink is inband.	Discovered at VLAN discover or ZTP discovery time
ztp.bootstrap.uplink.port	Uplink port without encapsulation value (VLAN)	1/2/c1/1	No. Always available.	Discovered at VLAN discover or ZTP discovery time
ztp.bootstrap.uplink.vlan	Uplink VLAN (encapsulation value)	“1000”	Yes. Available when uplink has a vlan.	Discovered at VLAN discover or ZTP discovery time
ztp.bootstrap.connector	Uplink connector ID	1/1/c1	Yes. Available when uplink is a connector-port.	Discovered at VLAN discover or ZTP discovery time

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Symbol name	Description	Example value	Conditional	Discovered
ztp.bootstrap.breakout	Connector breakout type	c1-10g	Yes. Available when uplink is a connector port.	Discovered at VLAN discover or ZTP discovery time
ztp.bootstrap.rs-fec	Connector RS-FEC mode setting		Yes. If connector has a non-default rs-fec mode setting.	Discovered at VLAN discover or ZTP discovery time
ztp.bootstrap.uplink.rs-fec	Uplink port RS-FEC mode setting		Yes. If uplink port has a non-default rs-fec mode setting.	Discovered at VLAN discover or ZTP discovery time
ztp.bootstrap.uplink.speed	Uplink port speed setting		Yes. If uplink port has a non-default speed setting	Discovered at VLAN discover or ZTP discovery time
Ztp.bootstrap.ip	IP address used during bootstrap (IPv4 or IPv6)	1.2.3.4 1::344:2	No. Always available.	Discovered via DHCP offer
Ztp.bootstrap.prefixlen	The prefix length of the IP address used under interface during bootstrap		No. Always available.	Discovered via DHCP offer

9.4.6.3 Sample day 0 configuration template

The following is a sample of a day 0 configuration template included in a provisioning file.

Example

```
# Generate Day-0 Configuration
# ----------------------------
Write "cf3:/config-template.cfg" {
########################
# !!DAY0 CONFIG START!! #
########################
exit all
configure
#--------------------------------------------------
echo "System Configuration"
#--------------------------------------------------
    system
        name "chassis-name"
        snmp
        exit
        login-control
```


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```
            idle-timeout disable
        exit
        time
            ntp
                server 192.168.194.202
                no shutdown
            exit
        exit
        thresholds
            rmon
            exit
        exit
    exit
#------------------------------------------------
echo "System Security Configuration"
#------------------------------------------------
    system
        security
            telnet-server
            ftp-server
            snmp
                community "private" rwa version both
                community "public" r version both
            exit
        exit
    exit
#------------------------------------------------
echo "Log Configuration"
#------------------------------------------------
    log
        snmp-trap-group 90
            trap-target “”
        exit
        log-id 90
            from main change
            to snmp
        exit
    exit
exit all
configure
    router
#------------------------------------------------
echo "IP Configuration"
#------------------------------------------------
        interface "IF-1/1/c1/1"
            port $(ztp.bootstrap.uplink)
            address 192.168.0.1/31
            ipv6
            exit
            no shutdown
        exit
    exit
exit all
########################
# !!DAY0 CONFIG END!!   #
########################
}
# Generate New BOF File
# --------------------
bof {
  primary-image  cf3:/image.both
  primary-config cf3:/config-template.cfg
  autonegotiate
  duplex full
```


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```
  speed 100
  wait 3
  persist off
  console-speed 115200
}
```

9.4.7 Logs and events

ZTP displays detailed events about all stages of the auto-boot and auto-provisioning processes. All events are saved in a log file on the node at the end of the ZTP process.

9.5 Legacy SZTP (non RFC 8572-compliant)

The SR OS implementation of SZTP is a partial application of RFC 8572 and is evolving to meet all RFC 8572 aspects. SZTP is an extension of ZTP as follows:

- The provisioning file and the node discovery of the MDAs, IOMs, and ports with links up are supported in both ZTP and SZTP.
- The ports that are ZTP-capable are also SZTP-capable.

SZTP securely bootstraps the node and provides it with the information required to boot up the node in an operational mode; this information includes all the initial artifacts required to create a mutual trust relationship between the node and the bootstrap server. After the node boots, it discovers the bootstrap server IP address, communicates with the server, and authenticates both the server and itself. Finally, the node securely downloads the encrypted boot image and initial configuration information.

SR OS uses different bootstrapping methods to obtain the required TLS certificates, trust anchors, and redirect information to connect securely to the server and download all the necessary information to boot in an operational mode.

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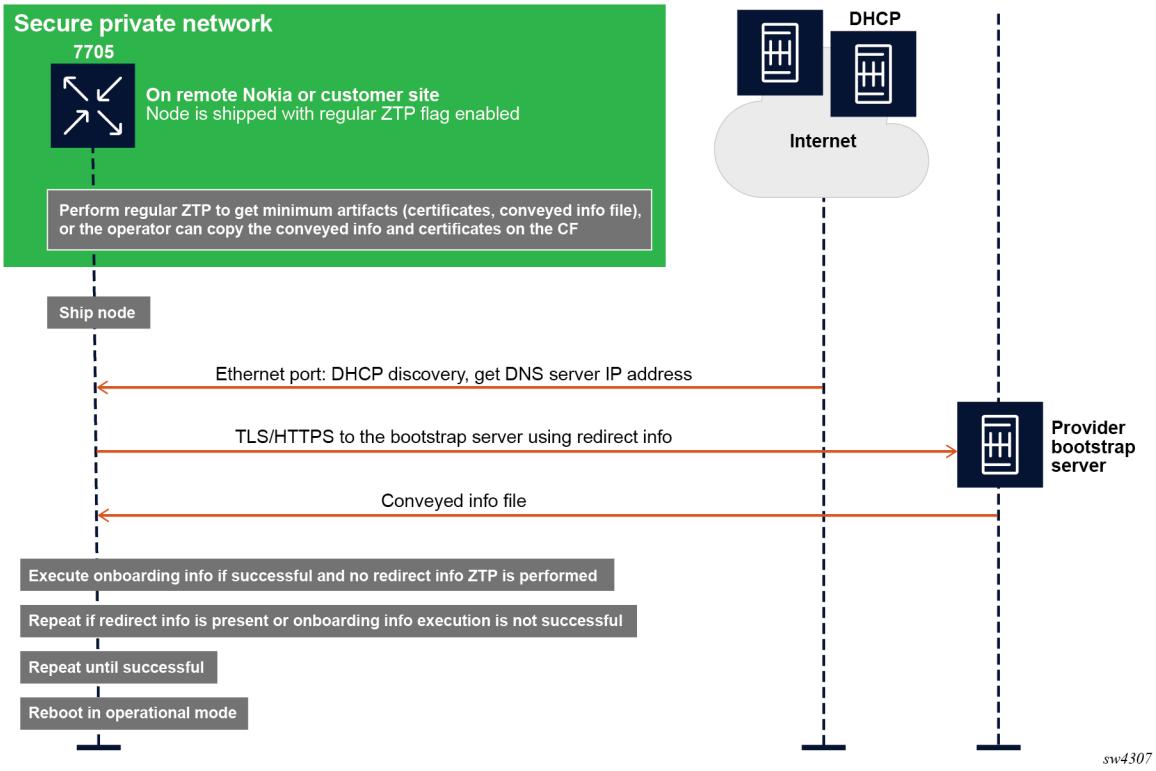
Figure 28: SZTP process



In the example shown in the preceding figure, one of the following methods can be used to bootstrap the node securely:

- The operator stages the node at their own site and bootstraps it using ZTP through a secure or private network. The node obtains the TLS certificates, trust anchors, and keys from a conveyed information file, which must be copied into the compact flash (CF). The Uniform Resource Identifier (URI) of this file is included in the ZTP provisioning file.
- If the node has CF, the operator copies manually to the CF the certificates, trust anchors, and conveyed information file. Optionally, the operator can also include redirect information in the conveyed information file.

After the node is bootstrapped securely, it is shipped to the installation site, where it boots.

If the node has redirect information, it tries to connect the bootstrap server specified in the redirect information and establish a TLS session to create mutual trust between the node and the server.

If the node does not have redirect information, it performs a DHCP discovery and tries to obtain the redirect information using DHCP option 143 (IPv4) or 136 (IPv6). After obtaining the redirect information, the node tries to connect to the bootstrap server using TLS.

The node uses option 67 from the DHCP server or the URI from the file field of the redirect information to locate the conveyed information from the bootstrap server. The conveyed information provides the node with one of the following:

- more redirect information for a new file server and other required resources to connect to the file server to download all the required information and files

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- onboarding information containing the URI of the boot image and the initial configuration
- both redirect information and onboarding information, in which case the node executes the onboarding information first and then executes the redirect information

9.5.1 Staging the secure environment

The following artifacts are required:

- node client certificates and keys
- bootstrap server certificates for the first redirect
- security artifacts file, which contains the trust anchor definitions and import instructions. Optionally, this file can also contain conveyed information, which consists of redirect, if applicable, and onboarding information.

The staging options are the following:

- Copy the artifacts to a CF that can be installed in `cf1:`, `cf2:`, or `cf3:` when the node is at the installation site.
- Alternatively, use ZTP to pre-stage the node and download the root security artifacts using a trusted DHCP server and provisioning file.

Note: Nokia recommends that the TLS client should have a certificate so that it is authenticated by the ZTP server. Although the client certification can be omitted for TLS configuration, this is not recommended.

9.5.2 Bootstrapping methods

The following bootstrapping methods are supported:

- Use DHCP option 143 (IPv4) or 136 (IPv6), as described in RFC 8572. Optionally, the operator can obtain the specific node URI (server and directory) by providing the DHCP server option 61 for the DHCP server, which in turn provides option 67 for the file directory, or option 143 (IPv4) or 136 (IPv6) with the server IP and file directory information. In this case, the TLS certificates, trust anchors, and keys must be installed on the node at the operator premises.
- Copy the following information to the CF:
  - redirect information for the bootstrap server
  - TLS certificates and trust anchors, and private keys
  - onboarding information
- Use ZTP to provide the following information to the node:
  - redirect information for the bootstrap server
  - TLS certificates and trust anchors, and private keys
  - onboarding information
- Redirect the node from the first bootstrap server to consecutive bootstrap servers. The bootstrap server can provide the node with additional redirect information in a secure encrypted manner. The redirect and onboarding information are provided in the conveyed information file.
  - redirect information to another bootstrap server

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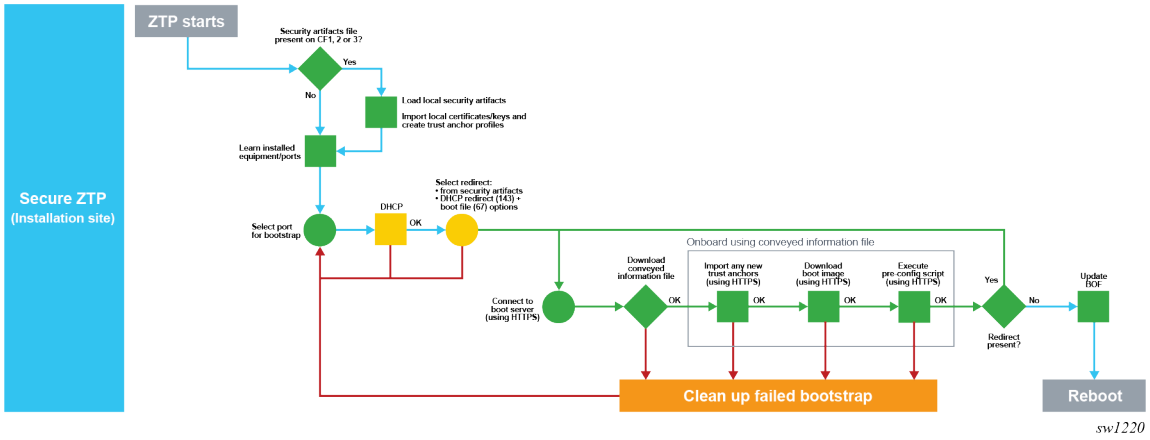
– required TLS certificates and trust anchors, and private keys
– onboarding information

9.5.3 Installation site process

At the installation site, the **auto-boot** flag in the BOF signals the ZTP process. The presence of a conveyed information file on the node signals to the node that it is a secure ZTP procedure.

The following figure shows the SZTP process at the installation site.

Figure 29: Installation site SZTP process



After staging, the port that has the link up is selected and SZTP is executed on it.

The node loads the security artifacts to install the TLS certificates and trust anchors. DHCP discovery messages are sent out on each port in sequence. If no DHCP offer is received, SZTP moves to the next port with the link up. The OOB port is examined first, followed by the untagged in-band ports. If no DHCP offer is received, VLAN discovery is performed on the in-band ports only by flooding VLAN 0 to 4196 with DHCP discovery.

After DHCP discovery completes, the node obtains an IP address and can optionally obtain option 143 (IPv4) or option 136 (IPv6) for redirect information. If the redirect information is present in the conveyed information file, it is preferred over the DHCP redirect information.

The node is connected to the bootstrap server as indicated by the redirect information and a TLS mutual authentication is established using the certificates. The bootstrap server must have the correct certificates, keys, and trust anchors to create the mutual TLS trust.

After the node authenticates the server and authenticates itself to the server, it downloads the conveyed information file from the server using HTTPS. The node obtains the server location of the conveyed information from DHCP option 67 or the file field in the redirect information.

If the conveyed information file contains redirect information, the node tries to connect to the new bootstrap server indicated in the new redirect information. The node can download the new certificates indicated in the conveyed information.

If the conveyed information file contains only onboarding information, the node downloads the onboarding file.

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If the conveyed information file contains both onboarding and redirect information to the next bootstrap server, the node executes the onboarding information first, then the redirect information.

The process is successful if the node executes the onboarding information without errors.

9.5.3.1 Initial conveyed information file

The conveyed information file (also referred to as `conveyed-info.ztp` file) contains the certificates, keys, and trust anchors required to establish the TLS connection. This is the minimum information that the node requires to start SZTP after staging at the installation site. The initial file must be added to `cf3:` by copying it on the CF manually or using regular ZTP procedures and the provisioning file.

Example: Contents of a conveyed information file

```
import {
   client {
      cert "cf3:/artifacts/node.cert"
      key "cf3:/artifacts/node.key" {
         format der
      }
   }
   trust-anchor BOOTSERVER {
      cert "cf3:/artifacts/bootserver.cert"
   }
}
```

The certificates, keys, and trust anchor information can be encrypted using the **encrypt** command, as shown in the following example. When the **encrypt** keyword is present, the information is downloaded from the URI and encrypted using AES256.

Example: Using the encrypt command

```
import {
   client {
      encrypt
      cert "cf3:/artifacts/node.cert"
      key "cf3:/artifacts/node.key" {
         format der
      }
   }
   trust-anchor BOOTSERVER {
      encrypt
      cert "cf3:/artifacts/bootserver.cert"
   }
}
```

Optionally, the file can contain the redirect information as shown in the following example. It is not mandatory to include the redirect information in the file because the preliminary redirect information can be obtained using DHCP.

Note: The redirect information in the file is preferred over the DHCP redirect information because it is trusted.

Example: Redirect information in the file

```
import {
   client {
```


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```
      encrypt
      cert "cf3:/artifacts/node.cert"
      key "cf3:/artifacts/node.key" {
         format der
      }
   }
   trust-anchor BOOTSERVER {
      encrypt
      cert "cf3:/artifacts/bootserver.cert"
   }
}

redirect-information {
   boot-server "https://mybootserver.com/" {
      port 50
      trust-anchor BOOTSERVER
      file "conveyed.info"
   }
   boot-server "https://backupserver.com/" {
      port 50
      trust-anchor BOOTSERVER
      file "conveyed.info"
   }
}
```

The following example shows a file containing the entire conveyed information, including redirect and onboarding information. See Onboarding information.

Example: File with entire conveyed information

```
import {
   client {
      encrypt
      cert "cf3:/artifacts/node.cert"
      key "cf3:/artifacts/node.key" {
         format der
      }
   }
   trust-anchor BOOTSERVER {
      encrypt
      cert "cf3:/artifacts/bootserver.cert"
   }
}

redirect-information {
   boot-server "https://mybootserver.com/" {
      port 50
      trust-anchor BOOTSERVER
      file "conveyed.info"
   }
   boot-server "https://backupserver.com/" {
      port 50
      trust-anchor BOOTSERVER
      file "conveyed.info"
   }
}
onboarding-information {
   boot-image
      download-uri https://images.com/$(sys.platform).zip
   pre-configuration-script "https://config.com/provisioning.cfg"
}
```


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9.5.3.2 Onboarding information

The onboarding information is required to obtain all critical resources to boot the node in the normal mode of operation with the latest boot image and configuration. When processing the onboarding information, the device must first process the boot image information (if any), then execute the preconfiguration script (if any).

The onboarding information is present in the conveyed information file only. See Conveyed information.

Example: Onboarding information

```
onboarding-information {
   boot-image
      download-uri https://images.com/$(sys.platform).zip
   pre-configuration-script "https://config.com/provisioning.cfg"
}
```

The download-uri is the URI to the boot image in ZIP format only. A URI list can exist, each pointing to the primary, secondary, or tertiary `images.zip` file. SR OS has multiple images, for example, CPM image and IOM image, and these images can be downloaded in a ZIP file. The URI can point to the ZIP file bundle to download all the images from a primary source. If the image is downloaded using download-uri, the destination of the image is always `cf3:`.

Example: Using download-uri information

```
onboarding-information {
   boot-image {
      # Download-URI(Mandatory): URL to ZIP file of images. Up to 3 for primary,
 secondary, tertiary
      # -> Base directory is "cf3:/"
      download-uri "https://server.download.com/images.zip"
      download-uri "https://server2.download.com/images.zip"
      download-uri "https://server3.download.com/images.zip"
      # VERIFICATION (Optional): File within ZIP file to verify images
      image-verification {
         hash-algorithm sha256
         hash-value "53473e2727caf55f3a38fa466622af2147762e26a8587e9248240a572cdee849"
      }
   }

   # Another provisioning file that can be loaded. Downloaded as "cf3:/autoboot.cfg.1,2,3"
 based on chaining
   pre-configuration-script "https://server.file.com/someotherprovisioningfile.txt"
}
```

Optionally, the node can run a checksum on the downloaded ZIP file using a hash to ensure there are no download errors. The hash algorithm and the hash value are noted in the onboarding information, as shown in the previous onboarding information example. The supported hash algorithms are SHA256 and MD5.

The preconfiguration script can be used to download the provisioning file. The provisioning file and the ZTP provisioning file have the same format. The provisioning file has to be executed to completion for the ZTP process to be successful. The provisioning file can also contain the location of the image. The image can be downloaded using the download URI or the provisioning file. When downloading the image using the provisioning file, the destination of the image can be dictated. The BOF must be configured accordingly to boot from the image destination. The image destination must always be `cf3:` or a folder in `cf3:`.

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Note: The preconfiguration script is always required to clear the **auto-boot** flag from the BOF. A minimal BOF configuration is required in the provisioning file.

9.5.3.2.1 Preconfiguration script

The preconfiguration script is the actual ZTP provisioning file. SZTP supports all features of the ZTP provisioning file.

The preconfiguration script and provisioning file must be executed by the onboarding information to update the BOF configuration and remove the **auto-boot** flag. This ensures that the node comes back up in a normal mode of operation. For examples of the preconfiguration script and provisioning file information included in the onboarding information, see Onboarding information.

9.5.3.2.2 Additional capabilities in the ZTP provisioning file

The following optional capabilities of the provisioning file are supported for both ZTP and SZTP:

- **checksum for file download**
  SHA256 and MD5 are supported. The hash algorithm and hash value can be specifically configured for the file as shown in the following example. The file checksum is checked against the hash algorithm and hash value.

```
# List of Configuration Files to download
config "$(BOOT-PATH)/somefile.txt" {
    primary-url "$(FILESERVER)/somefile.txt"
        verification {
            hash-algorithm sha256
                hash-value
"53473e2727caf55f3a38fa466622af2147762e26a8587e9248240a572cdee849"
        }
}
```

- **file encryption using AES256**
  When a file is downloaded and if the file has the **encrypt** keyword enabled in the provisioning file, the file is encrypted using AES256 and placed on the CF. This is useful when downloading certificates, keys, and trust anchors for TLS. The following example shows an excerpt from the provisioning file. In this example, in the certificate import the keyword **encrypt** is used to encrypt each file on the CF after the file was downloaded. In addition, the checksum is calculated on each file and checked to ensure the files are downloaded without errors.

```
import {
    client {
        cert "$(CERT-PATH)/device.crt" {
            primary-url "$(FILESERVER)/device.crt"
                encrypt
                    verification {
                        hash-algorithm sha256
                            hash-value
"53473e2727caf55f3a38fa466622af2147762e26a8587e9248240a572cdee849"
                                }
           }
           key "$(CERT-PATH)/device.key" {
              format pem
              primary-url "$(FILESERVER)/device.key"
                       encrypt
                       verification {
```


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```
                          hash-algorithm sha256
                                 hash-value
"53473e2727caf55f3a38fa466622af2147762e26a8587e9248240a572cdee849"
                        }
    }
}
trust-anchor "NokiaSvcs" {
    cert "$(CERT-PATH)/owner-ca.crt" {
        format pem
        primary-url "$(FILESERVER)/owner-ca.crt"
                 encrypt
                  verification {
                      hash-algorithm sha256
                             hash-value
"53473e2727caf55f3a38fa466622af2147762e26a8587e9248240a572cdee849"
                  }
    }
    crl "$(CERT-PATH)/owner-ca.crl"
    format der
    primary-url "$(FILESERVER)/owner-ca.crl"
             encrypt
              verification {
                  hash-algorithm sha256
                      hash-value
"53473e2727caf55f3a38fa466622af2147762e26a8587e9248240a572cdee849"
              }
     }
    }
}
```

- **downloading the image files in ZIP file format**
  The files can be downloaded using the provisioning file with an optional checksum. The ZIP file is automatically unzipped and each individual file is placed on the CF. The checksum is checked across the entire ZIP file before it is unzipped.

  Note: The specified directory path must end with a forward slash (/).

```
image "$(BOOT-PATH)/images.zip" {
    primary-url "$(FILESERVER)/images.zip"
        unzip {
            directory "cf3:/ztp/"
        }
        verification {
            hash-algorithm sha256
                hash-value
"53473e2727caf55f3a38fa466622af2147762e26a8587e9248240a572cdee849"
        }
}
```

- **downloading a SHA256 or MD5 checksum file**
  The user can download a SHA256 or MD5 checksum file from Nokia servers for the ZIP image files. After the image file is unzipped, each `*.tim` file has its checksum checked against these checksum files.

  The following are examples of checksum files.

```
17717f13ecf19179e367d990277e943993d53d771b44d19fddf5d349b1e7e7c4 cf3:/ztp/cpm.tim
616656b2224e65e29d71355ea41d9dc548c281e9f729c97fe46f3a5c643acb09 cf3:/ztp/iom.tim
dd9455158dc2dfbf937eb372bbef73ebab97f951efa742eec16a4ed4edd3ca9b cf3:/ztp/support.tim
```


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Checksum or file decryption errors cause the failure of the ZTP or SZTP procedure, in which case the node generates an error and logs the event.

9.5.3.2.3 Certificate chaining

The following is an example of certificate chaining using a root and intermediate CA in the provisioning file.

Example: Certificate chaining

```
import {
    trust-anchor CMP_ROOT {
        cert "cf3:/root.crt" {
            format pem
            primary-url "http://ztp-server.com/pki/certificates/Classified_Plattform_Root_
CA-1.pem"
            secondary-url "http://ztp-server.com/pki/certificates/Classified_Plattform_
Root_CA-1.pem"
        }
    }
    trust-anchor CMP_ISSUING {
        cert "cf3:/issuing.crt" {
            format pem
            primary-url "http://ztp-server.com/pki/certificates/Classified_Plattform_
Issuing_CA_1.pem"
            secondary-url "http://ztp-server.com/pki/certificates/Classified_Plattform_
Issuing_CA_1.pem"
        }
        crl "cf3:/issuing.crl" {
            format der
            primary-url "http://ztp-server.com/pki/crls/Classified_Plattform_Issuing_CA_
1.crl"
            secondary-url "http://ztp-server.com/pki/crls/Classified_Plattform_Issuing_CA_
1.crl"
        }
    }
}

download {
    config "cf3:/config.cfg" {
        primary-url "https://ztp-server.com/config-ztp-ne21.cfg"
        secondary-url "https://ztp-server.com/config-ztp-ne21.cfg"
        primary-trust-anchor "CMP_ISSUING"
        secondary-trust-anchor "CMP_ISSUING"
    }
    config "cf3:/snmp.cfg" {
        primary-url "https://ztp-server.com/snmp.cfg"
        secondary-url "https://ztp-server.com/snmp.cfg"
        primary-trust-anchor "CMP_ISSUING"
        secondary-trust-anchor "CMP_ISSUING"
    }
}
bof {
    primary-image cf3:\TiMOS-SR-24.7.R1
    primary-config cf3:\config.cfg
    wait 3
    persist on
}
```


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9.5.3.3 Conveyed information

After SR OS authenticates successfully to the bootstrap server, the node can download the conveyed information using HTTPS. The operator can choose the name of the conveyed information file.

The SR OS conveyed information is trusted and does not require an additional signature verification.

Example: File with only onboarding information

The following conveyed information file example contains only onboarding information.

```
onboarding-information {
   boot-image
      download-uri https://images.com/$(sys.platform).zip
   pre-configuration-script "https://config.com/provisioning.cfg"
}
```

The conveyed information can also contain redirect information, in which case a recursive redirect can happen to another bootstrap server. If the conveyed information contains onboarding information and redirect information, the node executes the onboarding information first, then the redirect to the next bootstrap server.

Example: File with onboarding and redirect information

The following conveyed information file example contains onboarding and redirect information, and the certificates required for the second redirect.

```
onboarding-information {
   boot-image
      download-uri https://images.com/$(sys.platform).zip
   pre-configuration-script "https://config.com/provisioning.cfg"
}
import {
   client {
      cert "cf3:/artifacts/node.cert"
      key "cf3:/artifacts/node.key" {
         format der
      }
   }
   trust-anchor BOOTSERVER {
      cert "cf3:/artifacts/bootserver.cert"
   }
}

redirect-information {
   boot-server "https://mybootserver.com/" {
      port 50
      trust-anchor BOOTSERVER
      file "conveyed.info"
   }
   boot-server "https://backupserver.com/" {
      port 50
      trust-anchor BOOTSERVER
      file "conveyed.info"
   }
}
```

After the conveyed information is executed successfully, the BOF is loaded in the provisioning file to which the preconfiguration script is pointing and the **auto-boot** flag is cleared.

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9.6 RFC 8572-compliant SZTP

SR OS supports the following ZTP modes, flags, and features in the `bof.cfg` file:

- normal ZTP – auto-boot without prestaged conveyed information
- legacy SZTP (non RFC 8572-compliant) – auto-boot with prestaged conveyed information
- RFC 8572 SZTP – auto-boot securely (does not support prestaging)

SR OS supports SZTP compliant with RFC 8572. To use SZTP in accordance with RFC 8572, order the correct SR OS software part number so that the package includes a `bof.cfg` file that contains the following flag:

- **MD-CLI**

```
bof auto-boot dhcp secure
```

- **classic CLI**

```
bof auto-boot secure
```

When you power on the router in SZTP mode, SR OS uses the RESTCONF client and server, along with YANG models, to exchange artifacts in accordance with RFC 8572. SZTP runs on the same ports that support ZTP on each platform.

SZTP bootstraps a node securely. The process requires the following:

- initial artifacts that establish mutual trust between the device and the bootstrap server
- the bootstrap server IP address, which the device obtains through DHCP discovery
- a secure and encrypted download of critical data such as the image and configuration file from the servers named in the onboarding information

SR OS uses a dedicated bootstrapping method to obtain TLS certificates, trust anchors, and redirect information to connect securely to the bootstrap server and download everything needed to boot in operational mode.

Note: In IEEE 802.1AR, a Device Identifier (DevID) is the general term for a Secure Device Identifier. The Initial Device Identifier (IDevID) is a unique, manufacturer-provided identity bound to the device, typically stored in secure hardware, that represents the device's core identity. A Local Device Identifier (LDevID) is a locally significant device identity for short-term, environment-specific access.

SZTP performs the following steps:

- The ZTP bootstrap server (owned and managed by the user, and optionally Nokia CNDO) authenticates the router as Nokia-manufactured equipment. The router presents the IDevID certificate installed on the router.
- The router authenticates data from the ZTP bootstrap server as coming from its owner (the user who purchased it). The bootstrap server sends an Ownership Voucher (OV) to the router, and the router validates it.
- The router transfers ownership or trust to the customer by installing customer certificates and using them for later communication with the bootstrap server.

Initially, the customer bootstrap server stores:

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- DevID trust anchor certificates
- an ownership voucher for each purchased router (device), available from Nokia sZTP Portal
- optional redirect bootstrap server certificates and trust anchors if the customer redirects the router to an alternate server to download the image and configuration (the customer generates these)
- a list of artifacts (configurations, images, scripts, and so on)

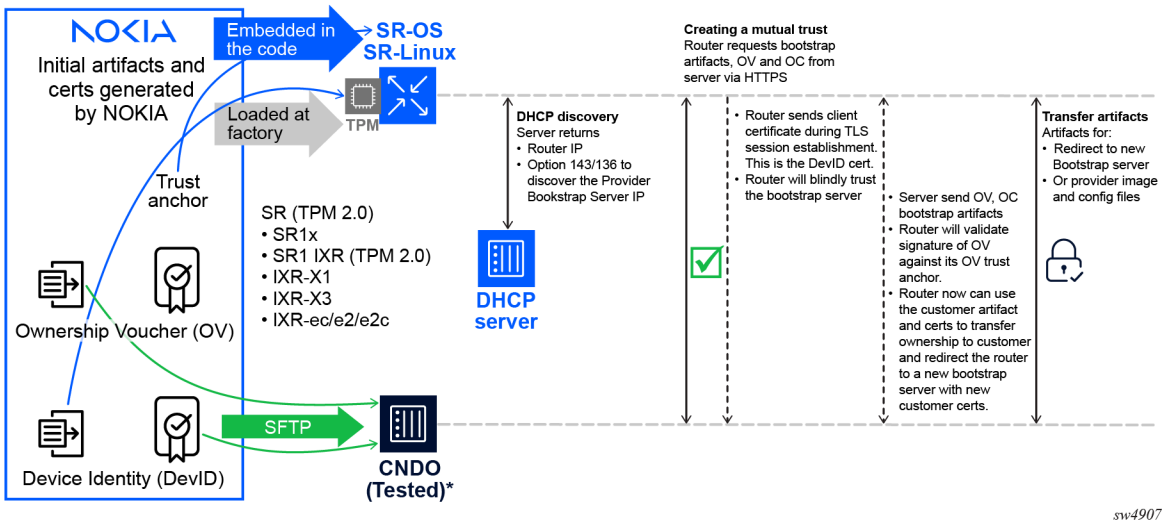
On the CPM, the following resides in the TPM:

- a per-CPM private key that generates the IDevID, valid for the lifetime of the CPM
- the DevID public certificate
- in the software, a Nokia CA trust anchor certificate that validates the signature of the ownership voucher

Note: The IDevID certificate subject matches the serial ID.

The following figure shows the SZTP user workflow.

Figure 30: SZTP user workflow



The detailed workflow displayed in Figure 30: SZTP user workflow is as follows:

1. At the Nokia factory, Nokia creates and signs a unique DevID certificate for each CPM and loads it onto the router.
2. The user obtains the DevID trust anchor from Nokia sZTP Portal.
3. The OV trust anchor is stapled to the Nokia image.
4. The user obtains the OV from Nokia sZTP Portal.
   a. Each OV is unique per router (by serial ID) and contains the pinned-domain-cert that the owner certificate (OC) must chain to.
   b. Nokia CAs sign each OV. Because each OV contains a unique node serial ID, each OV has its own signature.

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5. The DevID certificate and ownership voucher establish mutual trust between the router and the first bootstrap server. Each party holds the appropriate certificate, trust anchor, and key pairs.
6. To connect to Nokia sZTP Portal, the customer registers with Nokia IT, uploads a certificate, and establishes an HTTPS connection to download the certificates and material for steps 1 through 4.

These artifacts enable the node to bootstrap securely. Users can ship the node to the installation site, install it, and power it on. The node then performs the following sequence of events.

1. Performs DHCP discovery and obtains redirect information from DHCP option 143 (IPv4) or 136 (IPv6). After the node receives redirect information, it connects to the bootstrap server over HTTPS to establish mutual trust.
2. Uses HTTPS to establish trust with the bootstrap server:
   a. The router initially trusts the bootstrap server without verifying the TLS server identity.
   b. The router sends its DevID certificate so the bootstrap server can authenticate the router.
   c. The bootstrap server sends the router an OV, OC, and the appropriate artifacts. The router authenticates the OC using the appropriate trust anchor. After the router authenticates the OC, it can use the artifacts, redirect information, or onboarding information.

      Note: The OV and OC validate the artifacts, not the TLS connection; the TLS connection remains unverified.

      i. If signed redirect information is present and the router validates it using the OV and OC, the artifacts include the address of another bootstrap server and, optionally, the trust anchor so the router can connect to that bootstrap server over TLS and continue the bootstrapping process there.

      ii. If signed onboarding information is present and the router verifies it with the OV and OC, the router uses the image and configuration URLs to download the image and configuration. The router does not send a progress report in this case.

Note: If a provisioning file is present on the router, SR OS ignores it and runs the SZTP process instead.

9.6.1 TLS details

SZTP can use TLS 1.2 and TLS 1.3. At the time of the TLS handshake, all SR OS supported ciphers and signatures are advertised.

TLS 1.2 supports the following ciphers and signatures:

- `<cipher-suite-code>`:
  - tls-rsa-with-aes128-cbc-sha256
  - tls-rsa-with-aes256-cbc-sha256
  - tls-rsa-with-aes128-gcm-sha256
  - tls-rsa-with-aes256-gcm-sha384
  - tls-ecdhe-ecdsa-aes128-gcm-sha256
  - tls-ecdhe-ecdsa-aes256-gcm-sha384
  - tls-ecdhe-rsa-aes128-gcm-sha256

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  - tls-ecdhe-rsa-aes256-gcm-sha384
- SHA1 ciphers are excluded because they are outdated and not secure:
  - tls-rsa-with3des-ede-cbc-sha
  - tls-rsa-with-aes128-cbc-sha
  - tls-rsa-with-aes256-cbc-sha

TLS 1.3 supports the following ciphers and signatures:

- `<cipher-suite-code>`:
  - tls-aes128-gcm-sha256
  - tls-aes256-gcm-sha384
  - tls-chacha20-poly1305-sha256
  - tls-aes128-ccm-sha256
- `<group-suite-code>`:
  - tls-ecdhe-256
  - tls-ecdhe-384
  - tls-ecdhe-521
  - tls-x25519
  - tls-x448
- `<signature-suite-code>`:
  - tls-rsa-pss-rsae-sha256
  - tls-ecdsa-secp384r1-sha384

Note: SR OS cannot use other signature algorithms because OpenSSL uses this list for the server certificate signature, client certificate signature, and the client certificate that has a TPM2 private key. The current implementation only supports this signature algorithm.

9.6.2 Bootstrap methods

The following bootstrap methods are supported for SZTP (RFC 8572-compliant):

- DHCP – DHCP is only used for option 143 (IPv4) or 136 (IPv6) as per RFC 8572 and is not used as a bootstrapping method. DHCP provides option 143/136 with the bootstrap server IP address
- Bootstrap server – Nokia Service Node Automation (SNA) and third-party servers. Nokia has not tested ZTP with any other non-Nokia bootstrap server.

Additional redirects from the first bootstrap server to consecutive bootstrap servers are possible. The bootstrap server can provide the node with additional redirect information in a secure, encrypted manner.

Redirect information to another bootstrap server

The redirect information can include a trust anchor for the next bootstrap server. See Conveyed, redirect, and onboarding information support for information about how the trust anchor affects the connection.

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Note: Redirect information is provided as part of the conveyed information file. The conveyed information must not contain onboarding information.

9.6.3 Secure ZTP BOF flag

Because all TPM 2.0 nodes are shipped with appropriate certificates, it is impossible to determine whether the ZTP method is SZTP or normal ZTP from the presence of the certificates alone.

On SR OS, there is a specific SZTP BOF flag (separate from the ZTP flag) and a specific ordering part number.

The SZTP flag in the `bof.cfg` file is configured with the following command:

- **MD-CLI**

```
bof auto-boot dhcp secure
```

- **classic CLI**

```
bof auto-boot secure
```

9.6.4 Conveyed, redirect, and onboarding information support

When the router initiates communication with the bootstrap server, it uses the DevID to establish TLS communication. Until the OV is validated, the router considers this an untrusted server and accepts only the redirect information within the conveyed-information YANG data in the `ietf-sztp-conveyed-info` module.

SR OS supports signed or unsigned redirect artifacts:

- If the redirect is unsigned, the provided TLS certificates (trust anchor) from that unsigned redirect are not used.
- TLS certificates are accepted only when the redirect is signed.
- At any point in the redirect process, SR OS can accept signed onboarding information. Progress reports are sent only over a trusted (TLS-verified) connection. Onboarding received over an untrusted connection produces no progress report.

SR OS mandates that the trust anchor must be provided for each bootstrap server within the redirect information. If a signed redirect arrives without a trust anchor, SR OS treats this redirect as unsigned and requires a signed redirect from the next server.

Additionally, the CRL must be stapled to the redirect certificate. This certificate is used to promote the connection from untrusted to trusted as described in appendix B of RFC 8572.

Example: Redirect information YANG structure

```
+--:(redirect-information)
+-- redirect-information
   +-- bootstrap-server* [address]
      +-- address         inet:host
      +-- port?           inet:port-number
      +-- trust-anchor?   cms
```


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Example: Onboarding information YANG structure

After a trusted connection is established, SR OS supports the following onboarding information:

```
+--:(onboarding-information)
+-- onboarding-information
   +-- boot-image
   |  +-- os-name?              string
   |  +-- os-version?           string
   |  +-- download-uri*         inet:uri
   |  +-- image-verification* [hash-algorithm]
   |     +-- hash-algorithm    identityref
   |     +-- hash-value        yang:hex-string
   +-- configuration-handling?      enumeration
   +-- pre-configuration-script?    script
   +-- configuration?               binary
   +-- post-configuration-script?   script
```

The `pre-configuration-script` is supported; its format is described in Configuration script.

The `boot-image` container indicates the `download-uri` of the software image ZIP file containing all `SROS.tim` files, with a maximum of three URIs. The `image-verification` leaf is mandatory when a `download-uri` is supplied.

Download URI supports HTTPS, FTP, and HTTP, with HTTPS blindly accepting the server's end-entity certificate.

Note: Nokia recommends using the `boot-image` leaf in the onboarding information structure to download the image.

The following onboarding options are initially not supported:

- `configuration-handling`
- `configuration`
- `post-configuration-script`

9.6.5 Image download rules

Although Nokia does not recommend omitting the `boot-image` container,this method is supported to provide flexible image downloads. In this scenario, SR OS runs the `pre-configuration-script` (including the provisioning script or file), and the image object is processed. SR OS sends a `boot-image-installed-rebooting` message to the bootstrap server after successful processing.

Image URL in the boot-image container

If the `os-version` and `os-name` are not set, SR OS times out and moves to the next bootstrap server, or to the next port if no other server exists.

If `os-version` and `os-name` are set:

1. SR OS checks `os-version` against the running OS version.
   - If they match, the image URL setting does not matter; SR OS sends a `boot-image-complete` message.

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- If they do not match, `download-uri` and `image-verification` must be set. Otherwise, SR OS errors out, sends a `boot-image-error` message, and moves to the next bootstrap server or port.

2. If the current image version is not equal to `os-version`, SR OS sends `boot-image-mismatch`, downloads the image, verifies that the downloaded image version matches the `os-version`, and verifies the hash. If any step fails, SR OS sends a `boot-image-error` message and moves to the next bootstrap server.
3. SR OS processes the preconfiguration script and the provisioning script or file, including updating the BOF portion.
   - If the `boot-image` is set and the provisioning file is parsed with an image object in the provisioning script or file, SR OS errors out with `pre-script-error`.
4. On completion, SR OS sends the `boot-image-installed-rebooting` message to the bootstrap server.

9.6.6 Configuration script

The configuration script is a base64 encoded JSON structure defined as follows:

Example

```
yang-data config-script:
+--rw config-script
   +--rw type?           enumeration
   +--rw (location)
      +--:(embedded)
      |  +--rw embedded?       binary
      +--:(download-url)
         +--rw download-url*   types-sros:remote-file-url
```

Currently, one type of `config-script` is supported: `pre-boot-config-script`.

The pre-boot configuration script can be administered in two formats:

- provisioning script – embedded provisioning file in a preconfiguration script
- provisioning file – embedded URL in a preconfiguration script to download the provisioning file

9.6.6.1 Provisioning file format

Provisioning files do not support the legacy non-RFC 8572-compliant SZTP format, including onboarding information and redirect information. If onboarding or redirect information is present in the provisioning file, parsing fails while **auto-boot secure** is enabled in the BOF.

Note: For legacy secure ZTP, use the **auto-boot** flag in the BOF and not the **auto-boot secure** flag.

The `download-url` leaf-list supports up to three URL locations for downloading the provisioning file. SR OS supports FTP, HTTP, and HTTPS download protocols.

Note: Nokia recommends obtaining the provisioning file from the connected bootstrap server using TLS mutual authentication.

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The following ZTP provisioning file components are supported:

- configuration file URL (primary, secondary, tertiary)
- file download
- use the DNS in the provisioning file if present; otherwise, use the DHCP DNS
- generate a new BOF file to point it to the correct directory when the configuration and image are downloaded
- day-zero configuration

The following ZTP provisioning file components are not supported:

- onboarding information
- redirect information

It is not recommended to put the image file URL in the provisioning file.

Note: Nokia recommends using the `boot-image` leaf at the `onboarding-information` structure to download the image. Although the user can also use the provisioning file in the `pre-configuration-script` to download the image, this method is not recommended. Do not configure both options. If the `boot-image` container is set and the provisioning file also contains an image download, SR OS rejects the provisioning script with a pre-script error. See Image download rules for more information.

9.6.6.2 Provisioning script format

Day-zero configuration is not supported in the `pre-configuration-script` provisioning script format, but it is supported in the provisioning file format.

When the provisioning file contents are included with the provisioning script, they are supplied in the embedded leaf as base64-encoded.

The provisioning script supports a maximum of 10,000 characters.

When SZTP receives the `pre-configuration-script` with the provisioning script, it writes the received script to the CF. Because the script format is not checked until it is loaded on the router, Nokia recommends testing the script before deploying it in a production environment.

The provisioning script is saved in the form of a ZTP provisioning file and has limitations when the following command is enabled:

- **MD-CLI**

```
bof auto-boot dhcp secure
```

- **classic CLI**

```
bof auto-boot secure
```

9.6.6.3 Examples of the pre-configuration-script

Example: Preconfiguration script with download URLs

```
“pre-configuration-script” : “base64 encoded”
```


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```
{
  "config-script": {
    "type": "pre-boot-config-script",
    "location": {
      "download-url": [
        "https://<ip-address1>/path-to-pre-boot-script",
        "https://<ip-address2>/path-to-pre-boot-script",
        "https://<ip-address3>/path-to-pre-boot-script"
      ]
    }
  }
}
```

Example: Preconfiguration script with embedded provisioning

```
“pre-configuration-script” : “base64 encoded”
{
  "config-script": {
    "type": "pre-boot-config-script",
    "location": {
      "embedded": "base64-encrypted"
    }
  }
}
```

Example: Embedded provisioning script content

The following example displays embedded content (base64-encoded provisioning script body before encoding).

Note: Day zero configuration is not supported for embedded `pre-configuration-script` content.

```
{
"config-script": {
  "type": "pre-boot-config-script",
  "location": {
   "embedded": "setvar FILESERVER     = \"https://1.1.1.1/web/$(sys.platform)/
$(sys.type)\"\nsetvar BOOT-PATH      = \"cf3:/ztp\"\nsetvar CERT-PATH      = \
"$(BOOT-PATH)/certs\"\nsetvar DAY0-CONFIG    = \"$(BOOT-PATH)/day0.cfg\"\nsetvar
 NSP_IP         = \"192.3.4.5\"\n\nimport {\n   client {\n       cert \"$(CERT-
PATH)/device.crt\" {\n           primary-url \"$(FILESERVER)/device.crt\"\n\t
\t   encrypt\n\t\t   verification {\n\t\t      hash-algorithm sha256\n\t\t\t
 hash-value \"53473e2727caf55f3a38fa466622af2147762e26a8587e9248240a572cdee849\
"\n\t\t   }\n       }\n       key \"$(CERT-PATH)/device.key\" {\n
 format pem\n           primary-url \"$(FILESERVER)/device.key\"\n\t\t   encrypt
\n\t\t   verification {\n\t\t      hash-algorithm sha256\n\t\t\t  hash-value \
"53473e2727caf55f3a38fa466622af2147762e26a8587e9248240a572cdee849\"\n\t\t   }\n
  }             \n   }\n   trust-anchor \"NokiaSvcs\" {\n       cert \"$(CERT-PATH)/
owner-ca.crt\" {\n          format pem\n          primary-url \"$(FILESERVER)/owner-
ca.crt\"\n\t\t  encrypt\n\t\t   verification {\n\t\t      hash-algorithm sha256\n\t\
t\t  hash-value \"53473e2727caf55f3a38fa466622af2147762e26a8587e9248240a572cdee849\
"\n\t\t   }\n        }\n       crl \"$(CERT-PATH)/owner-ca.crl\" {\n
 format der\n          primary-url \"$(FILESERVER)/owner-ca.crl\"\n\t\t  encrypt
\n\t\t   verification {\n\t\t      hash-algorithm sha256\n\t\t\t  hash-value \
"53473e2727caf55f3a38fa466622af2147762e26a8587e9248240a572cdee849\"\n\t\t   }\t\t  \n
   }\n   }\n}\n"
  }
}
}
```


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Example: Provisioning script written into a file

```
setvar FILESERVER     = "https://1.1.1.1/web/$(sys.platform)/$(sys.type)"
setvar BOOT-PATH      = "cf3:/ztp"
setvar CERT-PATH      = "$(BOOT-PATH)/certs"
setvar DAY0-CONFIG    = "$(BOOT-PATH)/day0.cfg"
setvar NSP_IP         = "192.3.4.5"
 import {
   client {
       cert "$(CERT-PATH)/device.crt" {
           primary-url "$(FILESERVER)/device.crt"
                   encrypt
                   verification {
                      hash-algorithm sha256
                          hash-value
 "53473e2727caf55f3a38fa466622af2147762e26a8587e9248240a572cdee849"
                   }
       }
       key "$(CERT-PATH)/device.key" {
           format pem
           primary-url "$(FILESERVER)/device.key"
                   encrypt
                   verification {
                      hash-algorithm sha256
                          hash-value
 "53473e2727caf55f3a38fa466622af2147762e26a8587e9248240a572cdee849"
                   }
       }
   }
   trust-anchor "NokiaSvcs" {
       cert "$(CERT-PATH)/owner-ca.crt" {
          format pem
          primary-url "$(FILESERVER)/owner-ca.crt"
                  encrypt
                   verification {
                      hash-algorithm sha256
                          hash-value
 "53473e2727caf55f3a38fa466622af2147762e26a8587e9248240a572cdee849"
                   }
        }
       crl "$(CERT-PATH)/owner-ca.crl" {
          format der
          primary-url "$(FILESERVER)/owner-ca.crl"
                  encrypt
                   verification {
                      hash-algorithm sha256
                          hash-value
 "53473e2727caf55f3a38fa466622af2147762e26a8587e9248240a572cdee849"
                   }
        }
   }
}
```

9.6.7 Installation site

At the installation site, the following command in the BOF signals the SZTP process:

- **MD-CLI**

```
bof auto-boot dhcp secure
```


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- **classic CLI**

```
bof auto-boot secure
```

The following sequence of events occurs:

1. After the node is installed, the port with link up is selected and SZTP is executed on it. Port support for SZTP is the same as ZTP on a different chassis.
2. The node loads the IDevID certificates and OV trust anchor.
3. DHCP discovery is sent on each port in order. If there is no DHCP offer, SZTP moves to the next port with link up.
   a. The OOB port is examined first, then untagged in-band ports.
   b. If there is no offer, VLAN discovery is performed on in-band ports only (flood VLAN 0 through 4096 with DHCP discovery).
4. After DHCP discovery obtains an IP address, the node obtains option 143 (IPv4) or 136 (IPv6) for redirect information.
5. The node connects to the bootstrap server indicated by the redirect information from the DHCP option and establishes mutual authentication and trust using IDevID and OV certificates and trust anchors.
   a. The bootstrap server must have the correct OV, keys, and DevID trust anchor to create this mutual trust.
   b. Mutual trust uses HTTPS.
6. After the bootstrap server authenticates the node, the router blindly trusts the server and requests the conveyed information using RESTCONF from the server.
7. If the conveyed information from RESTCONF contains signed redirect information, the node connects to the new bootstrap server indicated in the redirect. The node can download a new trust anchor indicated by the redirect information.
8. If the conveyed information YANG contains only onboarding information, the node first processes the `boot-image` container (version check, download, hash verification), then runs the provisioning script carried in or downloaded using the `pre-configuration-script` leaf.
9. SZTP succeeds if the node executes onboarding information with no redirect information and the onboarding information executes without error.

9.6.8 Non-TPM 2.0 platforms

Non-TPM 2.0 platforms do not support RFC 8572-compliant SZTP. They support a legacy SZTP with the **auto-boot** flag, in which the user must stage the router by adding redirect, onboarding, and certificate files on the router directly.

9.6.9 Image download directory

Currently, SZTP onboarding information has no way to create a folder for a specific image download; all images are downloaded to the root directory of CF3.

Nokia recommends downloading the image as a ZIP file, which allows the OS to unzip the file and expand the file directory under the CF3 root directory.

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Include the image version in the ZIP filename. This prevents the download from accidentally overwriting existing versions.

In addition, after the root directory of the ZIP file is uncompressed, ensure the file is prefixed with the image software version, This naming convention prevents folder collisions or overwriting previously uncompressed image folders.

Example: Example ZIP filename

`Images-26.10.r1.zip`

The following example displays a root directory after uncompressing the file.

```
Images-26.10.r1
|---image
|   ...
```

9.6.10 Logs

SZTP supports the following log methods:

- console – when the user logs in to the router and the router is in SZTP processing mode, logs are displayed on the console CLI
- log files – logging files are generated automatically; use **tools dump auto-boot log** to view logs
- syslog – configured using the provisioning file (may result in lost logs for a perriod) or DHCPv4 Option 7

9.6.11 NTP and OV certificate date and time validation

If the DHCP offer includes NTP DHCP option 42 (for IPv4) or option 56 (for IPv6), the router validates the OV certificate date and time. If these NTP options are not present, the router bypasses this verification.

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10 Standards and protocol support

Note:
The information provided in this chapter is subject to change without notice and may not apply to all platforms.

Nokia assumes no responsibility for inaccuracies.

10.1 Bidirectional Forwarding Detection (BFD)

RFC 5880, *Bidirectional Forwarding Detection (BFD)*

RFC 5881, *Bidirectional Forwarding Detection (BFD) IPv4 and IPv6 (Single Hop)*

RFC 5882, *Generic Application of Bidirectional Forwarding Detection (BFD)*

10.2 Border Gateway Protocol (BGP)

draft-hares-idr-update-attrib-low-bits-fix-01, *Update Attribute Flag Low Bits Clarification*

draft-ietf-idr-add-paths-guidelines-08, *Best Practices for Advertisement of Multiple Paths in IBGP*

draft-ietf-idr-best-external-03, *Advertisement of the best external route in BGP*

draft-ietf-idr-bgp-gr-notification-01, *Notification Message support for BGP Graceful Restart*

draft-ietf-idr-bgp-optimal-route-reflection-10, *BGP Optimal Route Reflection (BGP-ORR)*

draft-ietf-idr-error-handling-03, *Revised Error Handling for BGP UPDATE Messages*

draft-ietf-idr-link-bandwidth-03, *BGP Link Bandwidth Extended Community*

RFC 1772, *Application of the Border Gateway Protocol in the Internet*

RFC 1997, *BGP Communities Attribute*

RFC 2385, *Protection of BGP Sessions via the TCP MD5 Signature Option*

RFC 2439, *BGP Route Flap Damping*

RFC 2545, *Use of BGP-4 Multiprotocol Extensions for IPv6 Inter-Domain Routing*

RFC 2858, *Multiprotocol Extensions for BGP-4*

RFC 2918, *Route Refresh Capability for BGP-4*

RFC 4271, *A Border Gateway Protocol 4 (BGP-4)*

RFC 4360, *BGP Extended Communities Attribute*

RFC 4364, *BGP/MPLS IP Virtual Private Networks (VPNs)*

RFC 4456, *BGP Route Reflection: An Alternative to Full Mesh Internal BGP (IBGP)*

RFC 4486, *Subcodes for BGP Cease Notification Message*

RFC 4659, *BGP-MPLS IP Virtual Private Network (VPN) Extension for IPv6 VPN*

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RFC 4684, *Constrained Route Distribution for Border Gateway Protocol/MultiProtocol Label Switching (BGP/MPLS) Internet Protocol (IP) Virtual Private Networks (VPNs)*

RFC 4724, *Graceful Restart Mechanism for BGP* – helper mode

RFC 4760, *Multiprotocol Extensions for BGP-4*

RFC 4798, *Connecting IPv6 Islands over IPv4 MPLS Using IPv6 Provider Edge Routers (6PE)*

RFC 5004, *Avoid BGP Best Path Transitions from One External to Another*

RFC 5065, *Autonomous System Confederations for BGP*

RFC 5291, *Outbound Route Filtering Capability for BGP-4*

RFC 5396, *Textual Representation of Autonomous System (AS) Numbers* – asplain

RFC 5492, *Capabilities Advertisement with BGP-4*

RFC 5668, *4-Octet AS Specific BGP Extended Community*

RFC 6286, *Autonomous-System-Wide Unique BGP Identifier for BGP-4*

RFC 6368, *Internal BGP as the Provider/Customer Edge Protocol for BGP/MPLS IP Virtual Private Networks (VPNs)*

RFC 6793, *BGP Support for Four-Octet Autonomous System (AS) Number Space*

RFC 6810, *The Resource Public Key Infrastructure (RPKI) to Router Protocol*

RFC 6811, *Prefix Origin Validation*

RFC 6996, *Autonomous System (AS) Reservation for Private Use*

RFC 7311, *The Accumulated IGP Metric Attribute for BGP*

RFC 7606, *Revised Error Handling for BGP UPDATE Messages*

RFC 7607, *Codification of AS 0 Processing*

RFC 7854, *BGP Monitoring Protocol (BMP)*

RFC 7911, *Advertisement of Multiple Paths in BGP*

RFC 7999, *BLACKHOLE Community*

RFC 8092, *BGP Large Communities Attribute*

RFC 8097, *BGP Prefix Origin Validation State Extended Community*

RFC 8212, *Default External BGP (EBGP) Route Propagation Behavior without Policies*

RFC 8277, *Using BGP to Bind MPLS Labels to Address Prefixes*

RFC 9294, *Application-Specific Link Attributes Advertisement Using the Border Gateway Protocol - Link State (BGP LS)*

RFC 9494, *Long-Lived Graceful Restart for BGP*

RFC 9552, *Distribution of Link-State and Traffic Engineering Information Using BGP*

10.3 Bridging and management

IEEE 802.1AB, *Station and Media Access Control Connectivity Discovery*

IEEE 802.1ad, *Provider Bridges*

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IEEE 802.1AX, *Link Aggregation*

IEEE 802.1D, *MAC Bridges*

IEEE 802.1p, *Traffic Class Expediting*

IEEE 802.1Q, *Virtual LANs*

IEEE 802.1s, *Multiple Spanning Trees*

IEEE 802.1w, *Rapid Reconfiguration of Spanning Tree*

10.4 Certificate management

RFC 4210, *Internet X.509 Public Key Infrastructure Certificate Management Protocol (CMP)*

RFC 4211, *Internet X.509 Public Key Infrastructure Certificate Request Message Format (CRMF)*

RFC 5280, *Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile*

RFC 6712, *Internet X.509 Public Key Infrastructure -- HTTP Transfer for the Certificate Management Protocol (CMP)*

RFC 7030, *Enrollment over Secure Transport*

RFC 7468, *Textual Encodings of PKIX, PKCS, and CMS Structures*

10.5 Ethernet

IEEE 802.3x, *Ethernet Flow Control*

10.6 Ethernet VPN (EVPN)

draft-ietf-bess-evpn-ip-mac-proxy-adv-00, *Proxy MAC-IP Advertisement in EVPNs*

draft-ietf-bess-evpn-l3mh-proto-00, *EVPN Multi-Homing support for L3 services*

RFC 7432, *BGP MPLS-Based Ethernet VPN*

RFC 8214, *Virtual Private Wire Service Support in Ethernet VPN*

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RFC 3412, *Message Processing and Dispatching for the Simple Network Management Protocol (SNMP)*

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RFC 3414, *User-based Security Model (USM) for version 3 of the Simple Network Management Protocol (SNMPv3)*

RFC 3415, *View-based Access Control Model (VACM) for the Simple Network Management Protocol (SNMP)*

RFC 3416, *Version 2 of the Protocol Operations for the Simple Network Management Protocol (SNMP)*

RFC 3417, *Transport Mappings for the Simple Network Management Protocol (SNMP)* – SNMP over UDP over IPv4

RFC 3418, *Management Information Base (MIB) for the Simple Network Management Protocol (SNMP)*

RFC 3419, *Textual Conventions for Transport Addresses*

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10.27 Storage sanitization

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10.28 Timing

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RFC 8573, *Message Authentication Code for the Network Time Protocol*

10.29 Two-Way Active Measurement Protocol (TWAMP)

RFC 5357, *A Two-Way Active Measurement Protocol (TWAMP)* – server, unauthenticated mode

RFC 5938, *Individual Session Control Feature for the Two-Way Active Measurement Protocol (TWAMP)*

RFC 6038, *Two-Way Active Measurement Protocol (TWAMP) Reflect Octets and Symmetrical Size Features*

RFC 8545, *Well-Known Port Assignments for the One-Way Active Measurement Protocol (OWAMP) and the Two-Way Active Measurement Protocol (TWAMP)* – TWAMP

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10.30 Virtual Private LAN Service (VPLS)

RFC 4761, *Virtual Private LAN Service (VPLS) Using BGP for Auto-Discovery and Signaling*

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RFC 7950, *The YANG 1.1 Data Modeling Language*

RFC 7951, *JSON Encoding of Data Modeled with YANG*

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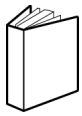

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