Multilink PPP Support for the Cisco 4000 Series Integrated Services Router

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The Multilink Point-to-Point Protocol (MLP) provides support to aggregate the bandwidth of low-speed WAN links into a single entity, referred to as a bundle interface. A bundle interface is a logical entity that provides a single point in which other features (Quality of Service (QoS)) can be attached. MLP provides incremental bandwidth on demand, by adding additional links to the bundle. MLP also allows interleaving of latency-sensitive priority traffic with non-priority fragmented traffic using link fragmentation and interleaving (LFI).

This document describes the features, limitations, and scaling of MLP on the Cisco 4000 series Integrated Services Router (Cisco 4000 Series ISR) running Cisco IOS XE software. The router supports MLP links for serial (T1 or E1 or NxDS0) topologies.

For further information about the configuration and operation of MLP in Cisco IOS XE software, see the "Configuring Multilink PPP" section in Configuring Media-Independent PPP and Multilink PPP.

Contents

This document includes the following sections:

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Feature Information

Your software release may not support all the features documented in this module. For the latest information about features and caveats, see 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 Table 1.

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

Not all commands may be available in your Cisco IOS software release. For release information about a specific command, see the corresponding command reference documentation.

Table 1 lists the features in this module and provides links to configuration information for features that were introduced or modified in Cisco IOS XE Release 3.10S or a later release.

Table 1 Feature Information for Multilink PPP Support

Feature Name	Releases	Feature Information
MLPoSerial	Cisco IOS XE Release 3.10S	In Cisco IOS XE Release 3.10S, support for MLPoSerial was introduced on the Cisco 4000 Series ISR.

Restrictions for Multilink Point-to-Point Protocol over Serial Interfaces

The following restrictions apply to using MLP over Serial Interfaces:

- A maximum of ten member links per MLP bundle is supported. The member links can be any combination of T1/E1 or fractional T1s/E1s (for example, NxDS0). Member-link interface speed above T1/E1 is not supported with the MLP over Serial feature. For better MLP performance, all the member links in a bundle must be of the same bandwidth.
- All the member links in a bundle must have the same encapsulation type.
- You cannot manually configure the bandwidth of an MLP bundle by using the **bandwidth** command on the multilink interface. The bandwidth of an MLP bundle is managed based on the aggregate bandwidth of all the active member links on the bundle. As the links are dynamically added or removed from an MLP bundle, the bandwidth is updated to reflect the aggregate of the active links. The bandwidth can be rate limited by applying an hierarchical QoS (HQoS) policy on the multilink interface and applying a shaper to the parent class-default class.
- MLP over Frame Relay is not supported; only MLP over Serial Interfaces is supported.
- MLP over ISDN is not supported.
- MLP over Frame Relay is not supported on Cisco Integrated Services Virtual Routers.
- The legacy IOS compression feature **compress** [**mppc | stac | predictor**] is not supported.

- LFI is supported on MLP bundles with any number of links in the bundle. When using a bundle with more than one member link, the order of the priority packets (PPP encapsulated) is not guaranteed. Priority packet distribution is handled in a manner similar to the IP per packet load sharing. MLP guarantees non-priority packet ordering that manages reordering at the peer device based on the MLP packet sequence number.
- There is an order issue for the LFI multiple member link, in the case of priority traffic. Although this can be addressed in some platforms using Multiclass Multilink Protocol (MCMP-RFC 2686), the Cisco 4000 Series ISR does not support MCMP.
- Only the MLP long-sequence number format is supported for the packet header format option.

Restriction for Multilink Point-to-Point Protocol over Ethernet Interfaces

Every physical Ethernet interface must have direct one-to-one mapping with dialer interfaces.

Information About the Multilink Point-to-Point Protocol Feature

The Multilink Point-to-Point Protocol (MLP) feature provides the load balancing functionality over multiple WAN links, while providing multivendor interoperability, packet fragmentation, proper sequencing, and load calculation on both inbound and outbound traffic. The Cisco implementation of MLP supports the fragmentation and packet sequencing specifications described in RFC 1990.

Interface Multilink versus Virtual Access Interfaces

On the Cisco 4000 Series ISR, the **interface multilink** command is used to configure MLP over Serial. Other Cisco IOS platforms may use the **interface multilink** command for both MLP over Serial (MLPoSerial) and MLP over ATM (MLPoA).

Quality of Service

Quality of Service (QoS) refers to the ability of a network to provide improved service to selected network traffic over various underlying technologies, including Frame Relay, ATM, Ethernet and 802.1 networks, Synchronous Optical NETwork (SONET), and IP-routed networks. For MLPoSerial deployments, apply the QoS policy to an MLP bundle on the multilink interface.

Restrictions for QoS applied to a Multilink Point-to-Point Protocol Bundle

The following restrictions apply to QoS for MLP:

- To rate limit a broadband MLP bundle session, use a Hierarchical QoS (HQoS) policy with a parent shaper in the class-default class.
- The Cisco 4000 Series ISR supports HQoS queuing only in the egress (output) direction, and not in the ingress direction.
- In Cisco IOS XE Release 3.10S, the **shape average** *shape-rate* **account user-defined** <*-63 to 63*> **[atm]** command supports MLP over the Serial interface.

- As packets transit the MLP transmit path, they are subject to two separate stages of queuing. The first stage is at the MLP bundle interface, where QoS may be applied and the second one is at the MLP member link interfaces. At the MLP bundle interface, the packets are processed according to the applied QoS policy. Packets that are classified as being priority are given preferential treatment over non-priority packets.

  In order for the priority classification to be honored at the MLP Member Link interface, the bundle must have **ppp multilink interleave** enabled. Interleaving allows the packet to be queued to a separate priority queue at the member link. If interleaving is not enabled on the bundle, the priority packet is placed in the member link session default queue and the knowledge that it is a priority packet will be lost. This is especially important if there are other PPP or MLP sessions sharing the same physical interface or subinterface. Without interleaving, any priority packets on the other sessions are given preferential treatment over the MLP priority packets that were reclassified as non-priority packets at the MLP member link queuing stage. See the "Downstream Link Fragmentation and Interleaving" section on page 5 for additional information on interleaving.

Scaling Limits for MLP Bundles

Release 3.10S

In this release, the MLP feature was introduced on the Cisco 4000 Series ISR. MLPoSerial was the first supported transport.

MLP bundles consist of up to 10 serial links. The bandwidth of each link interface does not have to be the same as the other links in the bundle. The router support links of types T1, E1, and NxDS0. MLP Link Fragmentation and Interleaving (LFI) are fully supported with MLPoSerial.

Table 2 shows the maximum scale numbers for MLP feature transports on the Cisco 4000 Series ISR.

Table 2 MLP Features and Maximum Scale Numbers

Transport	Maximum Number of Members per Bundle	Maximum Number of Bundles per System	Maximum Number of Member Links per System	Downstream LFI	Upstream Fragment Reassembly	Cisco IOS XE Release
MLPoSerial	10	56	56	Yes	Yes	3.10S

Packet Overhead Accounting for Shaping and Policing

MLP adjusts the packet length presented for shaping and policing to include a Layer 2 overhead for MLP. This shaping and policing overhead accounting includes the overhead for MLP and PPP Layer 2.

In Cisco IOS XE Release 3.10S, support for shaping and policing overhead accounting was added for Serial MLP on the Cisco 4000 Series ISR.

The shaping and policing overhead accounting does not include the additional overheads added by a Network Information Module (NIM) such as serial interface CRC, start of packet (SOP) delimiter, end of packet (EOP) delimiter, and serial-bit stuffing. The overhead added by a NIM can be included at the shaper using the QoS shape accounting **user-defined** option in the following command:

shape [average | peak] mean-rate [*burst-size*] [*excess-burst-size*] **account {{{qinq | dot1q} {aal5 | aal3} {subscriber-encapsulation}} | {user-defined** *offset* **[atm]}}**

By specifying the **user-defined** option, you can include the additional overhead added by an NIM.

For further information on overhead accounting when apply shaping to packets, see *Ethernet Overhead Accounting*.

Note You can configure and apply a QoS shaper to a multilink bundle--a "QoS user-defined shaper". Otherwise, if you do not configure and apply a QoS user-defined shaper for the multilink bundle interface, a default shaper is applied to the bundle based on the aggregate bandwidth of all the links that make up the multilink bundle. The information contained in this section applies to either a default shaper or a QoS user-defined shaper.

Priority packets that are interleaved are sent PPP encapsulated. The MLP Layer 2 overhead is not included because MLP encapsulation is not included in these packets. During overhead accounting for link fragmentation, overhead accounting calculations are performed prior to the actual link fragmentation and link selection for Multilink PPP load balancing. When all the member links in the corresponding multilink bundle use the same fragment size, the number of fragments are calculated and the overhead is adjusted to include the additional per-fragmentation Layer 2 header overhead for the shaper and policer. When one or more links in the bundle use different fragment sizes, the number of fragments cannot be calculated with 100% accuracy because link selection for load balancing and fragment size is not known until the QoS processing is completed at the bundle level (after shaping and policing). For links with unequal fragment size, a *best effort* attempt is made using the largest link fragment size on the bundle. By using the largest fragment size, MLP avoids under subscribing the member-link interfaces. If the links become oversubscribed, MLP will backpressure the bundle to avoid sustained oversubscription of the member links.

Enable overhead accounting using the following QoS command:

Note The **bandwidth** command must not be used to define the bundle bandwidth on the virtual template interface or the multilink interface. By default, the bundle bandwidth is the aggregate of the bandwidth of the individual member links that make up the bundle.

Downstream Link Fragmentation and Interleaving

Although Link Fragmentation and Interleaving (LFI) are thought of as a single feature, they are actually two independent features within MLP.

- MLP Link Fragmentation, page 5
- MLP Interleaving, page 6

MLP Link Fragmentation

MLP Link Fragmentation allows for larger packets to be Layer 2 fragmented by MLP, and for the fragments to be distributed across the various member links in the MLP bundle. These fragments are MLP encapsulated and sequenced. These fragments are then collected, reordered, and reassembled at the peer termination point for the MLP bundle interface.

Note For more information about interleaving with QoS, see "Quality of Service" section on page 3.

MLP Interleaving

MLP Interleaving enables you to reduce the transmission delay on delay-sensitive voice, video, and interactive application data by interleaving it with the MLP fragments. When interleaving is configured, the packets on the bundle interface that QoS classifies as priority packets are interleaved. These priority packets are PPP encapsulated and interleaved with the MLP-encapsulated fragments or packets. When the peer router receives the PPP packets, they can be immediately forwarded, whereas, the received MLP encapsulated packets have to be reordered and reassembled before being forwarded.

While LFI can be configured on any multilink bundle, it is beneficial only on bundles with link speeds of 1 Mbps or less. For higher bandwidth bundles, LFI should not be needed. In the case of these bundles, low packet transmission delays allow QoS prioritization of traffic to be sufficient.

One disadvantage of interleaving is that when there are two or more links in an MLP bundle, the order of the PPP-encapsulated packets cannot be guaranteed. In most applications sending data such as, voice, video, and telnet, this is not an issue because the gap between the packets on a given flow is large enough that the packets must not pass each other on the multiple links in the bundle. Since the order cannot be guaranteed for priority PPP-encapsulated packets that are interleaved, IP Header Compression (IPHC) is skipped on any packet that is classified as being priority-interleaved. IPHC will continue to occur for non-priority packets that are sent as MLP encapsulated because MLP guarantees reordering before the packets are forwarded to IPHC.

Although the Multi-Class Multilink Protocol (MCMP) (RFC-2686) addresses issues related to ordering of priority-interleaved packets, currently MCMP is not supported on the Cisco 4000 Series ISR.

In the context of interface multilink or interface virtual template, use the following commands to enable LFI:

- **ppp multilink fragment delay** (delay in milliseconds)—enables MLP link fragmentation on the member link serial interface
- **ppp multilink fragment size** (maximum fragment size, in bytes)—enables MLP link fragmentation on the member link serial interface
- **ppp multilink interleave**—enables MLP interleaving

  For MLP interleaving, you must also define a QoS policy with one or more priority classes, and attach the QoS to this interface using the **service-policy output** *policy-map name* command. This command classifies the priority traffic, which is interleaved by the MLP.
  If the **ppp multilink interleave** command is not configured, only MLP link fragmentation is enabled.

Note If the MLP bundle has only one active member link and interleaving is not enabled, MLP link fragmentation is disabled. In addition, all the packets are sent as PPP encapsulated instead of MLP encapsulated. When a second link in the bundle becomes active or interleaving is enabled, MLP link fragmentation is enabled.

See the QoS and LFI configuration examples in "Configuring Multilink PPP Connections":

Wide-Area Networking Configuration Guide: Multilink PPP, Cisco IOS XE Release 3S

When configuring MLP link fragmentation on the various Cisco platforms, the functionality of MLP link fragmentation and interleaving support on the various platforms may differ. The following information explains the configuration options and their interpretation on the Cisco 4000 Series ISR.

Based on the values of the MLP link fragmentation configuration commands, the MLP feature calculates two values that are used during MLP link fragmentation: link weight and maximum fragment size. These parameters are calculated for each member link in the bundle.

First, a link weight must be determined for each member link. The link weight indicates the number of bytes, and the MLP uses this value to balance the data amongst the links in the bundle. This parameter is especially important when the links in a bundle are of unequal bandwidth. The link weight is based on a combination of the bandwidth of the member link and the PPP multilink fragment delay value. If you do not configure the fragment delay value, a default delay value of 30 milliseconds is used.

Link Weight = (Member Link Interface Bandwidth in bps/8) * Fragment Delay

Caution Configuring the fragment delay to a smaller value results in smaller fragment size because the fragment delay value determines the default fragment size on the member link. This in turn implies loss of bandwidth due to the added Layer 2 header overhead.

The default maximum fragment size must be calculated per member link. The default maximum fragment size used will be the lesser value obtained from either of the following calculation:

- Link Weight – Multilink PPP + PPP Header Overhead (8)
- Interface MTU – Multilink PPP Header Overhead (4)

After the default maximum fragment size is calculated, if you have configured the **ppp multilink fragment size** (maximum) command at the multilink, virtual template, or serial interface level, the default maximum fragment size is compared against the configured maximum value and is capped accordingly. If the fragment size is configured at the serial interface level and also at the multilink interface level, the serial interface configuration takes precedence.

Unsupported Link Fragmentation Functionality on the Cisco 4000 Series ISR

On the Cisco 4000 Series ISR, the following MLP configuration commands are ignored:

- **ppp multilink fragment disable**
- **ppp multilink fragment maximum** *maximum number of fragments per packet*

These commands were used by a legacy method for implementing MLP fragmentation.

Unsupported Features

The Cisco 4000 Series ISR does not support the following MLP features:

- In-Service Software Upgrade (ISSU) and Stateful Switchover (SSO) for MLP bundles.
- Per-user firewall.
- Lawful intercept.
- MLP with MPLS-TE FRR.
- Layer 2 input QoS Classification.
- The Multiclass Multilink Protocol (MCMP) RFC 2686 extension to LFI.
- Only the MLP long-sequence number format is supported for the packet header format option.

Additional References

The following sections provide references related to the multilink point-to-point protocol connections.

Related Documents

Related Topic	Document Title
Cisco IOS commands	*Cisco IOS Master Commands List, All Releases*
Configuring Multilink PPP Connections for Broadband and Serial Topologies	*Configuring Multilink PPP Connections for Broadband and Serial Topologies*
MLP	*Wide-Area Networking Configuration Guide: Multilink PPP, Cisco IOS XE Release 3S*
PPP commands	*Cisco IOS Dial Technologies Command Reference*
Broadband Configuration	*Cisco IOS XE Broadband and DSL Configuration Guide*
Cisco IOS Configuration Fundamentals	*Cisco IOS Configuration Fundamentals Command Reference*

Standards

Standard	Title
None	—

MIBs

MIB	MIBs Link
None	To locate and download MIBs for selected platforms, Cisco IOS releases, and feature sets, use the Cisco MIB Locator found at the following URL: http://www.cisco.com/go/mibs

RFCs

RFC[1]	Title
RFC 1990	The PPP Multilink Protocol (MP)
RFC 2686	The Multi-Class Extension to Multi-Link PPP

1. Not all the supported RFCs are listed.

Technical Assistance

Description	Link
The Cisco Support website provides extensive online resources, including documentation and tools for troubleshooting and resolving technical issues with Cisco products and technologies. 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. Access to most tools on the Cisco Support website requires a Cisco.com user ID and password.	http://www.cisco.com/cisco/web/support/index.html

Feature Information for Multilink Point-to-Point

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 www.cisco.com/go/cfn to find information about platform support and Cisco software image support. An account on Cisco.com is not required.

Table 3 Feature Information for MLPPP - Multilink PPP

Feature Name	Releases	Feature Information
MLPPP - Multilink PPP	Cisco IOS XE Release 3.10	The MLPPP - Multilink PPP feature is provides support to aggregate the bandwidth of low-speed WAN links into a bundle interface. The interface provides a single point to which other features such as Quality of Service (QoS) can be attached. MLP provides incremental bandwidth on demand and allows interleaving of latency-sensitive priority traffic with non-priority fragmented traffic using link fragmentation and interleaving (LFI). This feature was introduced into Cisco IOS Release 3.10 for the Cisco ISR 4451-X.