



IP Routing: Protocol-Independent Configuration Guide, Cisco IOS XE 17 (Cisco ASR 900 Series)

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Americas Headquarters

Cisco Systems, Inc.
170 West Tasman Drive
San Jose, CA 95134-1706
USA
<http://www.cisco.com>
Tel: 408 526-4000
800 553-NETS (6387)
Fax: 408 527-0883

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CONTENTS

CHAPTER 1

Feature History 1

CHAPTER 2

IS-IS Overview and Basic Configuration 3

- Finding Feature Information 3
- Prerequisites for IS-IS Overview and Basic Configuration 4
- Restrictions for IS-IS on Cisco ASR 900 Series Routers 4
- Information About IS-IS Overview and Basic Configuration 4
 - IS-IS Functional Overview 4
 - IS Address Assignment 4
 - IS-IS PDU Types 5
 - IIHs 5
 - LSPs 5
 - SNPs 6
 - IS-IS Supported Circuit Types 6
 - Operation of IS-IS on Point-to-Point Circuits 6
 - Operation of IS-IS on Multiaccess Circuits 7
 - IS-IS Election of the Designated Intermediate System 7
 - IS-IS Overview of LSPDB Synchronization 8
 - Handling of Newer LSPs 8
 - Handling of Older LSPs 9
 - Handling LSPs That Are the Same 9
 - IS-IS Overview of the Shortest Path Calculation 10
- How to Create Monitor and Make Changes to a Basic IS-IS Network 11
 - Enabling IS-IS as an IP Routing Protocol on the Device 11
 - Enabling IS-IS as an IP Routing Protocol on the Interface 12
 - Monitoring IS-IS 13

| | |
|---|----|
| Troubleshooting Tips | 16 |
| Configuration Examples for a Basic IS-IS Network | 16 |
| Example: Configuring a Basic IS-IS Network | 16 |
| On-Change Notifications for IS-IS State | 19 |
| Configuration Examples: On-Change Notifications for IS-IS State | 20 |
| Verification of On-Change Notifications for IS-IS State Configuration | 21 |
| Where to Go Next | 26 |
| Additional References for IS-IS Overview and Basic Configuration | 27 |
| Glossary | 28 |

CHAPTER 3**Policy-Based Routing 29**

| | |
|---|----|
| Finding Feature Information | 29 |
| Information About Policy-Based Routing | 29 |
| Policy-Based Routing | 29 |
| Restrictions for Policy-Based Routing | 30 |
| How to Configure Policy-Based Routing | 30 |
| Configuring Policy-Based Routing | 30 |
| Verifying Policy-Based Routing | 32 |
| Configuration Examples for Policy-Based Routing | 32 |
| Example: Policy-Based Routing | 33 |
| Additional References | 33 |
| Feature Information for Policy-Based Routing | 33 |

CHAPTER 4**PPPoE Intermediate Agent 35**

| | |
|---|----|
| Information About PPPoE Intermediate Agent | 36 |
| Prerequisites for PPPoE Intermediate Agent | 36 |
| Restrictions for PPPoE Intermediate Agent | 36 |
| How to Configure PPPoE Intermediate Agent | 37 |
| Enabling or Disabling PPPoE IA on a Device | 37 |
| Configuring the Access Node Identifier for PPPoE IA | 37 |
| Configuring the Generic Error Message for PPPoE IA | 38 |
| Configuring the Identifier String, Option, and Delimiter for PPPoE IA | 38 |
| Enabling or Disabling PPPoE IA on an Interface | 38 |
| Enabling or Disabling PPPoE IA on BD | 38 |

| | |
|---|----|
| Configuring PPPoE IA Circuit-ID on an Interface | 39 |
| Configuring PPPoE IA Remote-ID on an Interface | 39 |
| Configuring PPPoE IA Rate Limiting Setting on an Interface | 40 |
| Configuring the PPPoE IA Trust Setting on an Interface | 41 |
| Configuring PPPoE IA Vendor-tag Stripping on an Interface | 41 |
| Verifying Ppoe IA Configuration | 41 |
| Clearing Packet Counters | 41 |
| Verifying Interface Statistics | 42 |
| Verifying PPPoE IA is Enabled | 43 |
| Verifying Configuration for PPPoE IA on an Interface | 43 |
| Troubleshooting Tips | 43 |
| Configuration Examples | 43 |
| Configuration Example for PPPoE IA on an Interface | 43 |
| Configuration Example for PPPoE IA on a Bridge Domain Interface | 44 |
| Configuration Example with Multiple Bridge Domains | 44 |
| Additional References for PPPoE Intermediate Agent | 45 |



CHAPTER 1

Feature History

The following table lists the new and modified features supported in the IP Routing: Protocol-Independent Configuration Guide in Cisco IOS XE 17 releases.

| Feature | Description |
|---|---|
| Cisco IOS XE Bengaluru 17.4.1 | |
| On-Change Notifications for IS-IS State | This feature allows you to externalize the internal state of the router for the operational data and thus enables you to access the internal state of the router. It helps in sending on-change notifications to the receiver for any change of state, for example, when the adjacency goes up or down. |



CHAPTER 2

IS-IS Overview and Basic Configuration

This module provides a technical overview of the Integrated Intermediate System-to-Intermediate System (IS-IS) routing protocol. IS-IS is a link-state Interior Gateway Protocol (IGP). Link-state protocols are characterized by the propagation of the information required to build a complete network connectivity map on each participating device. That map is then used to calculate the shortest path to destinations.

The IS-IS protocol was developed in the late 1980s by Digital Equipment Corporation (DEC) and was standardized by the International Standards Organization (ISO) in ISO/IEC 10589. The current version of this standard is ISO/IEC 10589:2002.

ISO/IEC 10589 defines support for the ISO Connectionless Network Protocol (CLNP) as defined in ISO 8473. However, the protocol was designed to be extensible to other network protocols. RFC 1195 defined IS-IS support for IP, and additional IETF extensions have defined IS-IS support for IPv6. Integration of support for multiple network layer protocols has led to the term Integrated IS-IS. The Cisco IOS IS-IS implementation supports CLNP, IPv4, and IPv6. This module and its related modules use the term IS-IS to refer to the Integrated IS-IS that is implemented by Cisco IOS software.

- [Finding Feature Information, on page 3](#)
- [Prerequisites for IS-IS Overview and Basic Configuration, on page 4](#)
- [Restrictions for IS-IS on Cisco ASR 900 Series Routers, on page 4](#)
- [Information About IS-IS Overview and Basic Configuration, on page 4](#)
- [How to Create Monitor and Make Changes to a Basic IS-IS Network, on page 11](#)
- [Configuration Examples for a Basic IS-IS Network, on page 16](#)
- [On-Change Notifications for IS-IS State, on page 19](#)
- [Where to Go Next, on page 26](#)
- [Additional References for IS-IS Overview and Basic Configuration, on page 27](#)
- [Glossary, on page 28](#)

Finding Feature Information

Your software release may not support all the features documented in this module. For the latest caveats and feature information, see [Bug Search Tool](#) and the release notes for your platform and software release. To find information about the features documented in this module, and to see a list of the releases in which each feature is supported, see the feature information table.

Use Cisco Feature Navigator to find information about platform support and Cisco software image support. To access Cisco Feature Navigator, go to <https://cfngn.cisco.com/>. An account on Cisco.com is not required.

Prerequisites for IS-IS Overview and Basic Configuration

- This document assumes knowledge of CLNS, IPv4, and IPv6.
- The amount of knowledge required for each technology is dependent on your deployment. You should know your network design and how you want traffic to flow through it before configuring IS-IS.
- Define areas, prepare an addressing plan for the devices (including defining the NETs), and determine the interfaces that will run Integrated IS-IS.
- To facilitate verification, a matrix of adjacencies should be prepared before you configure your devices, showing what neighbors should be expected in the adjacencies table.

Restrictions for IS-IS on Cisco ASR 900 Series Routers

- Maximum number of sessions for IS-IS is 350

Information About IS-IS Overview and Basic Configuration

IS-IS Functional Overview

A routing domain may be divided into one or more subdomains. Each subdomain is referred to as an area and is assigned an area address. Routing within an area is referred to as Level-1 routing. Routing between Level-1 areas is referred to as Level-2 routing. A device in Open Systems Interconnection (OSI) terminology is referred to as an Intermediate System (IS). An IS may operate at Level 1, Level 2, or both. ISs that operate at Level 1 exchange routing information with other Level-1 ISs in the same area. ISs that operate at Level 2 exchange routing information with other Level-2 devices regardless of whether they are in the same Level-1 area. The set of Level-2 devices and the links that interconnect them form the Level-2 subdomain, which must not be partitioned in order for routing to work properly.

IS Address Assignment

An IS is identified by an address known as a Network Entity Title (NET). The NET is the address of a Network Service Access Point (NSAP), which identifies an instance of the IS-IS routing protocol running on an IS. The NET may be 8 to 20 octets in length and consists of three parts:

- Area address—This field is 1 to 13 octets in length and is composed of high-order octets of the address.

**Note**

An IS-IS instance may be assigned multiple area addresses. When this is the case, all area addresses are considered synonymous. Multiple synonymous area addresses are useful when merging or splitting areas in the domain. In normal operation, for example, once the merge or split has been completed, there is no need to assign more than one area address to an IS-IS instance.

- System ID—This field is 6 octets long and immediately follows the area address. When the IS operates at Level 1, the system ID must be unique among all the Level-1 devices in the same area. When the IS operates at Level 2, the system ID must be unique among all devices in the domain.

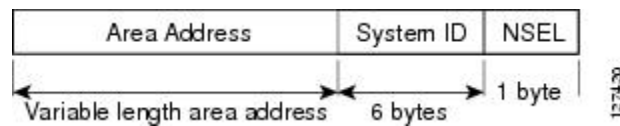


Note An IS instance is assigned exactly one system ID.

- NSEL—The N-selector field is 1 octet in length and immediately follows the system ID. It must be set to 00.

The figure below shows the format for the NET.

Figure 1: NET Format



IS-IS PDU Types

ISs exchange routing information with their peers using protocol data units (PDUs). The following types of PDUs are used:

IIHs

Intermediate System-to-Intermediate System Hello PDUs (IIHs) are exchanged between IS neighbors on circuits on which the IS-IS protocol is enabled. IIHs include the system ID of the sender, the assigned area address(es), and the identity of neighbors on that circuit that are known to the sending IS. Additional optional information may also be included.

There are three types of IIHs:

- Point-to-Point IIHs—These are sent on point-to-point circuits.
- Level-1 LAN IIHs—These are sent on multiaccess circuits when the sending IS operates as a Level-1 device on that circuit.
- Level-2 LAN IIHs—These are sent on multiaccess circuits when the sending IS operates as a Level-2 device on that circuit.

LSPs

An IS generates Link-State PDUs (LSPs) to advertise its neighbors and the destination that are directly connected to the IS. An LSP is uniquely identified by the following:

- System ID of the IS that generated the LSP
- Pseudonode ID—This value is always 0 except when the LSP is a pseudonode LSP (see “Operation of IS-IS on Multiaccess Circuits” section).
- LSP number (0 to 255)

- 32-bit sequence number

Whenever a new version of an LSP is generated, the sequence number is incremented.

Level-1 LSPs are generated by ISs that support Level 1. The Level-1 LSPs are flooded throughout the Level-1 area. The set of Level-1 LSPs generated by all Level-1 ISs in an area is the Level-1 LSP Database (LSPDB). All Level-1 ISs in an area will have an identical Level-1 LSPDB and will therefore have an identical network connectivity map for the area.

Level-2 LSPs are generated by ISs that support Level 2. Level-2 LSPs are flooded throughout the Level-2 subdomain. The set of Level-2 LSPs generated by all Level-2 ISs in the domain is the Level-2 LSP Database (LSPDB). All Level-2 ISs will have an identical Level-2 LSPDB and will therefore have an identical connectivity map for the Level-2 subdomain.

SNPs

Sequence Number PDUs (SNPs) contain a summary description of one or more LSPs. There are two types of SNPs for both Level 1 and Level 2:

- Complete Sequence Number PDUs (CSNPs) are used to send a summary of the LSPDB that an IS has for a given level.
- Partial Sequence Number PDUs (PSNPs) are used to send a summary of a subset of the LSPs for a given level that an IS either has in its database or needs to obtain.

For more information about how SNPs are used, see the “IS-IS Supported Circuit Types” section.

IS-IS Supported Circuit Types

IS-IS supports two generic circuit types:

- Point-to-point circuits
- Multiaccess circuits

Operation of IS-IS on Point-to-Point Circuits

A point-to-point circuit has exactly two ISs on the circuit. An IS forms a single adjacency to the other IS on the point-to-point circuit. The adjacency type describes what level(s) are supported on that circuit.

If both ISs support Level 1 on that circuit and the ISs are configured with at least one matching address, the adjacency supports Level 1. Level-1 LSPs and SNPs will be sent on that circuit.

If both ISs support Level 2 on that circuit, the adjacency supports Level 2. Level-2 LSPs and SNPs will be sent on that circuit.

The adjacency then can be Level 1, Level 2, or Level 1 and 2.

ISs send point-to-point IIHs on point-to-point circuits. These IIHs allow each IS to discover the identity of the neighbor, the configured area address(es), and the supported levels.

When an adjacency is first established, each IS sends a set of CSNPs for each level that is supported on the circuit. A CSNP set describes the current contents of the LSPDB at that level. By comparing the contents of the set of received CSNPs with the contents of the local LSPDB, each IS can determine where the databases differ and initiate procedures to exchange the necessary LSPs so that the databases are efficiently and reliably synchronized.

PSNPs are sent to acknowledge the receipt of an updated LSP.

Operation of IS-IS on Multiaccess Circuits

Multiaccess circuits support multiple ISs; for example, two or more operating on the circuit. The ability to address multiple systems utilizing a multicast or broadcast address is assumed.

An IS that supports Level 1 on a multiaccess circuit sends Level-1 LAN IIHs on the circuit. An IS that supports Level 2 on a multiaccess circuit sends Level-2 LAN IIHs on the circuit.

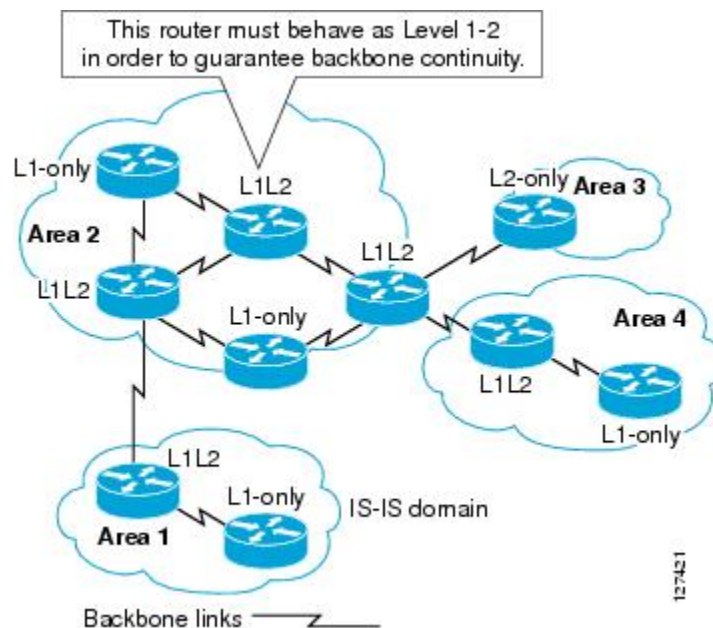
ISs form separate adjacencies for each level with neighbor ISs on the circuit.

An IS will form a Level-1 adjacency with other ISs that support Level 1 on the circuit and will have a matching area address. It is a misconfiguration to have two ISs with disjoint sets of area addresses supporting Level 1 on the same multiaccess circuit.

An IS will form a Level-2 adjacency with other ISs that support Level 2 on the circuit.

The devices in the IS-IS network topology in the figure below perform Level 1, Level 2, or Level 1 and 2 routing along the backbone of the network.

Figure 2: Level 1, Level 2, and Level 1-2 Devices in an IS-IS Network Topology



IS-IS Election of the Designated Intermediate System

If each IS advertised all of its adjacencies on a multiaccess circuit in its LSPs, the total number of advertisements required would be N^2 —where N is the number of ISs that operate at a given level on the circuit. To address this scalability issue, IS-IS defines a pseudonode to represent the multiaccess circuit. All ISs that operate on the circuit at a given level elect one of the ISs to act as the Designated Intermediate System (DIS) on that circuit. A DIS is elected for each level that is active on the circuit.

The DIS is responsible for issuing pseudonode LSPs. The pseudonode LSPs include neighbor advertisements for all of the ISs that operate on that circuit. All ISs that operate on the circuit (including the DIS) provide a neighbor advertisement to the pseudonode in their non-pseudonode LSPs and do not advertise any of their

neighbors on the multiaccess circuit. In this way the total number of advertisements required varies as a function of N —the number of ISs that operate on the circuit.

A pseudonode LSP is uniquely classified by the following identifiers:

- System ID of the DIS that generated the LSP
- pseudonode ID—ALWAYS NON-ZERO
- LSP number (0 to 255)
- 32-bit sequence number

The nonzero pseudonode ID is what differentiates a pseudonode LSP from a nonpseudonode LSP and is chosen by the DIS to be unique among any other LAN circuits for which it is also the DIS at this level.

The DIS is also responsible for sending periodic CSNPs on the circuit. This provides a complete summary description of the current contents of the LSPDB on the DIS. Other ISs on the circuit can then perform the following activities:

- Flood LSPs that they have that are absent from or are newer than those that are described in the CSNPs sent by the DIS.
- Request an LSP by sending a PSNP for LSPs that are described in the CSNPs sent by the DIS that are absent from the local database or older than what is described in the CSNP set.

In this way, the LSPDBs of all ISs on a multiaccess circuit are efficiently and reliably synchronized.

IS-IS Overview of LSPDB Synchronization

Proper operation of IS-IS requires a reliable and efficient process to synchronize the LSPDBs on each IS. In IS-IS this process is called the update process. This section provides a brief overview of the operation of the update process. The update process operates independently at each supported level.

LSPs may be locally generated, in which case they always are new LSPs. LSPs may also be received from a neighbor on a circuit, in which case they may be generated by some other IS or may be a copy of an LSP generated by the local IS. Received LSPs may be older, the same age, or newer than the current contents of the local LSPDB.

Handling of Newer LSPs

A newer LSP is added to the local LSPDB. If an older copy of the same LSP currently exists in the LSPDB, it is replaced. The newer LSP is marked to be sent on all circuits on which the IS currently has an adjacency in the UP state at the level associated with the newer LSP—excluding the circuit on which the newer LSP was received.

On point-to-point circuits, the newer LSP will be flooded periodically until the neighbor acknowledges its receipt by sending a PSNP or by sending an LSP that is the same or newer than the LSP being flooded.

On multiaccess circuits, the IS will flood the newer LSP once. The IS examines the set of CSNPs that are sent periodically by the DIS for the multiaccess circuit. If the local LSPDB contains one or more LSPs that are newer than what is described in the CSNP set (this includes LSPs that are absent from the CSNP set) those LSPs are reflooded over the multiaccess circuit. If the local LSPDB contains one or more LSPs that are older than what is described in the CSNP set (this includes LSPs described in the CSNP set that are absent from the local LSPDB), a PSNP is sent on the multiaccess circuit with descriptions of the LSPs that require updating. The DIS for the multiaccess circuit responds by sending the requested LSPs.

Handling of Older LSPs

An IS may receive an LSP that is older than the copy in the local LSPDB. An IS may receive an SNP (complete or partial) that describes an LSP that is older than the copy in the local LSPDB. In both cases the IS marks the LSP in the local database to be flooded on the circuit on which the older LSP or SNP that contained the older LSP was received.

At this point, the actions taken are identical to the actions that are described in the “Handling of Newer LSPs” section after a new LSP has been added to the local database.

Handling LSPs That Are the Same

Because of the distributed nature of the update process, it is possible that an IS may receive copies of an LSP that is the same as the current contents of the local LSPDB.

On a point-to-point circuit, receipt of such an LSP is ignored. Periodic transmission of a CSNP set by the DIS for that circuit will serve as an implicit acknowledgement to the sender that the LSP has been received.

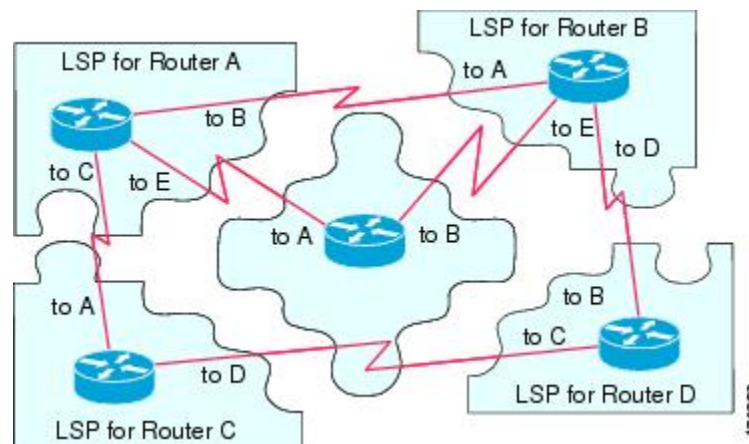
In a multiaccess circuit, receipt of such an LSP is ignored. Periodic transmission of a CSNP set by the DIS for that circuit will serve as an implicit acknowledgement to the sender that the LSP has been received.

The figure below shows how the LSPs are used to create a network map. Imagine the network topology as a jigsaw puzzle. Each LSP (representing an IS) is considered one of the jigsaw pieces.



Note The figure below is applicable to all Level-1 devices in an area or to all Level-2 devices in a Level-2 subdomain.

Figure 3: IS-IS Network Map

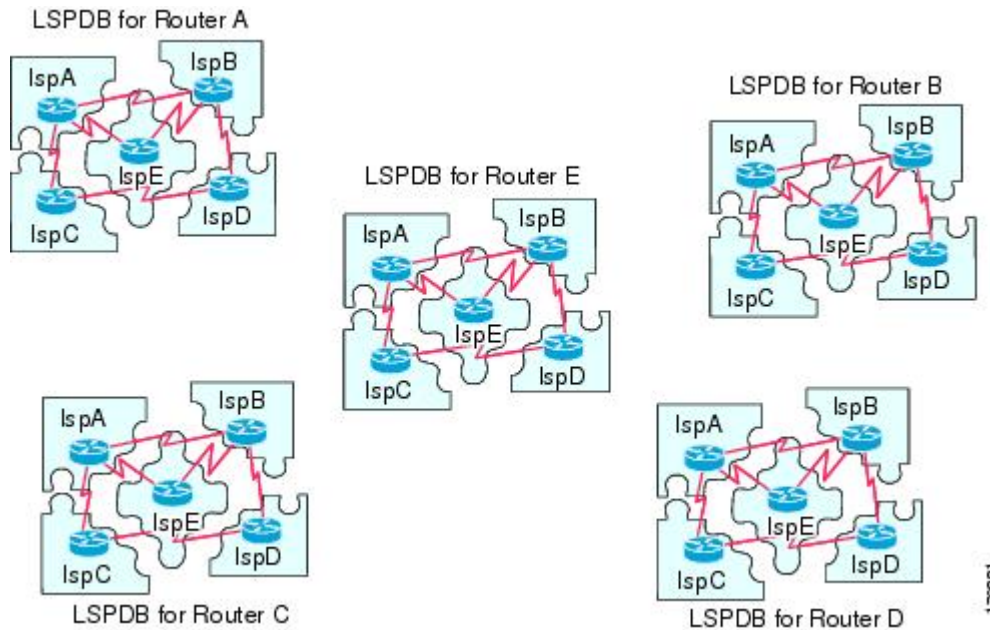


The figure below shows each device in the IS-IS network with its fully updated link-state database, after the adjacencies have been formed among the neighbor devices.



Note The figure below is applicable to all Level-1 devices in an area or to all Level-2 devices in a Level-2 subdomain.

Figure 4: IS-IS Devices with Synchronized LSPDBs



IS-IS Overview of the Shortest Path Calculation

When the contents of the LSPDB change, each IS independently reruns a shortest path calculation. The algorithm is based on the well-known Dijkstra algorithm for finding the shortest paths along a directed graph where the ISs are the vertices of the graph and the links between the ISs are edges with a nonnegative weight. A two-way connectivity check is performed before considering a link between two ISs as part of the graph. This prevents the use of stale information in the LSPDB, for example, when one IS is no longer operating in the network but did not purge the set of LSPs that it generated before ceasing operation.

The output of the SPF is a set of tuples (destination, next hop). The destinations are protocol-specific; for example, they would be prefixes when the supported protocol is IP, NSAPs of end systems when the supported protocol is CLNP. Multiple equal-cost paths are supported, in which case multiple next hops would be associated with the same destination.

Independent SPF calculations are performed for each level supported by the IS. In cases in which the same destination is reachable by both Level-1 and Level-2 paths, the Level-1 path is preferred.

A Level-2 IS that indicates that it has one or more Level-2 neighbors in other areas may be used by Level-1 devices in the same area as the path of last resort, also called the default route. The Level-2 IS indicates its attachment to other areas by setting an attached bit (ATT) in its Level-1 LSP 0.



Note An IS can generate up to 256 LSPs at each level. The LSPs are identified by the numbers 0 through 255. LSP 0 has special properties, including the significance of the setting of the ATT bit to indicate attachment to other areas. When LSPs that are numbered 1 through 255 have the ATT bit set, it is not significant.

How to Create Monitor and Make Changes to a Basic IS-IS Network

Enabling IS-IS as an IP Routing Protocol on the Device

Procedure

| | Command or Action | Purpose |
|---------------|---|--|
| Step 1 | enable Example: Device> enable | Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted. |
| Step 2 | configure terminal Example: Device# configure terminal | Enters global configuration mode. |
| Step 3 | router isis [area-tag] Example: Device(config)# router isis | Assigns a tag to an IS-IS process. Enters router configuration mode. <ul style="list-style-type: none"> • Configure tags to identify multiple IS-IS processes by giving a meaningful name for each routing process. If the tag is not specified, a null tag (0) is assumed and the process is referenced with a null tag. The tag name must be unique among all IP router processes for the device. |
| Step 4 | net network-entity-title Example: Device(config-router)# net 49.0001.0000.0000.000b.00 | Configures the NET on the device. <ul style="list-style-type: none"> • The NET identifies the device for IS-IS. |
| Step 5 | end Example: Device(config-router)# end | Exits router configuration mode and returns to privileged EXEC mode. |

Enabling IS-IS as an IP Routing Protocol on the Interface

Procedure

| | Command or Action | Purpose |
|---------------|---|---|
| Step 1 | enable Example: Device> enable | Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted. |
| Step 2 | configure terminal Example: Device# configure terminal | Enters global configuration mode. |
| Step 3 | interface <i>type number</i> Example: | Enters interface configuration mode. |
| Step 4 | ip address <i>ip-address mask [secondary]</i> Example: Device(config-if)# ip address 172.16.1.27 255.255.255.0 | Sets the primary IP address on the interface. |
| Step 5 | ip router isis [<i>area-tag</i>] Example: Device(config-if)# ip router isis company1 | Enables IS-IS on the interfaces that are to use IS-IS to distribute their IP information (and additionally that might be used to establish IS-IS adjacencies). <ul style="list-style-type: none"> • Use the <i>area-tag</i> argument to specify to which IS-IS process the device belongs. • If there is more than one IS-IS process on the device, repeat the ip router isis command for each interface, specifying an area tag for each interface to associate each interface with the specific process to which it belongs. |
| Step 6 | end Example: Device(config-if)# end | Exits interface configuration mode and returns to privileged EXEC mode. |

Monitoring IS-IS

Procedure

| | Command or Action | Purpose |
|---------------|---|---|
| Step 1 | enable Example: Device> enable | Enables privileged EXEC mode. <ul style="list-style-type: none"> • Enter your password if prompted. |
| Step 2 | configure terminal Example: Device# configure terminal | Enters global configuration mode. |
| Step 3 | isis display delimiter [return count character count] Example: Device(config)# isis display delimiter return 3 | Makes output from multiarea displays easier to read by specifying the delimiter to use to separate displays of information. |
| Step 4 | exit Example: Device(config)# exit | Returns to privileged EXEC mode. |
| Step 5 | show ip protocols Example: Device# show ip protocols | Displays the parameters and current state of the active routing protocol process. <ul style="list-style-type: none"> • You can use this command to learn what protocols are active, what interfaces they are active on, what networks they are routing for, and other parameters that relate to the routing protocols. |
| Step 6 | show clns area-tag is-neighbors [type number] [detail] Example: Device# show clns is-neighbors detail | Displays IS-IS information for IS-IS device adjacencies. |
| Step 7 | show clns interface [type number] Example: Device# show clns interface | List the CLNS-specific information about each interface. |
| Step 8 | show clns area-tag neighbors [type number] [area] [detail] | Displays both ES and IS neighbors. |

| | Command or Action | Purpose |
|----------------|--|--|
| | <p>Example:</p> <pre>Device# show clns area3 neighbors</pre> | <ul style="list-style-type: none"> The show clns neighbor command output verifies that the right adjacencies have established. A matrix of adjacencies should be prepared before you configure your devices, showing what neighbors should be expected in the adjacencies table, to facilitate verification. |
| Step 9 | <p>show clns <i>area-tag</i> traffic</p> <p>Example:</p> <pre>Device# show clns area3 traffic</pre> | <p>Displays traffic statistics.</p> <p>To monitor IS-IS for stability once it has been deployed across your network, enter the show clns traffic command to check the following important statistics: high numbers of SPFs, checksum errors, and retransmissions. To troubleshoot IS-IS behavior, you can use the output from the show clns traffic command to check for the following indicators:</p> <ul style="list-style-type: none"> The number of link-state PDUs (LSPs) can help you determine the stability of the IS-IS network. The number of LSPs should never be zero. However, an LSP count that keeps increasing over a short time period indicates a network issue. LSP retransmissions should stay low. A later execution of the show clns traffic command that shows an increase in LSP retransmissions, as compared to an earlier execution of the command, can indicate instability or traffic problems. To check for partial route calculations (PRCs), enter the show clns traffic command. PRCs are flooded when a change that does not affect topology is reported through an LSP; typical examples include the addition or removal of a prefix or metric changes for external or passive interfaces. A PRC update queue that remains full or increases to the maximum value for long periods of time indicates network instability. LSP checksum errors indicate a problem. The update queue should not stay full and should not drop much. |
| Step 10 | <p>show ip route [<i>ip-address</i> [<i>mask</i>]] [[longer-prefixes] <i>protocol</i> [<i>process-id</i>] list]</p> | Displays the current state of the routing table. |

| | Command or Action | Purpose |
|----------------|---|--|
| | <p><code>[access-list-number access-list-name] static download]]</code></p> <p>Example:</p> <pre>Device# show ip route 172.16.0.21</pre> | |
| Step 11 | <p><code>show isis [process-tag] database [level-1] [level-2] [11] [12] [detail] [lspid]</code></p> <p>Example:</p> <pre>Device# show isis database detail</pre> | <p>Displays additional information about the IS-IS database.</p> <ul style="list-style-type: none"> Displays the link-state database for Level-1 and Level-2, the contents for each LSP, and the link-state protocol PDU identifier. |
| Step 12 | <p><code>show isis database verbose</code></p> <p>Example:</p> <pre>Device# show isis database verbose</pre> | <p>Displays additional information about the IS-IS database such as the sequence number, checksum, and holdtime for LSPs.</p> |
| Step 13 | <p><code>show isis lsp-log</code></p> <p>Example:</p> <pre>Device# show isis lsp-log</pre> | <p>Displays a log of LSPs including time of occurrence, count, interface, and the event that triggered the LSP.</p> |
| Step 14 | <p><code>show isis [area-tag] [ipv6 *] spf-log</code></p> <p>Example:</p> <pre>Device# show isis spf-log</pre> | <p>Displays how often and why the device has run a full shortest path first (SPF) calculation.</p> <ul style="list-style-type: none"> If the device continues to run SPF without ceasing, there might be an issue regarding a change in the network (intra-area). The cause for the continued SPF calculations could be an interconnecting link that is transitioning up/down/up/down or a metric change. It is normal for the SPF calculation to run a few times when a network change occurs, but then it should cease. |
| Step 15 | <p><code>show isis [process-tag] [ipv6 *] topology</code></p> <p>Example:</p> <pre>Device# show isis topology</pre> | <p>Displays a list of all connected devices in all areas.</p> |
| Step 16 | <p><code>show isis [area-tag] neighbors [detail]</code></p> <p>Example:</p> <pre>Device# show isis neighbors detail</pre> | <p>Displays IS-IS adjacency information.</p> <ul style="list-style-type: none"> The <code>show isis neighbor detail</code> command output verifies that the right adjacencies have established. A matrix of adjacencies should be prepared before you configure your devices, showing what neighbors |

| | Command or Action | Purpose |
|--|-------------------|--|
| | | should be expected in the adjacencies table, to facilitate verification. |

Example

When the **show isis neighbors** command is entered with the **detail** keyword, the output provides information about the IS-IS adjacencies that have formed.

```
Device1# show isis neighbors detail
```

```
System Id      Type Interface IP Address      State Holdtime Circuit Id
Device2        L2  Et1/0      10.1.1.0        UP    255      Circuit3.01
Area Address(es): 32
SNPA: aabb.cc00.2001
State Changed: 00:00:14
LAN Priority: 64
Format: Phase V
```

Troubleshooting Tips

You can use the following two system debugging commands to check your IS-IS IPv4 implementation.

- If adjacencies are not coming up properly, use the **debug isis adj-packets** command.
- To display a log of significant events during an IS-IS SPF calculation, use the **debug isis spf-events** command.

Configuration Examples for a Basic IS-IS Network

Example: Configuring a Basic IS-IS Network

The following example shows how to configure three devices to run IS-IS as an IP routing protocol.

Device A Configuration

```
router isis
 net 49.0001.0000.0000.000a.00
 interface ethernet0/0
 ip address 10.1.1.1 255.255.255.0
 ip router isis
 interface serial 2/0
 ip router isis
 ip address 192.168.1.2 255.255.255.0
```

Device B Configuration

```
router isis
 net 49.0001.0000.0000.000b.00
```

```

interface ethernet0/0
 ip router isis
 ip address 172.17.1.1 255.255.255.0
interface serial2/0
 ip router isis
 ip address 192.168.1.1 255.255.255.0
interface serial5/0
 ip router isis
 ip address 172.21.1.1 255.255.255.0

```

Device C Configuration

```

router isis
 net 49.0001.0000.0000.000c.00
interface ethernet2/0
 ip router isis
 ip address 172.21.1.2 255.255.255.0
interface serial5/0
 ip router isis
 ip address 172.22.1.1 255.255.255.0

```

The **show isis topology** command displays the following information about how the devices are connected within the IS-IS network:

```
DeviceB# show isis topology
```

```

IS-IS paths to level-1 routers
System Id      Metric  Next-Hop      Interface  SNPA
DeviceA        10     DeviceA       Se2/0      *HDLC*
DeviceB        --
DeviceC        10     DeviceC       Se5/0      *HDLC*
IS-IS paths to level-2 routers
System Id      Metric  Next-Hop      Interface  SNPA
DeviceA        10     DeviceA       Se2/0      *HDLC*
DeviceB        --
DeviceC        10     DeviceC       Se5/0      *HDLC*

```

The **show isis database** command displays following information for the Level 1 and Level 2 LSPs for each device in the IS-IS network.

```
DeviceB# show isis database
```

```

IS-IS Level-1 Link State Database:
LSPID          LSP Seq Num  LSP Checksum  LSP Holdtime  ATT/P/OL
DeviceA.00-00  0x00000005  0x1A1D        1063           0/0/0
DeviceB.00-00  * 0x00000006  0xD15B        1118           0/0/0
DeviceC.00-00  0x00000004  0x3196        1133           1/0/0
IS-IS Level-2 Link State Database:
LSPID          LSP Seq Num  LSP Checksum  LSP Holdtime  ATT/P/OL
DeviceA.00-00  0x00000008  0x0BF4        1136           0/0/0
DeviceB.00-00  * 0x00000008  0x1701        1137           0/0/0
DeviceC.00-00  0x00000004  0x3624        1133           0/0/0

```

The **show ip route** command displays information about the interfaces of each device, including their IP addresses and how they are connected to Device B:

```
DeviceB# show ip route
```

```

Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area

```

Example: Configuring a Basic IS-IS Network

```

N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
E1 - OSPF external type 1, E2 - OSPF external type 2
i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
ia - IS-IS inter area, * - candidate default, U - per-user static route
o - ODR, P - periodic downloaded static route
Gateway of last resort is not set
  172.17.0.0/24 is subnetted, 1 subnets
C    172.17.1.0 is directly connected, Ethernet0/0
  172.16.0.0/24 is subnetted, 1 subnets
C    172.16.1.0 is directly connected, Serial4/0
  172.21.0.0/24 is subnetted, 1 subnets
C    172.21.1.0 is directly connected, Serial5/0
  172.22.0.0/24 is subnetted, 1 subnets
i L1  172.22.1.0 [115/20] via 172.21.1.2, Serial5/0
  10.0.0.0/24 is subnetted, 1 subnets
i L1  10.1.1.0 [115/20] via 192.168.1.2, Serial2/0
C    192.168.1.0/24 is directly connected, Serial2/0
C    192.168.3.0/24 is directly connected, Serial3/0

```

The **show isis spf-log** command displays logs of Level 1 and Level 2 LSPs including time of occurrence, duration, count, and the event that triggered the LSP.

```
DeviceC## show isis spf-log
```

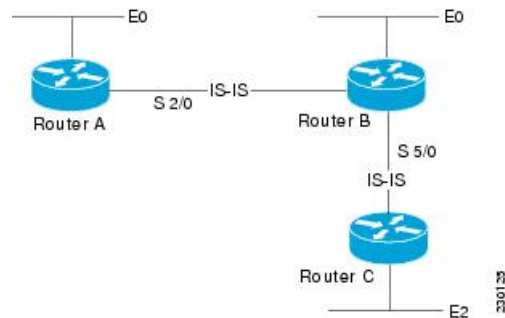
```

level 1 SPF log
When Duration Nodes Count First trigger LSP Triggers
00:01:30 0 3 7 DeviceB.00-00 PERIODIC NEWADJ NEWLSP TLVT
level 2 SPF log
When Duration Nodes Count First trigger LSP Triggers
00:01:31 0 3 7 DeviceB.00-00 PERIODIC NEWADJ NEWLSP TLVT

```

The figure below illustrates the sample configuration.

Figure 5: IS-IS Routing



On-Change Notifications for IS-IS State

Table 1: Feature History

| Feature Name | Release Information | Description |
|---|-------------------------------|---|
| On-Change Notifications for IS-IS State | Cisco IOS XE Bengaluru 17.4.1 | This feature allows you to externalize the internal state of the router for the operational data and thus enables you to access the internal state of the router. It helps in sending on-change notifications to the receiver for any change of state, for example, when the adjacency goes up or down. |

Prior to Cisco IOS XE Bengaluru Release 17.4.1, it was not possible to externalize the internal IOS state for operational data. Thus, the on-change notifications were not generated for any change of state.

Starting with Cisco IOS XE Bengaluru Release 17.4.1, you can access the internal IOS state of the router to configure or view the running state of the router. The feature allows the externalization of the internal state of the router for the operational data. It helps in sending on-change notifications to the receiver for any change of state, for example, when the adjacency goes up or down.

IOS State

The IOS state can be divided into the following conceptual groups:

- Configuration or config state includes:
 - Feature default config state (use **show running-config all** command with no user configuration)
 - Non-default config state (use **show running-config** command)
 - Nonvisible non-persistent feature config state (subscriber profiles)
- Operational state includes:
 - Feature state that is not config state (adjacency, Link-State Protocol Data Units or LSPs, and so on)

Telemetry and IS-IS

Telemetry is the process of measuring the state of the components in a system and transmitting it to a remote location for further processing and analysis. Event-driven Telemetry (EDT) optimizes data collected at the receiver by streaming data only when a state transition occurs (for example, stream data only when an interface state transitions, IP route updates, and so on). For IS-IS, the on-change notifications are sent when the adjacency state changes.

For more information on the Telemetry feature, see the [Programmability Configuration Guide, Cisco IOS XE Amsterdam 17.1.x](#).

The following events are supported:

- IS-IS Neighbor UP
- IS-IS Neighbor DOWN

- IS-IS Neighbor INIT

Configuration Examples: On-Change Notifications for IS-IS State

The following examples show the configurations for on-change notifications for IS-IS:

Router 1

Configuration for IPv4/IPv6 Adjacency

```
interface GigabitEthernet 0/1/5
ip address <ipv4 address>
ip router isis 1
shutdown
negotiation auto
cdp enable
no cdp tlv app
ipv6 address 10:1:1::1/64
ipv6 router isis 1
isis network point-to-point
end
```

```
router isis 1
net 49.0009.0000.0000.0001.00
is-type level-1
metric-style wide
log-adjacency-changes
```

Sample Configuration for Notification

```
telemetry ietf subscription 11
encoding encode-tdl
filter tdl-uri /services;serviceName=ios_emul_oper/isis_instance;tag=CORE/isis_neighbor
source-vrf Mgmt-intf
stream native
update-policy on-change
receiver ip address 173.39.61.144 45000 protocol native
```

Router 2

Configuration for IPv4/IPv6 Adjacency

```
interface GigabitEthernet 0/1/5
ip address <ipv4 address>
ip router isis 1
negotiation auto
cdp enable
no cdp tlv app
ipv6 address 10:1:1::2/64
ipv6 router isis 1
isis network point-to-point
end
```

```
router isis 1
net 49.0009.0000.0000.0002.00
is-type level-1
metric-style wide
log-adjacency-changes
```

Configuration for Notification

```
telemetry ietf subscription <subscription_id>
encoding encode-tdl
filter <uri path>
```

```

/services;serviceName=ios_emul_oper/isis_instance;tag=<isis_tag>/isis_neighbor
source-vrf Mgmt-intf
stream native
update-policy on-change
receiver ip address <ip address> <port number> protocol <protocol name>

```

Verification of On-Change Notifications for IS-IS State Configuration

The following output shows the verification of on-change notifications for IS-IS State configuration:

```

INFO: __main__:Message TYPE CNDP_SESSION_MSG - ENCODING CNDP_MSG_ENCODING_TDL - VERSION 1 -
  FLAGS NO_FLAG - LENGTH 175
INFO: __main__:Cndp session request received: Request_id 1 - {
  "request_id": 1,
  "device_id": "ASR-903:FOC2042NFR2",
  "sw_version": "17.04.01.0.1182.1602302245..Bengaluru",
  "src_ip": "ip address",
  "capability_flag": [
    "CNDP_SESSION_CAPABILITY_KEEP_ALIVE",
    "CNDP_SESSION_CAPABILITY_SESSION_RESPONSE"
  ],
  "ch_serial_num": "ASR-903:FOX2046P1MP",
  "serial_num": "ASR-903:FOC2042NFR2"
} -
INFO: __main__:Sending cndp session request: Request_id 1 - {
  "request_id": 1,
  "status": 0,
  "capability": {
    "capability": [
      "CNDP_SESSION_CAPABILITY_KEEP_ALIVE"
    ],
    "capability_union": {
      "ka_params": {
        "ka_frequency": 30,
        "ka_max_timeout": 90
      }
    }
  }
} -
INFO: __main__:Telemetry message received from <ip address> at 2020-10-15 10:51:49
INFO: __main__:Message TYPE CNDP_KEEPALIVE_MSG - ENCODING CNDP_MSG_ENCODING_TDL - VERSION 1
  - FLAGS NO_FLAG - LENGTH 28
INFO: __main__:SEQUENCE_ID 222028829 TIMESTAMP 2020-10-15 16:21:46.304162
INFO: __main__:Sending keep_alive response with sequence id 222028829
INFO: __main__:Telemetry message received from <ip address> at 2020-10-15 10:51:49
INFO: __main__:Message TYPE CNDP_TELEMETRY_EVENT_MSG - ENCODING CNDP_MSG_ENCODING_TDL -
  VERSION 1 - FLAGS NO_FLAG - LENGTH 391
INFO: __main__:{
  "subscription_id": 11,
  "capture_time": {
    "second": 1602759106,
    "microsec": 937026
  },
  "data": {
    "result": {
      "exec_ctx": "ios_emul_oper_db_context",
      "params_id": {
        "which": [],
        "which_union": {}
      },
      "result_code": "GREEN_RES_OK",
      "notf_str": "",
      "err_str": ""
    }
  }
}

```

```

    "num_entry": 0
  },
  "data": {
    "table_luid": [
      "tbl_isis_neighbor",
      "190 55 188 213 227 103 66 189 42 56 218 39 4 45 119 7"
    ],
    "cursor": {
      "len": 0,
      "data": "",
      "issu_checking": 0
    },
    "num_entry": 1,
    "entry": [
      {
        "keys": {
          "num_key_field_ids": 0,
          "num_key_luids": 0,
          "num_key": 0,
          "field_ids": "",
          "luids": [],
          "keys": [],
          "num_src_ids": 0,
          "src_ids": ""
        },
        "op": "GREEN_RECORD_UPDATE",
        "len": 164,
        "entry_data": {
          "isis_neighbor_rec": {
            "ipv4_address": "ip address",
            "ipv6_address": null,
            "state": "ISIS_INIT",
            "holdtime": 29
          },
          "isis_neighbor_key": {
            "system_id": {
              "addr_len": 6,
              "addr": "0 0 0 0 0 50"
            },
            "level": "ISIS_LEVEL_1",
            "if_name": "GigabitEthernet0/1/5"
          }
        },
        "e": [],
        "ext_metadata": {
          "t": "GREEN_EXT_META_NONE",
          "t_union": {}
        },
        "link_entry_info_list": []
      }
    ]
  }
},
"location": {
  "fru": "BINOS_FRU_RP",
  "slot": 0,
  "bay": 0,
  "chassis": -1,
  "node": 0
}
}
INFO: __main__:Telemetry message received from <ip address> at 2020-10-15 10:51:50
INFO: __main__:Message TYPE CNDF_TELEMETRY_EVENT_MSG - ENCODING CNDF_MSG_ENCODING_TDL -
VERSION 1 - FLAGS NO_FLAG - LENGTH 391

```

```

INFO: __main__:{
  "subscription_id": 11,
  "capture_time": {
    "second": 1602759107,
    "microsec": 977053
  },
  "data": {
    "result": {
      "exec_ctx": "ios_emul_oper_db_context",
      "params_id": {
        "which": [],
        "which_union": {}
      },
      "result_code": "GREEN_RES_OK",
      "notf_str": "",
      "err_str": "",
      "num_entry": 0
    },
    "data": {
      "table_luid": [
        "tbl_isis_neighbor",
        "190 55 188 213 227 103 66 189 42 56 218 39 4 45 119 7"
      ],
      "cursor": {
        "len": 0,
        "data": "",
        "issu_checking": 0
      },
      "num_entry": 1,
      "entry": [
        {
          "keys": {
            "num_key_field_ids": 0,
            "num_key_luids": 0,
            "num_key": 0,
            "field_ids": "",
            "luids": [],
            "keys": [],
            "num_src_ids": 0,
            "src_ids": ""
          },
          "op": "GREEN_RECORD_UPDATE",
          "len": 164,
          "entry_data": {
            "isis_neighbor_rec": {
              "ipv4_address": "ip address",
              "ipv6_address": null,
              "state": "ISIS_UP",
              "holdtime": 9
            },
            "isis_neighbor_key": {
              "system_id": {
                "addr_len": 6,
                "addr": "0 0 0 0 0 50"
              },
              "level": "ISIS_LEVEL_1",
              "if_name": "GigabitEthernet0/1/5"
            }
          },
          "e": [],
          "ext_metadata": {
            "t": "GREEN_EXT_META_NONE",
            "t_union": {}
          }
        }
      ]
    }
  }
}

```

```

        "link_entry_info_list": []
    }
}
},
"location": {
    "fru": "BINOS_FRU_RP",
    "slot": 0,
    "bay": 0,
    "chassis": -1,
    "node": 0
}
}
INFO: __main__:Telemetry message received from <ip address> at 2020-10-15 10:51:50
INFO: __main__:Message TYPE CNDP_TELEMETRY_EVENT_MSG - ENCODING CNDP_MSG_ENCODING_TDL -
VERSION 1 - FLAGS NO_FLAG - LENGTH 391
INFO: __main__: {
    "subscription_id": 11,
    "capture_time": {
        "second": 1602759107,
        "microsec": 977747
    },
    "data": {
        "result": {
            "exec_ctx": "ios_emul_oper_db_context",
            "params_id": {
                "which": [],
                "which_union": {}
            },
            "result_code": "GREEN_RES_OK",
            "notf_str": "",
            "err_str": "",
            "num_entry": 0
        },
        "data": {
            "table_luid": [
                "tbl_isis_neighbor",
                "190 55 188 213 227 103 66 189 42 56 218 39 4 45 119 7"
            ],
            "cursor": {
                "len": 0,
                "data": "",
                "issu_checking": 0
            },
            "num_entry": 1,
            "entry": [
                {
                    "keys": {
                        "num_key_field_ids": 0,
                        "num_key_luids": 0,
                        "num_key": 0,
                        "field_ids": "",
                        "luids": [],
                        "keys": [],
                        "num_src_ids": 0,
                        "src_ids": ""
                    },
                    "op": "GREEN_RECORD_UPDATE",
                    "len": 164,
                    "entry_data": {
                        "isis_neighbor_rec": {
                            "ipv4_address": "ip address",
                            "ipv6_address": null,
                            "state": "ISIS_INIT",

```

```

        "holdtime": 30
      },
      "isis_neighbor_key": {
        "system_id": {
          "addr_len": 6,
          "addr": "0 0 0 0 0 50"
        },
        "level": "ISIS_LEVEL_2",
        "if_name": "GigabitEthernet0/1/5"
      }
    },
    "e": [],
    "ext_metadata": {
      "t": "GREEN_EXT_META_NONE",
      "t_union": {}
    },
    "link_entry_info_list": []
  }
}
}
},
"location": {
  "fru": "BINOS_FRU_RP",
  "slot": 0,
  "bay": 0,
  "chassis": -1,
  "node": 0
}
}
INFO: __main__:Telemetry message received from <ip address> at 2020-10-15 10:51:51
INFO: __main__:Message TYPE CNDP_TELEMETRY_EVENT_MSG - ENCODING CNDP_MSG_ENCODING_TDL -
VERSION 1 - FLAGS NO_FLAG - LENGTH 391
INFO: __main__:{
  "subscription_id": 11,
  "capture_time": {
    "second": 1602759108,
    "microsec": 963576
  },
  "data": {
    "result": {
      "exec_ctx": "ios_emul_oper_db_context",
      "params_id": {
        "which": [],
        "which_union": {}
      },
      "result_code": "GREEN_RES_OK",
      "notf_str": "",
      "err_str": "",
      "num_entry": 0
    },
    "data": {
      "table_luid": [
        "tbl_isis_neighbor",
        "190 55 188 213 227 103 66 189 42 56 218 39 4 45 119 7"
      ],
      "cursor": {
        "len": 0,
        "data": "",
        "issu_checking": 0
      },
      "num_entry": 1,
      "entry": [
        {
          "keys": {

```

```

        "num_key_field_ids": 0,
        "num_key_luids": 0,
        "num_key": 0,
        "field_ids": "",
        "luids": [],
        "keys": [],
        "num_src_ids": 0,
        "src_ids": ""
    },
    "op": "GREEN_RECORD_UPDATE",
    "len": 164,
    "entry_data": {
        "isis_neighbor_rec": {
            "ipv4_address": "ip address",
            "ipv6_address": null,
            "state": "ISIS_UP",
            "holdtime": 9
        },
        "isis_neighbor_key": {
            "system_id": {
                "addr_len": 6,
                "addr": "0 0 0 0 0 50"
            },
            "level": "ISIS_LEVEL_2",
            "if_name": "GigabitEthernet0/1/5"
        }
    },
    "e": [],
    "ext_metadata": {
        "t": "GREEN_EXT_META_NONE",
        "t_union": {}
    },
    "link_entry_info_list": []
}
    ]
}
}
    },
    "location": {
        "fru": "BINOS_FRU_RP",
        "slot": 0,
        "bay": 0,
        "chassis": -1,
        "node": 0
    }
}
}

```

Where to Go Next

- To initially configure and enable IS-IS, see the “Configuring a Basic IS-IS Network” module.
- To customize IS-IS for your network design, see the “Customizing IS-IS for Your Network Design” module.
- To customize IS-IS for achieving fast convergence and scalability, see the following modules:
 - “Overview of IS-IS Fast Convergence”
 - “Setting Best Practice Parameters for IS-IS Fast Convergence”
 - “Reducing Failure Detection Times in IS-IS Networks”
 - “Reducing Link Failure and Topology Change Notification Times in IS-IS Networks”
 - “Reducing Alternate-Path Calculation Times in IS-IS Networks”

- To enhance IS-IS network security, see the "Enhancing Security in an IS-IS Network" module.

Additional References for IS-IS Overview and Basic Configuration

Related Documents

| Related Topic | Document Title |
|--------------------------------------|--|
| IPv6 Routing: IS-IS Support for IPv6 | "IPv6 Routing: IS-IS Support for IPv6 " module |
| IPv6 Routing: Route Redistribution | "IPv6 Routing: Route Redistribution" module |
| IPv6 Routing: IS-IS Support for IPv6 | "IPv6 Routing: IS-IS Support for IPv6 " module |

Standards

| Standard | Title |
|---------------|--|
| ISO 8473 | <i>CLNP, Connectionless Network Protocol</i> |
| ISO 9542 | <i>ES-IS Routing Information Exchange Protocol</i> |
| ISO/IEC 10589 | <i>IS-IS Protocol</i> |

MIBs

| MIB | MIBs Link |
|---|--|
| No new or modified MIBs are supported, and support for existing MIBs has not been modified. | To locate and download MIBs for selected platforms, Cisco IOS releases, and feature sets, use Cisco MIB Locator found at the following URL: http://www.cisco.com/go/mibs |

RFCs

| RFC | Title |
|----------|--|
| RFC 1195 | <i>Use of OSI IS-IS for Routing in TCP/IP and Dual Environments</i> (http://www.ietf.org/rfc/rfc1195.txt) |

Technical Assistance

| Description | Link |
|---|---|
| The Cisco Support and Documentation website provides online resources to download documentation, software, and tools. Use these resources to install and configure the software and to troubleshoot and resolve technical issues with Cisco products and technologies. Access to most tools on the Cisco Support and Documentation website requires a Cisco.com user ID and password. | http://www.cisco.com/cisco/web/support/index.html |

Glossary

area —A physically connected portion of a routing domain in which all devices are assigned a common area address. Also known as the Level-1 subdomain. A routing domain may consist of multiple areas that are reachable by traversing the Level-2 subdomain.

area address —The high-order octets of the Network Entity Title (NET) assigned to an IS. All ISs in the same Level-1 area are assigned the same area address.

CLNP —ISO Connectionless Network Protocol as defined in ISO 8473.

DIS —Designated Intermediate System. An IS elected by all the ISs operating on a multiaccess circuit at a given level to represent the multiaccess circuit. The DIS sends pseudonode LSPs on behalf of the circuit advertising adjacencies to all the ISs operating on that circuit.

domain —The portion of a network on which the IS-IS protocol is configured to operate. The routing domain consists of all Level-1 areas and the Level-2 subdomain.

ES —end system. An ES is any nonrouting host or node.

Integrated IS-IS —Extended form of IS-IS that supports multiple network protocols. Extensions have been defined in IETF documents, especially RFC 1195.

IS —intermediate system. OSI term for a device.

IP —Internet Protocol Version 4, also known as IPv4.

IPv6 —Internet Protocol Version 6.

IS-IS —Intermediate System-to-Intermediate System. Routing protocol as defined in ISO/IEC 10589.

Level-1 router —An IS that supports Level-1 routing for its assigned area.

Level-2 router —An IS that supports Level-2 routing.

Level-2 subdomain —All Level-2 capable devices in a domain and the links that interconnect them. Level-1 areas are interconnected via the Level-2 subdomain. For routing in a domain to work properly, the Level-2 subdomain must not be partitioned.

NET —Network Entity Title. An address assigned to an instance of the IS-IS protocol. The NET includes an area address, a system ID, and an N-selector. When multiple NETs are assigned to an IS-IS instance, only the area address portion of the NET may differ.

NSEL —N-selector. The least significant octet of a Network Entity Title. It is always assigned the value 00.

system ID —The part of the NET that immediately follows the area address. The field is 6 octets long.



CHAPTER 3

Policy-Based Routing



Note This feature is not applicable on the Cisco RSP3 module.

The Policy-Based Routing feature is a process whereby a device puts packets through a route map before routing the packets. The route map determines which packets are routed next to which device. Policy-based routing is a more flexible mechanism for routing packets than destination routing.

- [Finding Feature Information, on page 29](#)
- [Information About Policy-Based Routing, on page 29](#)
- [How to Configure Policy-Based Routing, on page 30](#)
- [Configuration Examples for Policy-Based Routing, on page 32](#)
- [Additional References, on page 33](#)
- [Feature Information for Policy-Based Routing, on page 33](#)

Finding Feature Information

Your software release may not support all the features documented in this module. For the latest caveats and feature information, see [Bug Search Tool](#) and the release notes for your platform and software release. To find information about the features documented in this module, and to see a list of the releases in which each feature is supported, see the feature information table.

Use Cisco Feature Navigator to find information about platform support and Cisco software image support. To access Cisco Feature Navigator, go to <https://cfng.cisco.com/>. An account on Cisco.com is not required.

Information About Policy-Based Routing

Policy-Based Routing

Policy-based routing is a process whereby the device puts packets through a route map before routing them. The route map determines which packets are routed next to which device. You might enable policy-based routing if you want certain packets to be routed in a certain way other than the obvious shortest path. Possible applications for policy-based routing are to provide equal access, protocol-sensitive routing, source-sensitive

routing, routing based on interactive versus batch traffic, and routing based on dedicated links. Policy-based routing is a more flexible mechanism for routing packets than destination routing.

To enable policy-based routing, you must identify which route map to use for policy-based routing and create the route map. The route map itself specifies the match criteria and the resulting action if all of the match clauses are met.

To enable policy-based routing on an interface, indicate which route map the device should use by using the **ip policy route-map** *map-tag* command in interface configuration mode. A packet arriving on the specified interface is subject to policy-based routing except when its destination IP address is the same as the IP address of the device's interface. This **ip policy route-map** command disables fast switching of all packets arriving on this interface.

To define the route map to be used for policy-based routing, use the **route-map** *map-tag* [**permit**] [*sequence-number*] global configuration command.

To define the criteria by which packets are examined to learn if they will be policy-based routed, use the **match ip address** {*access-list-number* | *access-list-name*} command or both in route map configuration mode. No match clause in the route map indicates no packet match.

To display the cache entries in the policy route cache, use the **show ip cache policy** command.



Note PBR is supported only in a video template.

Restrictions for Policy-Based Routing

- The following command is not supported:

```
ip local policy route-map <route-map_name>
```



Note Local Policy based routing is not supported.

How to Configure Policy-Based Routing

Configuring Policy-Based Routing

Procedure

| | Command or Action | Purpose |
|---------------|--|--|
| Step 1 | enable Example: Router> enable | Enables privileged EXEC mode. <ul style="list-style-type: none"> Enter your password if prompted. |

| | Command or Action | Purpose |
|---------------|---|--|
| Step 2 | configure terminal Example: Router# configure terminal | Enters global configuration mode. |
| Step 3 | sdm prefer video Example: Router(config)#sdm prefer video | Configures the video mode. Note This requires a reload of the system. The configuration of the following steps will only be effective after the SDM template is changed to video template. |
| Step 4 | ip access-list extended <name> Example: Router(config)#ip access-list extended pbr-acl1 | Configures an Extended ACL named "pbr-acl1" and enters extended-acl configuration mode. |
| Step 5 | permit protocol source [source-wildcard] destination [destination-wildcard] Example: Router(config-ext-nacl)#permit ip 10.0.0.0 0.255.255.255 200.0.0.0 0.255.255.255 | Creates a match statement to match the specified source & destination IP address. |
| Step 6 | exit Example: Router(config-ext-nacl)#exit | Returns to global configuration mode. |
| Step 7 | Route-map <route_map_name> permit <sequence_number> Example: Router(config)#route-map pbr permit 10 | Creates a Route-map statement named "pbr" for redistributing routes from one routing protocol into another routing protocol or enables policy-based routing and enters route-map configuration mode. |
| Step 8 | match ip address <match_criteria_name> Example: Router(config-route-map)#match ip address pbr-acl1 | Defines the match criteria by which packets are examined to learn if they will be policy-based routed. |
| Step 9 | set ip next-hop <ip_address> set ip vrf <vrf_name> next-hop <ip_address> set vrf <vrf_name> Example: | Specifies where to output packets that pass a match clause of a route map for policy routing. |

| | Command or Action | Purpose |
|----------------|---|---|
| | <pre>Router(config-route-map)#set ip next-hop 30.0.0.2 Router(config-route-map)#set ip vrf vrf1 next-hop 30.0.0.1 Router(config-route-map)#set vrf vrf1</pre> | |
| Step 10 | <p>exit</p> <p>Example:</p> <pre>Router(config-route-map)#exit</pre> | Returns to global configuration mode. |
| Step 11 | <p>interface type number</p> <p>Example:</p> <pre>Router(config)#interface Gi0/0/10</pre> | Configures an interface type and enters interface configuration mode. |
| Step 12 | <p>ip policy route-map <route_map_name></p> <p>Example:</p> <pre>Router(config-if)#ip policy route-map pbr</pre> | Identifies a route map to use for policy routing on an interface. |
| Step 13 | <p>exit</p> <p>Example:</p> <pre>Router(config-if)#exit</pre> | Returns to global configuration mode. |

Verifying Policy-Based Routing

Use this command to verify that the SDM template is changed to video template.

show sdm prefer current

```
PE1#show sdm prefer current
The current template is "video" template
```

Use this command to display the cache entries in the policy route cache.

show ip cache policy

```
CE1#show ip policy
Interface      Route map
Gi0/0/10      equal-access
CE1#
```

Configuration Examples for Policy-Based Routing

This section shows sample configuration for Policy-Based Routing.

Example: Policy-Based Routing

The following is a sample configuration for Policy-Based Routing.

```
Device# conf t
Device(config)# access-list 1 permit host 10.1.1.1
Device(config)# access-list 2 permit host 172.17.2.2
Device(config)# exit

Device# conf t
Device(config)# route-map equal-access permit 10
Device(config-route-map)# match ip address 1
Device(config-route-map)# set ip next-hop 172.16.6.6
Device(config-route-map)# exit
Device(config)# route-map equal-access permit 20
Device(config-route-map)# match ip address 2
Device(config-route-map)# set ip next-hop 192.168.7.7
Device(config-route-map)# exit
Device(config)#exit

Device# conf t
Device(config)# interface GigabitEthernet0/0/2
Device(config-if)# ip policy route-map equal-access
Device(config-if)# exit
```

Additional References

Related Documents

| Related Topic | Document Title |
|--|--|
| IP routing protocol-independent commands | Cisco IOS IP Routing: Protocol-Independent Command Reference |

Technical Assistance

| Description | Link |
|---|---|
| The Cisco Support and Documentation website provides online resources to download documentation, software, and tools. Use these resources to install and configure the software and to troubleshoot and resolve technical issues with Cisco products and technologies. Access to most tools on the Cisco Support and Documentation website requires a Cisco.com user ID and password. | http://www.cisco.com/cisco/web/support/index.html |

Feature Information for Policy-Based Routing

The following table provides release information about the feature or features described in this module. This table lists only the software release that introduced support for a given feature in a given software release train. Unless noted otherwise, subsequent releases of that software release train also support that feature.

Use Cisco Feature Navigator to find information about platform support and Cisco software image support. To access Cisco Feature Navigator, go to www.cisco.com/go/cfn. An account on Cisco.com is not required.

Table 2: Feature Information for Policy-Based Routing

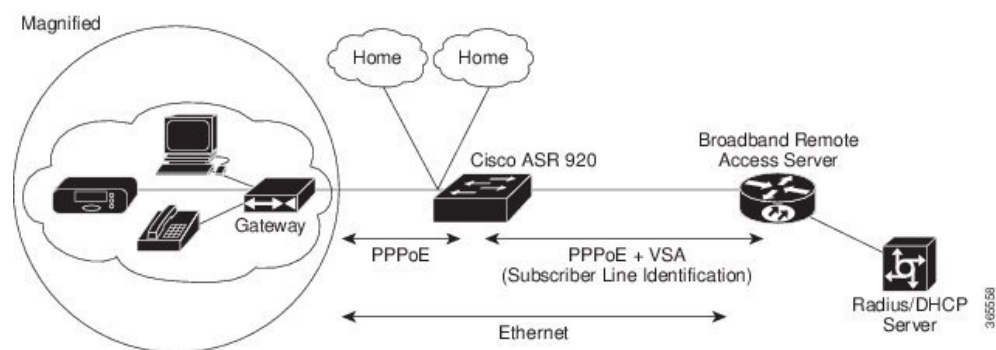


CHAPTER 4

PPPoE Intermediate Agent

Point-to-point protocol over Ethernet intermediate agent (PPPoE IA) is placed between a subscriber and broadband remote access server (BRAS). PPPoE IA helps the service provider BRAS to distinguish between end hosts connected over Ethernet and an access device. The topology of a typical PPPoE implementation is shown in the figure below.

Figure 6: PPP in an Ethernet Scenario



Finding Feature Information

Your software release may not support all the features documented in this module. For the latest caveats and feature information, see Bug Toolkit and the release notes for your platform and software release. To find information about the features documented in this module, and to see a list of the releases in which each feature is supported, see the feature information table at the end of this module.

- [Information About PPPoE Intermediate Agent, on page 36](#)
- [Prerequisites for PPPoE Intermediate Agent, on page 36](#)
- [Restrictions for PPPoE Intermediate Agent, on page 36](#)
- [How to Configure PPPoE Intermediate Agent, on page 37](#)
- [Verifying PPoE IA Configuration, on page 41](#)
- [Troubleshooting Tips, on page 43](#)
- [Configuration Examples, on page 43](#)
- [Additional References for PPPoE Intermediate Agent, on page 45](#)

Information About PPPoE Intermediate Agent

On the access switch, PPPoE IA enables subscriber line identification by appropriately tagging Ethernet frames of different users. The tag contains specific information such as, which subscriber is connected to the switch and ethernet flow point (EFP).

PPPoE IA acts as mini security firewall between host and BRAS by intercepting all PPPoE Active Discovery (PAD) messages on a per-port per-EFP basis. It provides specific security feature such as, verifying the intercepted PAD message from untrusted port, performing per-port PAD message rate limiting, inserting and removing VSA Tags into and from PAD messages respectively.

Prerequisites for PPPoE Intermediate Agent

- Interface and per-Bridge Domain(per-BD) based PPPoE IA configurations take effect only when the PPPoE IA feature is enabled globally. Discovery packets are switched or bridged if PPPoE IA is disabled globally.
- PPPoE IA feature supports global/per-port/per-BD based format configuration for generating the circuit-id and remote-id. Choose the appropriate option to meet the requirements.
- To configure a large number of intermediate agent devices for PPPoE IA, use the **pppoe intermediate-agent** command for automatically generating subscriber-line information in the VSA tag by the feature.
- Enable PPoE IA globally, per-Interface and per-BD.

Restrictions for PPPoE Intermediate Agent

- PPPoE IA is not supported on routed interfaces.
- PPPoE IA is not supported on Port-Channel.
- You can enable either PPPoE IA or PPPoE client on the device. You can not have PPPoE IA and PPPoE client on the same device.
- More than 6000 PPPoE sessions are not supported in the device acting as an intermediate agent.
- PPoE IA is only supported on physical interface and Bridge Domain.
- BRAS connected ports are configured as trusted and Host connected port as untrusted.
- When PPPoE IA is enabled globally on the device, the discovery packets received on the Interface, which has PPPoE IA disabled, is dropped.
- Circuit-id and remote-id is configured globally, at interface or at the Bridge Domain level. PPPoE IA uses this to create tag in the following way:
 - If PPoE IA is enabled per-BD, the circuit-id and remote-id configured for that BD is used. If not global values are used.

- If PPPoE IA is enabled per-interface, the circuit-id and remote-id configured for that interface is used. If not global values are used.

How to Configure PPPoE Intermediate Agent

The following tasks describe how to configure PPPoE IA on a device:

- [Enabling or Disabling PPPoE IA on a Device, on page 37](#)
- [Configuring the Access Node Identifier for PPPoE IA, on page 37](#)
- [Configuring the Generic Error Message for PPPoE IA, on page 38](#)
- [Configuring the Identifier String, Option, and Delimiter for PPPoE IA, on page 38](#)
- [Enabling or Disabling PPPoE IA on an Interface, on page 38](#)
- [Configuring PPPoE IA Circuit-ID on an Interface, on page 39](#)
- [Configuring PPPoE IA Remote-ID on an Interface, on page 39](#)
- [Configuring PPPoE IA Rate Limiting Setting on an Interface, on page 40](#)
- [Configuring the PPPoE IA Trust Setting on an Interface, on page 41](#)
- [Configuring PPPoE IA Vendor-tag Stripping on an Interface, on page 41](#)
- [Enabling or Disabling PPPoE IA on BD, on page 38](#)
- [Configuring PPPoE IA Circuit-ID on BD, on page 39](#)
- [Configuring PPPoE IA Remote-ID on BD, on page 40](#)

Enabling or Disabling PPPoE IA on a Device

To enable or disable PPPoE IA globally on the device, complete the following steps:

```
enable
configure terminal
pppoe intermediate-agent
end
```

Configuring the Access Node Identifier for PPPoE IA



Note If you do not specify the access node identifier of the switch, the value is automatically set as 0.0.0.0.

```
enable
configure terminal
pppoe intermediate-agent format-type access-node-id string switch123
end
```

Configuring the Generic Error Message for PPPoE IA



Note PPPoE IA sends a generic error message only on specific error condition. If you do not specify **string** {*message*}, the error message is not added.

```
enable
configure terminal
pppoe intermediate-agent format-type generic-error-message string
end
```

Configuring the Identifier String, Option, and Delimiter for PPPoE IA

The **pppoe intermediate-agent format-type identifier-string string circuit1 option** command has the following options

- pv Port + Vlan
- sp Slot + Port
- spv Slot + Port + Vlan
- sv Slot + Vlan

```
enable
configure terminal
pppoe intermediate-agent format-type identifier-string string circuit1 option spv delimiter
:
end
```

Enabling or Disabling PPPoE IA on an Interface



Note This setting applies to all frames passing through this interface, regardless of the EFP to which they belong. By default the PPPoE IA feature is disabled on all interfaces. You need to run this command on every interface that requires this feature.

Before You Begin

You must enable PPPoE IA on the device in the global configuration mode.

```
enable
configure terminal
interface GigabitEthernet 0/0/1
pppoe intermediate-agent
end
```

Enabling or Disabling PPPoE IA on BD

PPPoE IA can be configured to add specific information as part of subscriber identification. This can be configured on a per-port and per-port-per-bridge domain basis. When specific packets received on a particular Bridge-domain need to be differentiated with other packets received on that interface.

To enable or disable PPPoE IA on BD, complete the following steps:

Before You Begin

You must enable PPPoE IA on the device in the global configuration mode.

```
enable
configure terminal
interface GigabitEthernet 0/1/1
pppoe intermediate-agent bridge-domain 40
end
```

Configuring PPPoE IA Circuit-ID on an Interface

You can configure Circuit-ID on interface level. The PADI, PADR and PADT packets (PPPoE Discovery packets) received on this physical interface gets IA-tagged using the configured circuit-id using the **pppoe intermediate-agent format-type circuit-id string word** command, irrespective of the Bridge Domain (BD). This command over-writes global level circuit-id configuration or automatic generation of circuit-id by the Switch.

This parameter is not set by default.



Note If BD is enabled with PPPoE IA, BD level circuit-id configuration overwrites all other circuit-id configuration, for the packets that are received on that particular BD.

To configure the circuit-ID on an interface, complete the following steps:

```
enable
configure terminal
interface GigabitEthernet 0/0/1
pppoe intermediate-agent format-type circuit-id string root
end
```

Configuring PPPoE IA Circuit-ID on BD

This configuration overrides the circuit-id configuration specified at interface or global level. The packets received on the specified bridge-domain gets the PPPoE IA tag with configured circuit-id. By default the **pppoe intermediate-agent bridge-domain <bridge-domain_num> circuit-id {string {WORD}}** command is not configured.

Before You Begin

You must enable PPPoE IA globally and on particular BD.

To configure the circuit-ID on BD, complete the following steps:

```
enable
configure terminal
interface GigabitEthernet 0/0/1
pppoe intermediate-agent bridge-domain 50 circuit-id ct1
end
```

Configuring PPPoE IA Remote-ID on an Interface

You can configure remote-id on interface level. The PADI, PADR and PADT packets (PPPoE Discovery packets) received on this physical interface gets IA-tagged using the configured remote-id using the **pppoe intermediate-agent format-type remote-id string word** command irrespective of the BD. This command over-writes global level remote-id configuration or automatic generation of remote-id by the device.

This parameter is not set by default.



Note If BD is enabled with PPPoE IA, BD level remote-id configuration overwrites all other remote-id configuration, for the packets that are received on that particular BD.

```
enable
configure terminal
interface GigabitEthernet 0/0/1
pppoe intermediate-agent format-type remote-id string granite
end
```

Configuring PPPoE IA Remote-ID on BD

This configuration overrides the remote-id configuration specified at interface/global level and the packets received on the specified bridge-domain, will get PPPoE IA tag with remote-id configured. By default the **pppoe intermediate-agent bridge-domain <bridge-domain_num> remote-id {string {WORD}}** command is not configured.



Note The default value of remote-id is the router MAC address (for all bridge-domains).

Before You Begin

You must enable PPPoE IA globally and on particular BD.

To configure the remote-ID on BD, complete the following steps:

```
enable
configure terminal
interface GigabitEthernet 0/1/1
pppoe intermediate-agent bridge-domain 50 remote-id RD1
end
```

Configuring PPPoE IA Rate Limiting Setting on an Interface

You can limit the rate (packets per second) at which PPPoE discovery packets (PADI, PADO, PADR, PADS, and PADT) are received on an interface. When the incoming packet rate achieves or exceeds the configured limit, a port enters an error-disabled state and shuts down.



Note This limit applies to the physical interface to counter misbehaving hosts. Even if a single EFP misbehaves on an interface in trunk mode, the entire interface is shut down (error-disabled), bringing down other EFP traffic on the interface.

If you set the limit on the interface that connect the access switch to BRAS, use a higher value since the BRAS aggregates all the PPPoE traffic to the access switch through this interface.

```
enable
configure terminal
interface GigabitEthernet 0/1/1
pppoe intermediate-agent limit rate 30
end
```

Configuring the PPPoE IA Trust Setting on an Interface

Interfaces that connect the device to the PPPoE server are configured as trusted. Interfaces that connect the device to users (PPPoE clients) are untrusted.

This setting is disabled by default.

```
enable
configure terminal
interface GigabitEthernet 0/0/1
pppoe intermediate-agent
pppoe intermediate-agent trust
end
```

Configuring PPPoE IA Vendor-tag Stripping on an Interface

Vendor-specific tags (VSAs) carry subscriber and line identification information in the packets.

Vendor-tag stripping involves removing the VSAs from PADO, PADS, and PADT packets that are received on an interface before forwarding them to the user.

You can configure vendor-tag stripping on interfaces connected to the PPPoE server.

This setting is disabled by default.



Note BRAS automatically strips the vendor-specific tag off of the PPPoE discovery packets before sending them downstream to the access switch. To operate with older BRAS which does not possess this capability, use the **pppoe intermediate-agent vendor-tag strip** command on the interface connecting the access switch to BRAS

To enable stripping on an interface , complete the following steps:

Before You Begin

1. Enable PPPoE on an interface.
2. Set the PPPoE interface to trust.

```
enable
configure terminal
interface GigabitEthernet 0/0/1
pppoe intermediate-agent vendor-tag strip
end
```

Verifying PPOE IA Configuration

Clearing Packet Counters

Use the following command to clear packet counters for all PPPoE discovery packets (PADI,PADO,PADR,PADS,PADT) on all interfaces (per-port and per-port-per-EFP):

```
Router# clear pppoe intermediate-agent statistics
```

Use the following command to clear packet counters on a selected interface:

```
Router# clear pppoe intermediate-agent statistics interface type typeslot /subslot /port
```

Example:

```
Router# clear pppoe intermediate-agent statistics interface gigabitEthernet 0/0/3
```

Verifying Interface Statistics

Use the following command to view the statistics of all the interfaces on which PPPoEIA is enabled:

```
Router# show pppoe intermediate-agent statistics
```

```
PPPOE IA Per-Port Statistics
-----

Interface : GigabitEthernet0/0/24
Packets received
  All = 53
  PADI = 17 PADO = 0
  PADR = 17 PADS = 0
  PADT = 19
Packets dropped:
  Rate-limit exceeded = 0
  Server responses from untrusted ports = 0
  Client requests towards untrusted ports = 0
  Malformed PPPoE Discovery packets = 0
BD 40: Packets received PADI = 8 PADO = 0 PADR = 8 PADS = 0 PADT = 9
BD 50: Packets received PADI = 9 PADO = 0 PADR = 9 PADS = 0 PADT = 10
Interface : GigabitEthernet0/0/24
Packets received
  All = 59
  PADI = 0 PADO = 19
  PADR = 0 PADS = 26
  PADT = 14
Packets dropped:
  Rate-limit exceeded = 0
  Server responses from untrusted ports = 0
  Client requests towards untrusted ports = 0
  Malformed PPPoE Discovery packets = 0
BD 40: Packets received PADI = 0 PADO = 12 PADR = 0 PADS = 15 PADT = 7
BD 50: Packets received PADI = 0 PADO = 7 PADR = 0 PADS = 11 PADT = 7
```

Use the following command to view the packet details on an interface:

```
Router# show pppoe intermediate-agent statistics interface type typeslot /subslot /port
```

Example:

```
Router# show pppoe intermediate-agent statistics interface gigabitEthernet 0/0/3
```

```
Interface : Gi 0/0/3
Packets received
  All = 0
  PADI = 0 PADO = 0
  PADR = 0 PADS = 0
  PADT = 0
Packets dropped:
  Rate-limit exceeded = 0
  Server responses from untrusted ports = 0
  Client requests towards untrusted ports = 0
  Malformed PPPoE Discovery packets = 0
```



```
BD 40: Packets received PADI = 0 PADO = 0 PADR = 0 PADS = 0 PADT = 0
BD 50: Packets received PADI = 0 PADO = 0 PADR = 0 PADS = 0 PADT = 0
```

Verifying PPPoE IA is Enabled

```
show pppoe intermediate-agent info

PPPoE Intermediate-Agent is enabled

Global access-node-id is default
Global generic error msg is not set
Global identifier-string and delimiter are not set

PPPoE Intermediate-Agent trust/rate is configured on the following Interfaces:
```

| Interface | IA | Trusted | Vsa Strip | Rate limit (pps) |
|-----------------------|-----|---------|-----------|------------------|
| GigabitEthernet0/0/10 | yes | no | no | unlimited |

```
PPPoE Intermediate-Agent is configured on following bridge domains:
40,50
```

Verifying Configuration for PPPoE IA on an Interface

```
show pppoe intermediate-agent info interface GigabitEthernet 0/0/10
```

| Interface | IA | Trusted | Vsa Strip | Rate limit (pps) |
|-----------|-----|---------|-----------|------------------|
| Gi 0/0/10 | yes | no | no | unlimited |

```
PPPoE Intermediate-Agent is configured on following bridge domains:
40,50
```

Troubleshooting Tips

The following debug commands can help you troubleshoot an improper PPPoE intermediate agent configuration and its related features:

- **debug pppoe intermediate-agent packet**—Displays the contents of a packet received in the software: source and destination MAC address of Ethernet frame, code, version and type of PPPoE Discovery packet and a list of TAGs present.
- **debug pppoe intermediate-agent event**—Provides debugging information about PPPoE events.
- **debug radius**—Generates a report that includes information about the incoming access interface, where discovery frames are received, and about the session being established in PPPoE extended NAS-Port format (format d).

Configuration Examples

Configuration Example for PPPoE IA on an Interface

```
enable
configure terminal
```

```

interface GigabitEthernet0/0/1
no ip address
media-type rj45
negotiation auto
pppoe intermediate-agent format-type circuit-id string cktid10
pppoe intermediate-agent format-type remote-id string rmtid10
pppoe intermediate-agent
service instance 1 ethernet
  encapsulation dot1q 10
  rewrite ingress tag pop 1 symmetric
  bridge-domain 40
!
end

```

Configuration Example for PPPoE IA on a Bridge Domain Interface

```

enable
configure terminal
interface GigabitEthernet0/0/1
no ip address
media-type rj45
negotiation auto
pppoe intermediate-agent bridge-domain 40 circuit-id string cktid-20
pppoe intermediate-agent bridge-domain 40 remote-id string rmtid-20
pppoe intermediate-agent bridge-domain 40
service instance 1 ethernet
  encapsulation dot1q 10
  rewrite ingress tag pop 1 symmetric
  bridge-domain 40
!
end

```

Configuration Example with Multiple Bridge Domains

```

enable
configure terminal
interface GigabitEthernet0/0/1
no ip address
media-type rj45
negotiation auto
pppoe intermediate-agent bridge-domain 40 circuit-id string cktid-20
pppoe intermediate-agent bridge-domain 40 remote-id string rmtid-20
pppoe intermediate-agent format-type circuit-id string cktid10
pppoe intermediate-agent format-type remote-id string rmtid10
pppoe intermediate-agent bridge-domain 40
pppoe intermediate-agent
service instance 1 ethernet
  encapsulation dot1q 20
  rewrite ingress tag pop 1 symmetric
  bridge-domain 40
!
service instance 2 ethernet
  encapsulation dot1q 10
  rewrite ingress tag pop 1 symmetric
  bridge-domain 30
!
end

```

In this example:

- the packet received on bd 40 will have circuit and remote id as cktid-20 and rmtid-20 respectively

- the packet received on bd 30 will have circuit & remote id as cktid-10 and rmtid-10 respectively

Additional References for PPPoE Intermediate Agent

The following sections provide references related to the PPPoE IA feature.

MIBs

| MIB | MIBs link |
|-------|--|
| None. | To locate and download MIBs for selected platforms, Cisco IOS releases, and feature sets, use Cisco MIB Locator found at the following URL: http://tools.cisco.com/ITDIT/MIBS/servlet/index |

RFCs

| RFC | Title |
|---|-------|
| No new or modified RFCs are supported, and support for existing RFCs has not been modified. | — |

Technical Assistance

| Description | Link |
|---|---|
| <p>The Cisco Support website provides extensive online resources, including documentation and tools for troubleshooting and resolving technical issues with Cisco products and technologies.</p> <p>To receive security and technical information about your products, you can subscribe to various services, such as the Product Alert Tool (accessed from Field Notices), the Cisco Technical Services Newsletter, and Really Simple Syndication (RSS) Feeds.</p> <p>Access to most tools on the Cisco Support website requires a Cisco.com user ID and password.</p> | http://www.cisco.com/cisco/web/support/index.html |

