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Detecting MPLS Data Plane Failures

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Status of this Memo

Abstract

This document describes a simple and efficient mechanism that can be used to detect data plane failures in Multi-Protocol Label Switching (MPLS) Label Switched Paths (LSPs). There are two parts to this document: information carried in an MPLS "echo request" and "echo reply" for the purposes of fault detection and isolation; and mechanisms for reliably sending the echo reply.

Contents

1. Introduction

This document describes a simple and efficient mechanism that can be used to detect data plane failures in MPLS LSPs. There are two parts to this document: information carried in an MPLS "echo request" and "echo reply"; and mechanisms for transporting the echo reply. The first part aims at providing enough information to check correct operation of the data plane, as well as a mechanism to verify the data plane against the control plane, and thereby localize faults. The second part suggests two methods of reliable reply channels for the echo request message, for more robust fault isolation.

An important consideration in this design is that MPLS echo requests follow the same data path that normal MPLS packets would traverse. MPLS echo requests are meant primarily to validate the data plane, and secondarily to verify the data plane against the control plane. Mechanisms to check the control plane are valuable, but are not covered in this document.

1.1. Conventions

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [KEYWORDS].

The term "Must be Zero" (MBZ) is used in object decriptions for reserved fields. These fields MUST be set to zero when sent and ignored on receipt.

1.2. Structure of this document

The body of this memo contains four main parts: motivation, MPLS echo request/reply packet format, LSP ping operation, and a reliable return path. It is suggested that first-time readers skip the actual packet formats and read the Theory of Operation first; the document is structured the way it is to avoid forward references.

1.3. Contributors

The following made vital contributions to all aspects of this document, and much of the material came out of debate and discussion among this group.

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2. Motivation

When an LSP fails to deliver user traffic, the failure cannot always be detected by the MPLS control plane. There is a need to provide a tool that would enable users to detect such traffic "black holes" or misrouting within a reasonable period of time; and a mechanism to isolate faults.

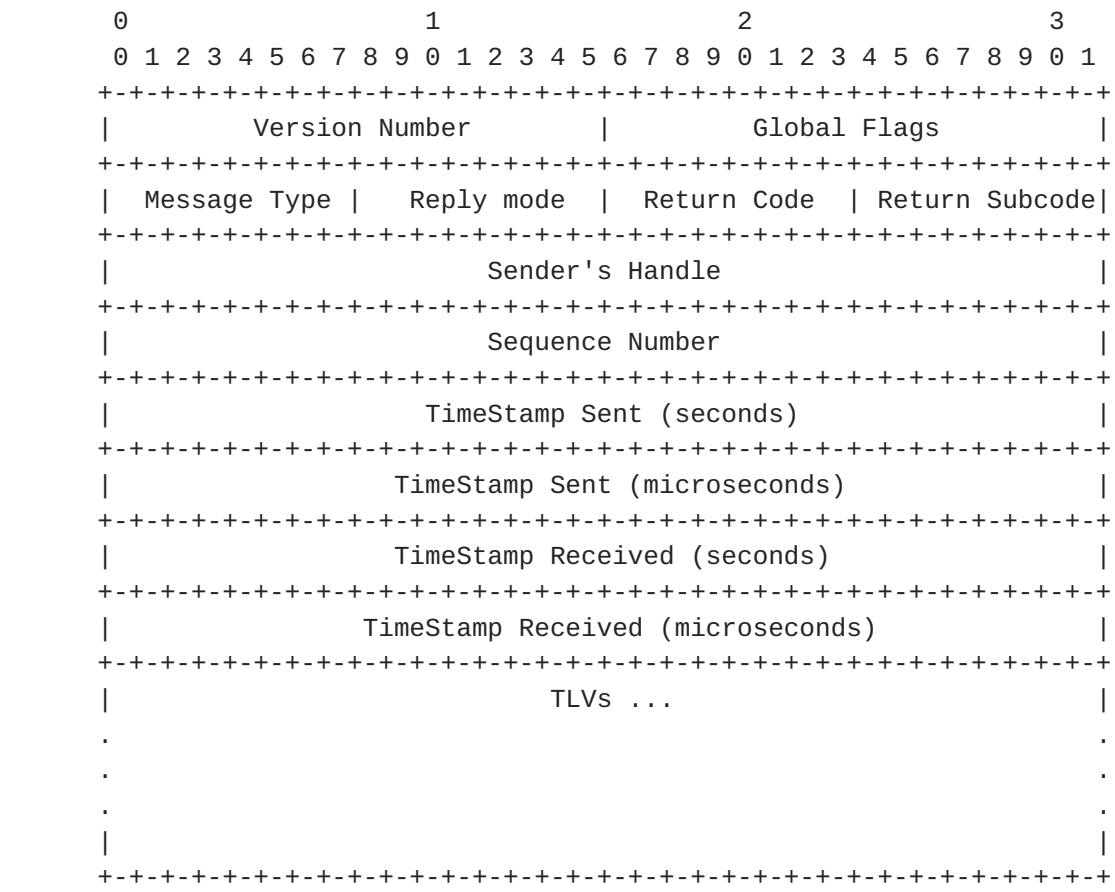
In this document, we describe a mechanism that accomplishes these goals. This mechanism is modeled after the ping/traceroute paradigm: ping (ICMP echo request [ICMP]) is used for connectivity checks, and traceroute is used for hop-by-hop fault localization as well as path tracing. This document specifies a "ping mode" and a "traceroute" mode for testing MPLS LSPs.

The basic idea is to verify that packets that belong to a particular Forwarding Equivalence Class (FEC) actually end their MPLS path on a Label Switching Router (LSR) that is an egress for that FEC. This document proposes that this test be carried out by sending a packet (called an "MPLS echo request") along the same data path as other packets belonging to this FEC. An MPLS echo request also carries information about the FEC whose MPLS path is being verified. This echo request is forwarded just like any other packet belonging to that FEC. In "ping" mode (basic connectivity check), the packet should reach the end of the path, at which point it is sent to the control plane of the egress LSR, which then verifies whether it is indeed an egress for the FEC. In "traceroute" mode (fault isolation), the packet is sent to the control plane of each transit LSR, which performs various checks that it is indeed a transit LSR for this path; this LSR also returns further information that helps check the control plane against the data plane, i.e., that forwarding matches what the routing protocols determined as the path.

One way these tools can be used is to periodically ping a FEC to ensure connectivity. If the ping fails, one can then initiate a traceroute to determine where the fault lies. One can also periodically traceroute FECs to verify that forwarding matches the control plane; however, this places a greater burden on transit LSRs and thus should be used with caution.

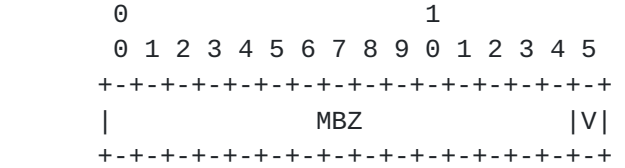
3. Packet Format

An MPLS echo request is a (possibly labeled) IPv4 or IPv6 UDP packet; the contents of the UDP packet have the following format:



The Version Number is currently 1. (Note: the Version Number is to be incremented whenever a change is made that affects the ability of an implementation to correctly parse or process an MPLS echo request/reply. These changes include any syntactic or semantic changes made to any of the fixed fields, or to any TLV or sub-TLV assignment or format that is defined at a certain version number. The Version Number may not need to be changed if an optional TLV or sub-TLV is added.)

The Global Flags field is a bit vector with the following format:



One flag is defined for now, the V bit; the rest MUST be set to zero when sending, and ignored on receipt.

The V (Validate FEC Stack) flag is set to 1 if the sender wants the receiver to perform FEC stack validation; if V is 0, the choice is left to the receiver.

The Message Type is one of the following:

Value	Meaning
1	MPLS Echo Request
2	MPLS Echo Reply

The Reply Mode can take one of the following values:

Value	Meaning
1	Do not reply
2	Reply via an IPv4/IPv6 UDP packet
3	Reply via an IPv4/IPv6 UDP packet with Router Alert
4	Reply via application level control channel

An MPLS echo request with 1 (Do not reply) in the Reply Mode field may be used for one-way connectivity tests; the receiving router may log gaps in the sequence numbers and/or maintain delay/jitter statistics. An MPLS echo request would normally have 2 (Reply via an IPv4/IPv6 UDP packet) in the Reply Mode field. If the normal IP return path is deemed unreliable, one may use 3 (Reply via an IPv4/IPv6 UDP packet with Router Alert). Note that this requires that all intermediate routers understand and know how to forward MPLS echo replies. The echo reply uses the same IP version number as the received echo request, i.e., an IPv4 encapsulated echo reply is sent in response to an IPv4 encapsulated echo request.

Any application which supports an IP control channel between its control entities may set the Reply Mode to 4 (Reply via application level control channel) to ensure that replies use that same channel. Further definition of this codepoint is application specific and thus beyond the scope of this document.

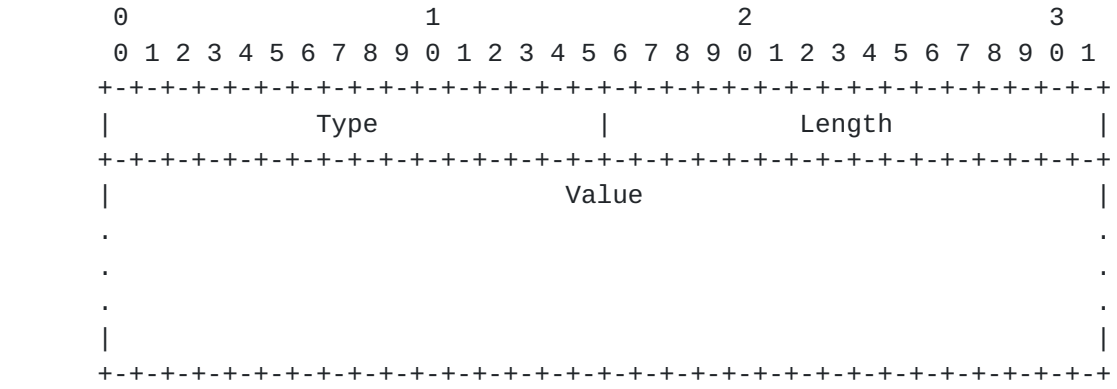
Return Codes and Subcodes are described in the next section.

the Sender's Handle is filled in by the sender, and returned unchanged by the receiver in the echo reply (if any). There are no semantics associated with this handle, although a sender may find this useful for matching up requests with replies.

The Sequence Number is assigned by the sender of the MPLS echo request, and can be (for example) used to detect missed replies.

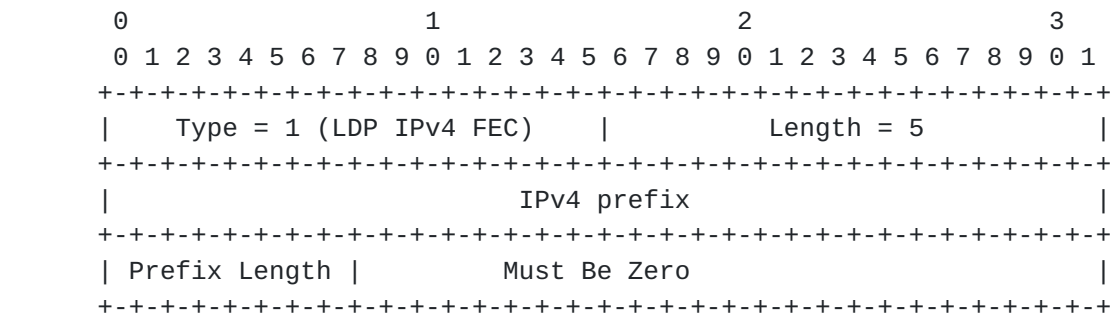
The TimeStamp Sent is the time-of-day (in seconds and microseconds, according to the sender's clock) when the MPLS echo request is sent. The TimeStamp Received in an echo reply is the time-of-day (according to the receiver's clock) that the corresponding echo request was received.

TLVs (Type-Length-Value tuples) have the following format:

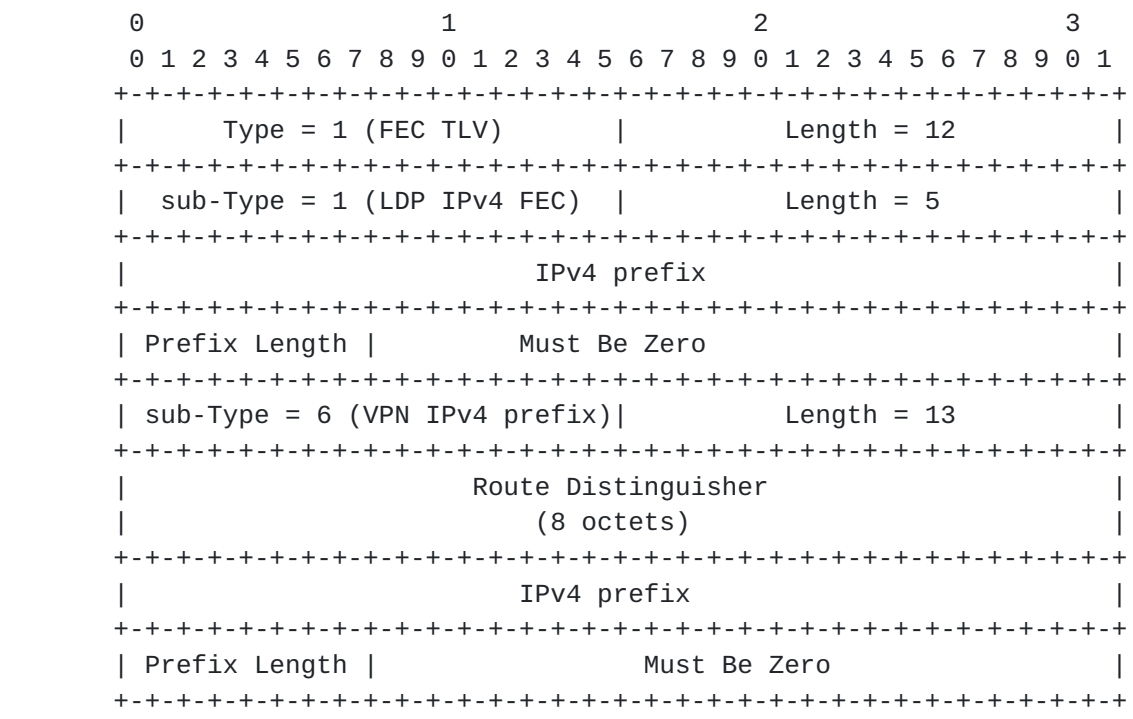


Types are defined below; Length is the length of the Value field in octets. The Value field depends on the Type; it is zero padded to align to a four-octet boundary. TLVs may be nested within other TLVs, in which case the nested TLVs are called sub-TLVs. Sub-TLVs have independent types and MUST also be four-octet aligned.

Two examples follow. The LDP IPv4 FEC sub-TLV has the following format:



The Length for this TLV is 5. A Target FEC Stack TLV which contains an LDP IPv4 FEC sub-TLV and a VPN IPv4 prefix sub-TLV has the format:



A description of the Types and Values of the top level TLVs for LSP ping are given below:

Type #	Value Field
1	Target FEC Stack
2	Downstream Mapping
3	Pad
4	Not Assigned
5	Vendor Enterprise Code
6	Not Assigned
7	Interface and Label Stack
8	Not Assigned
9	Errored TLVs
10	Reply TOS Byte

Types less than 32768 (i.e., with the high order bit equal to 0) are mandatory TLVs that MUST either be supported by an implementation or result in the return code of 2 ("One or more of the TLVs was not understood") being sent in the echo response.

Types greater than or equal to 32768 (i.e., with the high order bit equal to 1) are optional TLVs that SHOULD be ignored if the implementation does not understand or support them.

3.1. Return Codes

The Return Code is set to zero by the sender. The receiver can set it to one of the values listed below. The notation <RSC> refers to the Return Subcode. This field is filled in with the stack-depth for those codes which specify that. For all other codes the Return Subcode MUST be set to zero.

Value	Meaning
0	No return code
1	Malformed echo request received
2	One or more of the TLVs was not understood
3	Replying router is an egress for the FEC at stack depth <RSC>
4	Replying router has no mapping for the FEC at stack depth <RSC>
5	Downstream Mapping Mismatch (See Note 1)
6	Upstream Interface Index Unknown (See Note 1)
7	Reserved
8	Label switched at stack-depth <RSC>
9	Label switched but no MPLS forwarding at stack-depth <RSC>
10	Mapping for this FEC is not the given label at stack depth <RSC>
11	No label entry at stack-depth <RSC>
12	Protocol not associated with interface at FEC stack depth <RSC>
13	Premature termination of ping due to label stack shrinking to a single label

Note 1

The Return Subcode contains the point in the label stack where processing was terminated. If the RSC is 0, no labels were processed. Otherwise the packet would have been label switched at depth RSC.

3.2. Target FEC Stack

A Target FEC Stack is a list of sub-TLVs. The number of elements is determined by looking at the sub-TLV length fields.

Sub-Type	Length	Value Field
1	5	LDP IPv4 prefix
2	17	LDP IPv6 prefix
3	20	RSVP IPv4 LSP
4	56	RSVP IPv6 LSP
5		Not Assigned
6	13	VPN IPv4 prefix
7	25	VPN IPv6 prefix
8	14	L2 VPN endpoint
9	10	"FEC 128" Pseudowire (deprecated)
10	14	"FEC 128" Pseudowire
11	16+	"FEC 129" Pseudowire
12	5	BGP labeled IPv4 prefix
13	17	BGP labeled IPv6 prefix
14	5	Generic IPv4 prefix
15	17	Generic IPv6 prefix
16	4	Nil FEC

Other FEC Types will be defined as needed.

Note that this TLV defines a stack of FECs, the first FEC element corresponding to the top of the label stack, etc.

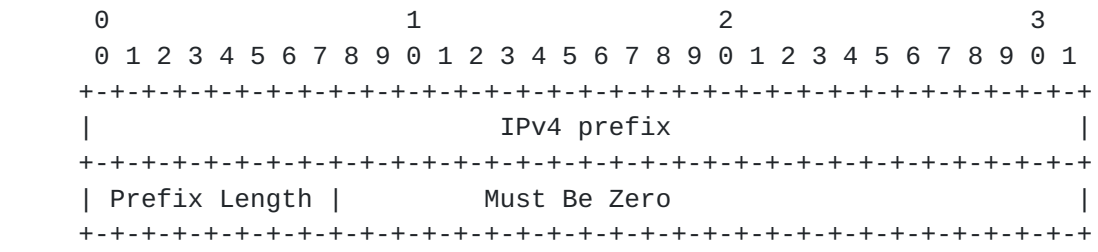
An MPLS echo request MUST have a Target FEC Stack that describes the FEC stack being tested. For example, if an LSR X has an LDP mapping [see LDP] for 192.168.1.1 (say label 1001), then to verify that label 1001 does indeed reach an egress LSR that announced this prefix via LDP, X can send an MPLS echo request with a FEC Stack TLV with one FEC in it, namely of type LDP IPv4 prefix, with prefix 192.168.1.1/32, and send the echo request with a label of 1001.

Say LSR X wanted to verify that a label stack of <1001, 23456> is the right label stack to use to reach a VPN IPv4 prefix [see section 3.2.5] of 10/8 in VPN foo. Say further that LSR Y with loopback address 192.168.1.1 announced prefix 10/8 with Route Distinguisher

RD-foo-Y (which may in general be different from the Route Distinguisher that LSR X uses in its own advertisements for VPN foo), label 23456 and BGP nexthop 192.168.1.1 [see BGP]. Finally, suppose that LSR X receives a label binding of 1001 for 192.168.1.1 via LDP. X has two choices in sending an MPLS echo request: X can send an MPLS echo request with a FEC Stack TLV with a single FEC of type VPN IPv4 prefix with a prefix of 10/8 and a Route Distinguisher of RD-foo-Y. Alternatively, X can send a FEC Stack TLV with two FECs, the first of type LDP IPv4 with a prefix of 192.168.1.1/32 and the second of type of IP VPN with a prefix 10/8 with Route Distinguisher of RD-foo-Y. In either case, the MPLS echo request would have a label stack of <1001, 23456>. (Note: in this example, 1001 is the "outer" label and 23456 is the "inner" label.)

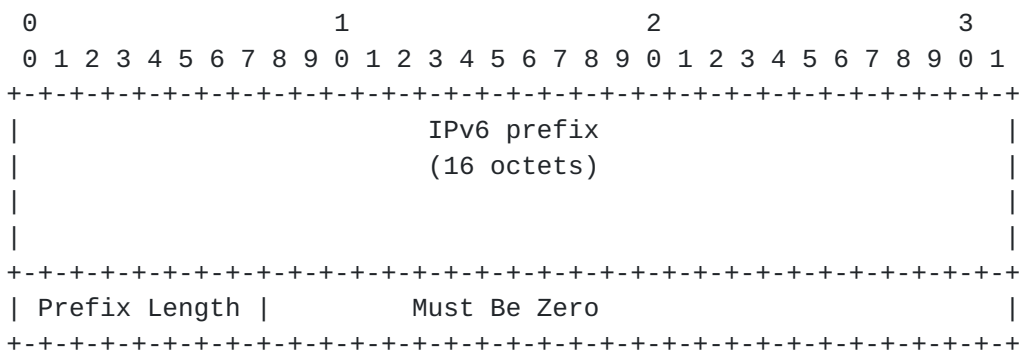
3.2.1. LDP IPv4 Prefix

The IPv4 Prefix FEC is defined in [LDP]. When a LDP IPv4 prefix is encoded in a label stack, the following format is used. The value consists of four octets of an IPv4 prefix followed by one octet of prefix length in bits; the format is given below. The IPv4 prefix is in network byte order; if the prefix is shorter than 32 bits, trailing bits SHOULD be set to zero. See [LDP] for an example of a Mapping for an IPv4 FEC.



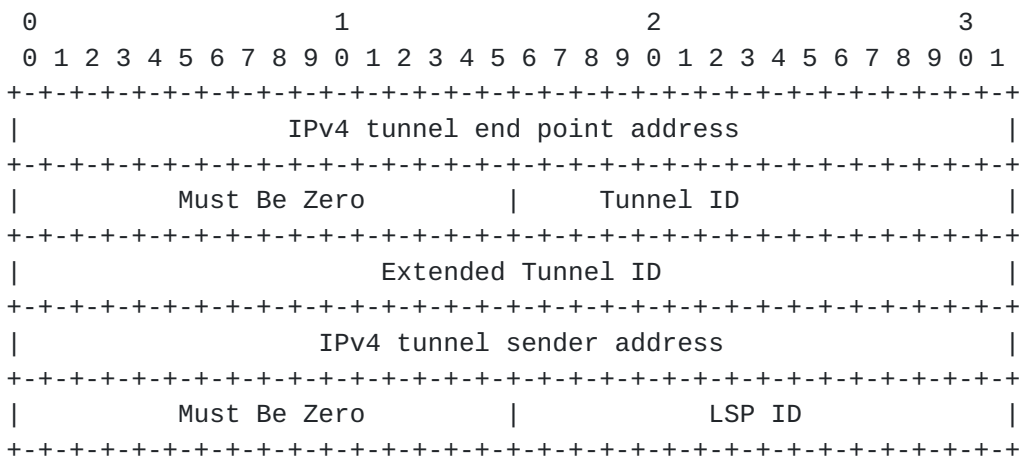
3.2.2. LDP IPv6 Prefix

The IPv6 Prefix FEC is defined in [LDP]. When a LDP IPv6 prefix is encoded in a label stack, the following format is used. The value consists of sixteen octets of an IPv6 prefix followed by one octet of prefix length in bits; the format is given below. The IPv6 prefix is in network byte order; if the prefix is shorter than 128 bits, the trailing bits SHOULD be set to zero. See [LDP] for an example of a Mapping for an IPv6 FEC.



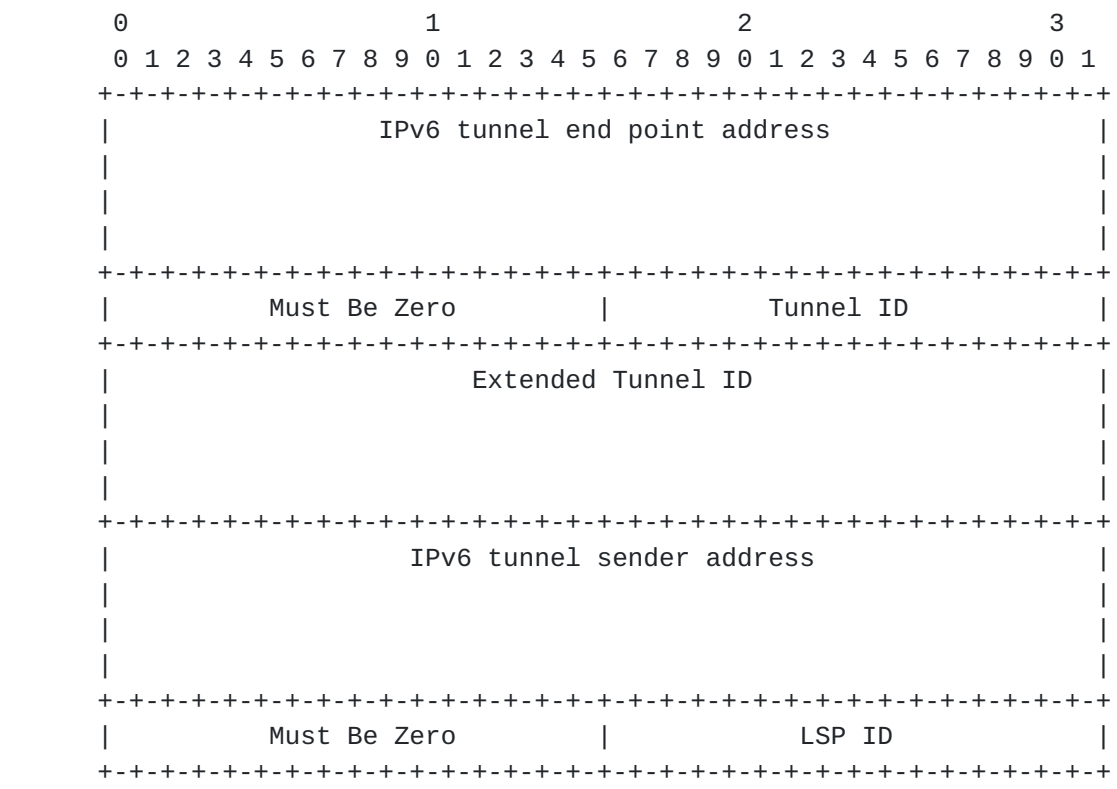
3.2.3. RSVP IPv4 LSP

The value has the format below. The value fields are taken from RFC3209, sections 4.6.1.1 and 4.6.2.1. See [RSVP-TE].



3.2.4. RSVP IPv6 LSP

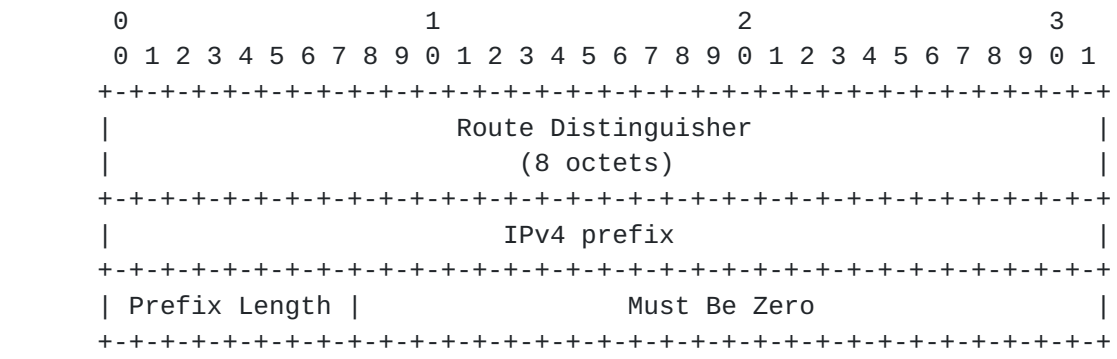
The value has the format below. The value fields are taken from RFC3209, sections 4.6.1.2 and 4.6.2.2. See [RSVP-TE].



3.2.5. VPN IPv4 Prefix

VPN-IPv4 NLRI (Network Layer Routing Information) is defined in [MPLS-L3-VPN]. This document uses the term VPN IPv4 prefix for a VPN-IPv4 NLRI which has been advertised with an MPLS label in BGP. See [BGP-LABEL].

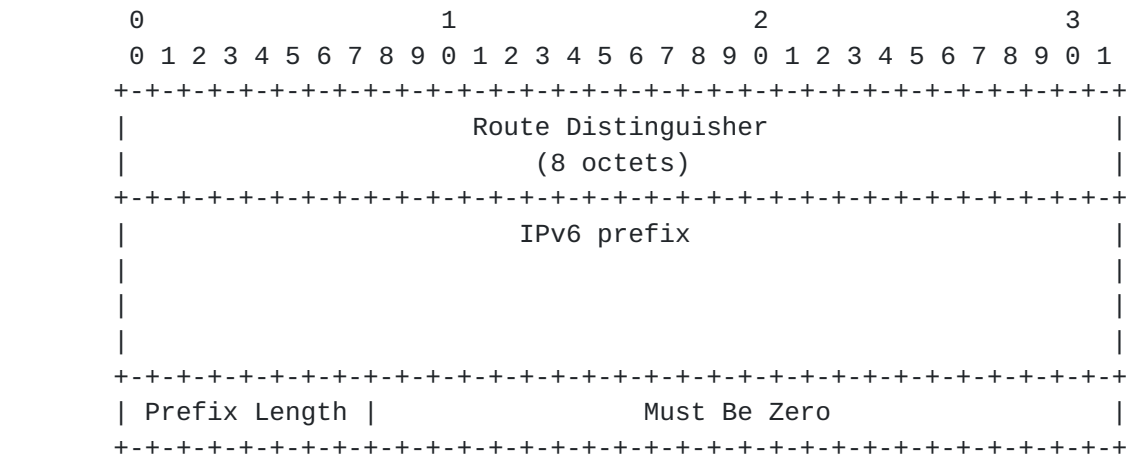
When a VPN IPv4 prefix is encoded in a label stack, the following format is used. The value field consists of the Route Distinguisher advertised with the VPN IPv4 prefix, the IPv4 prefix (with trailing 0 bits to make 32 bits in all) and a prefix length, as follows:



3.2.6. VPN IPv6 Prefix

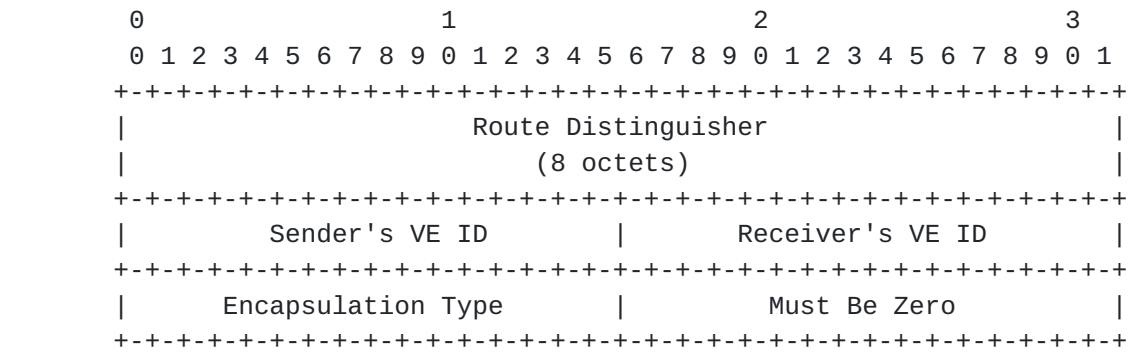
VPN-IPv6 NLRI (Network Layer Routing Information) is defined in [MPLS-L3-VPN]. This document uses the term VPN IPv6 prefix for a VPN-IPv6 NLRI which has been advertised with an MPLS label in BGP. See [BGP-LABEL].

When a VPN IPv6 prefix is encoded in a label stack, the following format is used. The value field consists of the Route Distinguisher advertised with the VPN IPv6 prefix, the IPv6 prefix (with trailing 0 bits to make 128 bits in all) and a prefix length, as follows:



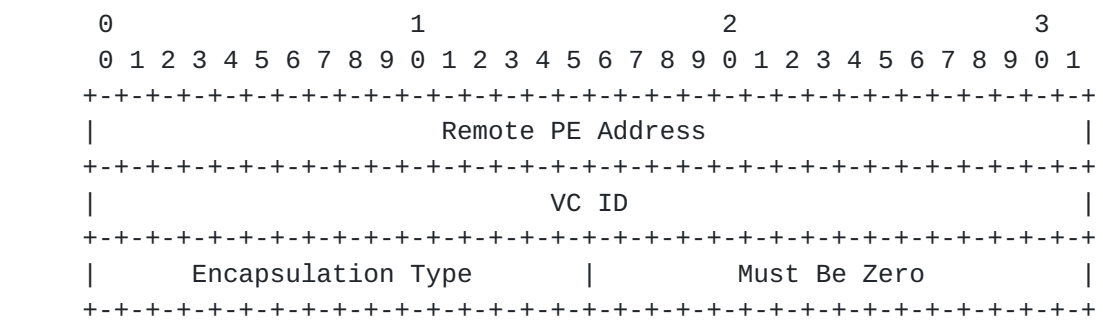
3.2.7. L2 VPN Endpoint

VPLS BGP NLRI and VE ID are defined in [VPLS]. This document uses the simpler term L2 VPN endpoint when refering to a VPLS BGP NLRI. When an L2 VPN endpoint is encoded in a label stack, the following format is used. The value field consists of a Route Distinguisher (8 octets), the sender (of the ping)'s VE ID (2 octets), the receiver's VE ID (2 octets), and an encapsulation type (2 octets), formatted as follows:



3.2.8. FEC 128 Pseudowire (Deprecated)

FEC 128 and the term VC ID are defined in [PW-CONTROL]. When a FEC 128 is encoded in a label stack, the following format is used. The value field consists of the remote PE address (the destination address of the targeted LDP session), a VC ID and an encapsulation type, as follows:

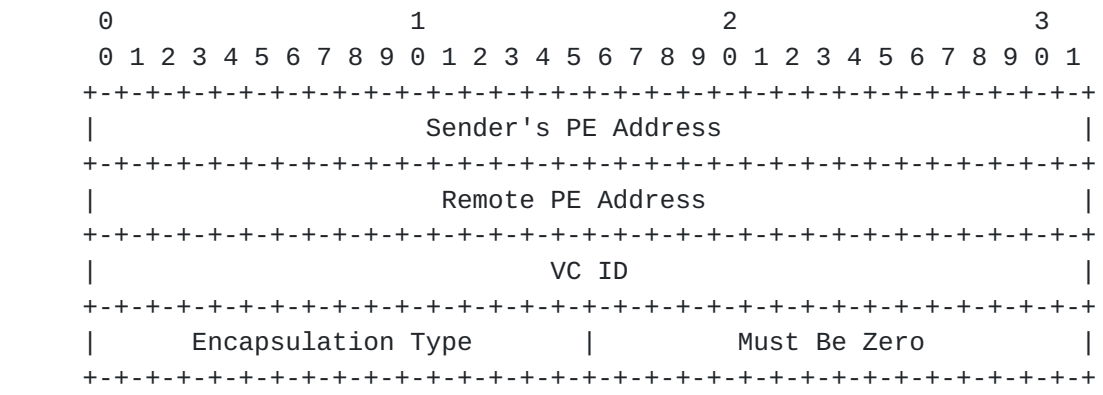


This FEC is deprecated and is retained only for backward compatibility. Implementations of LSP ping SHOULD accept and process this TLV, but SHOULD send LSP ping echo requests with the new TLV (see next section), unless explicitly configured to use the old TLV.

An LSR receiving this TLV SHOULD use the source IP address of the LSP echo request to infer the Sender's PE Address.

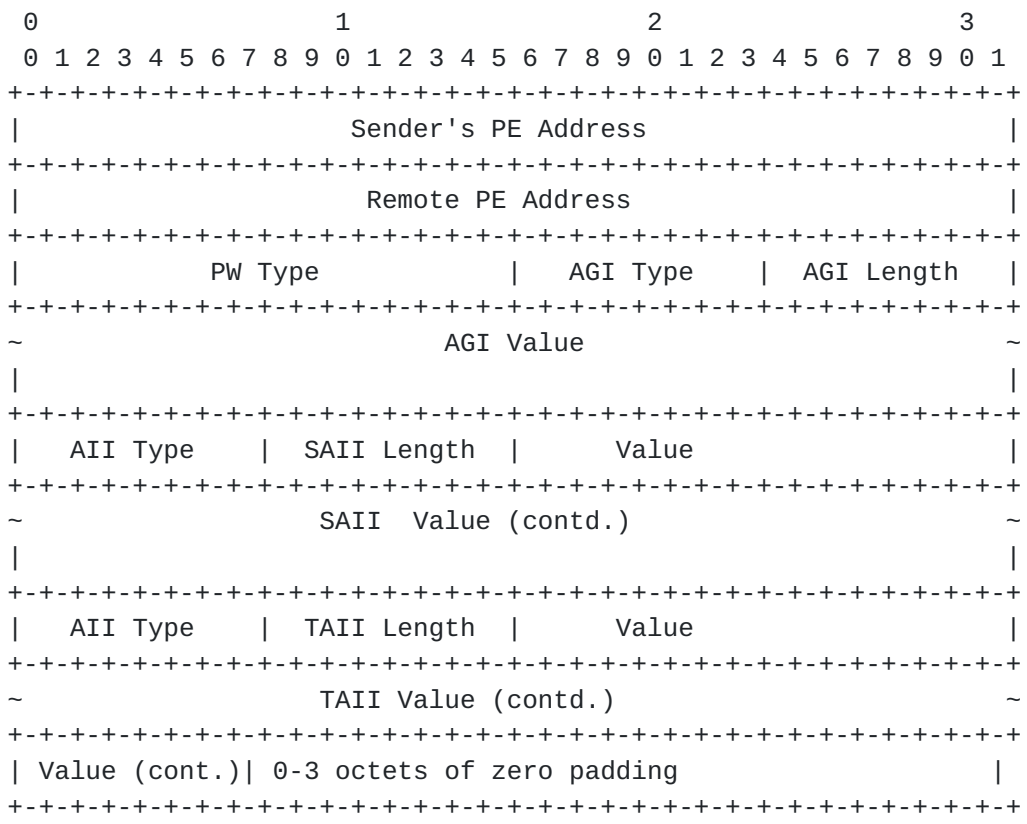
3.2.9. FEC 128 Pseudowire (Current)

FEC 128 and the term VC ID are defined in [PW-CONTROL]. When a FEC 128 is encoded in a label stack, the following format is used. The value field consists of the sender's PE address (the source address of the targeted LDP session), the remote PE address (the destination address of the targeted LDP session), a VC ID and an encapsulation type, as follows:



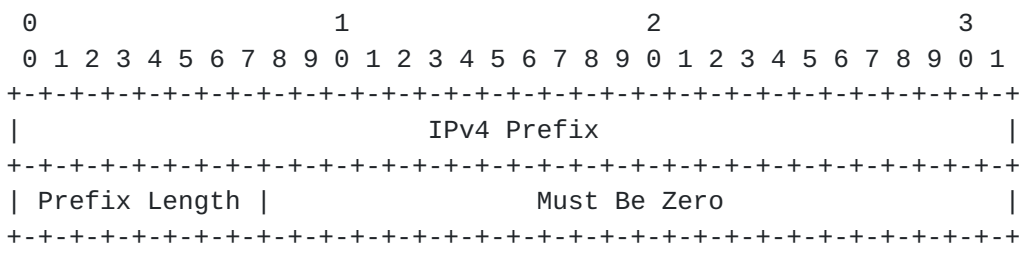
3.2.10. FEC 129 Pseudowire

FEC 129 and the terms AII, AGI, SAII, and TAII are defined in [PW-CONTROL]. When a FEC 129 is encoded in a label stack, the following format is used. The Length of this TLV is 16 + AGI length + SAII length + TAII length. Padding is used to make the total length a multiple of 4; the length of the padding is not included in the Length field.



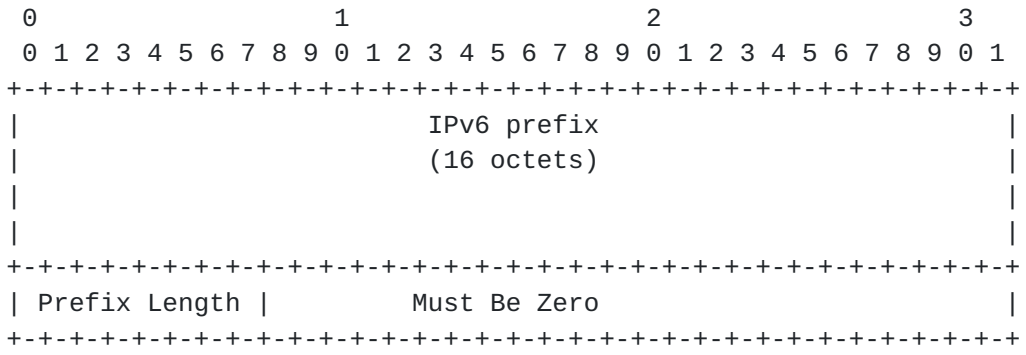
3.2.11. BGP Labeled IPv4 Prefix

BGP labeled IPv4 prefixes are defined in [BGP-LABEL]. When a BGP labeled IPv4 prefix is encoded in a label stack, the following format is used. The value field consists the IPv4 prefix (with trailing 0 bits to make 32 bits in all), and the prefix length, as follows:



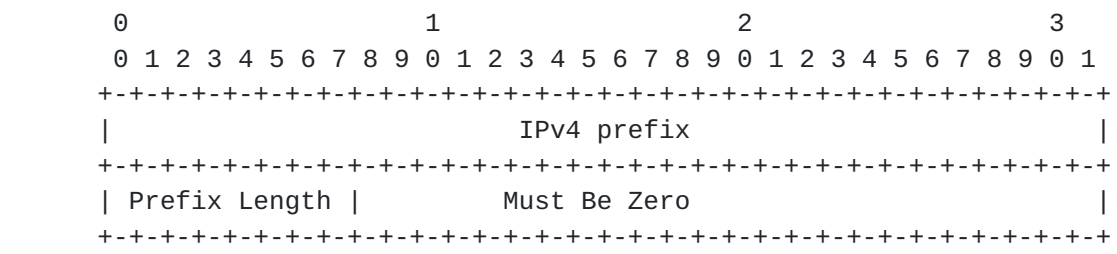
3.2.12. BGP Labeled IPv6 Prefix

BGP labeled IPv6 prefixes are defined in [BGP-LABEL]. When a BGP labeled IPv6 prefix is encoded in a label stack, the following format is used. The value consists of sixteen octets of an IPv6 prefix followed by one octet of prefix length in bits; the format is given below. The IPv6 prefix is in network byte order; if the prefix is shorter than 128 bits, the trailing bits SHOULD be set to zero.



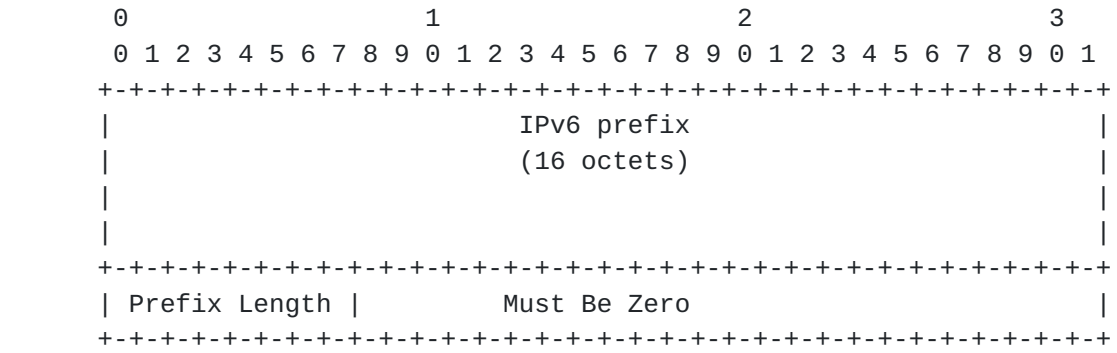
3.2.13. Generic IPv4 Prefix

The value consists of four octets of an IPv4 prefix followed by one octet of prefix length in bits; the format is given below. The IPv4 prefix is in network byte order; if the prefix is shorter than 32 bits, trailing bits SHOULD be set to zero. This FEC is used if the protocol advertising the label is unknown, or may change during the course of the LSP. An example is an inter-AS LSP that may be signaled by LDP in one AS, by RSVP-TE [RSVP-TE] in another AS, and by BGP between the ASes, such as is common for inter-AS VPNs.



3.2.14. Generic IPv6 Prefix

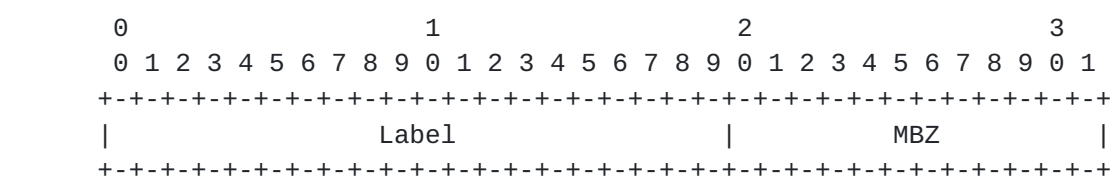
The value consists of sixteen octets of an IPv6 prefix followed by one octet of prefix length in bits; the format is given below. The IPv6 prefix is in network byte order; if the prefix is shorter than 128 bits, the trailing bits SHOULD be set to zero.



3.2.15. Nil FEC

At times labels from the reserved range, e.g. Router Alert and Explicit-null, may be added to the label stack for various diagnostic purposes such as influencing load-balancing. These labels may have no explicit FEC associated with them. The Nil FEC stack is defined to allow a Target FEC stack sub-TLV to be added to the target FEC stack to account for such labels so that proper validation can still be performed.

The Length is 4. Labels are 20 bit values treated as numbers. stack.



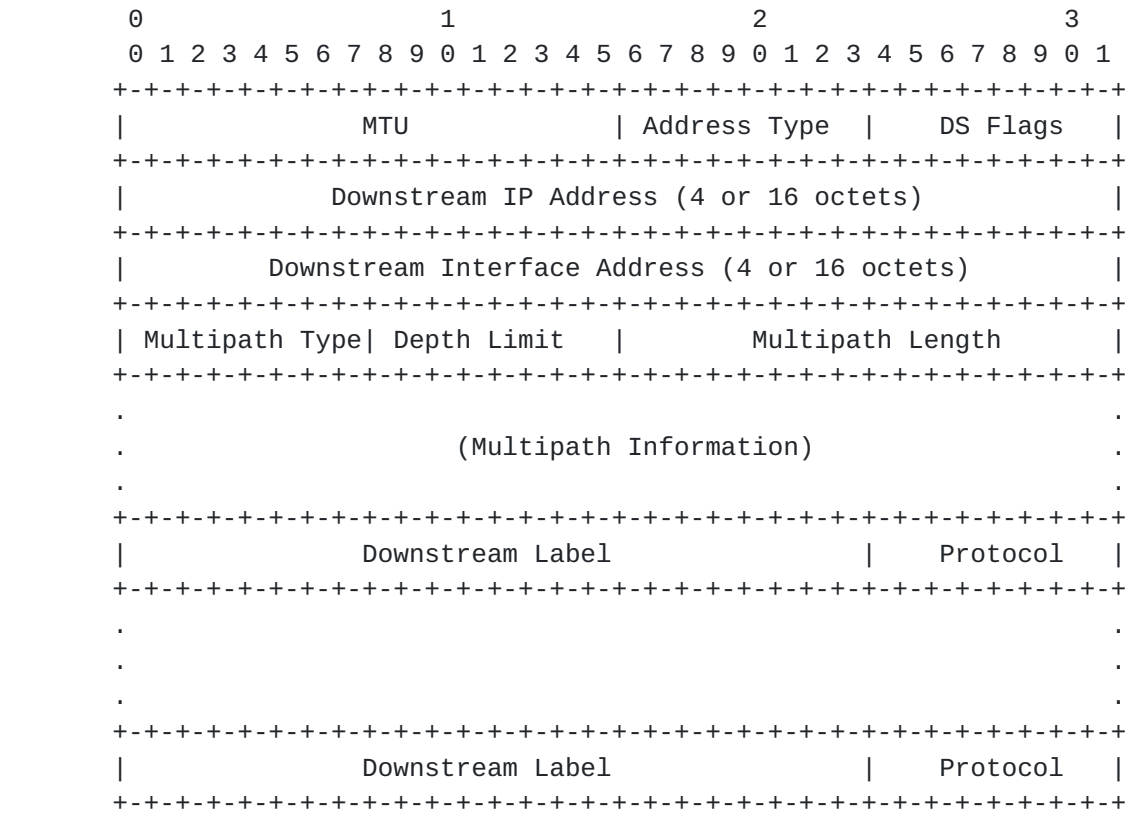
Label is the actual label value inserted in the label stack; the MBZ

fields MUST be zero when sent, and ignored on receipt.

3.3. Downstream Mapping

The Downstream Mapping object is a TLV which MAY be included in an echo request message. Only one Downstream Mapping object may appear in an echo request. The presence of a Downstream Mapping object is a request that Downstream Mapping objects be included in the echo reply. If the replying router is the destination of the FEC, then a Downstream Mapping TLV SHOULD NOT be included in the echo reply. Otherwise the replying router SHOULD include a Downstream Mapping object for each interface over which this FEC could be forwarded. For a more precise definition of the notion of "downstream", see section 3.3.2, "Downstream Router and Interface".

The Length is K + M + 4*N octets, where M is the Multipath Length, and N is the number of Downstream Labels. Values for K are found in the description of Address Type below. The Value field of a Downstream Mapping has the following format:



Maximum Transmission Unit (MTU)

The MTU is the size in octets of the largest MPLS frame (including label stack) that fits on the interface to the Downstream LSR.

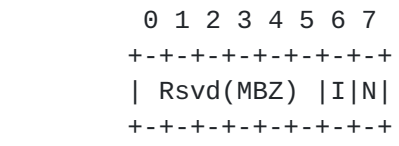
Address Type

The Address Type indicates if the interface is numbered or unnumbered. It also determines the length of the Downstream IP Address and Downstream Interface fields. The resulting total for the initial part of the TLV is listed in the table below as "K Octets". The Address Type is set to one of the following values:

Type #	Address Type	K Octets
1	IPv4 Numbered	16
2	IPv4 Unnumbered	16
3	IPv6 Numbered	40
4	IPv6 Unnumbered	28

DS Flags

The DS Flags field is a bit vector with the following format:



Two flags are defined currently, I and N. The remaining flags MUST be set to zero when sending, and ignored on receipt.

Flag	Name and Meaning
I	Interface and Label Stack Object Request When this flag is set, it indicates that the replying router SHOULD include an Interface and Label Stack Object in the echo reply message
N	Treat as a Non-IP Packet Echo request messages will be used to diagnose non-IP flows. However, these messages are carried in IP packets. For a router which alters its ECMP algorithm based on the FEC or deep packet examination, this flag requests that the router treat this as it would if the determination of an IP payload had failed.

Downstream IP Address and Downstream Interface Address

IPv4 addresses and and interface indices are encoded in 4 octets, IPv6 addresses are encoded in 16 octets.

If the interface to the downstream LSR is numbered, then the Address Type MUST be set to IPv4 or IPv6, the Downstream IP Address MUST be set to either the downstream LSR's Router ID or the interface address of the downstream LSR, and the Downstream Interface Address MUST be set to the downstream LSR's interface address.

If the interface to the downstream LSR is unnumbered, the Address Type MUST be IPv4 Unnumbered or IPv6 Unnumbered, the Downstream IP Address MUST be the downstream LSR's Router ID, and the Downstream Interface Address MUST be set to the index assigned by the upstream LSR to the interface.

If an LSR does not know the IP address of its neighbor, then it MUST set the Address Type to either IPv4 Unnumbered or IPv6 Unnumbered. For IPv4 it must set the Downstream IP Address to 127.0.0.1, for IPv6 the address is set to 0::1. In both cases the interface index MUST be set to 0. If an LSR receives an Echo Request packet with either of these addresses in the Downstream IP Address field, this indicates that it MUST bypass interface verification but continue with label validation.

If the originator of an Echo Request packet wishes to obtain Down-stream mapping information but does not know the expected label stack

then it SHOULD set the Address Type to either IPv4 Unnumbered or IPv6 Unnumbered. For IPv4 it MUST set the Downstream IP Address to 224.0.0.2, for IPv6 the address MUST be set to FF02::2. In both cases the interface index MUST be set to 0. If an LSR receives an Echo Request packet with the all-routers multicast address, then this indicates that it MUST bypass both interface and label stack validation, but return Downstream Mapping TLVs using the information provided.

Multipath Type

The following Multipath Types are defined:

Key	Type	Multipath Information
0	no multipath	Empty (Multipath Length = 0)
2	IP address	IP addresses
4	IP address range	low/high address pairs
8	Bit-masked IPv4 address set	IP address prefix and bit mask
9	Bit-masked label set	Label prefix and bit mask

Type 0 indicates that all packets will be forwarded out this one interface.

Types 2, 4, 8 and 9 specify that the supplied Multipath Information will serve to exercise this path.

Depth Limit

The Depth Limit is applicable only to a label stack, and is the maximum number of labels considered in the hash; this SHOULD be set to zero if unspecified or unlimited.

Multipath Length

The length in octets of the Multipath Information.

Multipath Information

Address or label values encoded according to the Multipath Type. See the next section below for encoding details.

Downstream Label(s)

The set of labels in the label stack as it would have appeared if this router were forwarding the packet through this interface. Any Implicit Null labels are explicitly included. Labels are treated as numbers, i.e. they are right justified in the field.

A Downstream Label is 24 bits, in the same format as an MPLS label minus the TTL field, i.e., the MSBit of the label is bit 0, the LSbit is bit 19, the EXP bits are bits 20-22, and bit 23 is the S bit. The replying router SHOULD fill in the EXP and S bits; the LSR receiving the echo reply MAY choose to ignore these bits.

Protocol

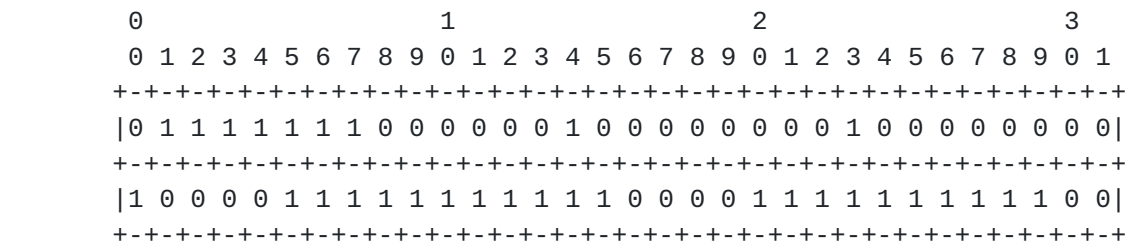
The Protocol is taken from the following table:

Protocol #	Signaling Protocol
0	Unknown
1	Static
2	BGP
3	LDP
4	RSVP-TE

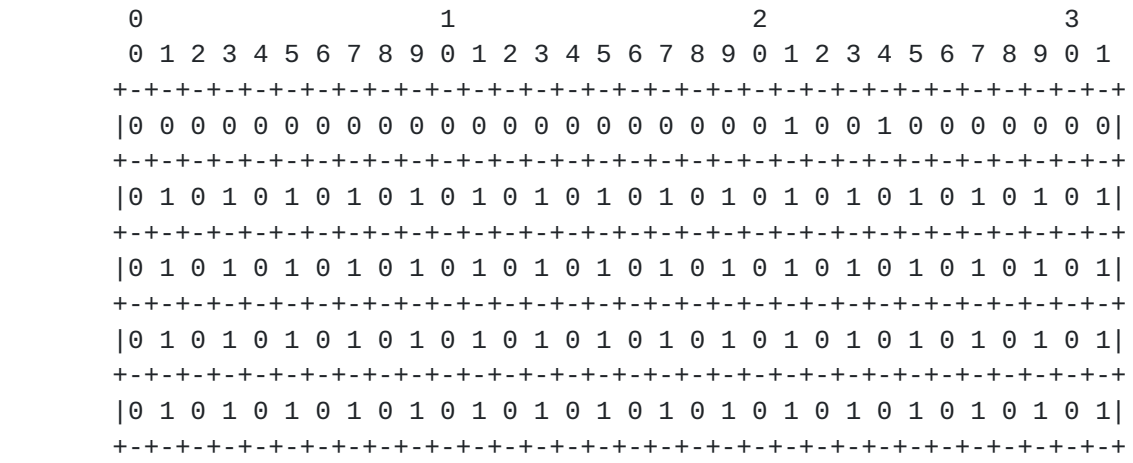
3.3.1. Multipath Information Encoding

The multipath information encodes labels or addresses which will exercise this path. The multipath information depends on the multi-path type. The contents of the field are shown in the table above. IP addresses are drawn from the range 127/8. Labels are treated as numbers, i.e. they are right justified in the field. For Type 4, ranges indicated by Address pairs MUST NOT overlap and MUST be in ascending sequence.

Type 8 allows a denser encoding of IP address. The IPv4 prefix is formatted as a base IPv4 address with the non-prefix low order bits set to zero. The maximum prefix length is 27. Following the prefix is a mask of length 2^(32-prefix length) bits. Each bit set to one represents a valid address. The address is the base IPv4 address plus the position of the bit in the mask where the bits are numbered left to right beginning with zero. For example the IP addresses 127.2.1.0, 127.2.1.5-127.2.1.15, and 127.2.1.20-127.2.1.29 would be encoded as follows:



Type 9 allows a denser encoding of Labels. The label prefix is formatted as a base label value with the non-prefix low order bits set to zero. The maximum prefix (including leading zeros due to encoding) length is 27. Following the prefix is a mask of length 2^(32-prefix length) bits. Each bit set to one represents a valid Label. The label is the base label plus the position of the bit in the mask where the bits are numbered left to right beginning with zero. Label values of all the odd numbers between 1152 and 1279 would be encoded as follows:



If the received multipath information is non-null, the labels and IP addresses MUST be picked from the set provided. If none of these labels or addresses map to a particular downstream interface, then for that interface, the type MUST be set to 0. If the received multipath information is null, (i.e. Multipath Length = 0, or for Types 8 and 9 a mask of all zeroes) the receiver the type MUST be set to 0.

For example, suppose LSR X at hop 10 has two downstream LSRs Y and Z for the FEC in question. The received X could return Multipath Type 4, with low/high IP addresses of 127.1.1.1->127.1.1.255 for downstream LSR Y and 127.2.1.1->127.2.1.255 for downstream LSR Z. The head end reflects this information to LSR Y. Y, which has three downstream LSRs U, V and W, computes that 127.1.1.1->127.1.1.127 would go to U and 127.1.1.128-> 127.1.1.255 would go to V. Y would then respond with 3 Downstream Mappings: to U, with Multipath Type 4 (127.1.1.1->127.1.1.127); to V, with Multipath Type 4

(127.1.1.127->127.1.1.255); and to W, with Multipath Type 0.

Note that computing multi-path information may impose a significant processing burden on the receiver. A receiver MAY thus choose to process a subset of the received prefixes. The sender, on receiving a reply to a Downstream Map with partial information, SHOULD assume that the prefixes missing in the reply were skipped by the receiver, and MAY re-request information about them in a new echo request.

3.3.2. Downstream Router and Interface

The notion of "downstream router" and "downstream interface" should be explained. Consider an LSR X. If a packet that was originated with TTL n>1 arrived with outermost label L and TTL=1 at LSR X, X must be able to compute which LSRs could receive the packet if it was originated with TTL=n+1, over which interface the request would arrive and what label stack those LSRs would see. (It is outside the scope of this document to specify how this computation is done.) The set of these LSRs/interfaces are the downstream routers/interfaces (and their corresponding labels) for X with respect to L. Each pair of downstream router and interface requires a separate Downstream Mapping to be added to the reply.

The case where X is the LSR originating the echo request is a special case. X needs to figure out what LSRs would receive the MPLS echo request for a given FEC Stack that X originates with TTL=1.

The set of downstream routers at X may be alternative paths (see the discussion below on ECMP) or simultaneous paths (e.g., for MPLS multicast). In the former case, the Multipath Information is used as a hint to the sender as to how it may influence the choice of these alternatives.

3.4. Pad TLV

The value part of the Pad TLV contains a variable number (>= 1) of octets. The first octet takes values from the following table; all the other octets (if any) are ignored. The receiver SHOULD verify that the TLV is received in its entirety, but otherwise ignores the contents of this TLV, apart from the first octet.

Value	Meaning
1	Drop Pad TLV from reply
2	Copy Pad TLV to reply
3-255	Reserved for future use

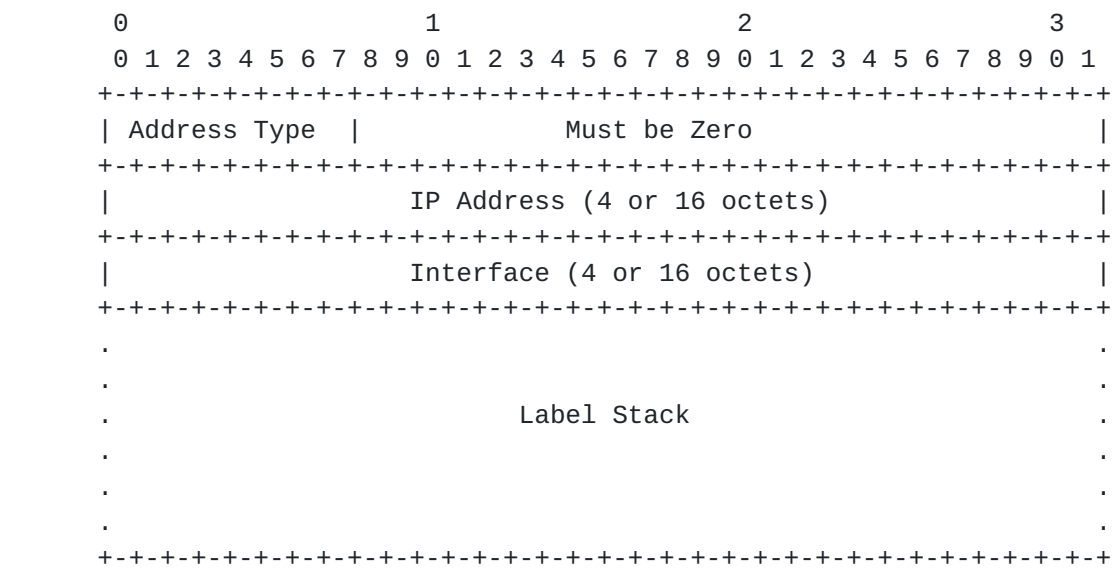
3.5. Vendor Enterprise Code

The Length is always 4; the value is the SMI Enterprise code, in network octet order, of the vendor with a Vendor Private extension to any of the fields in the fixed part of the message, in which case this TLV MUST be present. If none of the fields in the fixed part of the message have vendor private extensions, inclusion of this this TLV in is OPTIONAL. Vendor private ranges for Message Types, Reply Modes, and Return Codes have been defined. When any of these are used the Vendor Enterprise Code TLV MUST be included in the message.

3.6. Interface and Label Stack

The Interface and Label Stack TLV MAY be included in a reply message to report the interface on which the request message was received and the label stack which was on the packet when it was received. Only one such object may appear. The purpose of the object is to allow the upstream router to obtain the exact interface and label stack information as it appears at the replying LSR.

The Length is K + 4*N octets, N is the number of labels in the Label Stack. Values for K are found in the description of Address Type below. The Value field of a Downstream Mapping has the following format:



Address Type

The Address Type indicates if the interface is numbered or unnumbered. It also determines the length of the IP Address and Interface fields. The resulting total for the initial part of the TLV is listed in the table below as "K Octets". The Address Type is set to one of the following values:

Type #	Address Type	K Octets
1	IPv4 Numbered	12
2	IPv4 Unnumbered	12
3	IPv6 Numbered	36
4	IPv6 Unnumbered	24

IP Address and Interface

IPv4 addresses and and interface indices are encoded in 4 octets, IPv6 addresses are encoded in 16 octets.

If the interface upon which the echo request message was received is numbered, then the Address Type MUST be set to IPv4 or IPv6, the IP Address MUST be set to either the LSR's Router ID or the interface address, and the Interface MUST be set to the interface address.

If the interface unnumbered, the Address Type MUST be either IPv4 Unnumbered or IPv6 Unnumbered, the IP Address MUST be the LSR's Router ID, and the Interface MUST be set to the index assigned to the interface.

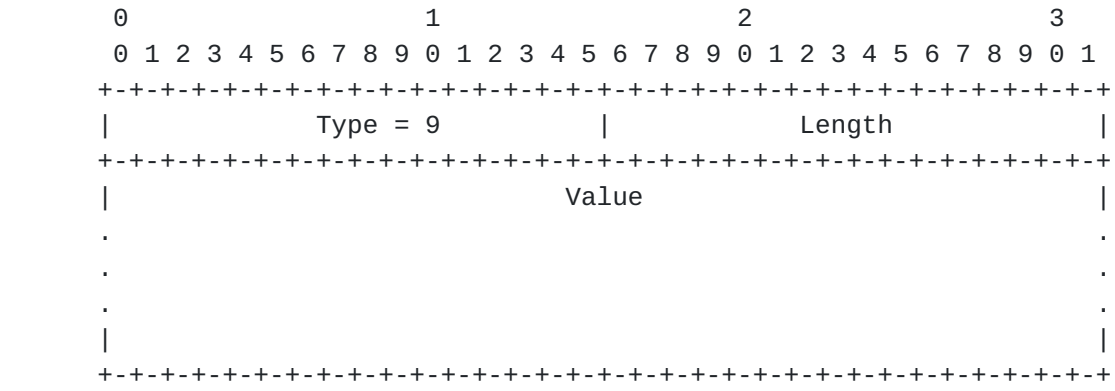
Label Stack

The label stack of the received echo request message. If any TTL values have been changed by this router, they SHOULD be restored.

3.7. Errored TLVs

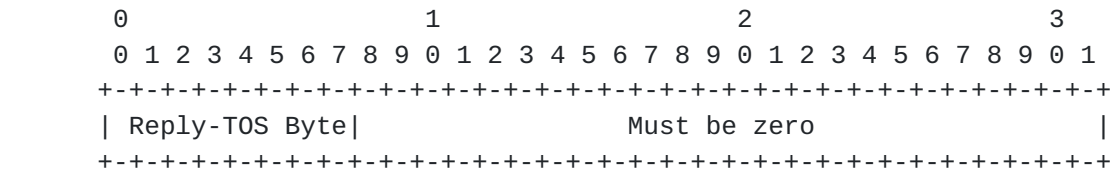
The following TLV is a TLV which MAY be included in an echo reply to inform the sender of an echo request of Mandatory TLVs either not supported by an implementation, or parsed and found to be in error.

The Value field contains the TLVs that were not understood, encoded as sub-TLVs.



3.8. Reply TOS Byte TLV

This TLV MAY be used by the originator of the echo request to request that a echo reply be sent with the IP header TOS byte set to the value specified in the TLV. This TLV has a length of 4 with the following value field.



4. Theory of Operation

An MPLS echo request is used to test a particular LSP. The LSP to be tested is identified by the "FEC Stack"; for example, if the LSP was set up via LDP, and is to an egress IP address of 10.1.1.1, the FEC stack contains a single element, namely, an LDP IPv4 prefix sub-TLV with value 10.1.1.1/32. If the LSP being tested is an RSVP LSP, the FEC stack consists of a single element that captures the RSVP Session and Sender Template which uniquely identifies the LSP.

FEC stacks can be more complex. For example, one may wish to test a VPN IPv4 prefix of 10.1/8 that is tunneled over an LDP LSP with egress 10.10.1.1. The FEC stack would then contain two sub-TLVs, the bottom being a VPN IPv4 prefix, and the top being an LDP IPv4 prefix. If the underlying (LDP) tunnel were not known, or was considered irrelevant, the FEC stack could be a single element with just the VPN IPv4 sub-TLV.

When an MPLS echo request is received, the receiver is expected to verify that the control plane and data plane are both healthy (for the FEC stack being pinged), and that the two planes are in sync. The procedures for this are in section 4.4 below.

4.1. Dealing with Equal-Cost Multi-Path (ECMP)

LSPs need not be simple point-to-point tunnels. Frequently, a single LSP may originate at several ingresses, and terminate at several egresses; this is very common with LDP LSPs. LSPs for a given FEC may also have multiple "next hops" at transit LSRs. At an ingress, there may also be several different LSPs to choose from to get to the desired endpoint. Finally, LSPs may have backup paths, detour paths and other alternative paths to take should the primary LSP go down.

To deal with the last two first: it is assumed that the LSR sourcing MPLS echo requests can force the echo request into any desired LSP, so choosing among multiple LSPs at the ingress is not an issue. The problem of probing the various flavors of backup paths that will typically not be used for forwarding data unless the primary LSP is down will not be addressed here.

Since the actual LSP and path that a given packet may take may not be known a priori, it is useful if MPLS echo requests can exercise all possible paths. This, while desirable, may not be practical, because the algorithms that a given LSR uses to distribute packets over alternative paths may be proprietary.

To achieve some degree of coverage of alternate paths, there is a

certain latitude in choosing the destination IP address and source UDP port for an MPLS echo request. This is clearly not sufficient; in the case of traceroute, more latitude is offered by means of the Multipath Information of the Downstream Mapping TLV. This is used as follows. An ingress LSR periodically sends an MPLS traceroute message to determine whether there are multipaths for a given LSP. If so, each hop will provide some information how each of its downstream paths can be exercised. The ingress can then send MPLS echo requests that exercise these paths. If several transit LSRs have ECMP, the ingress may attempt to compose these to exercise all possible paths. However, full coverage may not be possible.

4.2. Testing LSPs That Are Used to Carry MPLS Payloads

To detect certain LSP breakages, it may be necessary to encapsulate an MPLS echo request packet with at least one additional label when testing LSPs that are used to carry MPLS payloads (such as LSPs used to carry L2VPN and L3VPN traffic. For example, when testing LDP or RSVP-TE LSPs, just sending an MPLS echo request packet may not detect instances where the router immediately upstream of the destination of the LSP ping may forward the MPLS echo request successfully over an interface not configured to carry MPLS payloads because of the use of penultimate hop popping. Since the receiving router has no means to differentiate whether the IP packet was sent unlabeled or implicitly labeled, the addition of labels shimmed above the MPLS echo request (using the Nil FEC) will prevent a router from forwarding such a packet out unlabeled interfaces.

4.3. Sending an MPLS Echo Request

An MPLS echo request is a (possibly) labeled UDP packet. The IP header is set as follows: the source IP address is a routable address of the sender; the destination IP address is a (randomly chosen) address from 127/8; the IP TTL is set to 1. The source UDP port is chosen by the sender; the destination UDP port is set to 3503 (assigned by IANA for MPLS echo requests). The Router Alert option is set in the IP header.

If the echo request is labeled, one may (depending on what is being pinged) set the TTL of the innermost label to 1, to prevent the ping request going farther than it should. Examples of this include pinging a VPN IPv4 or IPv6 prefix, an L2 VPN end point or a pseudowire. This can also be accomplished by inserting a router alert label above this label; however, this may lead to the undesired side effect that MPLS echo requests take a different data path than actual data.

In "ping" mode (end-to-end connectivity check), the TTL in the outermost label is set to 255. In "traceroute" mode (fault isolation mode), the TTL is set successively to 1, 2, ...

The sender chooses a Sender's Handle, and a Sequence Number. When sending subsequent MPLS echo requests, the sender SHOULD increment the sequence number by 1. However, a sender MAY choose to send a group of echo requests with the same sequence number to improve the chance of arrival of at least one packet with that sequence number.

The TimeStamp Sent is set to the time-of-day (in seconds and microseconds) that the echo request is sent. The TimeStamp Received is set to zero.

An MPLS echo request MUST have a FEC Stack TLV. Also, the Reply Mode must be set to the desired reply mode; the Return Code and Subcode are set to zero. In the "traceroute" mode, the echo request SHOULD include a Downstream Mapping TLV.

4.4. Receiving an MPLS Echo Request

An LSR X that receives an MPLS echo request first parses the packet to ensure that it is a well-formed packet, and that the TLVs that are not marked "Ignore" are understood. If not, X SHOULD send an MPLS echo reply with the Return Code set to "Malformed echo request received" or "TLV not understood" (as appropriate), and the Subcode set to zero. In the latter case, the misunderstood TLVs (only) are included in the reply.

If the echo request is good, X notes the interface I over which the echo was received, and the label stack with which it came.

For reporting purposes the bottom of stack is considered to be stack-depth of 1. This is to establish an absolute reference for the case where the stack may have more labels than are in the FEC stack. Further, in all the error codes listed in this document a stack-depth of 0 means "no value specified". This allows compatibility with existing implementations which do not use the Return Subcode field.

X employs two variables, called FEC-stack-depth and Label-stack-depth. X sets Label-stack-depth to the number of labels in the received label stack. If the label-stack-depth is 0, assume there is one implicit null label and set label-stack-depth to 1. FEC-stack-depth is used later and need not be initialized. Processing now continues with the following steps:

Label_Validation:

If the label at Label-stack-depth is valid, goto Label_Operation. If not, set Best-return-code to 11, "No label entry at stack-depth" and Best-return-subcode to Label-stack-depth. Goto Send_Reply_Packet.

Label_Operation:

Switch on label operation.

Case: Pop and Continue Processing (Note: this includes Explicit_Null and Router_Alert)

If Label-stack-depth is greater than 1, decrement Label-stack-depth and goto Label_Validation. Otherwise, set FEC-stack-depth to 1, set Best-return-code to 3 "Replying router is an egress for the FEC at stack depth", set Best-return-subcode to 1 and goto Egress_Processing.

Case: Swap or Pop and Switch based on Popped Label

If the label operation is either swap or pop and switch based on the popped label, Best-return-code to 8, "Label switched at stack-depth" and Best-return-subcode to Label-stack-depth.

If a Downstream Mapping TLV is present, a Downstream mapping TLVs SHOULD be created for each multipath.

Determine the output interface. If it is not valid to forward a labeled packet on this interface, set Best-return-code to Return Code 9, "Label switched but no MPLS forwarding at stack-depth" and set Best-return-subcode to Label-stack-depth and goto Send_Reply_Packet. (Note: this return code is set even if Label-stack-depth is one.)

If no Downstream Mapping TLV is present, or the Downstream IP Address is set to the All-Routers multicast address goto Send_Reply_Packet.

Verify that the IP address, interface address and label stack match the received interface and label stack. If the IP address is either 127.0.0.1 or 0::1 bypass the interface check, and set Best-return-code to 6, "Upstream Interface Index Unknown". For any other error, set Best-return-code to 5, "Downstream Mapping Mis-match". For either error, an Interface and Label Stack TLV SHOULD be created. If Best-return-code equals 5, goto

Send_Reply_Packet.

If the "Validate FEC Stack" flag is not set, goto Send_Reply_Packet.

Locate the label at Label-stack-depth in the Downstream Labels by counting from the bottom of the stack, skipping over, but counting Implicit Null labels and set FEC-stack-depth to that depth. (Note: If the Downstream Labels contain one or more Implicit Null labels, this may be at a depth greater than Label-stack-depth.)

If the depth of the FEC stack is greater than or equal to FEC-stack-depth, Perform FEC Checking. If FEC-status is 2, set Best-return-code to 10, "Mapping for this FEC is not the given label at stack-depth".

If the return code is 1 set Best-return-code to FEC-return-code and Best-return-subcode to FEC-stack-depth.

Goto Send_Reply_Packet.

Egress_Processing:

If no Downstream Mapping TLV is present, goto Egress_FEC_Validation.

Verify that the IP address, interface address and label stack match the received interface and label stack. If not, set Best-return-code to 5, "Downstream Mapping Mis-match". A Received Interface and Label Stack TLV SHOULD be created. Goto Send_Reply_Packet.

Egress_FEC_Validation:

Perform FEC checking. If FEC-status is 1, set Best-return-code to FEC-code and Best-return-subcode to FEC-stack-depth. Goto Send_Reply_Packet.

Increment FEC-stack-depth. If FEC-stack-depth is greater than the number of FECs in the FEC-stack, goto Send_Reply_Packet. If FEC-status is 0, increment Label-stack-depth. Goto Egress_FEC_Validation.

Send_Reply_Packet:

Send an MPLS echo reply with a Return Code of Best-return-code,

and a Return Subcode of Best-return-subcode. Include any TLVs created during the above process. The procedures for sending the echo reply are found in the next subsection below.

FEC_Checking:

This routine accepts a FEC, Label, and Interface. It returns two values, FEC-status and FEC-return-code, both of which are initialized to 0.

If the FEC is the Nil FEC, check that Label is either Explicit_Null or Router_Alert. If so return. Else set FEC-return-code to 10, "Mapping for this FEC is not the given label at stack-depth". Set FEC-status to 1 and return.

Check that the label mapping for FEC. If no mapping exists, set FEC-return-code to Return 4, "Replying router has no mapping for the FEC at stack-depth". Set FEC-status to 1. Return.

If the label mapping for FEC is Implicit Null, set FEC-status to 2. Goto Check_Protocol.

If the label mapping for FEC is Label, goto Check_Protocol. Else set FEC-return-code to 10, "Mapping for this FEC is not the given label at stack-depth". Set FEC-status to 1 and return.

Check_Protocol:

Check what protocol would be used to advertise FEC. If it can be determined that no protocol associated with interface I would have advertised a FEC of that FEC-Type, set FEC-return-code to 12, "Protocol not associated with interface at FEC stack-depth". Set FEC-status to 1. Return.

4.5. Sending an MPLS Echo Reply

An MPLS echo reply is a UDP packet. It MUST ONLY be sent in response to an MPLS echo request. The source IP address is a routable address of the replier; the source port is the well-known UDP port for LSP ping. The destination IP address and UDP port are copied from the source IP address and UDP port of the echo request. The IP TTL is set to 255. If the Reply Mode in the echo request is "Reply via an IPv4 UDP packet with Router Alert", then the IP header MUST contain the Router Alert IP option. If the reply is sent over an LSP, the topmost label MUST in this case be the Router Alert label (1) (see

[LABEL-STACK]).

The format of the echo reply is the same as the echo request. The Sender's Handle, the Sequence Number and TimeStamp Sent are copied from the echo request; the TimeStamp Received is set to the time-of-day that the echo request is received (note that this information is most useful if the time-of-day clocks on the requester and the replier are synchronized). The FEC Stack TLV from the echo request MAY be copied to the reply.

The replier MUST fill in the Return Code and Subcode, as determined in the previous subsection.

If the echo request contains a Pad TLV, the replier MUST interpret the first octet for instructions regarding how to reply.

If the replying router is the destination of the FEC, then Downstream Mapping TLVs SHOULD NOT be included in the echo reply.

If the echo request contains a Downstream Mapping TLV, and the replying router is not the destination of the FEC, the replier SHOULD compute its downstream routers and corresponding labels for the incoming label, and add Downstream Mapping TLVs for each one to the echo reply it sends back.

If the Downstream Mapping TLV contains multipath information requiring more processing than the receiving router is willing to perform, the responding router MAY choose to respond with only a subset of multipaths contained in the echo request Downstream Map. (Note: The originator of the echo request MAY send another echo request with the multipath information that was not included in the reply.)

4.6. Receiving an MPLS Echo Reply

An LSR X should only receive an MPLS echo reply in response to an MPLS echo request that it sent. Thus, on receipt of an MPLS echo reply, X should parse the packet to assure that it is well-formed, then attempt to match up the echo reply with an echo request that it had previously sent, using the destination UDP port and the Sender's Handle. If no match is found, then X jettisons the echo reply; otherwise, it checks the Sequence Number to see if it matches. Gaps in the Sequence Number MAY be logged and SHOULD be counted. Once an echo reply is received for a given Sequence Number (for a given UDP port and Handle), the Sequence Number for subsequent echo requests for that UDP port and Handle SHOULD be incremented.

If the echo reply contains Downstream Mappings, and X wishes to

traceroute further, it SHOULD copy the Downstream Mapping(s) into its next echo request(s) (with TTL incremented by one).

4.7. Issue with VPN IPv4 and IPv6 Prefixes

Typically, a LSP ping for a VPN IPv4 prefix or VPN IPv6 prefix is sent with a label stack of depth greater than 1, with the innermost label having a TTL of 1. This is to terminate the ping at the egress PE, before it gets sent to the customer device. However, under certain circumstances, the label stack can shrink to a single label before the ping hits the egress PE; this will result in the ping terminating prematurely. One such scenario is a multi-AS Carrier's Carrier VPN.

To get around this problem, one approach is for the LSR that receives such a ping to realize that the ping terminated prematurely, and send back error code 13. In that case, the initiating LSR can retry the ping after incrementing the TTL on the VPN label. In this fashion, the ingress LSR will sequentially try TTL values until it finds one that allows the VPN ping to reach the egress PE.

4.8. Non-compliant Routers

If the egress for the FEC Stack being pinged does not support MPLS ping, then no reply will be sent, resulting in possible "false negatives". If in "traceroute" mode, a transit LSR does not support LSP ping, then no reply will be forthcoming from that LSR for some TTL, say n. The LSR originating the echo request SHOULD try sending the echo request with TTL=n+1, n+2, ..., n+k to probe LSRs further down the path. In such a case, the echo request for TTL > n SHOULD be sent with Downstream Mapping TLV "Downstream IP Address" field set to the ALLROUTERs multicast address until a reply is received with a Downstream Mapping TLV. The Label Stack MAY be omitted from the Downstream Mapping TLV. Further the "Validate FEC Stack" flag SHOULD NOT be set until an echo reply packet with a Downstream Mapping TLV is received.

5. References

Normative References

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Informative References

[BGP-LABEL] Rekhter, Y. and E. Rosen, "Carrying Label Information in BGP-4", RFC 3107, May 2001.

[ICMP] Postel, J., "Internet Control Message Protocol", RFC 792.

[LDP] Andersson, L., et al, "LDP Specification", RFC 3036, January 2001.

[MPLS-L3-VPN] Rekhter, Y. & Rosen, E., "BGP/MPLS IP VPNs", draft-ietf-l3vpn-rfc2547bis-03.txt, work-in-progress.

[PW-CONTROL] Martini, L. et al., "Pseudowire Setup and Maintenance using the Label Distribution Protocol", draft-ietf-pwe3-control-protocol-17.txt, work-in-progress.

[RSVP-TE] Awduche, D., et al., "RSVP-TE: Extensions to RSVP for LSP Tunnels", RFC 3209, December 2001.

[VPLS] Kompella, K. and Rekhter, Y., "Virtual Private LAN Service", draft-ietf-l2vpn-vpls-bgp-05, work-in-progress.

6. Security Considerations

Overall, the security needs for LSP Ping are are similar to those of ICMP Ping.

There are at least two approaches to attacking LSRs using the mechanisms defined here. One is a Denial of Service attack, by sending MPLS echo requests/replies to LSRs and thereby increasing their workload. The other is obfuscating the state of the MPLS data plane liveness by spoofing, hijacking, replaying or otherwise tampering with MPLS echo requests and replies.

To avoid potential Denial of Service attacks, it is RECOMMENDED that implementations regulate the LSP ping traffic going to the control plane. A rate limiter SHOULD be applied to the well-known UDP port defined below.

Replay and spoofing attacks are unlikely to be effective given that the Sender's Handle and Sequence Number need to be valid. Thus a replay would be discarded as the sequence has moved on. A spoof has only a small window of opportunity, however an implementation MAY provide a validation on the TimeStamp Sent to limit the window to the resolution of the system clock.

It is not clear how to prevent hijacking (non-delivery) of echo requests or replies; however, if these messages are indeed hijacked, LSP ping will report that the data plane isn't working as it should.

It doesn't seem vital (at this point) to secure the data carried in MPLS echo requests and replies, although knowledge of the state of the MPLS data plane may be considered confidential by some. Implementations SHOULD however provide a means of filtering the addresses to which Echo Reply messages may be sent.

7. IANA Considerations

The TCP and UDP port number 3503 has been allocated by IANA for LSP echo requests and replies.

The following sections detail the new name spaces to be managed by IANA. For each of these name spaces, the space is divided into assignment ranges; the following terms are used in describing the procedures by which IANA allocates values: "Standards Action" (as defined in [IANA]); "Expert Review" and "Vendor Private Use".

Values from "Expert Review" ranges MUST be registered with IANA. The request MUST be made via an Experimental RFC that describes the

format and procedures for using the code point; the actual assignment is made during the IANA actions for the RFC.

Values from "Vendor Private" ranges MUST NOT be registered with IANA; however, the message MUST contain an enterprise code as registered with the IANA SMI Network Management Private Enterprise Codes. For each name space that has a Vendor Private range, it must be specified where exactly the SMI Enterprise Code resides; see below for examples. In this way, several enterprises (vendors) can use the same code point without fear of collision.

7.1. Message Types, Reply Modes, Return Codes

It is requested that IANA maintain registries for Message Types, Reply Modes, and Return Codes. Each of these can take values in the range 0-255. Assignments in the range 0-191 are via Standards Action; assignments in the range 192-251 are made via Expert Review; values in the range 252-255 are for Vendor Private Use, and MUST NOT be allocated.

If any of these fields fall in the Vendor Private range, a top-level Vendor Enterprise Code TLV MUST be present in the message.

Message Types defined in this document are:

Value	Meaning
1	MPLS Echo Request
2	MPLS Echo Reply

Reply Modes defined in this document are:

Value	Meaning
1	Do not reply
2	Reply via an IPv4/IPv6 UDP packet
3	Reply via an IPv4/IPv6 UDP packet with Router Alert
4	Reply via application level control channel

Return Codes defined in this document are listed in section 3.1.

7.2. TLVs

It is requested that IANA maintain a registry for the Type field of top-level TLVs as well as for any associated sub-TLVs. Note the meaning of a sub-TLV is scoped by the TLV. The number spaces for the sub-TLVs of various TLVs are independent.

The valid range for TLVs and sub-TLVs is 0-65535. Assignments in the range 0-16383 and 32768-49161 are made via Standards Action as defined in [IANA]; assignments in the range 16384-31743 and 49162-64511 are made via Expert Review as defined above; values in the range 31744-32767 and 64512-65535 are for Vendor Private Use, and MUST NOT be allocated.

If a TLV or sub-TLV has a Type that falls in the range for Vendor Private Use, the Length MUST be at least 4, and the first four octets MUST be that vendor's SMI Enterprise Code, in network octet order. The rest of the Value field is private to the vendor.

TLVs and sub-TLVs defined in this document are:

Type	Sub-Type	Value Field
1		Target FEC Stack
	1	LDP IPv4 prefix
	2	LDP IPv6 prefix
	3	RSVP IPv4 LSP
	4	RSVP IPv6 LSP
	5	Not Assigned
	6	VPN IPv4 prefix
	7	VPN IPv6 prefix
	8	L2 VPN endpoint
	9	"FEC 128" Pseudowire (Deprecated)
	10	"FEC 128" Pseudowire
	11	"FEC 129" Pseudowire
	12	BGP labeled IPv4 prefix
	13	BGP labeled IPv6 prefix
	14	Generic IPv4 prefix
	15	Generic IPv6 prefix
	16	Nil FEC
2		Downstream Mapping
3		Pad
4		Not Assigned
5		Vendor Enterprise Code
6		Not Assigned
7		Interface and Label Stack
8		Not Assigned
9		Errored TLVs

	Any value	The TLV not understood
10		Reply TOS Byte

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