High-availability Seamless Redundancy

High-availability Seamless Redundancy

High-availability Seamless Redundancy overview

HSR is defined in International Standard IEC 62439-3-2016 clause 5. HSR is similar to Parallel Redundancy Protocol (PRP) but is designed to work in a ring topology. Instead of two parallel independent networks of any topology (LAN-A and LAN-B), HSR defines a ring with traffic in opposite directions. Port-A sends traffic counter clockwise in the ring, and Port-B sends traffic clockwise in the ring.

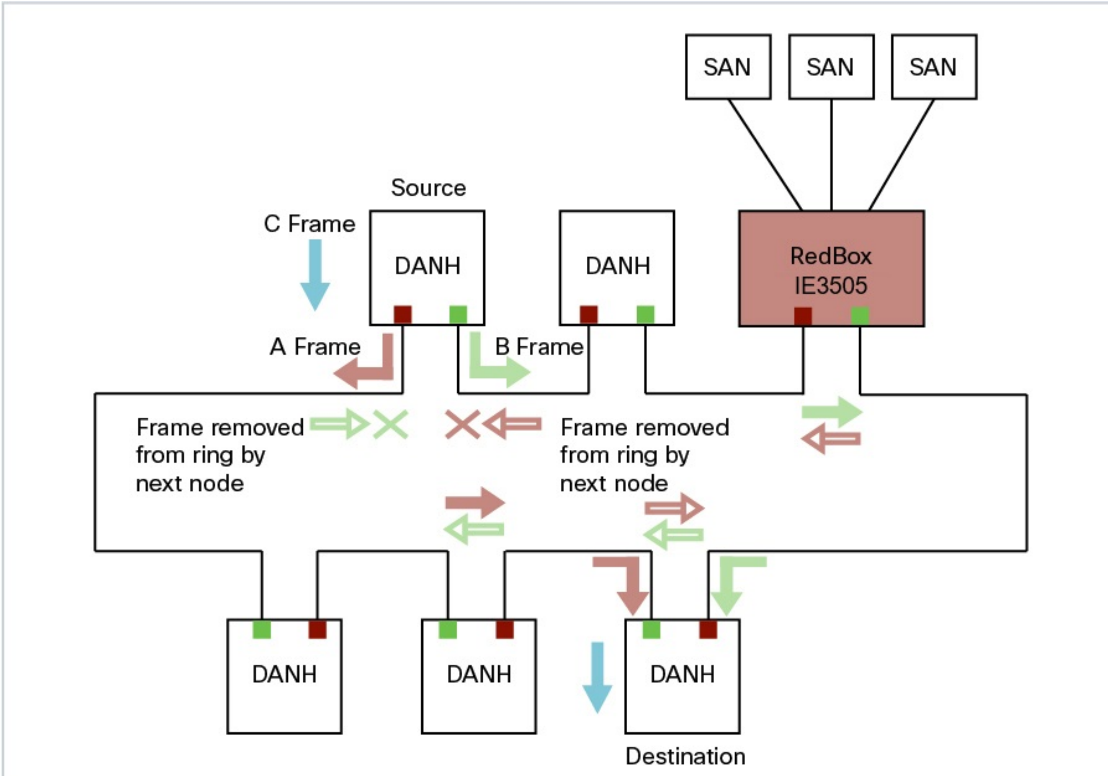
The HSR packet format is also different from PRP. To allow the switch to determine and discard duplicate packets, additional protocol specific information is sent with the data frame. For PRP, this is sent as part of a trailer called the redundancy control trailer (RCT), whereas for HSR this is sent as part of the header called the HSR header. Both the RCT and HSR header contain a sequence number, which is the primary data used to determine if the received frame is the first instance or a duplicate instance.

In this release, the switch supports only HSR-singly attached node (SAN) and only one HSR instance. If you have created a PRP instance, no HSR instance can be created.

The non-switching nodes with two interfaces attached to the HSR ring are referred to as Doubly Attached Nodes implementing HSR (DANHs). Similar to PRP, Singly Attached Nodes (SANs) are attached to the HSR ring through a device called a RedBox (Redundancy Box). The RedBox acts as a DANH for all traffic for which it is the source or the destination. The switch implements RedBox functionality using Gigabit Ethernet port connections to the HSR ring.

The following figure shows an example of an HSR ring as described in IEC 62439-3.

Figure 1: Example of HSR Ring Carrying Unicast Traffic



Devices that do not support HSR out of the box (for example, laptops and printers) cannot be attached to the HSR ring directly because all HSR capable devices must be able to process the HSR header on packets received from the ring and add the HSR header to all packets sent into the ring. These nodes are attached to the HSR ring through a RedBox. As shown in the figure above, the RedBox has two ports on the DANH side. Non-HSR SAN devices are attached to the upstream switch ports. The RedBox generates the supervision frames on behalf of these devices so that they are seen as DANH devices on the ring. Because the RedBox emulates these as DANH, they are called Virtual Doubly Attached Nodes (VDAN).

Switches that Support HSR

Table 1: The following Advanced base modules SKUs (PIDs) supports HSR.

Switch	PID
Cisco IE3505 Rugged Series Switch	IE-3505-8P3S
	IE-3505-8T3S
Cisco IE3505 Heavy-Duty Series Switch	IE-3505H-16T

Support for HSR is available on Network Essentials and Network Advantage licenses.

Supported HSR Features

IE-3505-8P3S, IE-3505-8T3S, and IE-3505H-16T switches support the following HSR features.

Maximum of one HSR ring is supported as shown in the following table:

Table 2: HSR Support for Cisco IE3505 Series Switch and Expansion Models

Switch	FPGA Profile	Number of Rings
Cisco IE3505 Rugged Series without expansion module	Default	1
	Redundancy	1
Cisco IE3505 Rugged Series with expansion module	Default	1
	Redundancy	1
IE-3505H-16T	Default	1
	Redundancy	1

Loop Avoidance

Each node in the HSR ring forwards frames received from one port to the other port of the HSR pair. To avoid loops and use network bandwidth effectively, the RedBox does not transmit frames that are already transmitted in same direction. When a node injects a packet into the ring, the packet is handled as follows to avoid loops:

- Unicast packet with destination inside the ring: When the unicast packet reaches the destination node, the packet is consumed by the respective node and is not forwarded.
- Unicast packet with destination not inside the ring: Because this packet does not have a destination node in the ring, it is forwarded by every node in the ring until it reaches the originating node. Because every node has a record of the packet it sent, along with the direction in which it was sent, the originating node detects that packet has completed the loop and drops the packet.
- Multicast packet: A multicast packet is forwarded by each node because there can be more than one consumer of this packet. For this reason a multicast packet always reaches the originating node. However, every node will check whether it has already forwarded the received packet through its outgoing interface. Once the packet reaches the originating node, the originating node determines that it already forwarded this packet and drops the packet instead of forwarding it again.

HSR RedBox Modes of Operation

The most basic mode of operation is HSR-SAN mode (single RedBox mode). In this mode, the RedBox is used to connect SAN devices to the HSR ring. The Redbox's responsibility in this mode is to represent SAN devices as VDANs on the ring.

HSR SAN Mode

In HSR-SAN mode, the RedBox inserts the HSR tag on behalf of the host and forwards the ring traffic, except for frames sent by the node itself, duplicate frames, and frames for which the node is the unique destination. In this mode, packets are handled as follows:

- A source DANH sends a frame passed from its upper layers (C frame), prefixes it with an HSR tag to identify frame duplicates, and sends the frame over each port (A frame and B frame).

- A destination DANH receives two identical frames from each port within a certain interval. The destination DANH removes the HSR tag of the first frame before passing it to its upper layers and discards any duplicate.
- Each node in the HSR ring forwards frames received from one port to the other port of the HSR pair. A node will not forward frames received on one port to the other under the following conditions:
  - The received frame returns to the originating node in the ring.
  - The frame is a unicast frame with a destination MAC address of a node upstream of the receiving node.
  - The node had already sent the same frame in the same direction. This rule prevents a frame from spinning in the ring in an infinite loop.

HSR-SAN interfaces

HSR-SAN mode is supported on interfaces GigabitEthernet 1/1-2 and GigabitEthernet 1/4-5. HSR ring 1 is configured as a pair of ports: Gi1/1 and Gi1/2 or Gi1/4 and Gi1/5.

Table 3: The supported HSR-SAN channel interfaces for IE3505 Rugged Series Switch

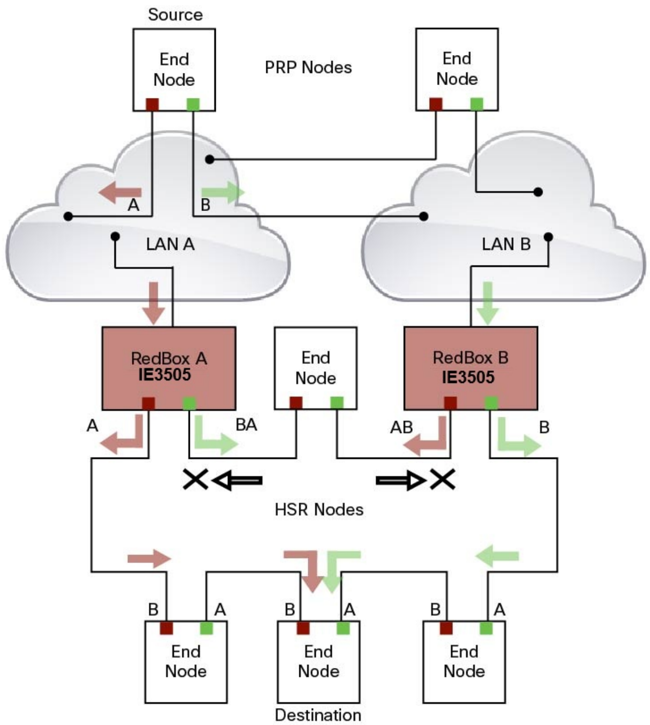
Mode	Module	Port Interface
HSR-SAN ring 1	Base Module	GigabitEthernet1/1 and 1/2 or GigabitEthernet1/4 and 1/5

HSR-PRP (Dual RedBox Mode)

HSR-PRP mode, also called Dual RedBox mode, is used to bridge HSR and PRP networks. Dual RedBox mode is supported on the Cisco IE3505 Series Switch.

In this mode, two different RedBoxes connect to LAN A and LAN B of the PRP network. Two ports connect to the HSR ring and one port connects to one of the two PRP LANs. The traffic on the upstream interlink port connecting the RedBox to the PRP network is PRP-tagged. In HSR-PRP mode, the RedBox extracts data from the PRP frame and generates the HSR frame using this data, and performs the reverse in the opposite direction. To avoid loops and use network bandwidth effectively, the RedBox does not transmit frames already transmitted in same direction (see Loop Avoidance, on page 3).

The following figure shows an HSR ring connected to a PRP network through two RedBoxes, one for each LAN. In this example, the source frame originates in the PRP network. RedBoxes are configured to support PRP traffic on the interlink ports and HSR traffic on the ring ports. Nodes connected to the HSR-PRP Redbox act as a SAN to the PRP Redbox and a VDAN to the HSR-PRP Dual Redbox.

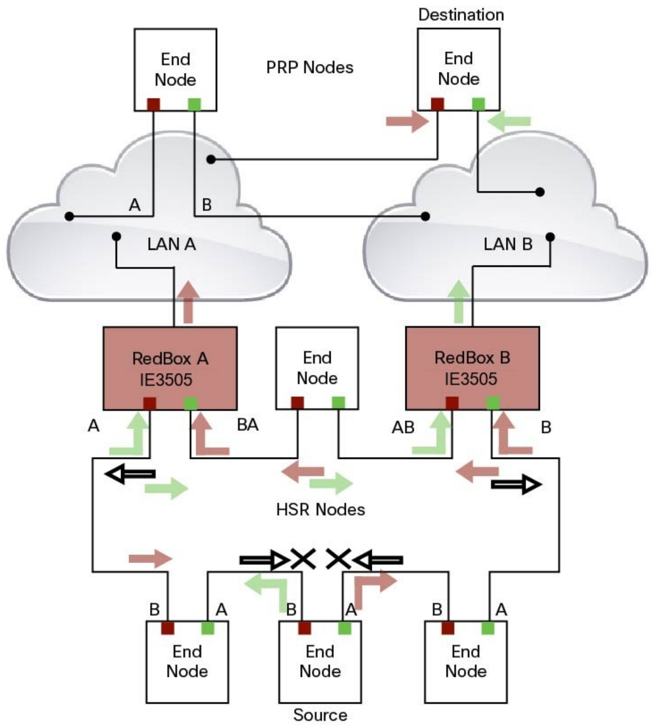


The sequence number from the PRP RCT is reused for the HSR tag and vice versa to allow frame identification from one redundancy network to the other and to identify the pairs and duplicates on either network. In the figure above, RedBox A and RedBox B send the same frame (A and AB and B and BA, respectively), but a RedBox does not transmit a frame that it already received.

Every DANH device generates its own sequence number, which is incremented for each outgoing frame. When a packet is switched from HSR to PRP or PRP to HSR, the sequence number is taken from the incoming packet so the same sequence number is used. Any node, whether it is an intermediate or final destination in the HSR or PRP network, uses the source MAC address and sequence number as the key for duplicate packet detection. Because the source address is expected to be unique for each node, there are no overlapping sequence numbers between different nodes.

Multicast frames or unicast frames without a receiver in the ring (arrows with the black outline in the figure) are removed by the RedBox that inserted them into the ring, if they originated from outside the ring. For this purpose, the frames carry a LAN identifier that is also the RedBox identifier.

The following figure shows an HSR ring coupled to a PRP network, where the source frame originates in the HSR ring.



To prevent frames from being reinjected into the PRP network through the other RedBox, each HSR frame carries the 4-bit PathId, which identifies the PRP network from which the frame came originally. RedBoxes are configured and identified by the PathId of the PRP LAN to which they are attached.

Different PathIds can be used to bridge more than one PRP network to an HSR ring. Likewise, more than one HSR ring can be bridged to a PRP network.

PRP is not needed for HSR-PRP to function in the IE3500 Rugged Series Switches. Any third port can be connected to PRP LAN A or LAN B network without PRP or any specific configurations.

PRP Supervision frames are sent toward PRP LAN A or LAN B from conversion of HSR Supervision Frames originated from DANHs and VDANs of HSR RedBoxes in the HSR ring. The HSR-PRP Redbox does not generate them but passes them along.

Packet flow in HSR-PRP

Packets coming from PRP network in the coupled PRP LAN-A or LAN-B are expected to have an RCT (Redundancy Control Trailer) tag. The switch removes the RCT and transfers the information to the HSR header using the programmed Net ID and LAN ID, recalculates the CRC, and sends the modified packet out to both ring A and ring B. If the packets originate from a SAN in the coupled PRP network, the switch treats it similarly as a VDAN to the HSR ring.

Egress Data Path—Packets coming from a SAN or PRP LAN A or LAN B to the HSR ring:

- For PRP packets, the switch converts the PRP RCT to an HSR tag for all packets (transfers Sequence Number and LAN ID from PRP to HSR).
- For SAN packets, the switch just inserts the HSR tag as is done in HSR-SAN RedBox mode.

- The switch needs to learn the MAC source address and add it to the Proxy Node table (VDAN table) with a new additional bit that allows the switch to distinguish between DANP or SAN. This allows the ingress path to determine whether to include the RCT trailer or not.

Ingress Data Path—Packets coming from the HSR ring to a SAN or PRP LAN A or LAN B:

- If the Proxy Node table or VDAN table lookup of the MAC destination address returns DANP, the switch converts the HSR tag to PRP RCT for accepted packets (transfers Sequence Number and LAN ID from HSR to PRP RCT).
- If the Proxy Node table or VDAN table lookup of the MAC destination address returns SAN, the switch strips the HSR tag and sends the packet without the RCT.

HSR-PRP Interfaces

In HSR-PRP Dual RedBox mode, two ports are connected to the HSR ring, and one port is connected to the PRP LAN A or LAN B network. The two ports that connect to the HSR ring are fixed (Gi1/1 and Gi1/2). When set to HSR-PRP mode, the two ports that connect to the HSR ring (Gi1/1 and Gi1/2) are automatically configured to HSR.

Table 4: The supported HSR-PRP channel interfaces for IE3505 Rugged Series Switch

Mode	Module	Port Interface
HSR-PRP	Base Module	GigabitEthernet1/1 and 1/2

The port connected to PRP LAN A or LAN B can be any other port from the base module or expansion module. All remaining ports of the HSR-PRP RedBox (base module or expansion module ports) can be used for any other purpose, for example, to connect a DHCP server.

These ports act as non-HSR/PRP nodes (SANs/VDANs) in the topology. The HSR-PRP RedBox can use all remaining ports (base module or expansion module ports) for other purposes, such as connecting a DHCP server. These non-PRP and non-HSR ports must be in the same VLAN as the HSR and PRP ports to achieve SAN/VDAN behavior.

Connecting Multiple PRP Networks to an HSR Ring

A maximum of six PRP networks, identified by the PathId, can be connected to the same HSR ring. The 4-bit PathId consists of the following:

- The 3-bit NetId (1 to 6), which identifies a PRP network and the two RedBoxes that connect the PRP network to an HSR ring.
- The 1-bit LanId (LAN A = 0 and LAN B = 1)

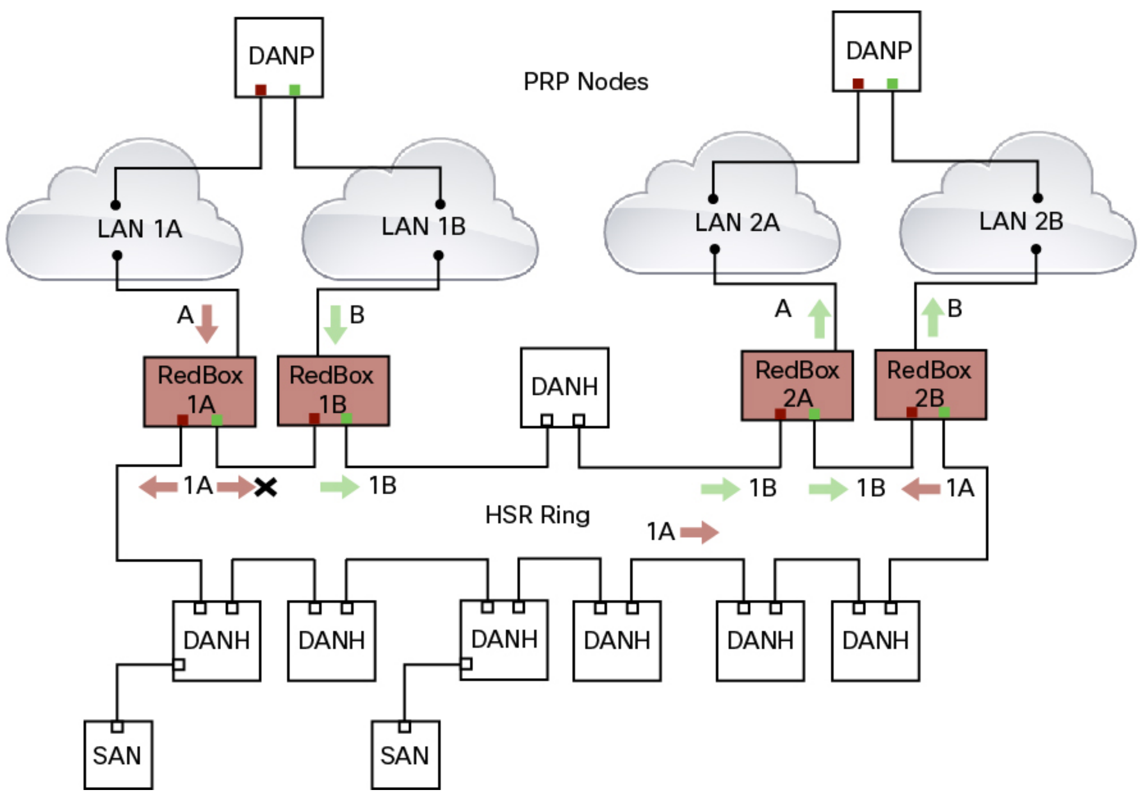
NetId values are as follows:

- 0 for regular HSR frames
- 1 to 6 for frames originating from a PRP network
- 7 is reserved

The following table lists the combinations of NetIds and LanIds for Redbox-A and Redbox-B.

PathId		
NetId	**LanId**	
	RedBox-A	**RedBox-B**
001	0	1
010	0	1
011	0	1
100	0	1
101	0	1
110	0	1
000	**Used for Local HSR Ring**	
111	**Reserved**	

The following figure shows an example of an HSR ring connected to two PRP networks.



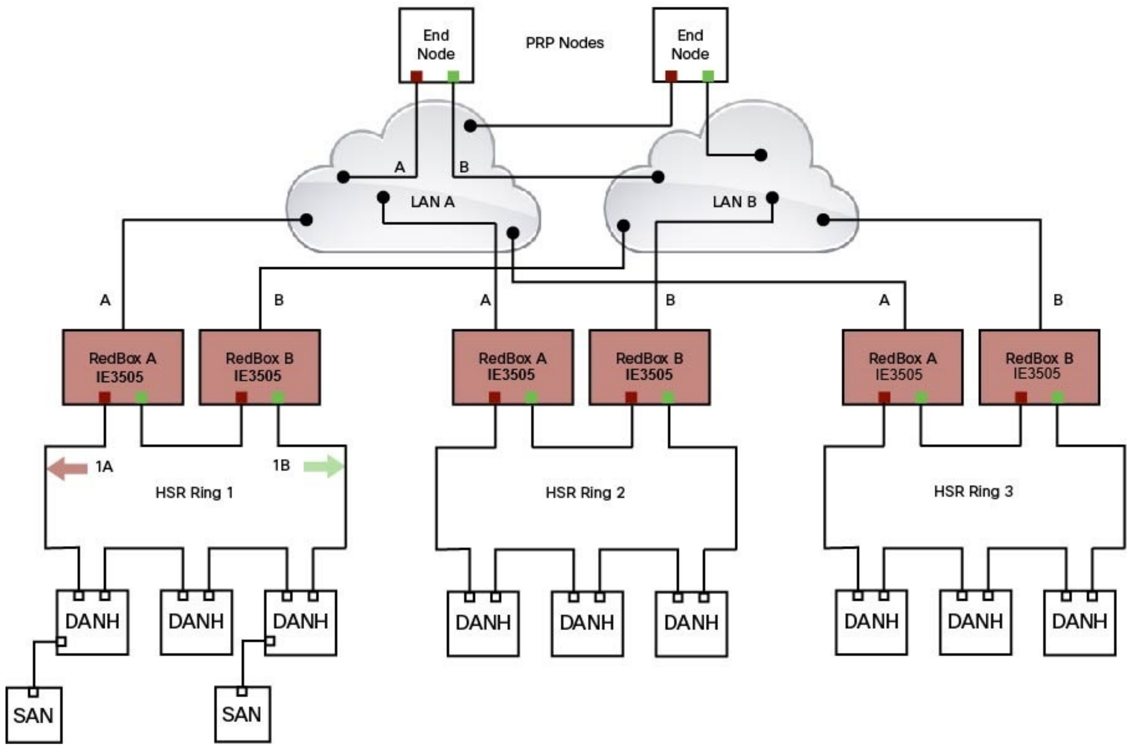
To prevent reinjection of frames coming from one PRP network into another PRP network or from the other LAN of the same PRP network, a RedBox only forwards frames that do not carry its own PathId from the HSR ring.

When a PRP frame from LAN A or from LAN B of a PRP network with a given NetId is inserted to the HSR ring, a RedBox inserts its own NetId and the LanId “A” or ”B” into the PathId of the HSR tag.

When forwarding a frame from the HSR ring to a PRP network, the RedBox inserts the LanId “A” or ”B” into the RCT.

Connecting Multiple HSR Rings to a PRP Network

A PRP network can be connected to any number of HSR rings, but these rings cannot be connected to each other because this would create loops. The following figure shows an example of three HSR rings connected to one PRP LAN.



CDP and LLDP for HSR

HSR supports the Cisco Discovery Protocol (CDP) and Link Layer Discovery Protocol (LLDP). CDP and LLDP are Layer 2 neighbor discovery protocols. Both CDP and LLDP can provide information about nodes directly connected to the device. They also provide additional information such as the local and remote interface and device names.

When CDP or LLDP is enabled, you can use the CDP or LLDP information to find the adjacent nodes on an HSR ring and their status. You can then use the neighbor information from each node to determine the complete HSR network topology and debug and locate ring faults.

CDP and LLDP are configured on physical interfaces only.

For more information, see Configuring an HSR Ring and Verifying Configuration.

PTP over HSR

Precision Time Protocol (PTP) is supported on the IE3500 Rugged and IE3500H Heavy Duty Series Switches for the PTP Power Profile only.

Because the PTP 1588 standard does not currently account for clocks synchronized over redundant, simultaneously active paths, HSR must handle PTP packets differently that other packet types. To provide high availability for PTP through redundancy, the HSR duplicate/discard logic is not used for PTP packets.

To understand how PTP clock syncronization works in an HSR network, suppose that a VDAN/SAN is the PTP grandmaster clock (GMC). Dually attached devices receive PTP synchronization information over both their HSR ports. However, only one of the ports (referred to as time recipient) is used to synchronize the local clock. The other HSR port (referred to as PASSIVE) continues to receive synchronization information, but is not used to synchronize the local clock. Suppose that RedBox 2 has its port-A as time recipient and port-B as PASSIVE. When port-A goes down, the port-B port takes over as the time recipient and is used to continue synchronizing the local clock on RedBox 2.

Note Cisco is moving from the traditional Master/Slave nomenclature. In this document, the terms *Grandmaster clock (GMC)* or *time source* and *time recipient* are used instead.

The PTP grandmaster in an HSR network can be a RedBox, a VDAN/SAN, or a DANH.

To use PTP over HSR, configure HSR and PTP separately. PTP over HSR works without any additional configuration. Note that in most cases, you do not need to perform any PTP configuration on the interfaces because PTP is enabled by default on all physical ethernet interfaces.

Supported PTP Profiles and Modes

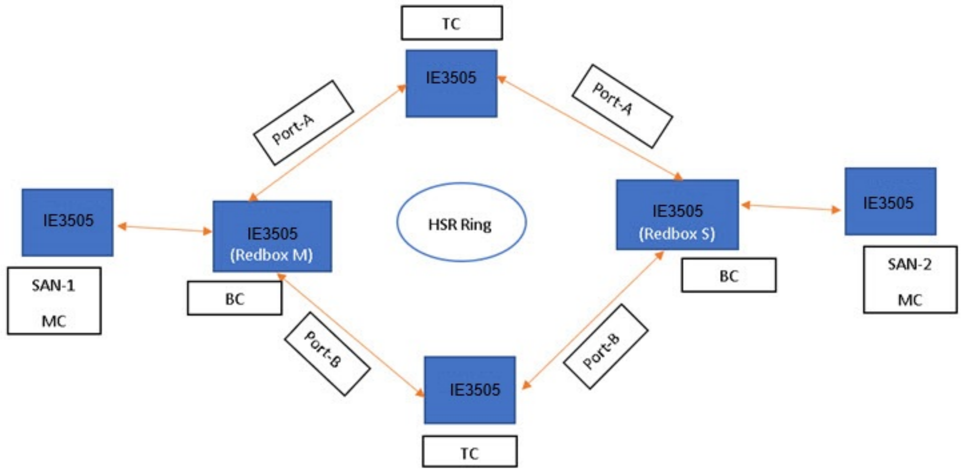
PTP over HSR is supported only for the for the PTP Power Profile. For unsupported PTP profiles, PTP traffic flows over HSR port-A only.

The following table shows the HSR support for PTP profiles, clock modes and RedBox types.

PTP Profile	Clock Mode	Supported?	HSR Redbox Type as per IEC 62439-3
Power Profile	BC	Yes	HSR RedBox as doubly attached BC (DABC) with P2P
	P2P TC	Yes	HSR RedBox as doubly attached TC (DATC) with P2P
	GMC-BC	No	Not applicable
	Forward	No	Not applicable
Default Profile	BC	No	Not applicable
	E2E TC	No	Not applicable

HSR RedBox as Doubly Attached BC (DABC) with P2P

This section describes the operation of PTP over HSR using an example where RedBox M and RedBox S are configured to run in Power Profile as Boundary Clocks that use the Peer-to-Peer delay measurement mechanism.



Assume for this example that SAN-1 is the GMC. All the clocks are configured to run Peer-to-Peer Delay measurement and the peer delay is regularly calculated and maintained on every link shown in the figure. The BMCA on RedBox M determines the port to SAN-1 to be connected to the time source. The PTP protocol running on RedBox M will forward Sync and Follow_up messages on ports A and B.

On RedBox S, the regular BMCA operation determines port A to be time recipient and port B to be PASSIVE. However, with the knowledge that ports A and B are part of the same HSR ring, port B is forced into PASSIVE_SLAVE state and port A becomes active for PTP.

Port A works as a regular time recipient port. It uses the Sync and Follow_Up messages along with their correction field to calculate the delay and offset from time source and synchronize the local clock. (Unlike an E2E BC, it does not need to generate Delay_Req messages since all the link delays and residence times along the PTP path are accumulated in the correction field of the Follow_Up messages.)

Port B, which is in PASSIVE_SLAVE state operates as follows: Just like port A, it maintains the delay and offset from time source, but does not perform any operation on the local clock. Having all the synchronization information available enables it to seamlessly take over as the new time recipient in case port A loses communication with the GMC. Note that on IE switch platforms we currently do not support PTP profile conversion. For example, if RedBox S in the figure above were an IE switch, it would not support the Delay_Req/Delay_Resp message exchange. It would only support the Peer-to-Peer delay measurement mechanism using PDelay messages.

Configuration Example

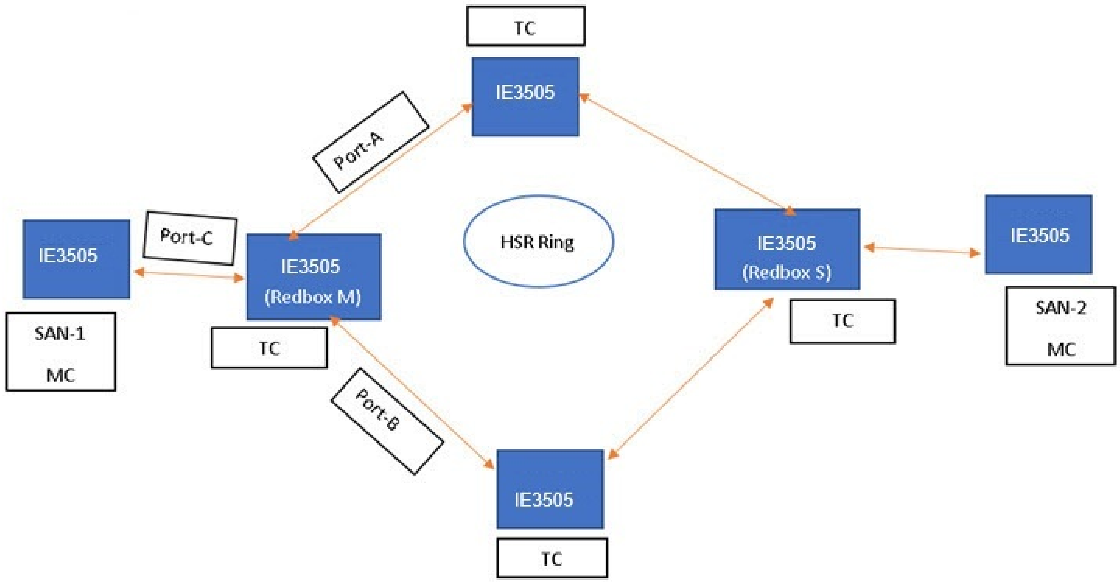
```
SAN-1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
SAN-1(config)#ptp profile power
SAN-1(config)#ptp mode boundary pdelay-req
SAN-1(config)#ptp priority1 1
SAN-1(config)#end

SAN-2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
SAN-2(config)#ptp profile power
SAN-2(config)#ptp mode boundary pdelay-req
```

```
SAN-2(config)#end

REDBOX-M#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
REDBOX-M(config)#ptp profile power
REDBOX-M(config)#ptp mode boundary pdelay-req
REDBOX-M(config)#end

REDBOX-S#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
REDBOX-S(config)#ptp profile power
REDBOX-S(config)#ptp mode boundary pdelay-req
REDBOX-S(config)#end

DANH-TOP#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
DANH-TOP(config)#ptp profile power
DANH-TOP(config)#ptp mode p2ptransparent
DANH-TOP(config)#end

DANH-BOTTOM#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
DANH-BOTTOM(config)#ptp profile power
DANH-BOTTOM(config)#ptp mode p2ptransparent
DANH-BOTTOM(config)#end

SAN-1#sh ptp parent
 PTP PARENT PROPERTIES
  Parent Clock:
  Parent Clock Identity: 0x0:35:1A:FF:FE:94:4F:0
  Parent Port Number: 0
  Observed Parent Offset (log variance): N/A
  Observed Parent Clock Phase Change Rate: N/A

  Grandmaster Clock:
  Grandmaster Clock Identity: 0x0:35:1A:FF:FE:94:4F:0
  Grandmaster Clock Quality:
 Class: 248
 Accuracy: Unknown
 Offset (log variance): N/A
 Priority1: 1
 Priority2: 128

SAN-2#sh ptp parent
 PTP PARENT PROPERTIES
  Parent Clock:
  Parent Clock Identity: 0x0:29:C2:FF:FE:3C:6A:C0
  Parent Port Number: 9
  Observed Parent Offset (log variance): N/A
  Observed Parent Clock Phase Change Rate: N/A

  Grandmaster Clock:
  Grandmaster Clock Identity: 0x0:35:1A:FF:FE:94:4F:0
  Grandmaster Clock Quality:
 Class: 248
 Accuracy: Unknown
 Offset (log variance): N/A
 Priority1: 1
 Priority2: 128

REDBOX-M#sh ptp parent
 PTP PARENT PROPERTIES
  Parent Clock:
  Parent Clock Identity: 0x0:35:1A:FF:FE:94:4F:0
```

```
  Parent Port Number: 3
  Observed Parent Offset (log variance): N/A
  Observed Parent Clock Phase Change Rate: N/A

  Grandmaster Clock:
  Grandmaster Clock Identity: 0x0:35:1A:FF:FE:94:4F:0
  Grandmaster Clock Quality:
 Class: 248
 Accuracy: Unknown
 Offset (log variance): N/A
 Priority1: 1
 Priority2: 128

REDBOX-S#sh ptp parent
 PTP PARENT PROPERTIES
  Parent Clock:
  Parent Clock Identity: 0x0:29:C2:FF:FE:3C:5D:80
  Parent Port Number: 3
  Observed Parent Offset (log variance): N/A
  Observed Parent Clock Phase Change Rate: N/A

  Grandmaster Clock:
  Grandmaster Clock Identity: 0x0:35:1A:FF:FE:94:4F:0
  Grandmaster Clock Quality:
 Class: 248
 Accuracy: Unknown
 Offset (log variance): N/A
 Priority1: 1
 Priority2: 128

DANH-TOP#sh ptp parent
 PTP PARENT PROPERTIES
  Parent Clock:
  Parent Clock Identity: 0x0:29:C2:FF:FE:3C:5D:80
  Parent Port Number: 3
  Observed Parent Offset (log variance): N/A
  Observed Parent Clock Phase Change Rate: N/A

  Grandmaster Clock:
  Grandmaster Clock Identity: 0x0:35:1A:FF:FE:94:4F:0
  Grandmaster Clock Quality:
 Class: 248
 Accuracy: Unknown
 Offset (log variance): N/A
 Priority1: 1
 Priority2: 128

DANH-BOTTOM#sh ptp parent
 PTP PARENT PROPERTIES
  Parent Clock:
  Parent Clock Identity: 0x0:29:C2:FF:FE:3C:5D:80
  Parent Port Number: 4
  Observed Parent Offset (log variance): N/A
  Observed Parent Clock Phase Change Rate: N/A

  Grandmaster Clock:
  Grandmaster Clock Identity: 0x0:35:1A:FF:FE:94:4F:0
  Grandmaster Clock Quality:
 Class: 248
 Accuracy: Unknown
 Offset (log variance): N/A
 Priority1: 1
 Priority2: 128
```

HSR RedBox as Doubly Attached TC (DATC) with P2P

This section describes the operation of PTP over HSR using an example where RedBox M and RedBox S are configured to run in Power Profile as Transparent Clocks.



Assume for this example that SAN-1 is the GMC. All the clocks are configured to run Peer-to-Peer Delay measurement and the peer delay is regularly calculated and maintained on every link shown in the figure. RedBox M and RedBox S run BMCA even though it is not mandatory for a P2P TC to run BMCA. On RedBox M, the BMCA on redbox M determines the port to SAN-1 to be connected to the time source. RedBox M forwards all Sync and Follow_Up messages received on port C out of ports A and B.

On RedBox S, port A is determined to be time recipient and port B to be PASSIVE_SLAVE as described earlier.

Port A operates as follows: It uses the Sync and Follow_Up messages along with their correction field to calculate the delay and offset from time source and synchronize the local clock. (Unlike a E2E BC, it does not need to generate Delay_Req messages since all the link delays and residence times along the PTP path are accumulated in the correction field of the Follow_Up messages.) It also forwards the Sync and Follow_Up messages out of port C.

Port B operates as follows: Just like port A, it maintains the delay and offset from time source, but does not perform any operation on the local clock. Having all the synchronization information available enables it to seamlessly take over as the new time recipient in case port A loses communication with the GMC. Post-processing, it drops the Sync/Follow_Up messages since the copy of Sync/Follow_Up that arrives on port A is forwarded out of port C.

Configuration Example

```
SAN-1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
SAN-1(config)#ptp profile power
SAN-1(config)#ptp mode boundary pdelay-req
SAN-1(config)#ptp priority1 1
SAN-1(config)#end
SAN-2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
```

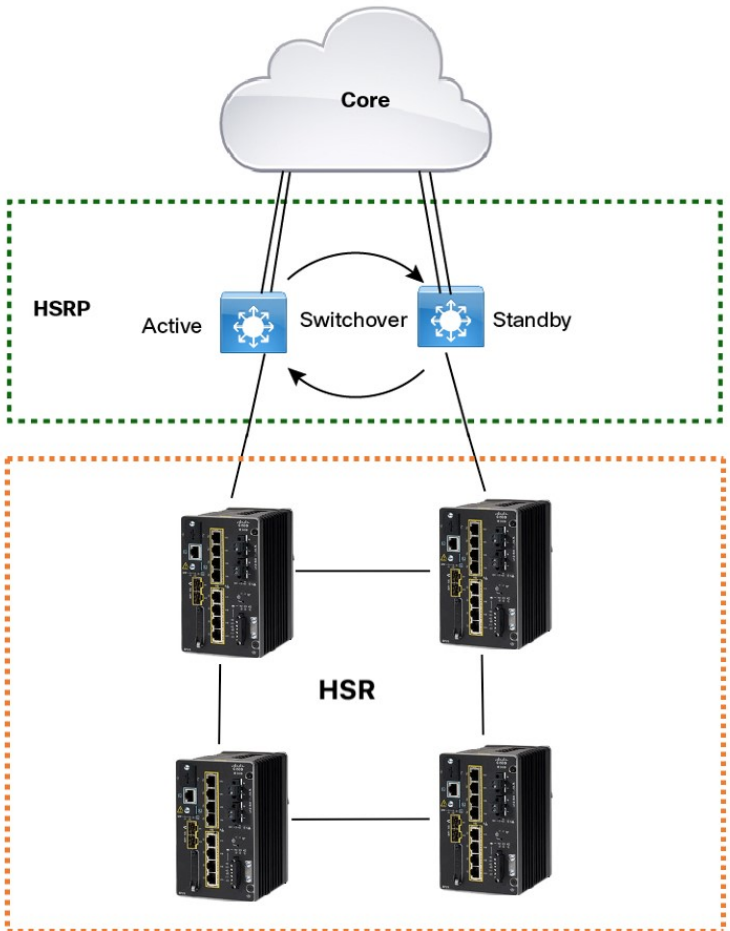
```
SAN-2(config)#ptp profile power
SAN-2(config)#ptp mode boundary pdelay-req
SAN-2(config)#end
REDBOX-M#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
REDBOX-M(config)#ptp profile power
REDBOX-M(config)# ptp mode p2ptransparent
REDBOX-M(config)#end
REDBOX-S#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
REDBOX-S(config)#ptp profile power
REDBOX-S(config)# ptp mode p2ptransparent
REDBOX-S(config)#end
DANH-TOP#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
DANH-TOP(config)#ptp profile power
DANH-TOP(config)#ptp mode p2ptransparent
DANH-TOP(config)#end
DANH-BOTTOM#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
DANH-BOTTOM(config)#ptp profile power
DANH-BOTTOM(config)#ptp mode p2ptransparent
DANH-BOTTOM(config)#end
SAN-1#sh ptp parent
 PTP PARENT PROPERTIES
  Parent Clock:
  Parent Clock Identity: 0x0:35:1A:FF:FE:94:4F:0
  Parent Port Number: 0
  Observed Parent Offset (log variance): N/A
  Observed Parent Clock Phase Change Rate: N/A

  Grandmaster Clock:
  Grandmaster Clock Identity: 0x0:35:1A:FF:FE:94:4F:0
  Grandmaster Clock Quality:
 Class: 248
 Accuracy: Unknown
 Offset (log variance): N/A
 Priority1: 1
 Priority2: 128
SAN-2#sh ptp parent
 PTP PARENT PROPERTIES
  Parent Clock:
  Parent Clock Identity: 0x0:35:1A:FF:FE:94:4F:0
  Parent Port Number: 3
  Observed Parent Offset (log variance): N/A
  Observed Parent Clock Phase Change Rate: N/A

  Grandmaster Clock:
  Grandmaster Clock Identity: 0x0:35:1A:FF:FE:94:4F:0
  Grandmaster Clock Quality:
 Class: 248
 Accuracy: Unknown
 Offset (log variance): N/A
 Priority1: 1
 Priority2: 128
REDBOX-M#sh ptp parent
 PTP PARENT PROPERTIES
  Parent Clock:
  Parent Clock Identity: 0x0:35:1A:FF:FE:94:4F:0
  Parent Port Number: 3
  Observed Parent Offset (log variance): N/A
  Observed Parent Clock Phase Change Rate: N/A

  Grandmaster Clock:
```

```
  Grandmaster Clock Identity: 0x0:35:1A:FF:FE:94:4F:0
  Grandmaster Clock Quality:
 Class: 248
 Accuracy: Unknown
 Offset (log variance): N/A
 Priority1: 1
 Priority2: 128
REDBOX-S#sh ptp parent
 PTP PARENT PROPERTIES
  Parent Clock:
  Parent Clock Identity: 0x0:35:1A:FF:FE:94:4F:0
  Parent Port Number: 3
  Observed Parent Offset (log variance): N/A
  Observed Parent Clock Phase Change Rate: N/A

  Grandmaster Clock:
  Grandmaster Clock Identity: 0x0:35:1A:FF:FE:94:4F:0
  Grandmaster Clock Quality:
 Class: 248
 Accuracy: Unknown
 Offset (log variance): N/A
 Priority1: 1
 Priority2: 128
DANH-TOP#sh ptp parent
 PTP PARENT PROPERTIES
  Parent Clock:
  Parent Clock Identity: 0x0:35:1A:FF:FE:94:4F:0
  Parent Port Number: 3
  Observed Parent Offset (log variance): N/A
  Observed Parent Clock Phase Change Rate: N/A

  Grandmaster Clock:
  Grandmaster Clock Identity: 0x0:35:1A:FF:FE:94:4F:0
  Grandmaster Clock Quality:
 Class: 248
 Accuracy: Unknown
 Offset (log variance): N/A
 Priority1: 1
 Priority2: 128
DANH-BOTTOM#sh ptp parent
 PTP PARENT PROPERTIES
  Parent Clock:
  Parent Clock Identity: 0x0:35:1A:FF:FE:94:4F:0
  Parent Port Number: 3
  Observed Parent Offset (log variance): N/A
  Observed Parent Clock Phase Change Rate: N/A

  Grandmaster Clock:
  Grandmaster Clock Identity: 0x0:35:1A:FF:FE:94:4F:0
  Grandmaster Clock Quality:
 Class: 248
 Accuracy: Unknown
 Offset (log variance): N/A
 Priority1: 1
 Priority2: 128
```

HSR Uplink Redundancy Enhancement

The HSR Uplink Redundancy Enhancement feature allows for flexible designs that enable two separate interfaces to connect upstream from the HSR ring through two separate HSR RedBoxes. This ensures there is no single point of failure exiting the HSR ring. Examples of protocols that can leverage this feature to improve high availability include HSRP, VRRP and REP. Prior to this enhancement, if these protocols were utilized on redundant uplinks, undesirable results could occur, such as next-hop split-brain conditions or slow REP failover times.

The following diagram shows an example network with HSR and HSRP that allows uplink next-hop gateway redundancy out of the HSR ring.



To implement HSR Uplink Redundancy, ensure that the **fpgamode-DualUplinkEnhancement** feature is not disabled. This feature is required to support the connectivity to a dual router (HSRP in this case) on the distribution layer:

```
Switch#show hsr ring 1 detail | include fpgamode
 fpgamode-DualUplinkEnhancement: Enabled
```

If the output shows *fpgamode-DualUplinkEnhancement,:Disabled* issue the following command:

```
Switch# conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# hsr-ring 1 fpgamode-DualUplinkEnhancement
Switch(config)# end
```

HSRP Configuration

The following example HSRP configuration applies to the two distribution switches Active & Standby in the above figure. In the following configuration, HSRP is configured in a Switch Virtual Interface (SVI).

```
Active# conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Active(config)# interface vlan 10
Active(config-if)# ip address 30.30.30.2 255.255.255.0
Active(config-if)# standby 1 ip 30.30.30.1
Active(config-if)# standby 1 priority 120
Active(config-if)# end

Standby# conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Standby(config)# interface Vlan10
Standby(config-if)# ip address 30.30.30.4 255.255.255.0
Standby(config-if)# standby 1 ip 30.30.30.1
Standby(config-if)# end

Active# show standby
Vlan10 - Group 1
  State is Active
    8 state changes, last state change 00:03:55
    Track object 1 (unknown)
  Virtual IP address is 30.30.30.1
  Active virtual MAC address is 0000.0c07.ac01 (MAC In Use)
    Local virtual MAC address is 0000.0c07.ac01 (v1 default)
  Hello time 200 msec, hold time 750 msec
    Next hello sent in 0.176 secs
  Preemption enabled, delay min 5 secs, reload 5 secs, sync 5 secs
  Active router is local
  Standby router is 30.30.30.4, priority 100 (expires in 0.656 sec)
  Priority 120 (configured 120)
  Group name is "hsrp-Vl10-1" (default)
  FLAGS: 0/1
Active# show standby brief
                     P indicates configured to preempt.
                     |
Interface   Grp  Pri P State   Active          Standby         Virtual IP
Vl10        1    120 P Active  local           30.30.30.4      30.30.30.1


Standby# show standby
Vlan10 - Group 1
  State is Standby
    13 state changes, last state change 00:04:17
    Track object 1 (unknown)
  Virtual IP address is 30.30.30.1
  Active virtual MAC address is 0000.0c07.ac01 (MAC Not In Use)
    Local virtual MAC address is 0000.0c07.ac01 (v1 default)
  Hello time 200 msec, hold time 750 msec
    Next hello sent in 0.064 secs
  Preemption enabled, delay min 5 secs, reload 5 secs, sync 5 secs
  Active router is 30.30.30.2, priority 120 (expires in 0.816 sec)
  Standby router is local
  Priority 100 (default 100)
  Group name is "hsrp-Vl10-1" (default)
  FLAGS: 0/1
Standby# show standby brief
                     P indicates configured to preempt.
                     |
Interface   Grp  Pri P State   Active          Standby         Virtual IP
Vl10        1    100 P Standby 30.30.30.2      local           30.30.30.1
```

Guidelines and Limitations

- HSR is supported only in a standalone deployment.
- Only one HSR instance is supported. Note that the switch supports only one HSR or one PRP instance, so if a PRP instance has been created, no HSR instance can be created.
- HSR ring 1 can only be configured as a pair of ports: Gi1/1 and Gi1/2 or Gi1/4 and Gi1/5. Using these port pairs, you can configure 1 HSR ring.
- The HSR feature requires the Network Essentials license.
- The HSR feature is not enabled by default and you must explicitly configure the HSR rings.
- HSR is disabled automatically if the required firmware image is not available on the system.
- Once a port is part of a ring, the media-type, speed, and duplex settings of the port cannot be changed. We recommend that you apply those settings before configuring ring membership.
- If mode of HSR interfaces is changed from access to trunk mode or vice-versa after configuring the ring,we recommended that you flap the HSR ring.
- The recommended maximum number of nodes in the node table is 512. Nodes are all the DANH and VDAN devices that can be connected to the ring at same time. This number is not an absolute limit, but higher numbers of entries may increase the number of duplicate packets received by the end devices.
- HSR ring ports can only be configured in L2 mode.
- HSR is supported on following port types:
  - 100 mbps, Full Duplex. Half duplex is not supported.
  - 1000 mbps, Full Duplex. Half duplex is not supported.
  - HSR is not supported on the uplink ports.
- Both ports of one ring must be of same speed and type (that is, both can be SFPs or both can be copper)
- The following protocols and features are mutually exclusive with HSR on the same port:
  - PRP
  - EtherChannels
  - Link Aggregation Control Protocol (LACP)
  - Port Aggregation Protocol (PAgP)
  - Resilient Ethernet Protocol (REP)
- MACsec, HSR, and PRP are not allowed together.
- HSR supports an MTU size of up to 1998 bytes of Ethernet payload.
- STP is not supported on the HSR ring. By default, all modes of Spanning Tree Protocol (STP) will be disabled on the ring ports.

- Switched Port Analyzer (SPAN) and Remote SPAN (RSPAN) are not supported on HSR. That is, SPAN and RSPAN should not be used to monitor the traffic on an HSR ring. In addition, traffic that has been monitored using RSPAN should not be transferred over an HSR ring.
- It is important for all interfaces in an HSR ring to have the same speed and duplex settings. It is recommended to apply those settings before configuring ring membership.
- Once a port is part of ring, the port cannot be shut down.

  For example, if Gi1/4 and Gi1/5 are part of an HSR ring and you try to shut down Gi1/4 or Gi1/5, the operation will not be permitted:

  ```
  Switch(config)# interface gi1/4
  Switch(config-if)#shutdown
   %Interface GigabitEthernet1/4 is configured in a HSR ring shutdown not permitted!
  Switch(config-if)#
  ```

  You can perform a shutdown of the HSR ring. For example:

  ```
  Switch# conf t
  Switch(config)#int hs1
  Switch(config-if)#shut
  ```

- VLAN configuration such as trunk and access mode must be the same on both the ports participating in the ring. For example, if Gi1/4 and Gi1/5 in an HSR ring are in trunk mode and you attempt to change the mode of one port to access, the ports in the ring will not be bundled:

  ```
  Switch(config)#interface range gi1/4
  Switch(config-if)#switchport mode  access
  Jul 27 22:00:27.809 IST: %EC-5-CANNOT_BUNDLE2: Gi1/4 is not compatible with Gi1/5 and
  will be suspended (trunk mode of Gi1/4 is access, Gi1/5 is dynamic)
  ```

- After an interface is added in the HSR ring, only the primary interface counters are updated. You should not need to configure and check the status of individual physical interfaces after they are added to the HSR ring.
- As soon as you configure an HSR ring on two ports of a switch, MAC flaps will be observed on other switches where the HSR configuration is yet to be applied. We recommend that you shut down the newly created HSR ring on the switch before configuring the ring on all switches, and then re-enable them one by one as shown below. For example, if there are four switches in the ring, disable the HSR ring interfaces on each switch:

  ```
  Switch1(config)#interface range gi1/1-2
  Switch1(config-if)#shutdown
  Switch1(config-if)#hsr-ring hs1
  Creating a HSR-ring interface hs1
  Switch1(config-if)#int hs1
  Switch1(config-if)#shutdown
  Switch1(config-if)#end
  ```

  After all four switches are configured with the ring, re-enable the HSR ports on each switch:

  ```
  Switch1#conf t
  Enter configuration commands, one per line. End with CNTL/Z.
  Switch1(config)#int hs1
  Switch1(config-if)#no shutdown
  Switch1(config-if)#end
  Switch1#
  ```

  This prevents interim MAC flapping during HSR ring configuration in member switches.

Default Settings

Table 5: HSR Ring Parameters

Parameter	Description	Range	Default Value
entryForgetTime	Time for clearing an inactive entry from duplicate discard table.	0-65535	400 ms
fpgamode-DualUplinkEnhancement	Set FPGA register for source mac filtering.	enable or disable	enable
nodeForgetTime	Time to clear an inactive entry from the node table.	0-65535	60000 ms
nodeRebootInterval	Time after which the RedBox must start sending supervision frames after bootup.	0-65535	500 ms
pauseFrameTime	Time interval between HSR pause frames.	0-65535	25 ms
proxyNodeTableForgetTime	Time to clear an inactive entry from the proxy node table or vdan table.	0-65535	60000 ms
supervisionFrameLifeCheckInterval	Life check interval value for supervision frames.	0-65535	2000 ms
supervisionFrameOption			
mac-da	The last bytes of the destination MAC address of supervision frames (01:15:4E:00:01:00). The last 00 is replaced by the value of this parameter.	1-255 MAC DA last eight bits option value	No default
vlan-cfi	Enable Canonical Format Indicator (CFI) for the VLAN tagged frame.	enable or disable	disable
vlan-cos	Class of Service (COS) value to be set in the VLAN tag of the Supervision frame.	0-7	0
vlan-id	The VLAN tag of the supervision frame.	0-4095	0

Parameter	Description	Range	Default Value
vlan-tagged	Set VLAN tagging option.	enable or disable	disable
supervisionFrameRedboxMacaddress	The RedBox MAC address in the supervision frames.	48-bit RedBox MAC address	The interface HSR ring MAC address
supervisionFrameTime	Time interval between supervision frames.	0-65535	3 ms

Configure an HSR Ring

Follow these steps to configure an HSR ring:

Before you begin

- Read and understand the Guidelines and Limitations, on page 19 section of this chapter.
- Ensure that the member interfaces of a HSR ring are not participating in any redundancy protocols such as FlexLinks, EtherChannel, REP, and so on before configuring a HSR ring.

Procedure

Step 1 Enter global configuration mode:

```
Switch# configure terminal
```

Step 2 (Optional) Globally enable CDP to provide information about HSR ring nodes:

```
Switch(config)# cdp run
```

Step 3 (Optional) Globally enable LLDP to provide information about HSR ring nodes:

```
Switch(config)# lldp run
```

Step 4 Enter interface configuration mode and disable PTP on the ports to be assigned to the HSR ring:

```
Switch(config)# interface range gi1/1-2
Switch(config-if-range)# no ptp enable
```

Step 5 (Optional) Enable CDP on the ports to be assigned to the HSR ring:

```
Switch(config-if-range)#cdp enable
```

Step 6 (Optional) Enable LLDP on the ports to be assigned to the HSR ring:

```
Switch(config-if-range)#lldp transmit
Switch(config-if-range)#lldp receive
```

Step 7 Shut down the ports before configuring the HSR ring:

```
Switch(config-if-range)# shutdown
```

Step 8 Create the HSR ring interface and assign the ports to the HSR ring:

```
Switch(config)# interface range gigabitEthernet 1/1-2
Switch(config-if-range)# hsr-ring 1
```

Step 9 (Optional) If required, configure HSR ring optional parameters. See the Default Settings section for the parameter descriptions, ranges and default values.

```
Switch(config-if-range)# hsr 1 supervisionFrameLifeCheckInterval 10000
```

Step 10 Turn on the HSR interface:

```
Switch(config-if-range)# no shutdown
Switch(config-if)# end
```

Example

```
Switch# conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# interface range gigabitEthernet 1/1-2
Switch(config-if-range)# no ptp enable
Switch(config-if-range)# shutdown
Switch(config-if-range)# hsr-ring 1
Switch(config-if-range)# hsr-ring 1 supervisionFrameLifeCheckInterval 10000
Switch(config-if-range)# no shutdown
Switch(config-if-range)# end
```

Configuring HSR-PRP

Follow these steps to enable HSR-PRP Redbox mode on the switch. Enabling HSR-PRP mode creates an HSR ring and bridges the the HSR ring to a PRP network.

Before you begin

- See Guidelines and Limitations, on page 19.

Procedure

Step 1 Enter global configuration mode:

```
switch# configure terminal
```

Step 2 Enable HSR-PRP mode and select LAN A or LAN B and the optional PRP Net ID:

hsr-prp-mode enable {prp-lan-a | prp-lan-b} [1-6]

- prp-lan-a: Redbox is connected to LAN A.
- prp-lan-b: Redbox is connected to LAN B.
- 1-6: PRP Net ID value from 1 to 6.

  The default is 1.

Note
Be sure to configure the same Net ID in Redbox A and B that is part of the same PRP network.

Example:

```
switch(config)#hsr-prp-mode enable prp-lan-a
```

To disable HSR-PRP Redbox mode, use the command **no hsr-prp-mode enable**.

Clear All Node Table and VDAN Table Dynamic Entries

Procedure

Step 1 To clear all dynamic entries in the node table, enter the following command: `clear hsr node-table`

Step 2 To clear all dynamic entries in the VDAN table, enter the following command; `clear hsr vdan-table`

Verifying the Configuration

Command	Purpose
show hsr ring 1 [**detail**]	Displays configuration details for the specified HSR ring.
show hsr statistics {**egressPacketStatistics** | **ingressPacketStatistics** | **nodeTableStatistics** | **pauseFrameStatistics**}	Displays statistics for HSR components. **Note** To clear HSR statistics information, enter the command **clear hsr statistics**.
show hsr node-table	Displays HSR node table.
show hsr vdan-table	Displays HSR Virtual Doubly Attached Node (VDAN) table. **Note** The VDAN table and Proxy node table are the same.
show cdp neighbors	Displays CDP neighbor information for an HSR ring.
show lldp neighbors	Displays LLDP neighbor information for an HSR ring.

Configuration Examples

HSR-SAN

This example shows the configuration of an HSR ring (Ring 1) using Gi1/1 and Gi1/2 ports between four devices.

```
Switch-1# conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Switch-1(config)#interface range gigabitEthernet 1/1-2
Switch-1(config-if-range)#shutdown
Switch-1(config-if-range)#hsr-ring 1
Creating a HSR-ring interface HSR-ring 1

Switch-1(config-if-range)#no shutdown
Switch-1(config-if-range)#exit
Switch-1(config)#exit
Switch-1#
Switch-2# conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Switch-2(config)#interface range gigabitEthernet 1/1-2
Switch-2(config-if-range)#shutdown
Switch-2(config-if-range)#hsr-ring 1
Creating a HSR-ring interface HSR-ring 1

Switch-2(config-if-range)#no shutdown
Switch-2(config-if-range)#exit
Switch-2(config)#exit
Switch-2#
Switch-3# conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Switch-3(config)#interface range gigabitEthernet 1/1-2
Switch-3(config-if-range)#shutdown
Switch-3(config-if-range)#hsr-ring 1
Creating a HSR-ring interface HSR-ring 1

Switch-3(config-if-range)#no shutdown
Switch-3(config-if-range)#exit
Switch-3(config)#exit
Switch-3#
Switch-4# conf t
Enter configuration commands, one per line.  End with CNTL/Z.
Switch-4(config)#interface range gigabitEthernet 1/1-2
Switch-4(config-if-range)#shutdown
Switch-4(config-if-range)#hsr-ring 1
Creating a HSR-ring interface HSR-ring 1

Switch-4(config-if-range)#no shutdown
Switch-4(config-if-range)#exit
Switch-4(config)#exit
Switch-4#
Switch-1# show hsr ring 1 detail
HSR-ring: HS1
------------
 Layer type = L2
 Operation Mode = mode-H
 Ports: 2       Maxports = 2
 Port state = hsr-ring is In use
 Protocol = Enabled  Redbox Mode = hsr-san
Ports in the ring:
```

```
  1) Port: Gi1/1
   Logical slot/port = 1/1      Port state = In use
        Protocol = Enabled
  2) Port: Gi1/2
   Logical slot/port = 1/2      Port state = In use
        Protocol = Enabled

Ring Parameters:
 Redbox MacAddr: 9433.d845.2a81
 Node Forget Time: 60000 ms
 Node Reboot Interval: 500 ms
 Entry Forget Time: 400 ms
 Proxy Node Forget Time: 60000 ms
 Supervision Frame COS option: 0
 Supervision Frame CFI option: 0
 Supervision Frame VLAN Tag option: Disabled
 Supervision Frame MacDa: 0x00
 Supervision Frame VLAN id: 0
 Supervision Frame Time: 3 ms
 Life Check Interval: 1600 ms
 Pause Time: 25 ms
 fpgamode-DualUplinkEnhancement: Enabled
```