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SEP Technical White Paper

Keywords

SEP, SEP segment, control VLAN, edge port, common port, port preemption

Abstract

This document describes the SEP function provided by Huawei AR industrial switching routers, including the concepts, implementation, and typical applications of SEP.

Abbreviation List

Acronym	Full Name
SEP	Smart Ethernet Protection
STP	Spanning Tree Protocol
RSTP	Rapid Spanning Tree Protocol
MSTP	Multiple Spanning Tree Protocol
FDB	Forwarding Database

Contents

1 Introduction to SEP

The Smart Ethernet Protection (SEP) protocol is a ring network protocol specially used for the Ethernet link layer. SEP eliminates loops on a Layer 2 network by blocking redundant links to prevent infinite packet transmission. This protocol prevents broadcast storms on the network.

2 Background

Ring technologies, including STP, connect network devices in a ring to implement communication between them.

- STP Ring

  STP is a standard ring protocol designed by IEEE and is widely used. However, STP cannot ensure high quality of data transmission on a network with a large diameter because a large STP network converges slowly.

3 Technical Characteristics

When a loop occurs on a Layer 2 switching network, packets will be generated and transmitted infinitely, causing a broadcast storm. All available bandwidth is consumed by the broadcast storm, and therefore valid packets cannot be transmitted on the network.

SEP prevents logical loops on a ring network by blocking redundant links.

SEP provides open ring, closed ring, single ring, and multi-ring, and implements link redundancy in these topologies. When there is no faulty link on the ring network, SEP can prevent loops on the Ethernet network. When a link fails on the ring network, SEP can fast restore communication between nodes in the ring. SEP is designed to implement failover within 50 ms on ring networks. Compared with other ring network protocols, SEP has the following advantages:

- Flexibly blocks ports and properly implements load balancing.
- Work with STP, RSTP, or MSTP.
- Switches traffic back to a link that recovers from a fault.
- Displays the SEP network topology.
- Simplifies the configuration on multi-ring networks.

3.1 Basic Concepts of SEP

3.1.1 Working Principle of SEP

As the basic unit of SEP, a SEP segment consists of a group of interconnected switches configured with the same segment ID and same control VLAN ID. Each switch can have only two ports in the same SEP segment.

To prevent loops in a SEP segment, a ring protection mechanism is used to selectively block ports to eliminate Ethernet redundant links. When a link on a ring network fails, the device running SEP immediately unblocks the blocked port and performs link switching to restore communication between nodes.

Figure 3-1 SEP open ring networking

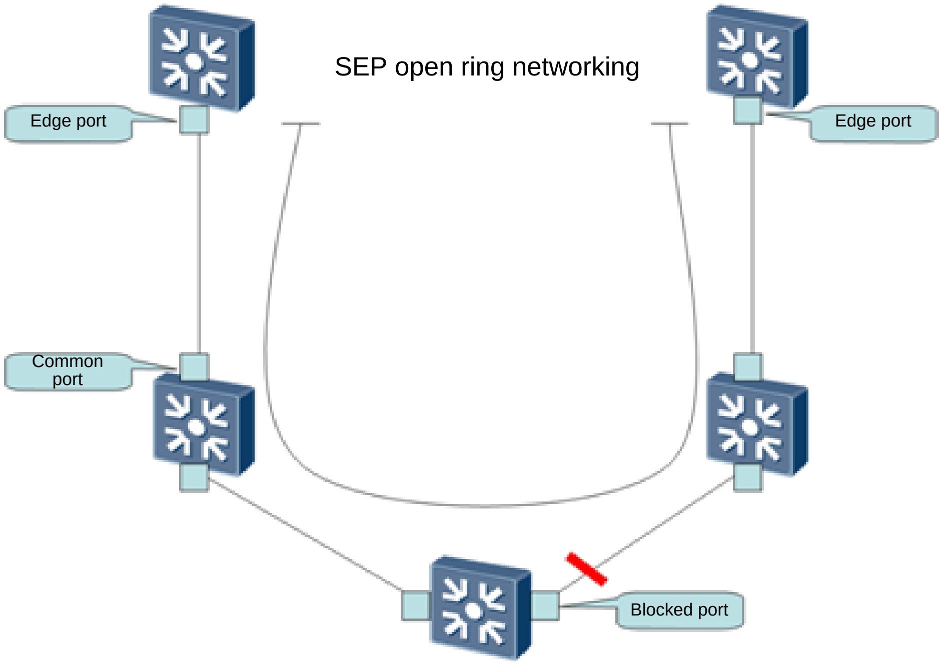


Figure 3-2 SEP ring networking

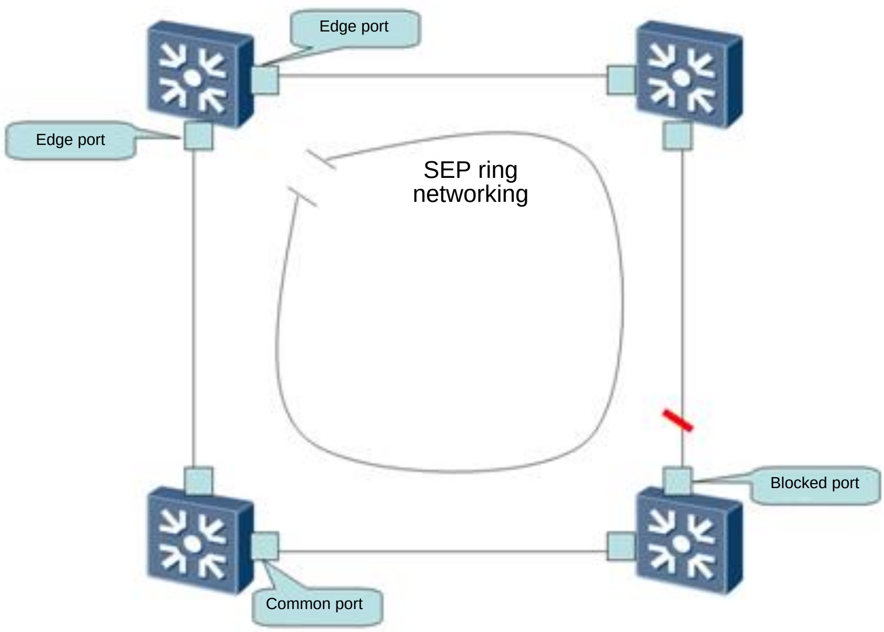
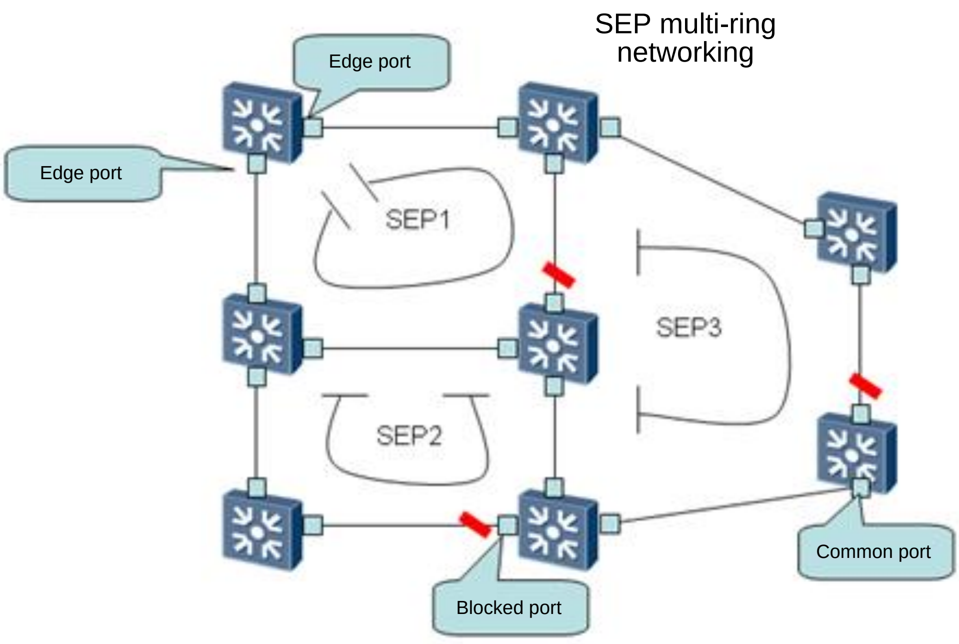


Figure 3-3 SEP multi-ring networking



A SEP segment involves the following entities:

- Control VLAN
- Node
- Edge port
- Common port

3.1.2 Control VLAN

In a SEP segment, the control VLAN is used to transmit SEP packets. Different from the control VLAN, a data VLAN is used to transmit data packets. Each SEP segment must be configured with a control VLAN and each port in the SEP segment must be added to the control VLAN.

3.1.3 Node

Each switch in a SEP segment is a node. Each node can have no more than two ports added to the same SEP segment.

3.1.4 Port Role

SEP defines two port roles: common and edge ports.

3.1.5 Edge Port

Edge ports are classified into primary edge ports, secondary edge ports, no-neighbor primary edge port, and no-neighbor secondary edge port.

- Primary edge port

A SEP segment has only one primary edge port, depending on the user-defined configuration and primary edge port election. The primary edge port initiates blocked port preemption, terminates packets, and sends topology change notification messages to other networks.

- Secondary edge port

  A SEP segment has only one secondary edge port, depending on the user-defined configuration and primary edge port election. The secondary edge port terminates packets and sends topology change notification messages to other networks.

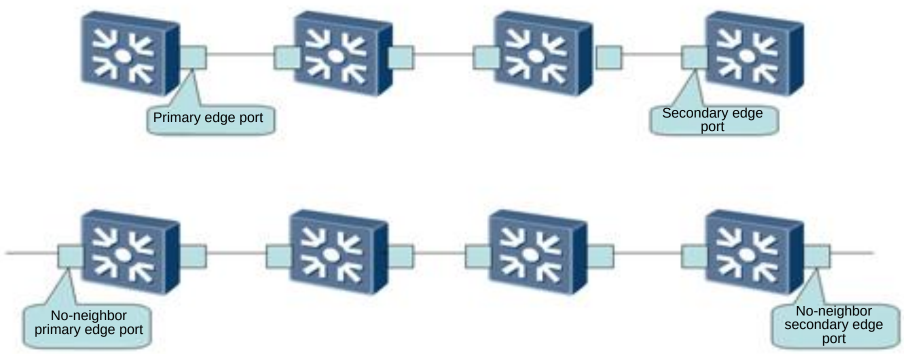
- No-neighbor primary edge port

  On an open ring network, a port at the edge of a SEP segment is a no-neighbor edge port, depending on the user-defined configuration and primary edge port election. The no-neighbor primary edge port is elected between the two no-neighbor edge ports. It initiates blocked port preemption, terminates packets, and sends topology change notification messages to other networks.

- No-neighbor secondary edge port

  On an open ring network, a port at the edge of a SEP segment is a no-neighbor edge port, depending on the user-defined configuration and primary edge port election. The no-neighbor secondary port is elected between the two no-neighbor edge ports. It terminates packets and sends topology change notification messages to other networks.

Figure 3-4 Edge port and no-neighbor edge port



3.1.6 Common Port

In a SEP segment, all ports except edge ports and the blocked port are common ports. A common port monitors the status of the directly-connected SEP link. When the link status changes, the port sends a Topology Change message to notify its neighbor. Then the topology change notification message is flooded on the link until it finally reaches the primary edge port. The primary edge port determines how to process the link change.

3.1.7 SEP Port States

SEP ports have two possible states, as described in Table 1.

Table 3-1 SEP port states

State	Description
Forwarding	A port in Forwarding state can forward service traffic and send/receive SEP packets.
Discarding	A port in Discarding state can receive only SEP packets.

A port may be in Forwarding or Discarding state regardless of its role. Table 2 shows the states supported by each port role.

Table 3-2 States of port roles

Port State	Common Port	Primary Edge Port	Secondary Edge Port	No-neighbor Primary Edge Port	No-neighbor Secondary Edge Port
Forwarding	√	√	√	√	√
Discarding	√	√	√	√	√

The symbol √ indicates that the port supports that state.

3.2 SEP Implementation

3.2.1 Neighbor Negotiation

After a port is added to a SEP segment, neighbor negotiation starts. The port and its neighboring port exchange neighbor protocol packets to establish a neighbor relationship. After neighbor negotiation is successful, the two ports continue to exchange neighbor protocol packets to detect their neighbor status. Neighbor protocol packets are untagged and sent only to the next hop. The neighboring port does not forward the received neighbor protocol packets. Neighbor protocol packets are sent at an interval of 1s, and the timeout interval of neighbor protocol packets is 3s.

Neighbor negotiation prevents unidirectional communication issues because neighbor negotiation is bidirectional. Ports at both ends of a link send neighbor protocol packets to each other. If a port does not receive any neighbor packet from the neighboring port, it considers that the neighboring port is Down.

Neighbor negotiation provides necessary information for obtaining the SEP segment topology. Ports establish neighbor relationships through neighbor negotiation and finally establish a complete SEP segment through links.

3.2.2 Link State Synchronization and Topology Display

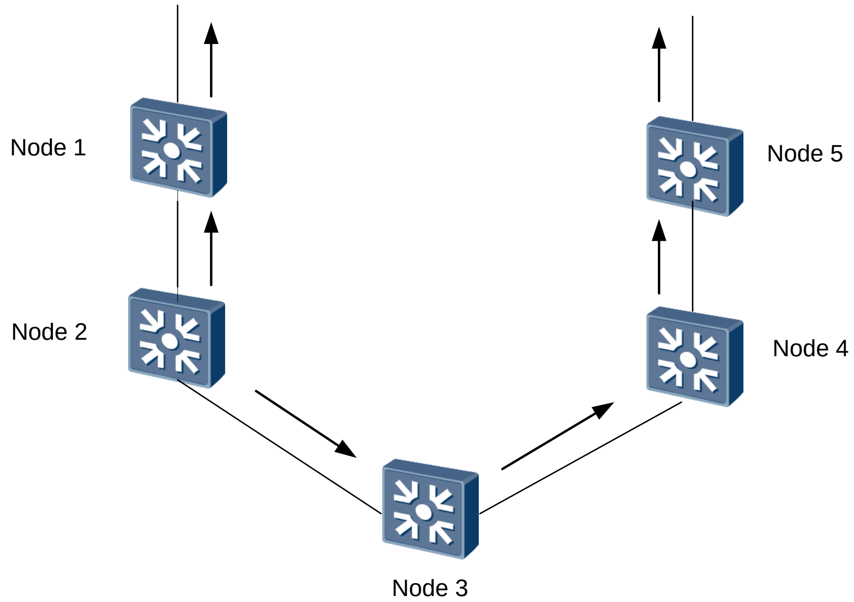
- Link state synchronization

  A SEP node periodically sends Link State Advertisements (LSAs), and all the nodes receiving LSAs update their link state databases (LSDBs). In this way, all nodes in a SEP segment maintain the same LSDB.

  SEP nodes synchronize the link states as follows:

  Each node periodically sends LSAs through SEP ports. LSAs are broadcast in the control VLAN, and all nodes in the SEP segment receive and process LSAs to update their LSDBs. When a port fails, it sends a fault notification packet to notify its neighboring port. Normally, each node sends an LSA every 20s (slow synchronization). When information about a node changes, the node sends an LSA immediately. Figure 3-5 shows the synchronization process.

Figure 3-5 Link state synchronization from node 2



An LSA contains the following contents: system name, port name, system MAC address, port priority, port index, link state, neighbor state, and port role.

- SEP topology display

  The topology display function allows you to view the topology with the highest network connectivity on any device in a SEP segment. Link state synchronization ensures that all devices in a SEP segment display the same topology.

  The topology of a SEP segment can be the following:

  - Ring topology: Each port in a SEP segment has a neighboring port in Up state, and each node has two ports in a SEP segment.
  - Linear topology: All topologies except ring topologies are linear topologies.

3.2.3 Port Blocking Mechanism

In a SEP segment, some ports are blocked to prevent loops. Any port in a SEP segment may be blocked. A SEP segment contains only one blocked port.

The blocked port is determined by the administrative priority and user-defined priority of each port. The port with the highest priority is blocked.

SEP compares port priorities as follows:

1. Compares the configured port priority values. A larger value indicates a higher priority.
2. Compares bridge MAC addresses of ports if their priority values are the same. A smaller bridge MAC address indicates a higher priority of the port.

3. Compares port numbers if their bridge MAC addresses are the same. A smaller port number indicates a higher priority of the port.

3.2.4 Blocked Port Preemption

After all faulty links recover, SEP selects a port to block on the link that recovers last. This port may be replaced by another port through preemption, depending on the preemption mode.

- SEP supports the following preemption modes:
  1. No preemption
  2. Delayed preemption
  3. Manual preemption
- Preemption is triggered when the following conditions are met:
  1. The SEP segment has a primary edge node.
  2. The blocked port is specified and a port has been blocked.
  3. All faulty links have recovered.
- Blocked port preemption involves the following mechanisms:
  - Primary edge port election

    Only the ports configured as the primary/secondary edge ports and no-neighbor edge ports can participate in the primary edge port election. After SEP is enabled on a port, the port considers itself as the primary edge port if it is qualified for the primary edge port election. In addition, the port sends packets for primary edge port election at intervals and does not need to wait until the neighbor negotiation succeeds.

    If an edge port receives a fault notification packet or does not receive any packet for primary edge port election from the primary edge port within certain intervals (three intervals by default), the port becomes the primary edge port.

    When a ring network has faulty links, two primary edge ports exist in the ring. Both the two ports send packets for primary edge port election at intervals. After all faulty links recover, both the two primary edge ports receive packets for primary edge port election. Then they elect a new primary edge port within one interval.
  - Specifying a port to block

    You can specify any port to block. The specified port is not blocked immediately. Normally, the blocked port is one of the two ports that complete neighbor negotiation last. The specified port preempts to be the blocked port only after the preemption mechanism takes effect.

SEP supports the following methods to select a port to block:

1. Blocks the port with the highest priority.
2. Blocks the port in the middle of a SEP segment.
3. Blocks the port with a certain hop count. As defined in SEP, the hop count of the primary edge port is 1. Hop counts of other ports increase at a step of 1 in the downstream direction of the primary edge port.
4. Blocks the port with the specified name on the specified device. If the device name or port name is changed after the port is specified, the specified port cannot preempt as the blocked port.

3.2.5 Topology Change Notification

Topology change notification is deployed on the device on the upper-layer and lower-layer networks, and enables this device to notify the upper-layer network that the topology of the lower-layer network changes. SEP considers that the topology of a SEP-enabled network changes in either of the following situations:

- A port in a SEP segment fails.

  A port in a complete SEP segment fails. A port fault can be a link fault or the incorrect neighbor status on a port.
- Port faults are rectified and blocked port preemption takes effect.

  When all faulty ports recover, blocked port preemption is triggered.

When the topology of an SEP segment changes, all nodes in the SEP segment must be notified quickly. To meet the preceding requirements, SEP provides the following notification modes:

- Fast notification: The topology change notification is multicast to each node in the SEP segment through the hardware. In this mode, nodes are notified of the topology change quickly so that they can react to the topology change fast.
- Reliable notification: The topology change notification is sent to each node in the SEP segment hop by hop through neighbor negotiation.

In SEP+STP networking (see Figure 4-4), the following topology change notification mode is used:

- In this networking, nodes where the edge ports are deployed are added to an STP region, and a SEP open ring is connected to an STP network to implement redundancy. When the topology of the SEP segment changes, SEP nodes send topology change notifications to nodes in the STP region.

3.2.6 Load Balancing

SEP implements load balancing by blocking a node in a SEP segment. The best choice is to block the node in the middle of a SEP segment.

3.2.7 Link Switching Performance

When faults occur in a SEP segment, notification messages are multicast to all nodes in the SEP segment. The hardware directly forwards the notification messages, so the notification messages can be rapidly sent to each node in a SEP segment and services can be switched in a short time. Hardware-based forwarding requires little time, so the link switching time is irrelevant to the number of nodes on a SEP segment.

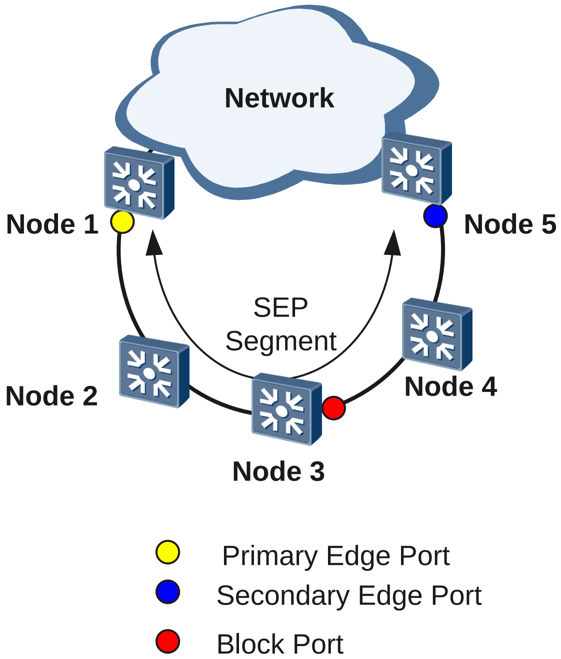
4 Applications

Huawei AR series industrial switching router supports SEP in the industrial Ethernet field. It provides open ring, closed ring, single ring, and multi-ring topologies, and implements link redundancy in these topologies. Compared with STP, SEP provides fast convergence. In addition, SEP prevents unidirectional links and supports topology display.

4.1 Open Ring Networking

As shown in Figure 4-1, Node1 to Node5 form an open ring network and connect to the upper-layer Layer 2 network. The open ring network is deployed at the access layer to implement Layer 2 transparent transmission of unicast and multicast packets. SEP runs at the access layer to implement link redundancy.

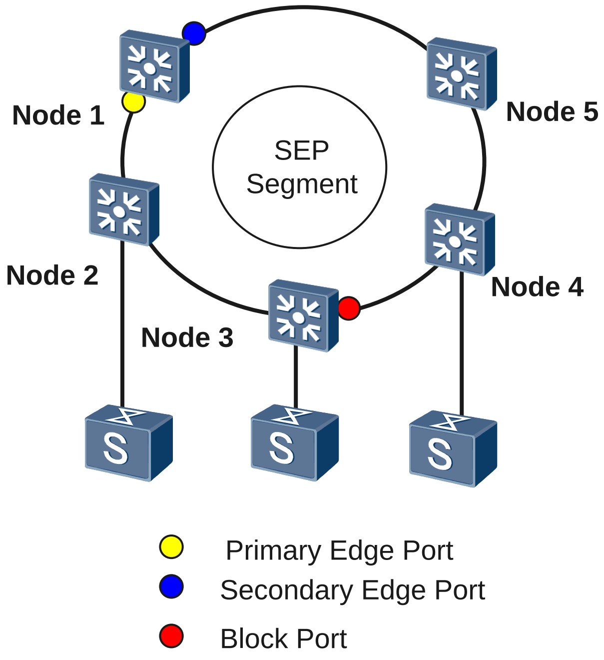
Figure 4-1 SEP open ring networking



4.2 Closed Ring Networking

As shown in Figure 4-2, CEs are dual-homed to the Layer 2 network through Node1 to Node5. The edge devices Node1 and Node5 are directly connected to each other. Node1 to Node5 form a closed ring network. The closed ring network is deployed at the aggregation layer to aggregate unicast and multicast services. SEP runs at the aggregation layer to implement link redundancy.

Figure 4-2 SEP closed-ring networking

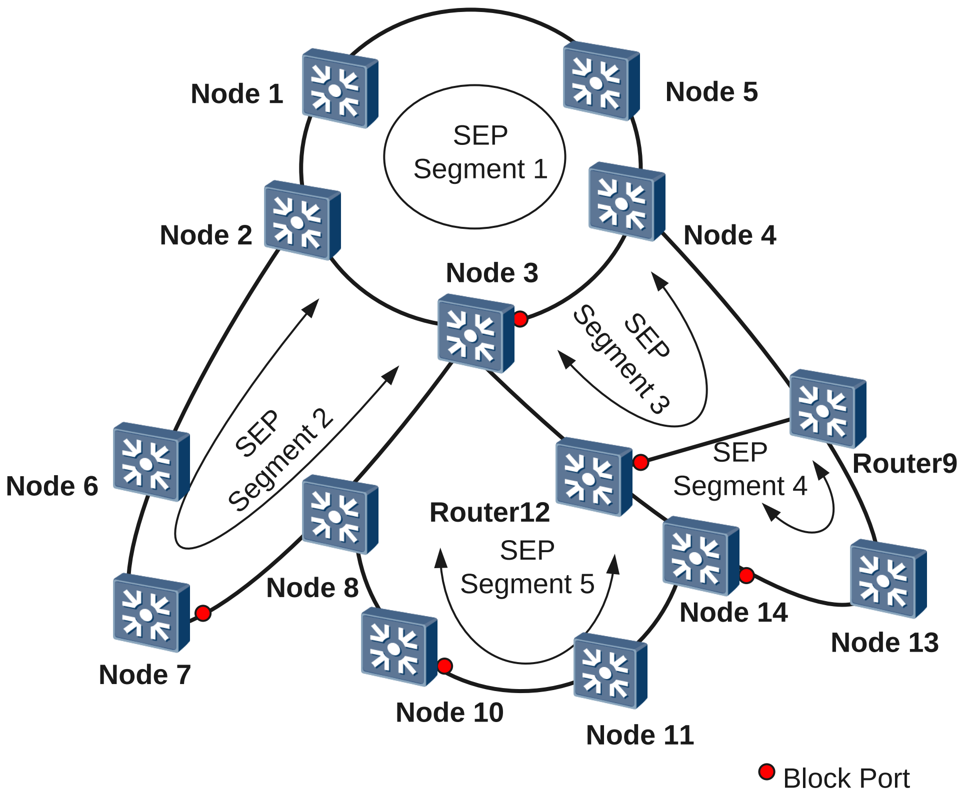


4.3 Multi-ring Networking

As shown in Figure 4-3, Node1 to Node4 form multiple rings; Node1 to Node5 are deployed at the aggregation layer; Node6 to Node14 are deployed at the access layer. Layer 2 services are transparently transmitted at access and aggregation layers. SEP runs at the aggregation layer and access layer to implement link redundancy.

If the topology of the access layer changes, a device in the SEP segment sends Flush-FDB packets to notify other devices so that these devices can update their MAC address tables and ARP tables. The edge devices of the SEP segment send TC packets to notify devices on the upper-layer network of the topology change.

Figure 4-3 SEP multi-ring networking

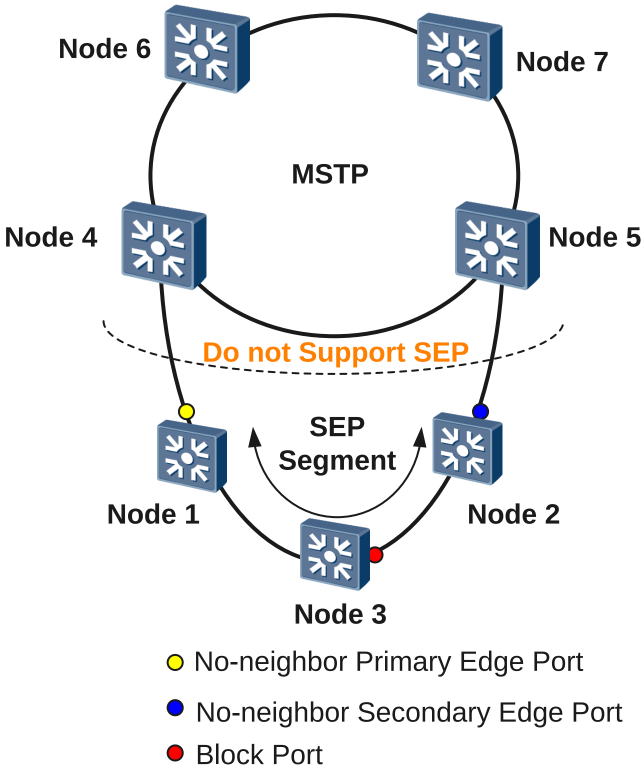


4.4 Hybrid Networking

As shown in Figure 4-4, Node1 to Node3 form a SEP segment, which is connected to an MSTP ring. The hybrid network is to implement Layer 2 transparent transmission of unicast and multicast packets. SEP runs at the access layer to implement link redundancy.

If the topology of the access layer changes, a device in the SEP segment sends Flush-FDB packets to notify other devices so that these devices can update their MAC address tables and ARP tables. The edge devices Node1 and Node2 of the SEP segment send TC packets to notify devices at the aggregation layer of the topology change.

Figure 4-4 Hybrid networking



5 SEP Implementation on AR Series

As industrial automation and intelligence develop, the industrial Ethernet inherits advantages of transparency and openness of the commercial Ethernet. The industrial Ethernet provides a uniform platform for data communication between machines and is the basis of the future IoT. SEP provides high reliability and QoS for the industrial Ethernet and prevents broadcast storms on ring networks. In addition, SEP implements fast convergence to ensure fast switching of links when link faults occur.

Huawei AR530 and AR550 series support STP and can be used in industrial automation fields such as electricity, transportation, and energy fields.