Preface

Document conventions

The document conventions describe text formatting conventions, command syntax conventions, and important notice formats used in Brocade technical documentation.

Text formatting conventions

Text formatting conventions such as boldface, italic, or Courier font may be used in the flow of the text to highlight specific words or phrases.

Format	Description
bold text	Identifies command names
	Identifies keywords and operands
	Identifies the names of user-manipulated GUI elements
	Identifies text to enter at the GUI
italic text	Identifies emphasis
	Identifies variables
	Identifies document titles
`Courier font`	Identifies CLI output
	Identifies command syntax examples

Command syntax conventions

Bold and italic text identify command syntax components. Delimiters and operators define groupings of parameters and their logical relationships.

Convention	Description
bold text	Identifies command names, keywords, and command options.
italic text	Identifies a variable.
value	In Fibre Channel products, a fixed value provided as input to a command option is printed in plain text, for example, **--show** WWN.

Convention	Description
[ ]	Syntax components displayed within square brackets are optional. Default responses to system prompts are enclosed in square brackets.
{ **x** | **y** | **z** }	A choice of required parameters is enclosed in curly brackets separated by vertical bars. You must select one of the options. In Fibre Channel products, square brackets may be used instead for this purpose.
x | **y**	A vertical bar separates mutually exclusive elements.
< >	Nonprinting characters, for example, passwords, are enclosed in angle brackets.
...	Repeat the previous element, for example, *member*[*member*...].
\	Indicates a “soft” line break in command examples. If a backslash separates two lines of a command input, enter the entire command at the prompt without the backslash.

Notes, cautions, and warnings

Notes, cautions, and warning statements may be used in this document. They are listed in the order of increasing severity of potential hazards.

NOTE
A Note provides a tip, guidance, or advice, emphasizes important information, or provides a reference to related information.

ATTENTION
An Attention statement indicates a stronger note, for example, to alert you when traffic might be interrupted or the device might reboot.

CAUTION
A Caution statement alerts you to situations that can be potentially hazardous to you or cause damage to hardware, firmware, software, or data.

DANGER
A Danger statement indicates conditions or situations that can be potentially lethal or extremely hazardous to you. Safety labels are also attached directly to products to warn of these conditions or situations.

Brocade resources

Visit the Brocade website to locate related documentation for your product and additional Brocade resources.

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To get up-to-the-minute information on Brocade products and resources, go to MyBrocade. You can register at no cost to obtain a user ID and password.

Release notes are available on MyBrocade under Product Downloads.

White papers, online demonstrations, and data sheets are available through the Brocade website.

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Brocade customers

For product support information and the latest information on contacting the Technical Assistance Center, go to http://www.brocade.com/services-support/index.html.

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Online	Telephone	E-mail
Preferred method of contact for non-urgent issues: • My Cases through MyBrocade • Software downloads and licensing tools • Knowledge Base	Required for Sev 1-Critical and Sev 2-High issues: • Continental US: 1-800-752-8061 • Europe, Middle East, Africa, and Asia Pacific: +800-AT FIBREE (+800 28 34 27 33) • For areas unable to access toll free number: +1-408-333-6061 • Toll-free numbers are available in many countries.	support@brocade.com Please include: • Problem summary • Serial number • Installation details • Environment description

Brocade OEM customers

If you have purchased Brocade product support from a Brocade OEM/Solution Provider, contact your OEM/Solution Provider for all of your product support needs.

- OEM/Solution Providers are trained and certified by Brocade to support Brocade® products.
- Brocade provides backline support for issues that cannot be resolved by the OEM/Solution Provider.

- Brocade Supplemental Support augments your existing OEM support contract, providing direct access to Brocade expertise. For more information, contact Brocade or your OEM.
- For questions regarding service levels and response times, contact your OEM/Solution Provider.

Document feedback

To send feedback and report errors in the documentation you can use the feedback form posted with the document or you can e-mail the documentation team.

Quality is our first concern at Brocade and we have made every effort to ensure the accuracy and completeness of this document. However, if you find an error or an omission, or you think that a topic needs further development, we want to hear from you. You can provide feedback in two ways:

- Through the online feedback form in the HTML documents posted on www.brocade.com.
- By sending your feedback to documentation@brocade.com.

Provide the publication title, part number, and as much detail as possible, including the topic heading and page number if applicable, as well as your suggestions for improvement.

About This Document

Audience

This document is designed for system administrators with a working knowledge of Layer2 and Layer3 switching and routing.

If you are using a Brocade device, you should be familiar with the following protocols if applicable to your network - IP, RIP, OSPF, BGP, ISIS, IGMP, PIM, MPLS, and VRRP.

Supported hardware and software

The following hardware platforms are supported by this release of this guide:

TABLE 1 Supported devices

Brocade NetIron XMR Series	Brocade MLX Series	NetIron CES 2000 and NetIron CER 2000 Series
Brocade NetIron XMR 4000	Brocade MLX-4	Brocade NetIron CES 2024C
Brocade NetIron XMR 8000	Brocade MLX-8	Brocade NetIron CES 2024F
Brocade NetIron XMR 16000	Brocade MLX-16	Brocade NetIron CES 2048C
Brocade NetIron XMR 32000	Brocade MLX-32	Brocade NetIron CES 2048CX
	Brocade MLXe-4	Brocade NetIron CES 2048F
	Brocade MLXe-8	Brocade NetIron CES 2048FX
	Brocade MLXe-16	Brocade NetIron CER 2024C
	Brocade MLXe-32	Brocade NetIron CER-RT 2024C
		Brocade NetIron CER 2024F
		Brocade NetIron CER-RT 2024F
		Brocade NetIron CER 2048C
		Brocade NetIron CER-RT 2048C
		Brocade NetIron CER 2048CX
		Brocade NetIron CER-RT 2048CX
		Brocade NetIron CER 2048F
		Brocade NetIron CER-RT 2048F
		Brocade NetIron CER 2048FX
		Brocade NetIron CER-RT 2048FX

Supported software

For the complete list of supported features and the summary of enhancements and configuration notes for this release, refer to the latest version of the Multi-Service IronWare 05.8.00 Release Notes.

Notice to the reader

This document may contain references to the trademarks of the following corporations. These trademarks are the properties of their respective companies and corporations.

These references are made for informational purposes only.

Corporation	Referenced Trademarks and Products
Microsoft Corporation	Internet Explorer
Mozilla Corporation	Mozilla Firefox
Sun Microsystems	Java Runtime Environment

Related publications

For the latest edition of these documents, which contain the most up-to-date information, see Documentation at http://www.brocade.com/ethernetproducts

- Multi-Service IronWare Administration Guide
- Multi-Service IronWare Security Configuration Guide
- Multi-Service IronWare Switching Configuration Guide
- Multi-Service IronWare Routing Configuration Guide
- Multi-Service IronWare Traffic Management Configuration Guide
- Multi-Service IronWare Multicast Configuration Guide
- Multi-Service IronWare Multiprotocol Label Switch (MPLS) Configuration Guide
- Multi-Service IronWare Software Defined Networking (SDN) Guide
- *Brocade MLX Series and NetIron Family YANG Guide*
- *Brocade MLX Series and NetIron XMR Series Diagnostic Reference*
- *Unified IP MIB Reference*
- *Multi-Service IronWare Software Upgrade Guide*
- *Brocade MLXe Series Installation Guide*
- *Brocade MLX Series and Brocade NetIron XMR Installation Guide*
- *Brocade NetIron CES 2000 Series and Brocade NetIron CER 2000 Series Hardware Installation Guide*

How command information is presented in this guide

For all new content, command syntax and parameters are documented in a separate command reference section at the end of the publication.

In an effort to provide consistent command line interface (CLI) documentation for all products, Brocade is in the process of preparing standalone Command References for the IP platforms. This process involves separating command syntax and parameter descriptions from configuration tasks. Until this process is completed, command information is presented in two ways:

- For all new content included in this guide, the CLI is documented in separate command pages. The new command pages follow a standard format to present syntax, parameters, usage guidelines, examples, and command history. Command pages are compiled in alphabetical order in a separate command reference chapter at the end of the publication.
- Legacy content continues to include command syntax and parameter descriptions in the chapters where the features are documented.

If you do not find command syntax information embedded in a configuration task, refer to the command reference section at the end of this publication for information on CLI syntax and usage.

Configuring MPLS Traffic Engineering

Overview

Table 2 displays the individual Brocade devices and the MPLS Traffic Engineering features they support.

TABLE 2 Supported Brocade MPLS traffic engineering features

Features supported	Brocade NetIron XMR Series Series	Brocade NetIron MLX Series	Brocade NetIron CES Series 2000 Series BASE package	Brocade NetIron CES Series 2000 Series ME_PREM package	Brocade NetIron CES Series 2000 Series L3_PREM package	Brocade NetIron CER Series 2000 Series Base package	Brocade NetIron CER Series 2000 Series Advanced Services package
Multiprotocol Label Switching (MPLS)	Yes	Yes	No	Yes	No	No	Yes
MPLS Traffic Engineering	Yes	Yes	No	Yes	No	No	Yes
OSPF-TE Link State Advertisements for MPLS Interfaces	Yes	Yes	No	Yes	No	No	Yes
MPLS Traffic Engineering - OSPF-TE	Yes	Yes	No	Yes	No	No	Yes
MPLS Traffic Engineering - IS-IS-TE	Yes	Yes	No	Yes	No	No	Yes
IS-IS Link State Protocol data units with TE Extensions for MPLS Interfaces	Yes	Yes	No	Yes	No	No	Yes
RSVP Message Authentication	Yes	Yes	No	Yes	No	No	Yes
MPLS over Virtual Ethernet Interfaces	Yes	Yes	No	Yes	No	No	Yes
MPLS Signaling: LDP and RSVP-TE support	Yes	Yes	No	Yes	No	No	Yes
RSVP soft preemption	Yes	Yes	No	Yes	No	No	Yes
MPLS Point-to-Multipoint Traffic Engineering	Yes	Yes	No	Yes	No	No	Yes

TABLE 2 Supported Brocade MPLS traffic engineering features (Continued)

Features supported	Brocade NetIron XMR Series Series	Brocade NetIron MLX Series	Brocade NetIron CES Series 2000 Series BASE package	Brocade NetIron CES Series 2000 Series ME_PREM package	Brocade NetIron CES Series 2000 Series L3_PREM package	Brocade NetIron CER Series 2000 Series Base package	Brocade NetIron CER Series 2000 Series Advanced Services package
Auto-bandwidth for RSVP LSPs	Yes	Yes	No	No	No	No	No
Dynamic Bypass LSP	Yes	Yes	No	Yes	Yes	No	Yes
Liberal Bypass Selection and Creation	Yes	Yes	No	Yes	No	Yes	Yes
New encryption code for passwords, authentication keys, and community strings	Yes	Yes	No	Yes	No	No	Yes
Traffic Engineering Database	Yes	Yes	No	Yes	No	No	Yes
MPLS Fast Reroute Using One-to-One Backup	Yes	Yes	No	Yes	No	No	Yes
FRR bypass LSPs	Yes	Yes	No	Yes	No	No	Yes
Link protection for FRR	Yes	Yes	No	Yes	No	No	Yes
Adaptive bypass LSPs	Yes	Yes	No	Yes	Yes	No	Yes
Resetting LSPs	Yes	Yes	No	Yes	No	No	Yes
Adaptive LSPs: timer-triggered LSP optimization	Yes	Yes	No	Yes	No	No	Yes
Hot-standby LSPs	Yes	Yes	No	Yes	No	No	Yes
RSVP Message Authentication	Yes	Yes	No	Yes	No	No	Yes
Signaled LSPs	Yes	Yes	No	Yes	No	No	Yes
LSP Accounting	Yes	Yes	No	No	No	No	No

TABLE 2 Supported Brocade MPLS traffic engineering features (Continued)

Features supported	Brocade NetIron XMR Series Series	Brocade NetIron MLX Series	Brocade NetIron CES Series 2000 Series BASE package	Brocade NetIron CES Series 2000 Series ME_PREM package	Brocade NetIron CES Series 2000 Series L3_PREM package	Brocade NetIron CER Series 2000 Series Base package	Brocade NetIron CER Series 2000 Series Advanced Services package
LSP accounting statistics for single-hop LSP routes	Yes	Yes	No	No	No	No	No
MPLS BFD	Yes	Yes	No	No	No	No	No
IP over MPLS Traceroute	Yes	Yes	No	Yes	Yes	No	Yes
Traps and Syslogs for LSPs	Yes	Yes	No	Yes	No	No	Yes
Show Command to Display TE path	Yes	Yes	No	Yes	No	No	Yes
Enhancements to MPLS path and route display	Yes	Yes	No	Yes	No	No	Yes
Display changes for MPLS show commands for long LSP and Path names	Yes	Yes	No	Yes	No	No	Yes
RSVP refresh reduction	Yes	Yes	No	Yes	No	No	Yes
RSVP reliable messaging	Yes	Yes	No	Yes	No	No	Yes
RSVP IGP Synchronization	Yes	Yes	No	Yes	No	No	Yes
RSVP IGP Synchronization for Remote Links	Yes	Yes	No	Yes	No	No	Yes
MPLS traffic engineering flooding reduction	Yes	Yes	No	Yes	No	No	Yes
Static Transit LSP	Yes	Yes	No	Yes	No	No	Yes
MPLS CSPF Scalability Optimization	Yes	Yes	No	Yes	No	No	Yes

TABLE 2 Supported Brocade MPLS traffic engineering features (Continued)

Features supported	Brocade NetIron XMR Series Series	Brocade NetIron MLX Series	Brocade NetIron CES Series 2000 Series BASE package	Brocade NetIron CES Series 2000 Series ME_PREM package	Brocade NetIron CES Series 2000 Series L3_PREM package	Brocade NetIron CER Series 2000 Series Base package	Brocade NetIron CER Series 2000 Series Advanced Services package
P2MP RSVP LSPs	Yes	Yes	No	No	No	No	Yes
Multicast IGP RPF Shortcuts	Yes	Yes	No	Yes	Yes	No	Yes

NOTE
MPLS cannot be configured on the system globally when a NI-MLX-10Gx8-D card is installed.

This chapter explains how to configure *Multiprotocol Label Switching (MPLS)* on the Brocade device for traffic engineering purposes. MPLS can be used to direct packets through a network over a pre-determined path of routers. Forwarding decisions in MPLS are based on the contents of a label applied to the packet.

Traffic engineering is the ability to direct packets through a network efficiently, using information gathered about network resources. When used as an application of MPLS, traffic engineering involves creating paths that make the best use of available network resources, avoiding points of congestion and making efficient use of high bandwidth interfaces. Packets traveling over these paths are forwarded using MPLS.

IETF RFC and Internet draft support

The implementation of MPLS supports the following IETF RFCs and Internet Drafts.

MPLS

RFC 3031 - Multiprotocol Label Switching Architecture

RFC 3032 - MPLS Label Stack Encoding

RFC 3036 - LDP Specification

RFC 2205 - *Resource ReSerVation Protocol (RSVP)* -- Version 1 Functional Specification

RFC 2209 - *Resource ReSerVation Protocol (RSVP)* -- Version 1 Message Processing Rule

RFC 3209 - RSVP-TE

RFC 3270 - MPLS Support of Differentiated Services

RFC 4090 - Facility backup and Fast Reroute

OSPF

RFC 3630 TE Extensions to OSPF v2

IS-IS

RFC 3784 Intermediate System to Intermediate System (IS-IS) Extensions for *Traffic Engineering (TE)*

How MPLS works

MPLS uses a *label switching* forwarding method to direct packets through a network. In label switching, a packet is assigned a label and passes along a predetermined path of routers. Forwarding decisions are based on the contents of the label, rather than information in the packet's IP header.

The following sections describe these basic MPLS concepts:

- How packets are forwarded through an MPLS domain
- The kinds of *Label Switched Paths (LSPs)* that can be configured on a device
- The components of an MPLS label header

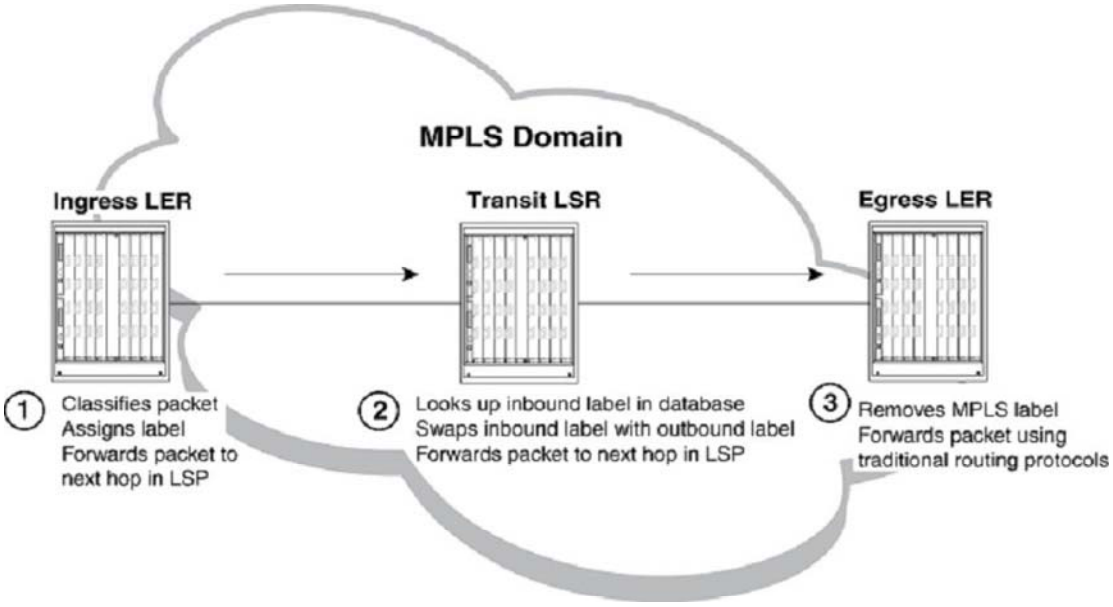
How packets are forwarded through an MPLS domain

An *MPLS domain* consists of a group of MPLS-enabled routers, called *Label Switching Routers (LSRs)*. In an MPLS domain, packets are forwarded from one MPLS-enabled router to another along a predetermined path, called an LSP. LSPs are one-way paths between MPLS-enabled routers on a network. To provide two-way traffic, the user configures LSPs in each direction.

The LSRs at the headend and tailend of an LSP are known as *Label Edge Routers (LERs)*. The LER at the headend, where packets enter the LSP, is known as the *ingress LER* . The LER at the tailend, where packets exit the LSP, is known as the *egress LER* . Each LSP has one ingress LER and one egress LER. Packets in an LSP flow in one direction: from the ingress LER towards the egress LER. In between the ingress and egress LERs there may be zero or more *transit LSRs* . A device enabled for MPLS can perform the role of ingress LER, transit LSR, or egress LER in an LSP. Further, a device can serve simultaneously as an ingress LER for one LSP, transit LSR for another LSP, and egress LER for some other LSP.

Label switching in an MPLS domain depicts an MPLS domain with a single LSP consisting of three LSRs: an ingress LER, a transit LSR, and an egress LER.

Label switching in an MPLS domain



Label switching in an MPLS domain works as described below.

1. The Ingress LER receives a packet and pushes a label onto it.

   When a packet arrives on an MPLS-enabled interface, the device determines to which LSP (if any) the packet are assigned. Specifically, the device determines to which *Forwarding Equivalence Class (FEC)* the packet belongs. An FEC is simply a group of packets that are all forwarded in the same way. For example, a FEC could be defined as all packets from a given *Virtual Leased Line (VLL)*. FECs are mapped to LSPs. When a packet belongs to a FEC, and an LSP is mapped to that FEC, the packet is assigned to the LSP.

   When a packet is assigned to an LSP, the device, acting as an ingress LER, applies (pushes) a tunnel label onto the packet. A label is a 32-bit, fixed-length identifier that is significant only to MPLS. Refer to MPLS label header encoding on page 33 for specific information about the contents of a label. From this point until the packet reaches the egress LER at the end of the path, the packet is forwarded using information in its label, not information in its IP header. The packet's IP header is not examined again as long as the packet traverses the LSP. The ingress LER may also apply a VC label onto the packet based on the VPN application.

   On the ingress LER, the label is associated with an outbound interface. After receiving a label, the packet is forwarded over the outbound interface to the next router in the LSP.

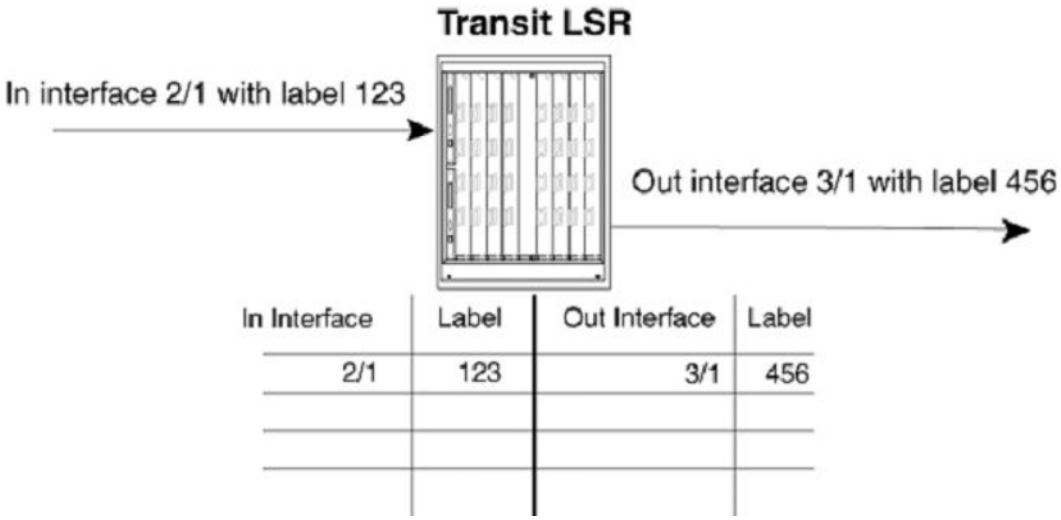
2. A transit LSR receives the labeled packet, swaps the label, and forwards the packet to the next LSR.

   In an LSP, zero or more transit LSRs can exist between the ingress and egress LERs. A transit LSR swaps labels on an MPLS packet and forwards the packet to the next router in the LSP.

   When a transit LSR receives an MPLS packet, it looks up the label in its *MPLS forwarding table* . This table maps the label and inbound interface to a new label and outbound interface. The transit LSR replaces the old label with the new label and sends the packet out the outbound interface specified in the table. This process repeats at each transit LSR until the packet reaches the next-to-last LSR in the LSP (for signaled LSPs).

   Figure 1 illustrates an example of the label swapping process on a transit LSR.

FIGURE 1 Label swapping on a transit LSR



In this example, a packet comes into interface 2/1 with label 123. The transit LSR then looks up this interface-label pair in its MPLS forwarding table. The inbound interface-label pair maps to an outbound-interface-label pair - in this example, interface 3/1 with label 456. The LSR swaps label 123 with label 456 and forwards the packet out interface 3/1.

3. The egress LER receives labeled packet, pops label, and forwards IP packet.

   When the packet reaches the egress LER, the MPLS label is removed (called *popping* the label), and the packet can then be forwarded to its destination using standard hop-by-hop routing protocols. On signaled LSPs, the label is popped at the penultimate (next to last) LSR, rather than the egress LER. Refer to Penultimate hop popping on page 32 for more information.

Types of LSPs

An LSP in an MPLS domain can be either *static* or *signaled*.

Signaled LSPs

Signaled LSPs are configured at the ingress LER only. When the LSP is enabled, RSVP signaling messages travel to each LSR in the LSP, reserving resources and causing labels to be dynamically associated with interfaces. When a packet is assigned to a signaled LSP, it follows a pre-established path from the LSPs ingress LER to its egress LER. This path can be one of the following:

- A path that traverses an explicitly specified set of MPLS routers
- The IGP shortest path across the MPLS domain, determined from local routing tables
- A traffic-engineered path calculated by the device using constraints such as bandwidth reservations, administrative groups, and network topology information

For more information, refer to How CSPF calculates a traffic-engineered path on page 38, How RSVP establishes a signaled LSP on page 39, and Setting up signaled LSPs on page 128.

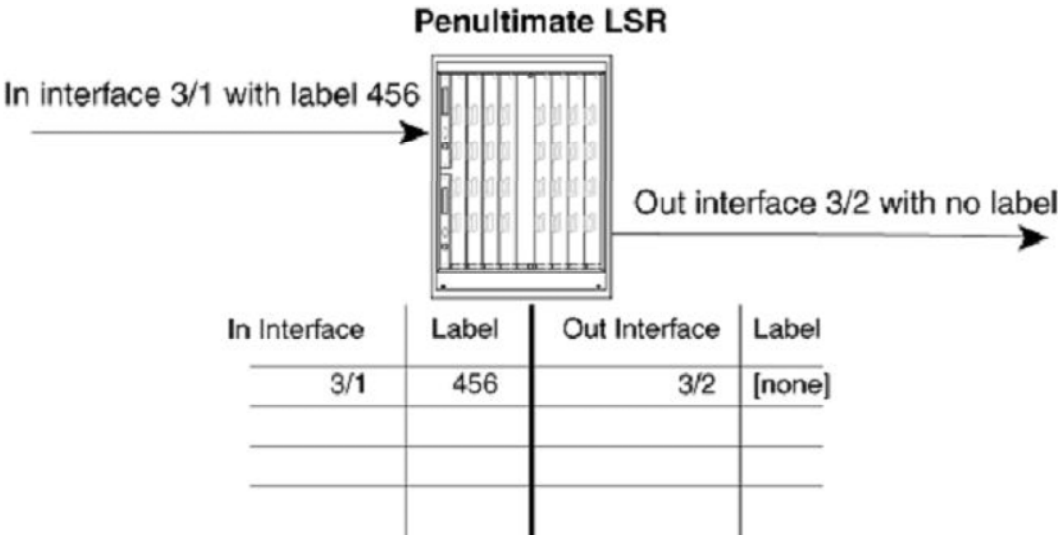
Penultimate hop popping

On signaled LSPs, the MPLS label is popped at the next-to-last LSR in the LSP, instead of at the egress LER. This action is called *penultimate hop popping*. Penultimate hop popping improves forwarding efficiency by allowing the egress LER to avoid performing both a MPLS forwarding table lookup and an IP forwarding table lookup for each packet exiting the LSP. Instead, the MPLS label is

popped at the penultimate (next-to-last) LSR, and the packet is forwarded to the egress LER with no MPLS encoding. The egress LER, in fact, does not recognize the packet as emerging from an LSP.

Figure 2 illustrates the operation that takes place at the penultimate LSR in an LSP.

FIGURE 2 Penultimate hop popping



When an LSR receives an MPLS packet, it looks up the label in its MPLS forwarding table. Normally, this table maps the label and inbound interface to a new label and outbound interface. However, when this is the penultimate LSR in an LSP, the label and inbound interface map only to an outbound interface. The penultimate LSR pops the label and forwards the packet - now a regular IP packet - out the outbound interface. When the packet reaches the egress LER, there is no indication that it had been forwarded over an LSP. The packet is forwarded using standard hop-by-hop routing protocols.

NOTE
Penultimate hop popping is always performed on signaled LSPs.

MPLS label header encoding

The following diagram illustrates the structure of the 32-bit MPLS label header. When a packet enters an LSP, the ingress LER pushes a label onto the packet.

FIGURE 3 Structure of an MPLS Label Header

An MPLS label header is composed of the following parts:

Label value (20 bits)

The label value is an integer in the range 16 - 1048575. (Labels 0 - 15 are reserved by the IETF for special usage.) For signaled LSPs, the device dynamically assigns labels in the range 1024 - 499999.

EXP field (3 bits)

The EXP field is designated for experimental usage. By default, a device uses the EXP field to define a Class of Service (CoS) value for prioritizing packets traveling through an LSP. Please refer to Configuring MPLS Traffic Engineering on page 25, for more information. Note that software forwarded VPLS packets do not use the EXP encode table.

S (Bottom of Stack) field (one bit)

An MPLS packet can be assigned multiple labels. When an MPLS packet has multiple labels, they are logically organized in a last-in, first-out *label stack*. An LSR performs a pop or swap operation on the topmost label; that is, the most recently applied label in the stack. The Bottom of Stack field indicates whether this label is the last (oldest) label in the stack. When the label is the last one in the stack, the Bottom of Stack field is set to one. If not, the Bottom of Stack field is set to zero.

A device acting as an LSR can perform one push, swap, or pop operation on an incoming MPLS packet. The device can accept MPLS packets that contain multiple labels, but only the topmost label is acted upon.

TTL field (eight bits)

The TTL field indicates the *Time To Live (TTL)* value for the MPLS packet. At the ingress LER, an IP packet's TTL value is copied to its MPLS TTL field. At each transit LSR hop, the MPLS TTL value is decremented by one. When the MPLS TTL value reaches zero, the packet is discarded. Optionally, the user can configure the LSRs not to decrement the MPLS TTL value at each hop.

OSPF-TE Link State Advertisements for MPLS interfaces

MPLS-enabled devices running OSPF can be configured to send out LSAs that have special extensions for traffic engineering. These LSAs, called *OSPF-TE LSAs*, contain information about interfaces configured for MPLS. The OSPF-TE LSAs are flooded throughout the OSPF area. LSRs that receive the OSPF-TE LSAs place the traffic engineering information into a TED, which maintains topology data about the nodes and links in the MPLS domain.

Traffic engineering information is carried in OSPF traffic engineering (OSPF-TE) LSAs. OSPF-TE LSAs are Type 10 Opaque LSAs, as defined in *RFC 2370*. Type 10 Opaque LSAs have area flooding scope.

OSPF-TE LSAs have special extensions that contain information related to traffic engineering; these extensions are described in *RFC 3630*. The extensions consist of *Type/Length/Value triplets (TLVs)* containing the following information:

- Type of link (either point-to-point or multi-access network)
- ID of the link (for point-to-point links, this is the Router ID of the LSR at the other end of the link; for multiaccess links, this is the address of the network's designated router)
- IP address of the local interface for the link
- IP address of the remote interface for the link (this could be zero for multicast links)
- Traffic engineering metric for the link (by default, this is equal to the OSPF link cost)
- Maximum bandwidth on the interface
- Maximum reservable bandwidth on the interface
- Unreserved bandwidth on the interface
- Administrative groups to which the interface belongs

When configured to do so, the device sends out OSPF-TE LSAs for each of its MPLS-enabled interfaces. The user can optionally specify the maximum amount of bandwidth that can be reserved on an interface, as well as assign interfaces to administrative groups. Refer to Setting traffic engineering parameters for MPLS interfaces on page 108 for more information.

The following events trigger the device to send out OSPF-TE LSAs:

- Change in the interface's administrative group membership
- Change in the interface's maximum available bandwidth or maximum reservable bandwidth
- Significant change in unreserved bandwidth per priority level:
  - If for any priority level, the difference between the previously advertised unreserved bandwidth and the current unreserved bandwidth exceeds five percent of the maximum reservable bandwidth
  - Any changes while the total reserved bandwidth exceeds 95 percent of the maximum reservable bandwidth

In addition, OSPF-TE LSAs can be triggered by OSPF; for example, when an interface's link state is changed. When an interface is no longer enabled for MPLS, the device stops sending out OSPF-TE LSAs for the interface.

Using MPLS in traffic engineering

Traffic engineering is the task of routing network traffic to avoid points of congestion and make efficient use of high bandwidth interfaces. When used as an application of MPLS, traffic engineering involves creating LSPs that make the best use of available network resources; that is, *traffic-engineered LSPs*. This section explains the process of creating traffic-engineered LSPs.

Creating traffic-engineered LSPs involves the following tasks:

- Gathering information about the network
- Using the gathered information to select optimal paths through the network
- Setting up and maintaining the paths

For traffic-engineered signaled LSPs, devices can perform these tasks dynamically. Figure 4 illustrates the process that takes place to configure, establish, and activate traffic-engineered signaled LSPs.

NOTE
Adaptive LSPs can have primary and secondary sessions up at the same time. Brocade devices only support 16k LSPs, and no more than a total of 32k sessions.