ConneXium

TCSESB Basic Managed Switch
Redundancy Configuration User Manual

S1A78418.00

www.schneider-electric.com

Contents

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Important Information

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Related Documents

Title of Documentation	Reference-Number
ConneXium TCSESB Basic Managed Switch Redundancy Configuration User Manual	S1A78418
ConneXium TCSESB Managed Switch Basic Configuration User Manual	S1A78213
ConneXium TCSESB Basic Managed Switch Command Line Interface Reference Manual	S1A78426
ConneXium TCSESB Basic Managed Switch Web-based Interface Reference Manual	S1A78429
ConneXium TCSESB Basic Managed Switch Installation Manual	S1A78204

Note: The Glossary is located in the Reference Manual “Command Line Interface”.

The “Redundancy Configuration” user manual contains extensive information you need to select a suitable redundancy procedure and configure that procedure.

The “Basic Configuration” user manual contains the information you need to start operating the device. It takes you step by step from the first startup operation through to the basic settings for operation in your environment.

The “Installation” user manual contains a device description, safety instructions, a description of the display, and the other information that you need to install the device.

The “Web-based Interface” reference manual contains detailed information on using the Web interface to operate the individual functions of the device.

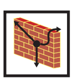
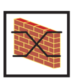
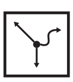
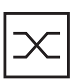
The “Command Line Interface” Reference Manual contains detailed information on using the Command Line Interface to operate the individual functions of the device.

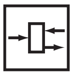
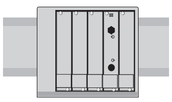
Key

The designations used in this manual have the following meanings:

▶	List
☐	Work step
■	Subheading
Link	Indicates a cross-reference with a stored link
Note:	A note emphasizes an important fact or draws your attention to a dependency.
`Courier`	ASCII representation in user interface
	Execution in the Web-based Interface user interface
	Execution in the Command Line Interface user interface

Symbols used:

	WLAN access point
	Router with firewall
	Switch with firewall
	Router
	Switch

	Bridge
	Hub
	A random computer
	Configuration Computer
	Server
	PLC - Programmable logic controller
	I/O - Robot

1 Introduction

The device contains a range of redundancy functions:

- HIPER-Ring
- MRP-Ring
- Rapid Spanning Tree Algorithm (RSTP)

1.1 Overview of Redundancy Topologies

To introduce redundancy onto layer 2 of a network, first clarify which network topology you require. Depending on the network topology selected, you then choose from the redundancy protocols that can be used with this network topology.

The following topologies are possible:

Network topology	Possible redundancy procedures	Comments
Tree structure without loops (cycle-free)	Only possible in combination with physical loop creation	-
Topology with 1 loop	RSTP, Ring Redundancy	Ring Redundancy procedures (HIPER-Ring or MRP) provide shorter switching times than RSTP
Topology with 2 loops	RSTP, Ring Redundancy, Sub-Ring	Ring Redundancy: one rimary ring or an MRP-Ring with an RSTP-Ring.

Table 1: Overview of Redundancy Topologies

1.2 Overview of Redundancy Protocols

Redundancy procedure	Network topology	Switch-over time
RSTP	Random structure	typically < 1 s (STP < 30 s), up to < 30 s - depends heavily on the number of devices
	Note: Up to 79 devices possible, depending on topology and configuration. If the default values (factory settings) are used, up to 39 devices are possible, depending on the topology (see page 33).	
HIPER-Ring	Ring	typically 80 ms, up to < 500 ms or < 300 ms (selectable) - the number of switches has a minimal effect on the switch-over time
MRP-Ring	Ring	typically 80 ms, up to < 500 ms or < 200 ms (selectable) - the number of switches has a minimal effect on the switch over time
	Note: In combination with RSTP in MRP compatibility mode, up to 39 devices are possible, depending on the configuration. If the default values (factory settings) for RSTP are used, up to 19 devices are possible (see page 33).	

Table 2: Comparison of the redundancy procedures

2 Ring Redundancy

The concept of ring redundancy allows the construction of high-availability, ring-shaped network structures.
With the help of the RM (**R**ing **M**anager) function, the two ends of a backbone in a line structure can be closed to a redundant ring. The ring manager keeps the redundant line open as long as the line structure is intact. If a segment becomes inoperable, the ring manager immediately closes the redundant line, and line structure is intact again.

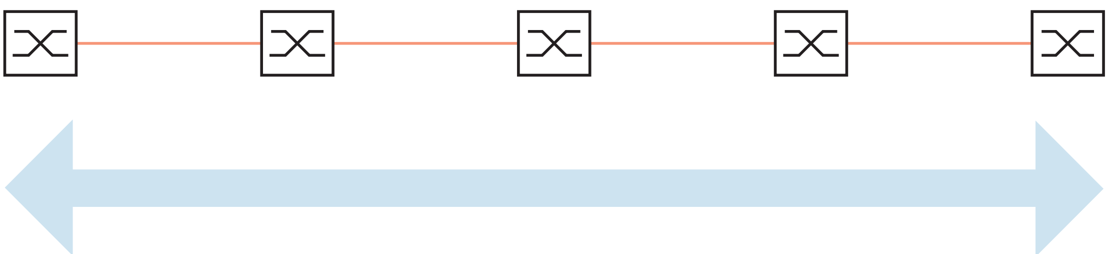


Figure 1: Line structure

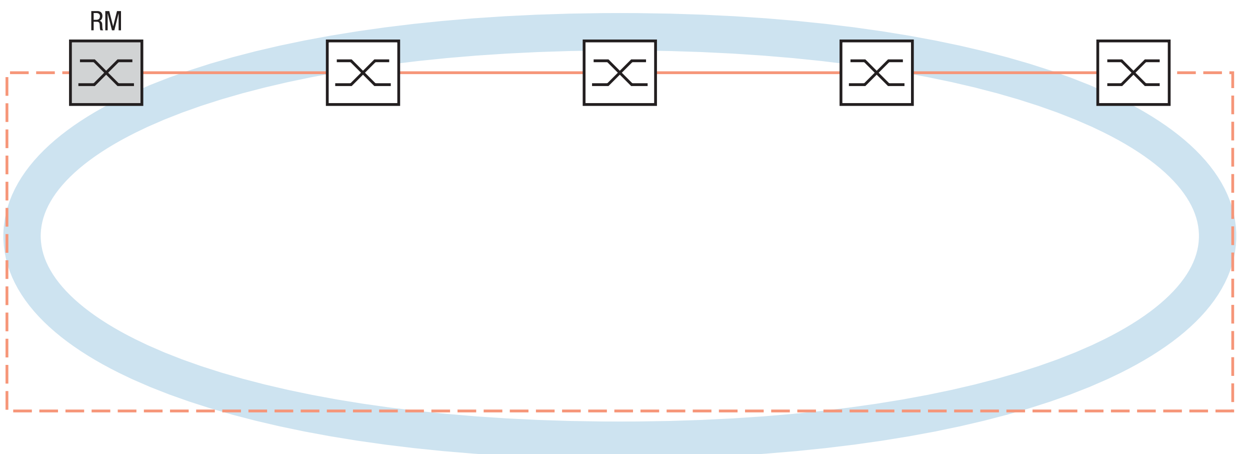


Figure 2: Redundant ring structure
RM = Ring Manager
—— main line
- - - redundant line

If a section is down, the ring structure of a

- HIPER-(**HI**GH **PE**RFORMANCE **R**EDUNDANCY) Ring with up to 50 devices typically transforms back to a line structure within 80 ms (possible settings: standard/accelerated).
- MRP (**M**edia **R**edundancy **P**rotocol) Ring (IEC 62439) of up to 50 devices typically transforms back to a line structure within 80 ms (adjustable to max. 200 ms/500 ms).

Devices with HIPER-Ring function capability:

- Within a HIPER-Ring, you can use any combination of the following devices:
  - TCSESM
  - TCSESM-E
  - TCSESB
- Within an MRP-Ring, you can use devices that support the MRP protocol based on IEC62439.
  - TCSESM
  - TCSESM-E
  - TCSESB

Note: Enabled Ring Redundancy methods on a device are mutually exclusive at any one time. When changing to another Ring Redundancy method, deactivate the function for the time being.

Note: The following usage of the term “ring manager” instead of “redundancy manager” makes the function easier to understand.

2.1 Example of a HIPER-Ring

A network contains a backbone in a line structure with 3 devices. To increase the redundancy reliability of the backbone, you have decided to convert the line structure to a HIPER-Ring. You use ports 1.1 and 1.2 of the devices to connect the lines[1].

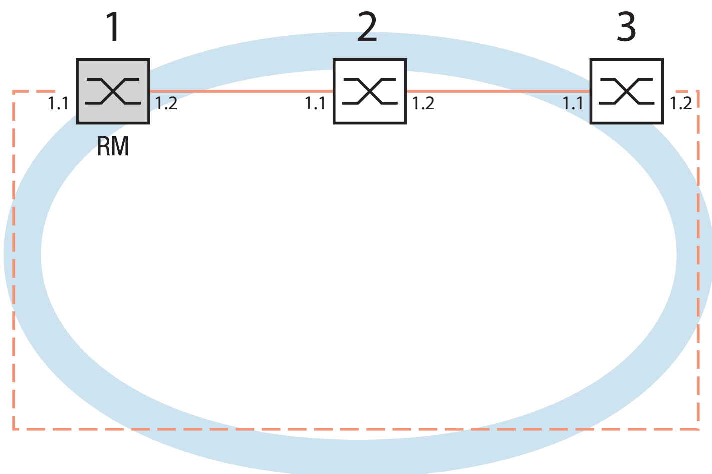


Figure 3: Example of HIPER-Ring
RM = Ring Manager
—— main line
- - - redundant line

The following example configuration describes the configuration of the ring manager device (1). The two other devices (2 to 3) are configured in the same way, but without activating the ring manager function. Select the “Standard” value for the ring recovery, or leave the field empty.

1. On modular devices the 1st number of the port designation specifies the module. The 2nd number specifies the port on the module. The specification pattern 1.x is also used on non-modular devices for consistency.

⚠ WARNING

RING LOOP HAZARD

To avoid loops during the configuration phase, configure all the devices of the HIPER-Ring individually. Before you connect the redundant line, you must complete the configuration of all the devices of the Ring.

Failure to follow these instructions can result in death, serious injury, or equipment damage.

2.1.1 Setting up and configuring the HIPER-Ring

☐ Set up the network to meet your demands.
☐ Configure all ports so that the transmission speed and the duplex settings of the lines correspond to the following table:

Bit rate	**100 Mbit/s**
Autonegotiation (automatic configuration)	off
Port	on
Duplex	Full

Table 3: Port settings for ring ports

Note: When activating the HIPER-Ring function, the device sets the corresponding settings for the pre-defined ring ports in the configuration table (transmission rate and mode). If you switch off the HIPER-Ring function, the ports, which are changed back into normal ports, keep the ring port settings.

☐ Select the `Redundancy:Ring Redundancy` dialog.
☐ Under “Version”, select `HIPER-Ring`.
☐ Define the desired ring ports 1 and 2 by making the corresponding entries in the module and port fields. If it is not possible to enter a module, then there is only one module in the device that is taken over as a default.

Display in “Operation” field:
– `active`: This port is switched on and has a link.
– `inactive`: This port is switched off or it has no link.

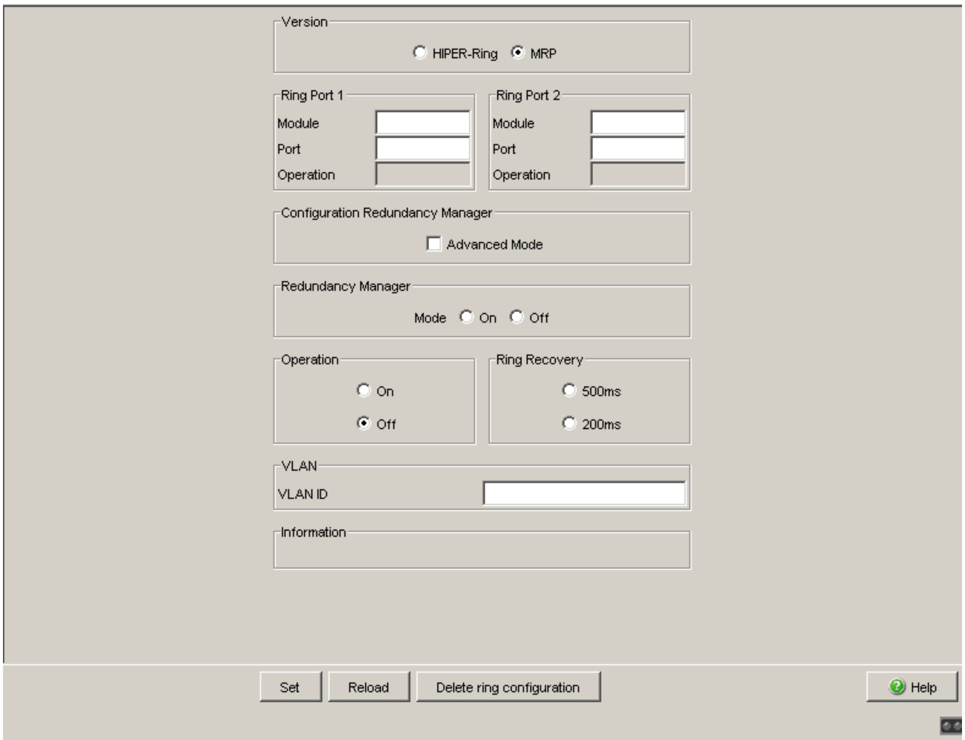


Figure 4: Ring Redundancy dialog

☐ Activate the ring manager for this device. Do not activate the ring manager for any other device in the HIPER-Ring.
☐ In the “Ring Recovery” frame, select the value “Standard” (default).

Note: Settings in the “Ring Recovery” frame only take effect for devices configured as ring managers.

☐ Click “Set” to temporarily save the entry in the configuration.

`enable`	Switch to the Privileged EXEC mode.
`configure`	Switch to the Configuration mode.
`hiper-ring mode ring-manager`	Select the HIPER-Ring ring redundancy and define the device as ring manager.
`Switch's HIPER Ring mode set to ring-manager`	
`hiper-ring port primary 1/1`	Define port 1 in module 1 as ring port 1.
`HIPER Ring primary port set to 1/1`	
`hiper-ring port secondary 1/2`	Define port 1 in module 2 as ring port 1.
`HIPER Ring secondary port set to 1/2`	
`exit`	Switch to the privileged EXEC mode.
`show hiper-ring`	Display the HIPER-Ring parameters.

```
HIPER Ring Mode of the Switch.................. ring-manager
  configuration determined by.................. management
HIPER Ring Primary Port of the Switch.......... 1/1, state active
HIPER Ring Secondary Port of the Switch........ 1/2, state active
HIPER Ring Redundancy Manager State............ active
HIPER Ring Redundancy State (red. exists).. no (rm is active)
HIPER Ring Setup Info (Config. failure)........ no error
HIPER Ring Recovery Delay...................... 500ms
```

☐ Now proceed in the same way for the other two devices.

Note: Deactivate the Spanning Tree protocol for the ports connected to the HIPER-Ring, because Spanning Tree and Ring Redundancy affect each other.

☐ Now you connect the line to the ring. To do this, you connect the 2 devices to the ends of the line using their ring ports.

The displays in the “Redundancy Manager Status” frame mean:
- “Active (redundant line)”: The ring is open, which means that a data line or a network component within the ring is down.
- “Inactive”: The ring is closed, which means that the data lines and network components are working.

The displays in the “Information” frame mean
- “Redundancy existing”: One of the lines affected by the function may be interrupted, with the redundant line then taking over the function of the interrupted line.
- "Configuration failure”: The function is incorrectly configured or the cable connections at the ring ports are improperly configured (e.g., not plugged into the ring ports).

2.2 Example of an MRP-Ring

A network contains a backbone in a line structure with 3 devices. To increase the availability of the backbone, you decide to convert the line structure to a redundant ring. In contrast to the previous example, devices from different manufacturers are used which do not all support the HIPER-Ring protocol. However, all devices support MRP as the ring redundancy protocol, so you decide to deploy MRP. You use ports 1.1 and 2.2 of the devices to connect the lines.

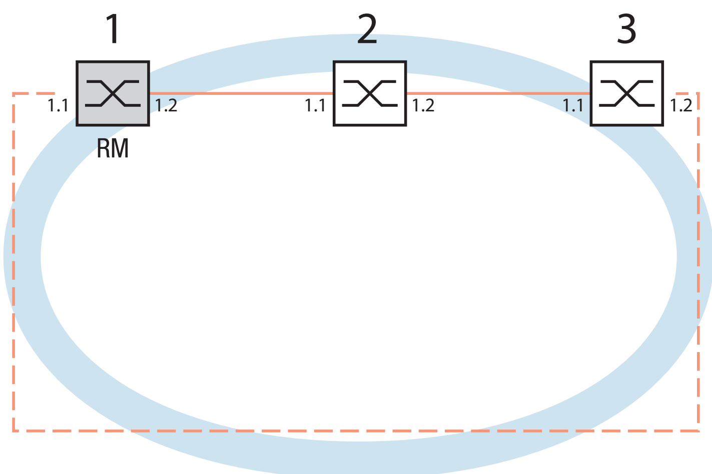


Figure 5: Example of MRP-Ring
RM = Ring Manager
—— main line
- - - redundant line

The following example configuration describes the configuration of the ring manager device (1). You configure the 2 other devices (2 to 3) in the same way, but without activating the ring manager function. This example does not use a VLAN. You have entered 200 ms as the ring recovery time, and all the devices support the advanced mode of the ring manager.

⚠ WARNING

RING LOOP HAZARD

To avoid loops during the configuration phase, configure all the devices of the MRP-Ring individually. Before you connect the redundant line, you must complete the configuration of all the devices of the Ring.

Failure to follow these instructions can result in death, serious injury, or equipment damage.

- ☐ Set up the network to meet your demands.
- ☐ Configure all ports so that the transmission speed and the duplex settings of the lines correspond to the following table:

Bit rate	**100 Mbit/s**
Autonegotiation (automatic configuration)	off
Port	on
Duplex	Full

Table 4: Port settings for ring ports

- ☐ Select the `Redundancy:Ring Redundancy` dialog.
- ☐ Under “Version”, select `MRP`.
- ☐ Define the desired ring ports 1 and 2 by making the corresponding entries in the module and port fields. If it is not possible to enter a module, then there is only one module in the device that is taken over as a default.

Display in “Operation” field:
- `forwarding`: this port is switched on and has a link.
- `blocked`: this port is blocked and has a link
- `disabled`: this port is disabled
- `not-connected`: this port has no link

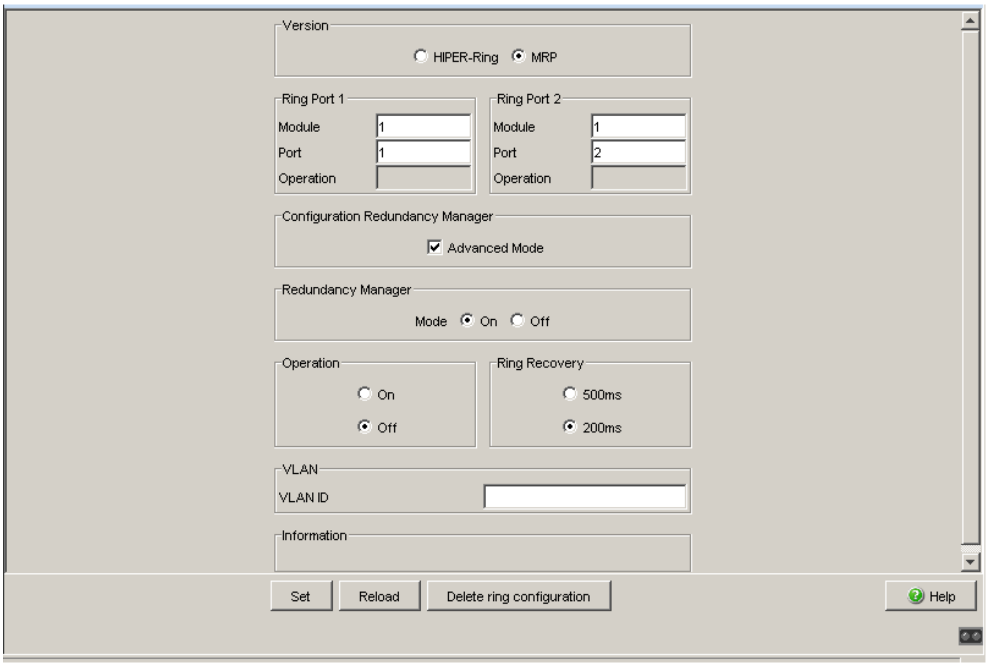


Figure 6: Ring Redundancy dialog

☐ In the “Ring Recovery” frame, select 200 ms.

Note: If selecting 200 ms for the ring recovery does not provide the ring stability necessary to meet the requirements of your network, you select 500 ms.

Note: Settings in the “Ring Recovery” frame only take effect for devices configured as ring managers.

☐ Under “Configuration Redundancy Manager”, activate the advanced mode.

☐ Activate the ring manager for this device. Do not activate the ring manager for any other device in the MRP-Ring.

☐ Switch the operation of the MRP-Ring on.

☐ Click “Set” to temporarily save the entry in the configuration.

The displays in the “Information” frame mean
- “Redundancy existing”: One of the lines affected by the function may be interrupted, with the redundant line then taking over the function of the interrupted line.
- "Configuration failure”: The function is incorrectly configured or the cable connections at the ring ports are improperly configured (e.g., not plugged into the ring ports).

Note: For all devices in an MRP-Ring, activate the MRP compatibility in the `Rapid Spanning Tree:Global` dialog if you want to use RSTP in the MRP-Ring. If this is not possible, perhaps because individual devices do not support the MRP compatibility, you deactivate the Spanning Tree protocol at the ports connected to the MRP-Ring. Spanning Tree and Ring Redundancy affect each other.

Note: When you are configuring an MRP-Ring using the Command Line Interface, you define an additional parameter. When configured using CLI, an MRP-Ring is addressed via its MRP domain ID. The MRP domain ID is a sequence of 16 number blocks (8-bit values). Use the default domain of 255 255 255 255 255 255 255 255 255 255 255 255 255 255 255 255 for the MRP domain ID.
This default domain is also used internally for a configuration via the Web-based interface.
Configure all the devices within an MRP-Ring with the same MRP domain ID.

`enable`	Switch to the Privileged EXEC mode.
`configure`	Switch to the Configuration mode.
`mrp new-domain default-domain`	Create a new MRP-Ring with the default domain ID 255.255.255.255.255.255.255.255.255.255.255.255.255.255.255.255

```
MRP domain created:
Domain ID:
255.255.255.255.255.255.255.255.255.255.255.255.255.255.255.255
  (Default MRP domain)
```

`mrp current-domain port primary 1/1`	Define port 1 in module 1 as ring port 1 (primary).

`Primary Port set to 1/1`	
`mrp current-domain port secondary 1/2`	Define port 2 in module 1 as ring port 2 (secondary).
`Secondary Port set to 1/2`	
`mrp current-domain mode manager`	Define this device as the ring manager.
`Mode of Switch set to Manager`	
`mrp current-domain recovery-delay 200ms`	Define 200ms as the value for the “Ring Recovery”.
`Recovery delay set to 200ms`	
`mrp current-domain advanced-mode enable`	Activate the “MRP Advanced Mode”.
`Advanced Mode (react on link change) set to Enabled`	
`mrp current-domain operation enable`	Activate the MRP-Ring.
`Operation set to Enabled`	
`exit`	Go back one level.
`show mrp`	Show the current parameters of the MRP-Ring (abbreviated display).

```
Domain ID:
255.255.255.255.255.255.255.255.255.255.255.255.255.255.255.255
(Default MRP domain)

Configuration Settings:
Advanced Mode (react on link change).... Enabled
Manager Priority........................ 32768
Mode of Switch (administrative setting). Manager
Mode of Switch (real operating state)... Manager
Domain Name............................. <empty>
Recovery delay.......................... 200ms
Port Number, Primary.................... 1/1, State: Not Connected
Port Number, Secondary.................. 1/2, State: Not Connected
VLAN ID................................. 0 (No VLAN)
Operation............................... Enabled
```

☐ Now you connect the line to the ring. To do this, you connect the 2 devices to the ends of the line using their ring ports.

2.3 Example for HIPER-Ring with Straight Cables

You can set up this example with models TCSESM, TCSESM-E or TCSESB.

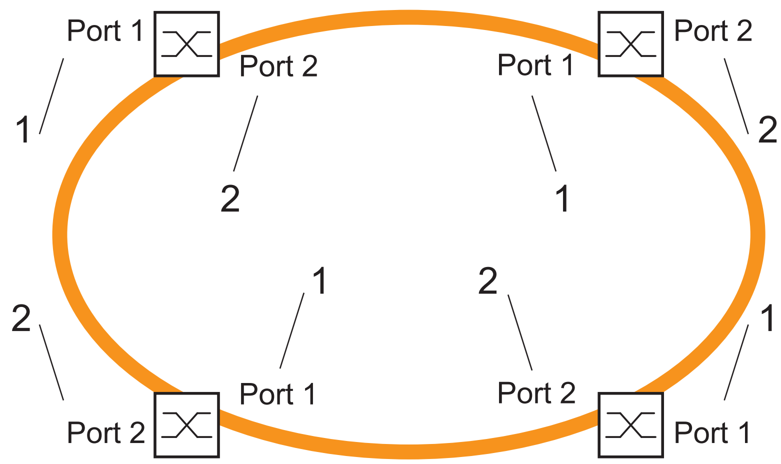


Figure 7: Example for a HIPER-Ring with straight cables
1 = Manual Cable Crossing disabled
2 = Manual Cable Crossing enabled

The following example configuration describes the configuration of a HIPER-Ring where straight cables are used between the switches, in contrast to the normal case, where crossed cables are used between switches.
The choice which switch is assigned the ring manager function as well as which line is assigned the redundant line in the normal mode of operation, is independent from that and is therefore not given in the example.

⚠ WARNING

RING LOOP HAZARD

To avoid loops during the configuration phase, configure all the devices of the HIPER-Ring individually. Before you connect the redundant line, you must complete the configuration of all the devices of the Ring.

Failure to follow these instructions can result in death, serious injury, or equipment damage.

Note: Configure all the devices of the HIPER-Ring individually. Before you connect the redundant line, you must complete the configuration of all the devices of the HIPER-Ring. You thus avoid loops during the configuration phase.

- ☐ Set up the network to meet your demands.
- ☐ Configure the transmission rate, the duplex mode and the manual cable crossing for all ring ports as given in the following table:

Port	1.1	1.2
Port on	yes (checked)	yes (checked)
Autonegotiation (Automatic Configuration)	no (not checked)	no (not checked)
Manual Configuration	100 Mbit/s FDX	100 Mbit/s FDX
Manual Cable Crossing	disable	enable

Table 5: Port settings for ring ports when using straight cables

Note: You can also use the ring redundancy protocol MRP instead of HIPER-Ring.

3 Rapid Spanning Tree

Note: The Spanning Tree and Rapid Spanning Tree protocols based on IEEE 802.1D-2004 and IEEE 802.1w respectively are protocols for MAC bridges. For this reason, the following description of these protocols usually employs the term bridge instead of switch.

Local networks are getting bigger and bigger. This applies to both the geographical expansion and the number of network participants. Therefore, it is advantageous to use multiple bridges, for example:

- to reduce the network load in sub-areas,
- to set up redundant connections and
- to overcome distance limitations.

However, using multiple bridges with multiple redundant connections between the subnetworks can lead to loops and thus loss of communication across of the network. In order to help avoid this, you can use Spanning Tree. Spanning Tree enables loop-free switching through the systematic deactivation of redundant connections. Redundancy enables the systematic reactivation of individual connections as needed.

RSTP is a further development of the Spanning Tree Protocol (STP) and is compatible with it. If a connection or a bridge becomes inoperable, the STP required a maximum of 30 seconds to reconfigure. This is no longer acceptable in time-sensitive applications. RSTP achieves average reconfiguration times of less than a second. When you use RSTP in a ring topology with 10 to 20 devices, you can even achieve reconfiguration times in the order of milliseconds.

Note: RSTP reduces a layer 2 network topology with redundant paths into a tree structure (Spanning Tree) that does not contain any more redundant paths. One of the Switches takes over the role of the root bridge here. The maximum number of devices permitted in an active branch (from the root bridge to the tip of the branch) is specified by the variable `Max Age` for the current root bridge. The preset value for `Max Age` is 20, which can be increased up to 40.
If the device working as the root is inoperable and another device takes over its function, the `Max Age` setting of the new root bridge determines the maximum number of devices allowed in a branch.

Note: The RSTP standard dictates that all the devices within a network work with the (Rapid) Spanning Tree Algorithm. If STP and RSTP are used at the same time, the advantages of faster reconfiguration with RSTP are lost in the network segments that are operated in combination.
A device that only supports RSTP works together with MSTP devices by not assigning an MST region to itself, but rather the CST (Common Spanning Tree).

3.1 The Spanning Tree Protocol

Because RSTP is a further development of the STP, all the following descriptions of the STP also apply to the RSTP.

3.1.1 The tasks of the STP

The Spanning Tree Algorithm reduces network topologies built with bridges and containing ring structures due to redundant links to a tree structure. In doing so, STP opens ring structures according to preset rules by deactivating redundant paths. If a path is interrupted because a network component becomes inoperable, STP reactivates the previously deactivated path again. This allows redundant links to increase the availabiliy of communication. STP determines a bridge that represents the STP tree structure‘s base. This bridge is called root bridge.

Features of the STP algorithm:

- automatic reconfiguration of the tree structure in the case of a bridge becoming inoperable or the interruption of a data path
- the tree structure is stabilized up to the maximum network size (up to 39 hops, depending on the setting for `Max Age`, (see table 8)
- stabilization of the topology within a short time period
- topology can be specified and reproduced by the administrator
- transparency for the terminal devices
- low network load relative to the available transmission capacity due to the tree structure created

3.1.2 Bridge parameters

In the context of Spanning Treee, each bridge and its connections are uniquely described by the following parameters:

- Bridge Identifier
- Root Path Cost for the bridge ports,
- Port Identifier

3.1.3 Bridge Identifier

The Bridge Identifier consists of 8 bytes. The 2 highest-value bytes are the priority. The default setting for the priority number is 32,768, but the Management Administrator can change this when configuring the network.
The 6 lowest-value bytes of the bridge identifier are the bridge's MAC address. The MAC address allows each bridge to have unique bridge identifiers.
The bridge with the smallest number for the bridge identifier has the highest priority.

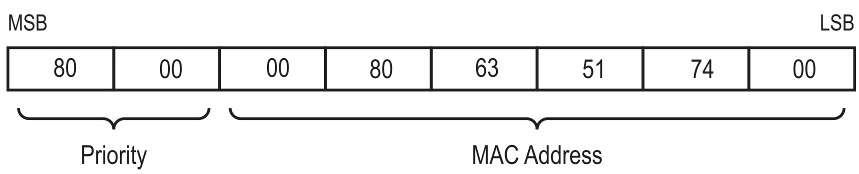


Figure 8: Bridge Identifier, Example (values in hexadecimal notation)

3.1.4 Root Path Cost

Each path that connects 2 bridges is assigned a cost for the transmission (path cost). The Switch determines this value based on the transmission speed (see table 6). It assigns a higher path cost to paths with lower transmission speeds.

Alternatively, the Administrator can set the path cost. Like the Switch, the Administrator assigns a higher path cost to paths with lower transmission speeds. However, since the Administrator can choose this value freely, he has a tool with which he can give a certain path an advantage among redundant paths.

The root path cost is the sum of all individual costs of those paths that a data packet has to traverse from a connected bridge‘s port and the root bridge.

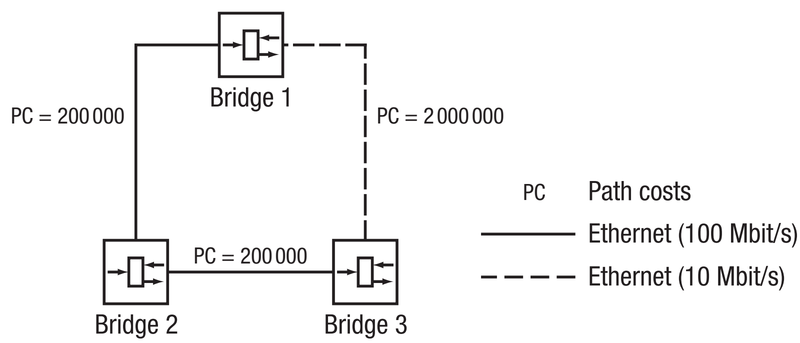


Figure 9: Path costs

Data rate	Recommended value	Recommended range	Possible range
<=100 kBit/s	200,000,000[a]	20,000,000-200,000,000	1-200,000,000
1 MBit/s	20,000,000[a]	2,000,000-200,000,000	1-200,000,000
10 MBit/s	2,000,000[a]	200,000-20,000,000	1-200,000,000
100 MBit/s	200,000[a]	20,000-2,000,000	1-200,000,000
1 GBit/s	20,000	2,000-200,000	1-200,000,000
10 GBit/s	2,000	200-20,000	1-200,000,000
100 GBit/s	200	20-2,000	1-200,000,000
1 TBit/s	20	2-200	1-200,000,000
10 TBit/s	2	1-20	1-200,000,000

Table 6: Recommended path costs for RSTP based on the data rate.

a. Bridges conforming to IEEE 802.1D-1998 that only support 16-bit values for path costs should use the value 65,535 for path costs when they are used in conjunction with bridges that support 32-bit values for the path costs.

3.1.5 Port Identifier

The port identifier consists of 2 bytes. One part, the lower-value byte, contains the physical port number. This provides a unique identifier for the port of this bridge. The second, higher-value part is the port priority, which is specified by the Administrator (default value: 128). It also applies here that the port with the smallest number for the port identifier has the highest priority.

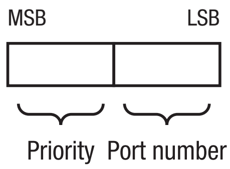


Figure 10: Port Identifier

3.2 Rules for Creating the Tree Structure

3.2.1 Bridge information

To determine the tree structure, the bridges need more detailed information about the other bridges located in the network.
To obtain this information, each bridge sends a BPDU (Bridge Protocol Data Unit) to the other bridges.

The contents of a BPDU include

- bridge identifier,
- root path cost and
- port identifier

(see IEEE 802.1D).

3.2.2 Setting up the tree structure

- The bridge with the smallest number for the bridge identifier is called the root bridge. It is (or will become) the root of the tree structure.
- The structure of the tree depends on the root path costs. Spanning Tree selects the structure so that the path costs between each individual bridge and the root bridge become as small as possible.

- If there are multiple paths with the same root path costs, the bridge further away from the root decides which port it blocks. For this purpose, it uses the bridge identifiers of the bridge closer to the root. The bridge blocks the port that leads to the bridge with the worse ID. If 2 bridges have the same priority, the ID with the larger MAC address is the worse one.
- If multiple paths with the same root path costs lead from one bridge to the same bridge, the bridge further removed from the root uses the port identifier of the other bridge as the last criterion (see fig. 10). In the process, the bridge blocks the port that leads to the port with the worse ID. If 2 ports have the same priority, the ID with the higher port number is the worse one.

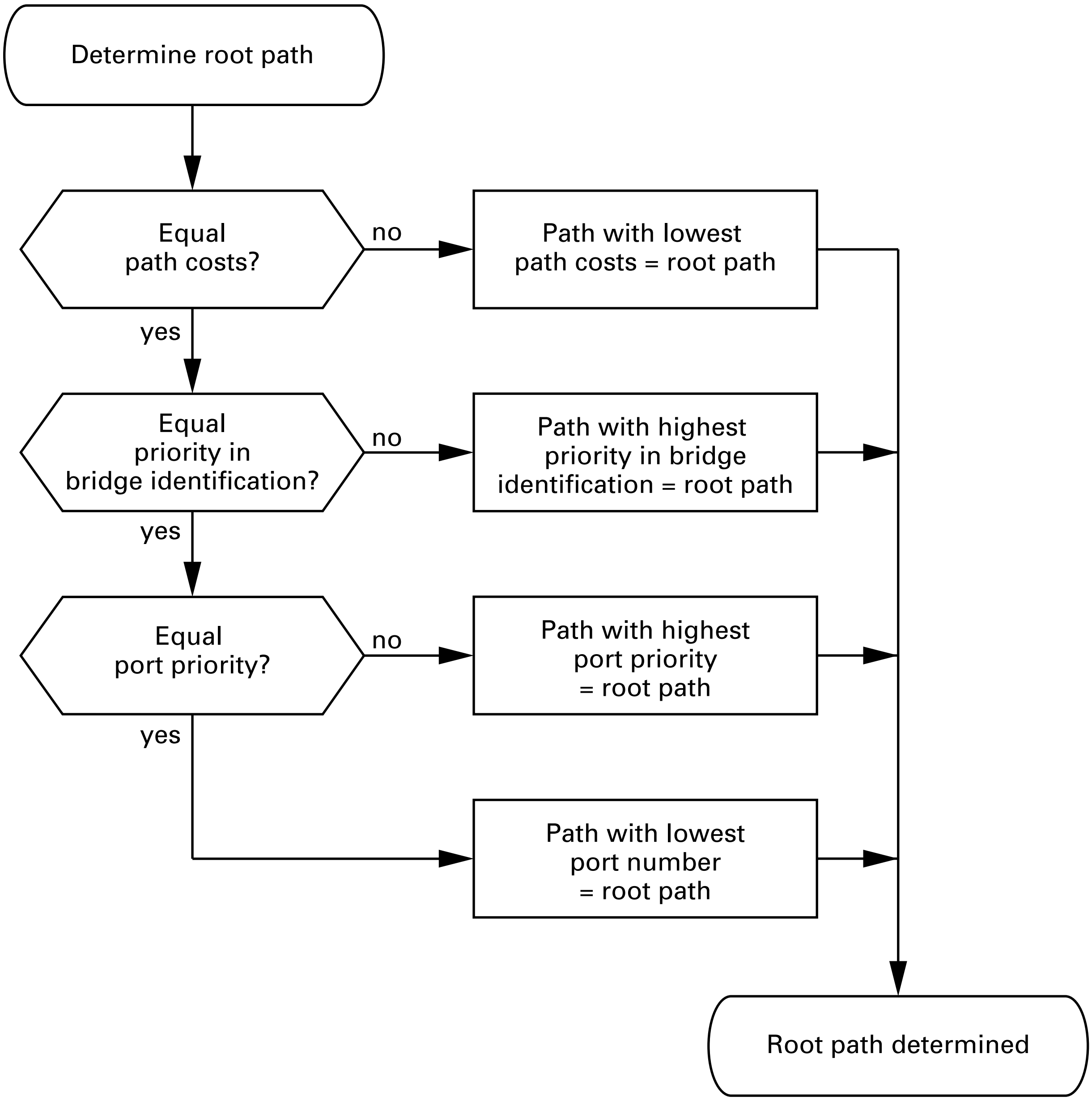


Figure 11: Flow diagram for specifying the root path

3.3 Example of Root Path Determination

The network plan (see fig. 12) can be used to create the flow diagram (see fig. 11) for defining the root path. The Administrator has defined a different priority for for each bridge's bridge identifier. The bridge with the smallest number for the bridge identifier will become the root bridge, in this case bridge 1. In the example, all the sub-paths have the same path costs. The path between bridge 2 and bridge 3 is blocked, because a connection from bridge 3 to the root bridge via bridge 2 has a higher path cost.

The path from bridge 6 to the root bridge is interesting:

- The path via bridge 5 and bridge 3 create the same root path costs as the path via bridge 4 and bridge 2.
- The path via bridge 4 is selected because the value 28,672 for its priority in the bridge identifier is smaller than value 32,768.
- However, there are also 2 paths between bridge 6 and bridge 4. The port identifier is decisive here.

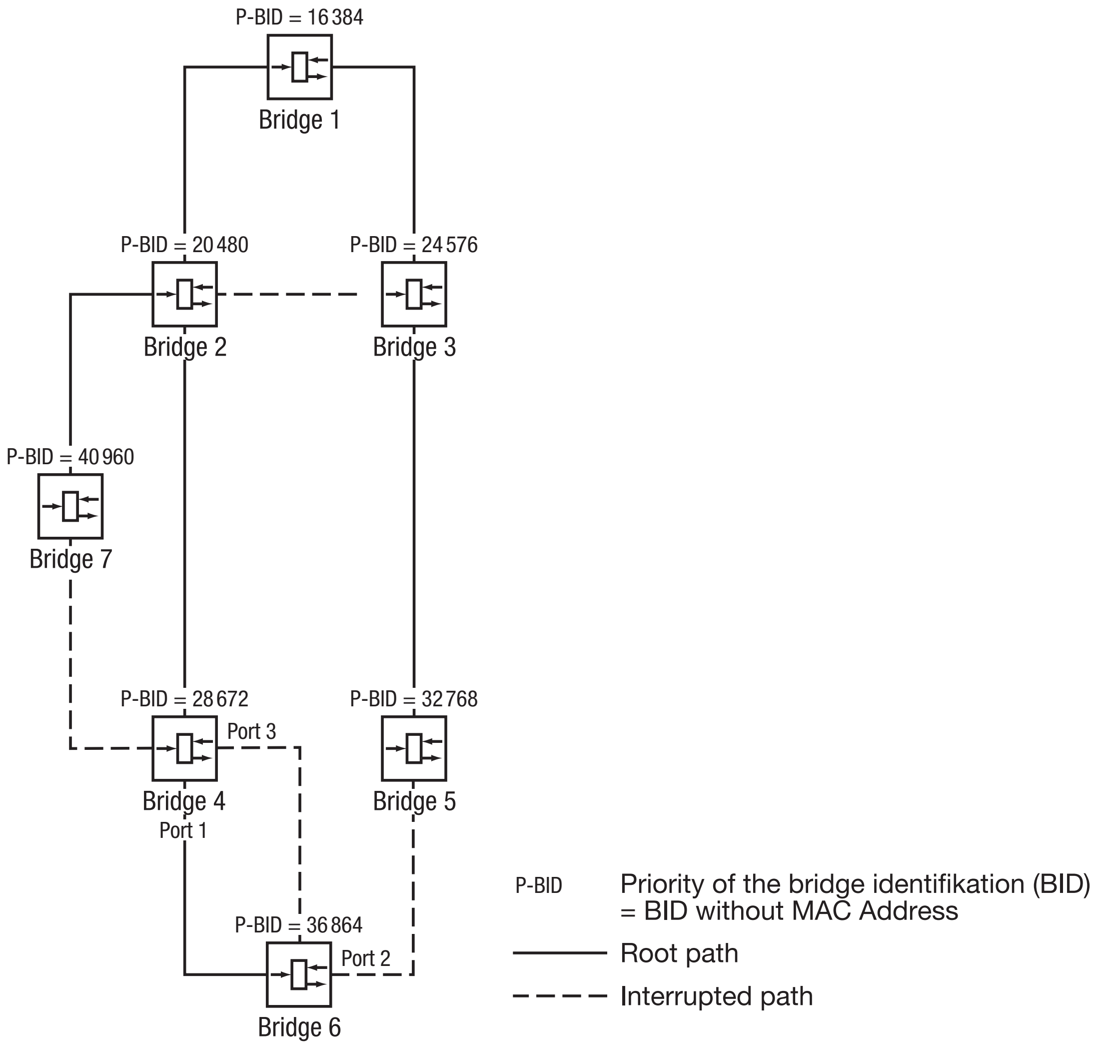


Figure 12: Example of root path determination

3.4 Example of Root Path Manipulation

The network plan (see fig. 12) can be used to create the flow diagram (see fig. 11) for defining the root path. The Administrator – left the default value of 32,768 for each bridge except for bridge 1,– bridge 1 value was set to 16,384, thus making it the root bridge. In the example, all the sub-paths have the same path costs. The path between bridge 2 and bridge 3 is blocked by the protocol because a connection from bridge 3 to the root bridge via bridge 2 has a higher path cost.

The path from bridge 6 to the root bridge is interesting:

- The path via bridge 5 and bridge 3 creates the same root path costs as the path via bridge 4 and bridge 2.
- STP selects the path using the bridge that has the lowest MAC address in the bridge identification (bridge 4 in the illustration).
- However, there are also 2 paths between bridge 6 and bridge 4. The port identifier is decisive here.

Note: Because the Administrator does not change the default values for the priorities of the bridges in the bridge identifier, apart from the value for the root bridge, the MAC address in the bridge identifier alone determines which bridge becomes the new root bridge if the root bridge becomes inoperable.

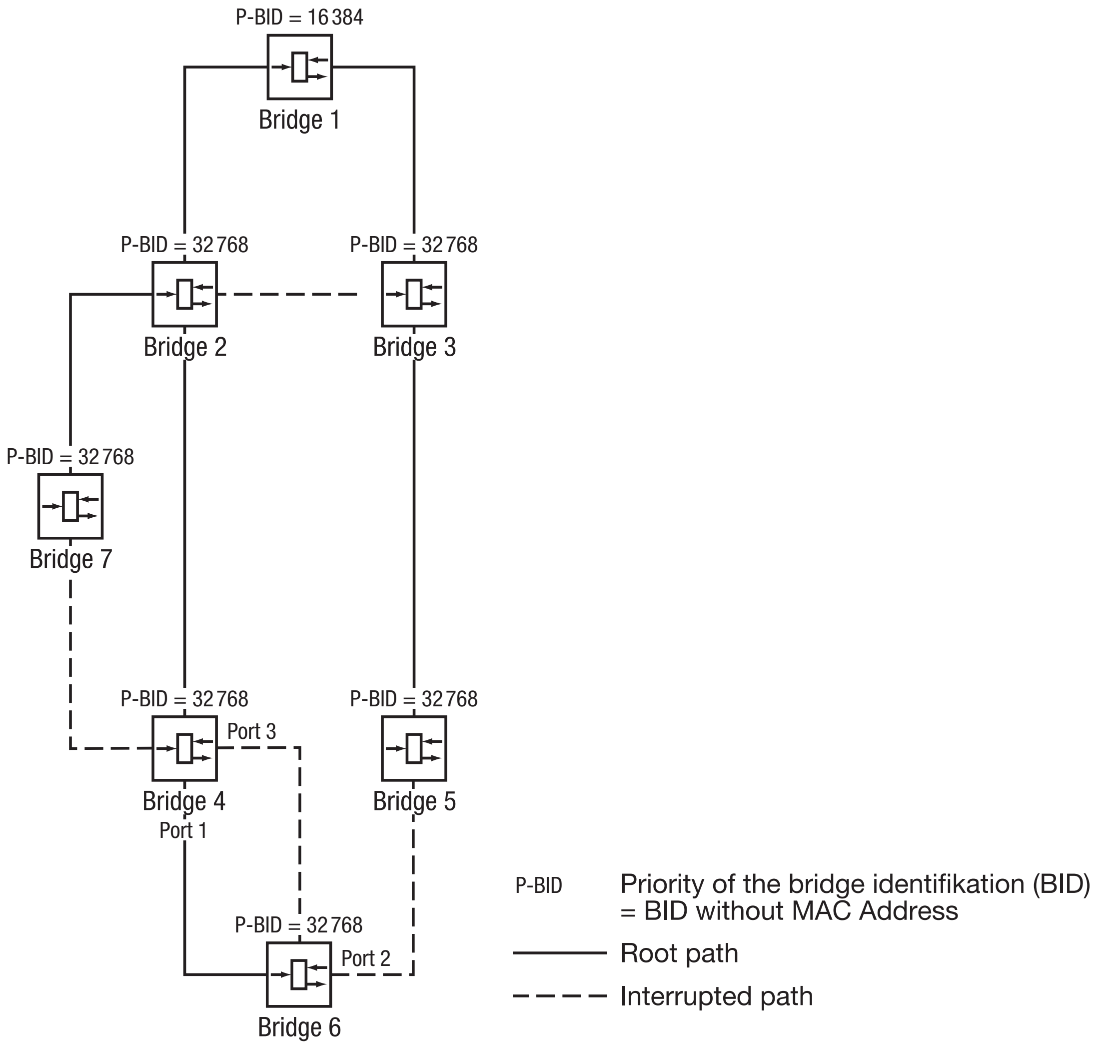


Figure 13: Example of root path manipulation

3.5 Example of Tree Structure Manipulation

The Management Administrator soon discovers that this configuration with bridge 1 as the root bridge (see page 43 „Example of Root Path Determination“) is unfavorable. On the paths from bridge 1 to bridge 2 and bridge 1 to bridge 3, the control packets which the root bridge sends to all other bridges are adding up.If the Management Administrator makes bridge 2 the root bridge, the burden of the control packets on the subnetworks is distributed much more evenly. The result is the configuration shown here (see fig. 14). The distances between the individual bridges and the root bridge are now shorter.

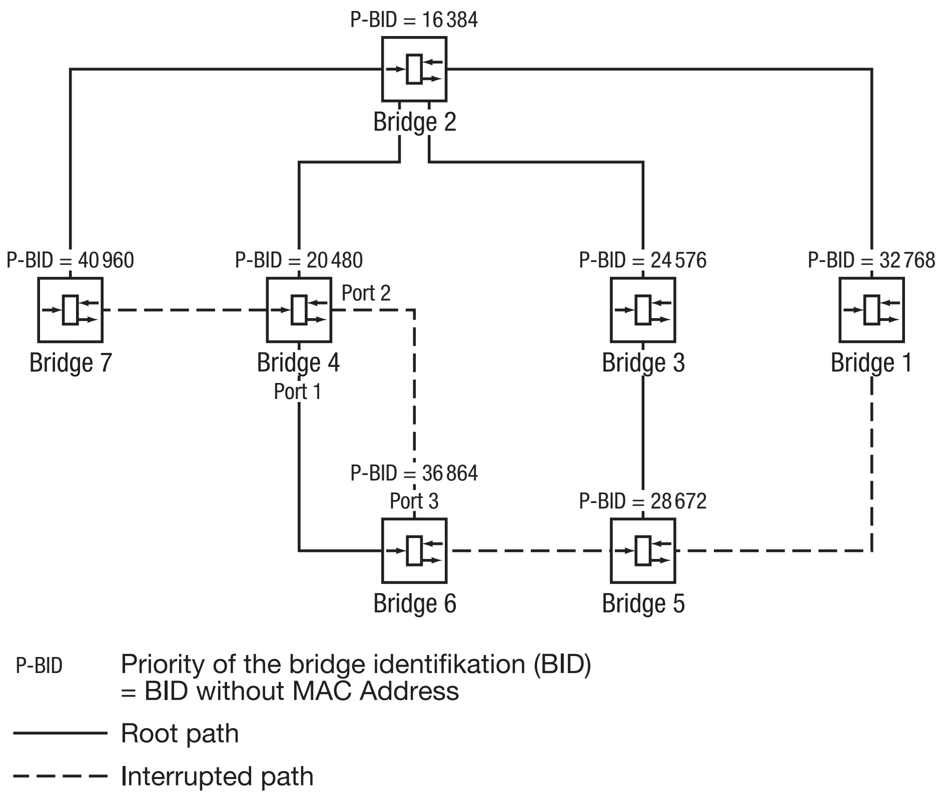


Figure 14: Example of tree structure manipulation

3.6 The Rapid Spanning Tree Protocol

The RSTP uses the same algorithm for determining the tree structure as STP. RSTP merely changes parameters, and adds new parameters and mechanisms that speed up the reconfiguration if a link or bridge becomes inoperable.
The ports play a significant role in this context.

3.6.1 Port roles

RSTP assigns each bridge port one of the following roles (see fig. 15):

- Root port
  This is the port on which a bridge receives data packets with the lowest path costs from the root bridge.
  If there is more than 1 port with the same low path costs, the bridge identifier determines which port is the root port.
  If there is more than 1 port with the same low path costs connected to the same bridge, the port identifier determines which port is the root port (see fig. 11).
  The root bridge itself does not have a root port.
- Designated port
  The bridge in a network segment that has the lowest root path costs is the designated bridge. If more than 1 bridge has the same root path costs, the bridge with the smallest value bridge identifier becomes the designated bridge. The port on this bridge that connects it to a network segment leading to the root bridge, is the designated port.

- Edge port
  Every network segment with no additional RSTP bridges is connected with exactly one designated port. In this case, this designated port is also an edge port. The distinction of an edge port is the fact that it does not receive any RST BPDUs (Rapid Spanning Tree Bridge Protocol Data Units).
- Alternate port
  This is a blocked port that takes over the task of the bridge port if the connection to the root bridge is lost. The alternate port provides a backup connection to the root bridge.
- Backup port
  This is a blocked port that serves as a backup in case the connection to the designated port of this network segment (without any RSTP bridges) is lost
- Disabled port
  This is the port that does not participate in the Spanning Tree Operation, i.e., is switched off or does not have any connection.

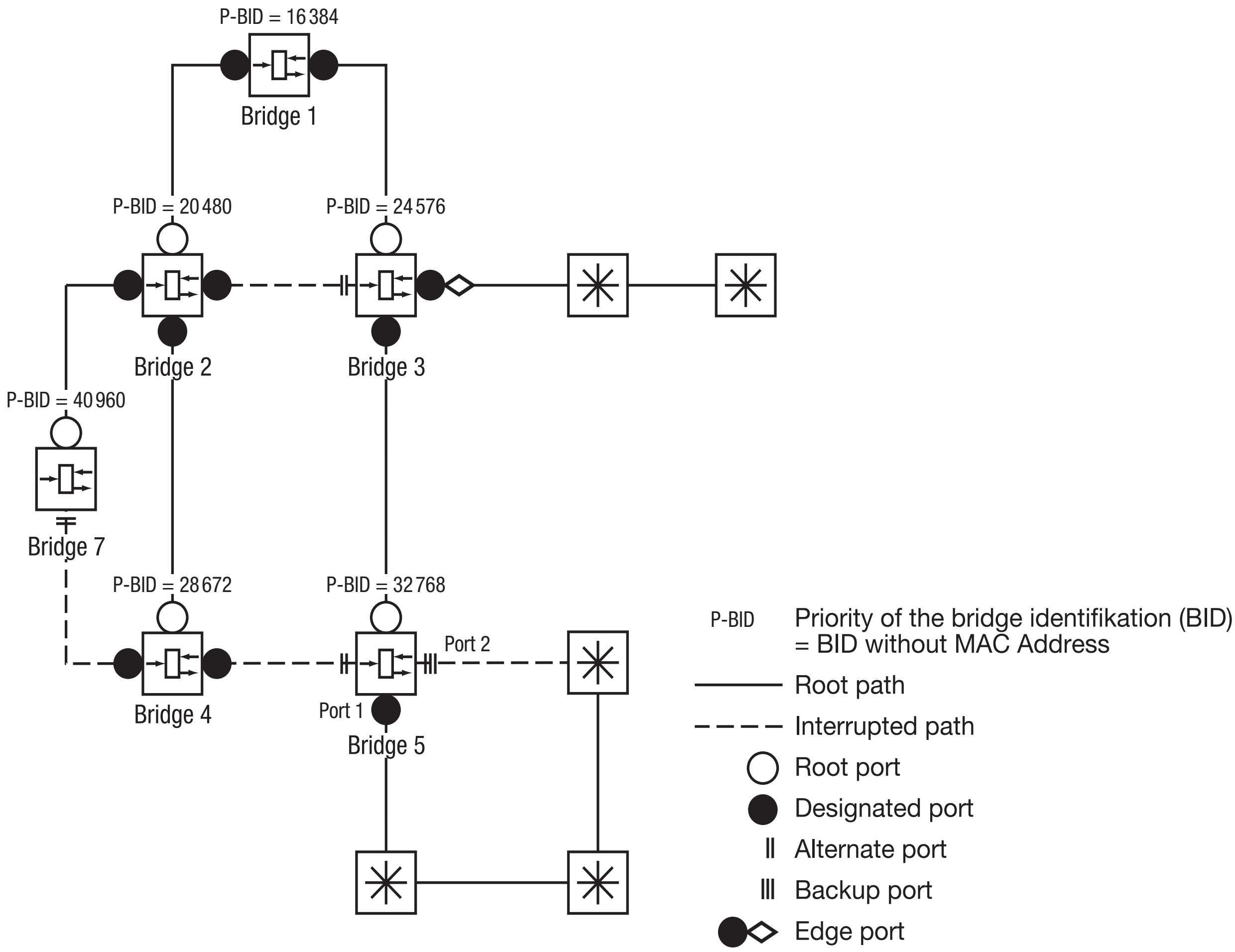


Figure 15: Port role assignment

3.6.2 Port states

Depending on the tree structure and the state of the selected connection paths, the RSTP assigns the ports their states.

STP port state	Administrative bridge port state	MAC operational	RSTP Port state	Active topology (port role)
DISABLED	Disabled	FALSE	Discarding[a]	Excluded (disabled)
DISABLED	Enabled	FALSE	Discarding[a]	Excluded (disabled)
BLOCKING	Enabled	TRUE	Discarding[b]	Excluded (alternate, backup)
LISTENING	Enabled	TRUE	Discarding[b]	Included (root, designated)
LEARNING	Enabled	TRUE	Learning	Included (root, designated)
FORWARDING	Enabled	TRUE	Forwarding	Included (root, designated)

Table 7: Relationship between port state values for STP and RSTP

a. The dot1d MIB shows “Disabled
b. The dot1d MIB shows “Blocked”

Meaning of the RSTP port states:

- Disabled: port does not belong to the active topology
- Discarding: no address learning in FDB, no data traffic except BPDUs
- Learning: address learning active (FDB), no data traffic except BPDUs
- Forwarding: address learning active (FDB), sending and receiving of all frame types (not only BPDUs)

3.6.3 Spanning Tree Priority Vector

To assign roles to the ports, the RSTP bridges exchange configuration information with each other. This information is known as the Spanning Tree Priority Vector. It is part of the RST BPDUs and contains the following information:

- Bridge identifier of the root bridge
- Root path costs for the sending bridge
- Bridge identifier for the sending bridge
- Port identifiers of the port through which the message was sent
- Port identifiers of the port that has received the message

Based on this information, the bridges participating in RSTP are able to determine port roles autonomously and define their local ports' states.

3.6.4 Fast reconfiguration

Why can RSTP react faster than STP to an interruption of the root path?

- Introduction of edge ports:
  During a reconfiguration, RSTP sets an edge port to the transmission mode after 3 seconds and then waits for the "Hello Time" (see table 8) to elapse, to ascertain that no BPDU-sending bridge is connected.
  When the user ascertains that a terminal device is connected at this port and will remain connected, he can switch off RSTP at this port. Thus no waiting times occur at this port in the case of a reconfiguration.
- Introduction of alternate ports:
  As the port roles are already determined in normal operation, a bridge can immediately switch from the root port to the alternate port after the connection to the root bridge is lost.
- Communication with neighboring bridges (point-to-point connections):
  The decentralized, direct communication between neighboring bridges enables immediate reaction to status changes in the spanning tree architecture.
- Address table:
  With STP, the age of the entries in the address table determines the updating of the communication. RSTP immediately deletes the entries for those ports affected by a reconfiguration.
- Reaction to events:
  Without having to adhere to any time specifications, RSTP immediately reacts to events such as connection interruptions, connection reinstatements, and the like.

Note: The drawback for this fast reconfiguration is the possibility that data packets may be duplicated or their sequence be altered during the reconfiguration phase. If this is unacceptable for your application, use the slower Spanning Tree Protocol or select one of the other, faster redundancy procedures described in this manual.

3.6.5 Configuring the Rapid Spanning Tree

☐ Set up the network to meet your demands.

⚠ WARNING

RSTP LOOP HAZARD

To avoid loops during the configuration phase, configure all the devices of the RSTP configuration individually. Before you connect the redundant lines, you must complete the configuration of all devices in the RSTP configuration.

Failure to follow these instructions can result in death, serious injury, or equipment damage.

☐ Select the `Redundancy:Rapid Spanning Tree:Global` dialog.

☐ Switch on RSTP on each device

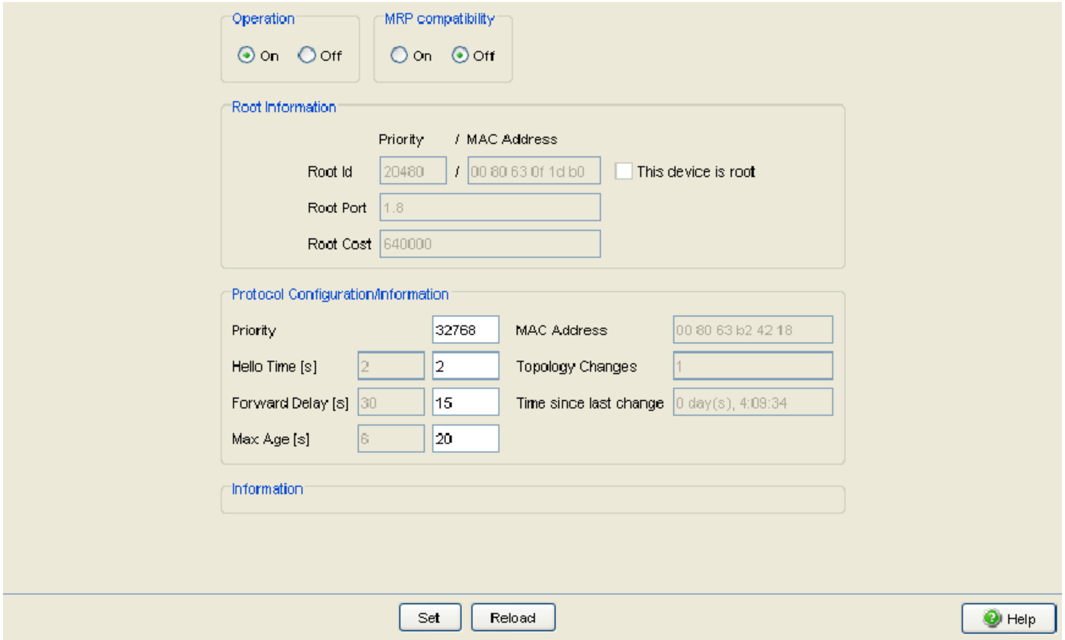


Figure 16: Operation on/off

☐ Define the desired Switch as the root bridge by assigning it the lowest priority in the bridge information among all the bridges in the network, in the “Protocol Configuration/Information” frame. Note that only multiples of 4,096 can be entered for this value (see table 8).
In the “Root Information” frame, the dialog shows this device as the root.
A root switch has no root port and a root cost of 0.

☐ If necessary, change the default priority value of 32,768 in other bridges in the network in the same way to the value you want (multiples of 4,096).
For each of these bridges, check the display
in the “Root Information” frame:
– Root-ID: Displays the root bridge’s bridge identifier
– Root Port: Displays the port leading to the root bridge
– Root Cost: Displays the root cost to the root bridge
in the “Protocol Configuration/Information” frame:
– Priority: Displays the priority in the bridge identifier for this bridge
– MAC Address: Displays the MAC address of this Switch
– Topology Changes: Displays the number of changes since the start of RSTP
– Time since last change: Displays the time that has elapsed since the last network reconfiguration

☐ If necessary, change the values for “Hello Time”, “Forward Delay” and “Max. Age” on the rootbridge. The root bridge then transfers this data to the other bridges. The dialog displays the data received from the root bridge in the left column. In the right column you enter the values which shall apply when this bridge becomes the root bridge. For the configuration, take note of table 8.

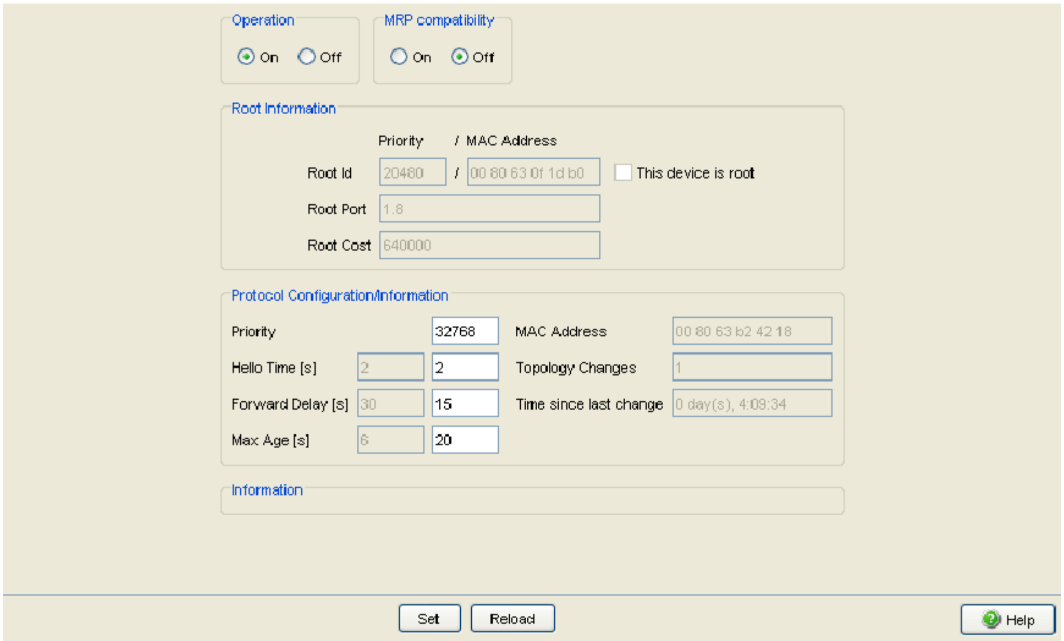


Figure 17: Assigning Hello Time, Forward Delay and Max. Age

The times entered in the RSTP dialog are in units of 1 s
Example: a Hello Time of 2 corresponds to 2 seconds.

☐ Now connect the redundant lines.

Parameter	Meaning	Possible Values	Default Setting
Priority	The priority and the MAC address go together to make up the bridge identification.	0 < n*4,096 (1000H) < 61,440 (F000H)	32,768 (8000H)
Hello Time	Sets the Hello Time. The local `Hello Time` is the time in seconds between the sending of two configuration messages (Hello packets). If the local device has the root function, the other devices in the entire network take over this value. Otherwise the local device uses the value of the root bridge in the “Root” column on the right.	1 - 2	2
Forward Delay	Sets the Forward Delay parameter. In the previous STP protocol, the Forward Delay parameter was used to delay the status change between the statuses `disabled`, `discarding`, `learning`, `forwarding`. Since the introduction of RSTP, this parameter has a subordinate role, because the RSTP bridges negotiate the status change without any specified delay. If the local device is the root, the other devices in the entire network take over this value. Otherwise the local device uses the value of the root bridge in the “Root” column on the right.	4 - 30 s See the note following this table.	15 s
Max Age	Sets the Max Age parameter. In the previous STP protocol, the Max Age parameter was used to specify the validity of STP BPDUs in seconds. For RSTP, Max Age signifies the maximum permissible branch length (number of devices to the root bridge). If the local device is the root, the other devices in the entire network take over this value. Otherwise the local device uses the value of the root bridge in the “Root” column on the right.	6 - 40 s See the note following this table.	20 s

Table 8: Global RSTP settings

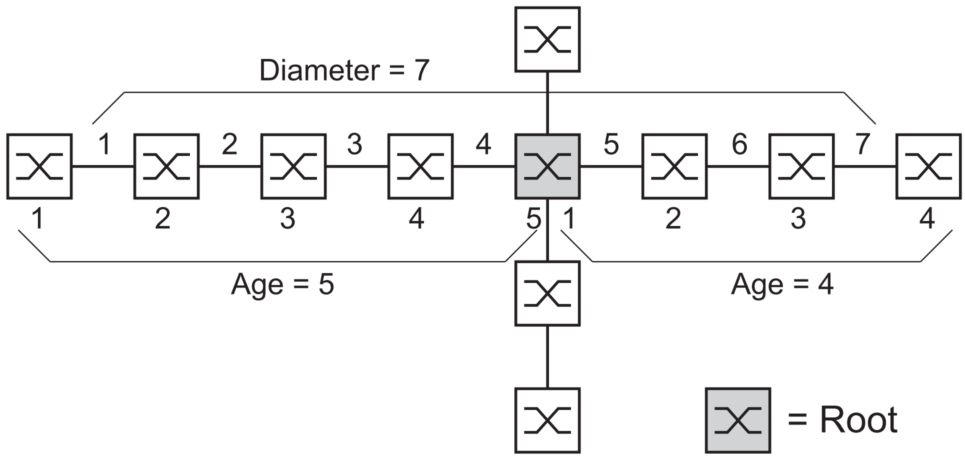


Figure 18: Definition of diameter and age

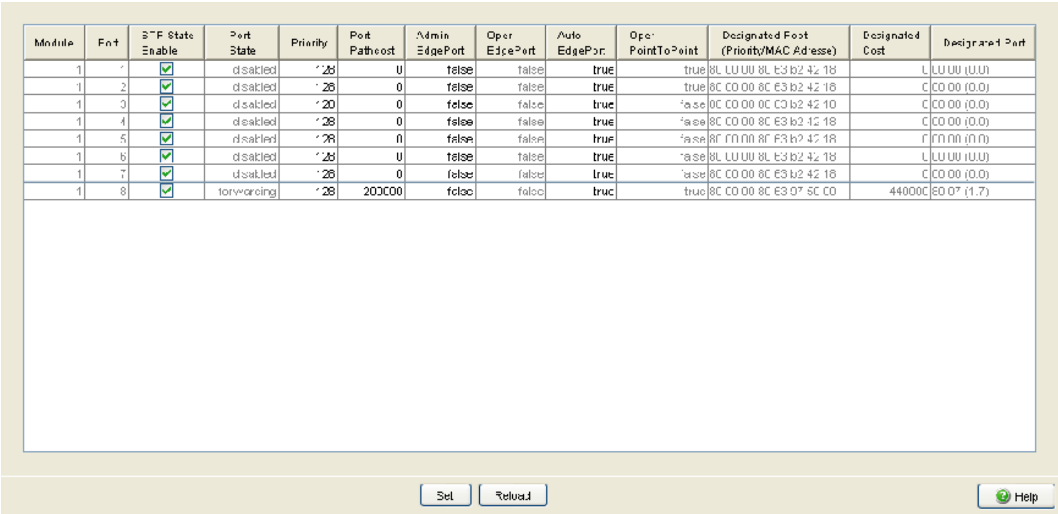
The network diameter is the number of connections between the two devices furthest away from the root bridge.

Note: The parameters
– Forward Delay and
– Max Age
have a relationship to each other:

Forward Delay ≥ (Max Age/2) + 1

If you enter values that do not conform to this relationship, the device then replaces these values with a default value or with the last valid values.

☐ When necessary, change and verify the settings and displays that relate to each individual port (dialog: `Rapid Spanning Tree:Port`).



Module	Port	STP State Enable	Port State	Priority	Port Pathcost	Admin EdgePort	Oper EdgePort	Auto EdgePort	Oper PointToPoint	Designated Root (Priority/MAC Adresse)	Designated Cost	Designated Port
1	1	☑	disabled	128	0	false	false	true	true	80 00 00 80 63 b2 42 18	0	00 00 (0.0)
1	2	☑	disabled	128	0	false	false	true	true	80 00 00 80 63 b2 42 18	0	00 00 (0.0)
1	3	☑	disabled	128	0	false	false	true	false	80 00 00 80 63 b2 42 18	0	00 00 (0.0)
1	4	☑	disabled	128	0	false	false	true	false	80 00 00 80 63 b2 42 18	0	00 00 (0.0)
1	5	☑	disabled	128	0	false	false	true	false	80 00 00 80 63 b2 42 18	0	00 00 (0.0)
1	6	☑	disabled	128	0	false	false	true	false	80 00 00 80 63 b2 42 18	0	00 00 (0.0)
1	7	☑	disabled	128	0	false	false	true	false	80 00 00 80 63 b2 42 18	0	00 00 (0.0)
1	8	☑	forwarding	128	200000	false	false	true	true	80 00 00 80 63 07 5C C0	440000	80 07 (1.7)

Figure 19: Configuring RSTP per port

Note: Deactivate the Spanning Tree Protocol on the ports connected to a redundant ring, because Spanning Tree and Ring Redundancy work with different reaction times.

Parameter	Meaning	Possible Values	Default Setting
STP State Enable	Here you can turn RSTP on or off for this port. If you turn RSTP off for this port while RSTP is globally enabled for the device, the device will discard RSTP frames received on this port.	on, off	on
Port State	Displays the RSTP-related port state	disabled, forwarding, discarding, blocking, learning	-
Priority	Here you enter the first byte of the port identification.	16 < n*16 < 240	128
Port Path Cost	Enter the path costs to indicate preference for redundant paths. If the value is 0, the Switch automatically calculates the path costs according to the transmission rate.	0 - 200,000,000	0
Admin Edge Port	If the parameter is set to "true“, the port will transition to the forwarding state. If the port nevertheless receives an RSTP frame, it will transition to the blocking state and the bridge will then determine the new port role. .If the parameter’s value is "false“, the port remains in the blocked state until the bridge has determined the port role. Only after that will the port transition to its final state.	true, false	false
Oper Edge Port	Is "true“ if no RSTP frames have been received, i. e., a terminal device that does notsend RSTP frames is connected to this port. Is "false“ if RSTP frames have been received, i. e., no terminal device but a bridge is connected.	true, false	-
Auto Edge Port	The setting for Auto Edge Port only takes effect if the parameter "Oper Edge Port“ has been set to "false“. if "Auto Edge Port“ is set to "true“, the port will transition to the forwarding state within 1.5 * Hello Time (3 seconds). If is is set to "false“, it will take 30 seconds until the edge port forwards data frames.	true, false	false

Table 9: Port-related RSTP settings and displays

Parameter	Meaning	Possible Values	Default Setting
Oper PointToPoint	If there is a full-duplex connection between two RSTP devices at this port, Oper PointToPoint is “true”; otherwise “false” is displayed (e.g. if a hub is connected). The point-to-point connection makes a direct connection between two RSTP devices. The direct, decentralized communication between the two Switches results in a fast reconfiguration time.	true, false	auto (determined from duplex mode: FDX: true HDX: false)
Designated Root	Displays the bridge identification of the designated root bridge for this port.	Bridge identification (hexadecimal)	-
Designated Cost	Display of the costs for the path from this port to the root Switch.	Cost	-
Designated Port	Display of the port identifier (on the designated Switch) of the port that connects to the root bridge - for the local port.	Port identification (hexadecimal) and port number	-

Table 9: Port-related RSTP settings and displays

3.7 Combining RSTP and MRP

In the MRP compatibility mode, the device allows you to combine RSTP with MRP.
With the combination of RSTP and MRP, the fast switching times of MRP are maintained.
The RSTP diameter (see fig. 18) depends on the “Max Age”. It applies to the devices outside the MRP-Ring.

Note: The combination of RSTP and MRP presumes that both the root bridge and the backup root bridge are located within the MRP-Ring.

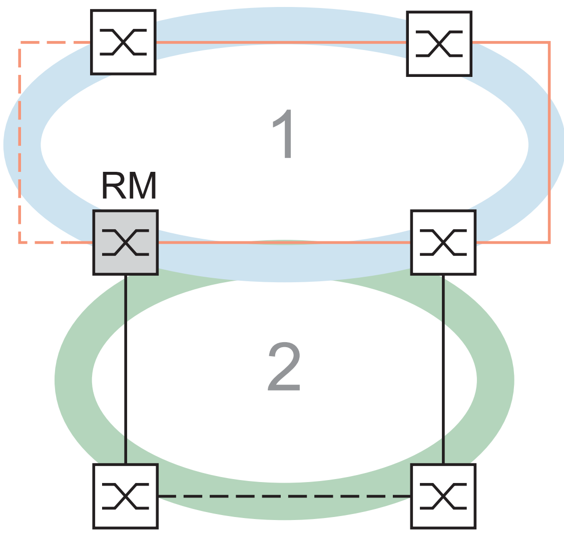


Figure 20: Combination of RSTP and MRP
1: MRP-Ring
2: RSTP-Ring
RM: Ring Manager

To combine RSTP with MRP, you perform the following steps in sequence:
- Configure MRP on each device in the MRP-Ring.
- Connect the redundant line in the MRP-Ring.

- Activate RSTP on the RSTP ports and on the MRP-Ring ports.
- Configure the RSTP root bridge and the RSTP backup root bridge in the MRP-Ring:
  - Set the priority.
  - If you exceed the RSTP diameter specified by the default value of Max Age = 20, modify “Max Age” and “Forward Delay” accordingly.
- Activate RSTP globally.
- Activate the MRP compatibility mode.
- After configuring all the participating devices, connect the redundant RSTP connection.

3.7.1 Application example for the combination of RSTP and MRP

The figure (see fig. 21) shows an example for the combination of RSTP and MRP.

Parameter	S1	S2	S3	S4	S5	S6
MRP settings						
Ring redundancy: MRP version	MRP	MRP			MRP	MRP
Ring port 1	1.2	1.1			1.1	1.1
Ring port 2	1.1	1.2			1.2	1.2
Port from MRP-Ring to the RSTP net	1.3	1.3	-	-	-	-
Redundancy Manager mode	On	Off	–	–	Off	Off
MRP operation	On	On	Off	Off	On	On
RSTP settings						
For each RSTP port: STP State Enable	On	On	On	On	On	On
Protocol Configuration: Priority (S2<S1<S3 and S2<S1<S4)	4,096	0	32,768	32,768	32.768	32.768
RSTP:Global: Operation	On	On	On	On	On	On
RSTP:Global: MRP compatibility	On	On	–	–	On	On

Table 10: Values for the switch configuration in the MRP/RSTP example

Prerequisities for further configuration:

- You have configured the MRP settings for the devices in accordance with the above table.
- The MRP-Ring’s redundant line is connected.

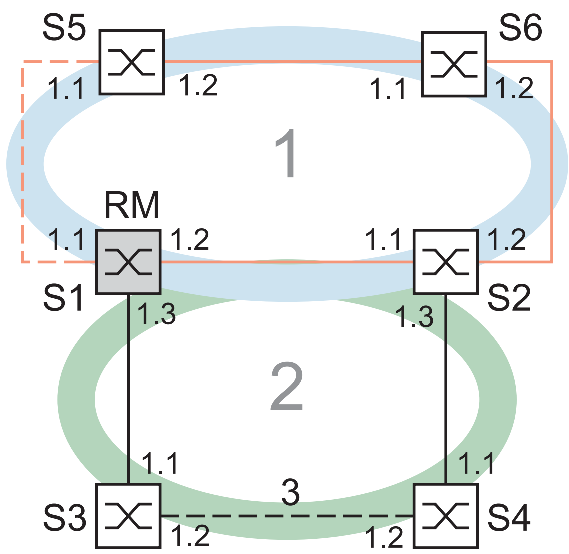


Figure 21: Application example for the combination of RSTP and MRP
1: MRP-Ring, 2: RSTP-Ring, 3: Redundant RSTP connection
RM: Ring Manager
S2 is RSTP Root Bridge
S1 is RSTP Backup Root Bridge

☐ Activate RSTP at the ports, using S1 as an example.

`enable`	Switch to the Privileged EXEC mode.
`configure`	Switch to the Configuration mode.
`interface 1/1`	Switch to the Interface Configuration mode of interface 1/1.
`spanning-tree port mode`	Activate RSTP on the port.
`exit`	Switch to the Configuration mode.
`interface 1/2`	Switch to the interface configuration mode for port 1.2.
`spanning-tree port mode`	Activate RSTP on the port.
`exit`	Switch to the Configuration mode.
`interface 1/3`	Switch to the interface configuration mode for port 1.3.
`spanning-tree port mode`	Activate RSTP on the port.
`exit`	Switch to the Configuration mode.

☐ Configure the global settings, using S1 as an example:
– the RSTP priority
– global operation
– the MRP compatibility mode

`spanning-tree mst priority 0 4096`	Set the RSTP priority for the MST instance 0 to the value 4,096. the MST instance 0 is the default instance.
`spanning-tree`	Activate RSTP operation globally.
`spanning-tree stp-mrp-mode`	Activate MRP compatibility.

☐ Configure the other switches S2 though S6 with their respective values (see table 10).

☐ Connect the redundant RSTP connection.

A Index