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Layer 3 Discovery and Liveness
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Abstract

In Massive Data Centers, BGP-SPF and similar routing protocols are used to build topology and reachability databases. These protocols need to discover IP Layer 3 attributes of links, such as logical link IP encapsulation abilities, IP neighbor address discovery, and link liveness. This Layer 3 Discovery and Liveness protocol collects these data, which may then be disseminated using BGP-SPF and similar protocols.

Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

Status of This Memo

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1. Introduction

The Massive Data Center (MDC) environment presents unusual problems of scale, e.g. O(10,000) forwarding devices, while its homogeneity presents opportunities for simple approaches. Approaches such as Jupiter Rising [JUPITER] use a central controller to deal with scaling, while BGP-SPF [I-D.ietf-lsvr-bgp-spf] provides massive scale-out without centralization using a tried and tested scalable distributed control plane, offering a scalable routing solution in Clos [Clos0][Clos1] and similar environments. But BGP-SPF and similar higher level device-spanning protocols, e.g. [I-D.malhotra-bess-evpn-lsoe], need logical link state and addressing data from the network to build the routing topology. They also need prompt but prudent reaction to (logical) link failure.

Layer 3 Discovery and Liveness (L3DL) provides brutally simple mechanisms for devices to

- Discover each other's unique endpoint identification,
- Discover mutually supported layer 3 encapsulations, e.g. IP/MPLS,
- Discover Layer 3 IP and/or MPLS addressing of interfaces of the encapsulations,
- Present these data, using a very restricted profile of a BGP-LS [RFC7752] API, to BGP-SPF which computes the topology and builds routing and forwarding tables,
- Enable Layer 3 link liveness such as BFD,
- Provide Layer 2 keep-alive messages for session continuity, and finally

o Provide for authenticity verification of protocol messages.

This protocol may be more widely applicable to a range of routing and similar protocols which need layer 3 discovery and characterisation.

2. Terminology

Even though it concentrates on the inter-device layer, this document relies heavily on routing terminology. The following attempts to clarify the use of some possibly confusing terms:

ASN: Autonomous System Number [RFC4271], a BGP identifier for an originator of Layer 3 routes, particularly BGP announcements.

BGP-LS: A mechanism by which link-state and TE information can be collected from networks and shared with external components using the BGP routing protocol. See [RFC7752].

BGP-SPF A hybrid protocol using BGP transport but a Dijkstra Shortest Path First decision process. See [I-D.ietf-lsvr-bgp-spf].

Clos: A hierarchic subset of a crossbar switch topology commonly used in data centers.

Datagram: The L3DL content of a single Layer 2 frame, sans Ethernet framing. A full L3DL PDU may be packaged in multiple Datagrams.

Encapsulation: Address Family Indicator and Subsequent Address Family Indicator (AFI/SAFI). I.e. classes of layer 2.5 and 3 addresses such as IPv4, IPv6, MPLS, etc.

Frame: A Layer 2 Ethernet packet.

Link or Logical Link: A logical connection between two logical ports on two devices. E.g. two VLANs between the same two ports are two links.

LLEI: Logical Link Endpoint Identifier, the unique identifier of one end of a logical link, see Section 9.

MAC Address: 48-bit Layer 2 addresses are assumed since they are used by all widely deployed Layer 2 network technologies of interest, especially Ethernet. See [IEEE.802_2001].

MDC: Massive Data Center, commonly composed of thousands of Top of Rack Switches (TORs).

MTU: Maximum Transmission Unit, the size in octets of the largest packet that can be sent on a medium, see [RFC1122] 1.3.3.

PDU: Protocol Data Unit, an L3DL application layer message. A PDU's content may need to be broken into multiple Datagrams to make it through MTU or other restrictions.

RouterID: An 32-bit identifier unique in the current routing domain, see [RFC6286].

Session: An established, via OPEN PDUs, session between two L3DL capable link end-points,
SPF: Shortest Path First, an algorithm for finding the shortest paths between nodes in a graph; AKA Dijkstra's algorithm.
System Identifier: An eight octet ISO System Identifier a la [RFC1629] System ID
TOR: Top Of Rack switch, aggregates the servers in a rack and connects to aggregation layers of the Clos tree, AKA the Clos spine.
ZTP: Zero Touch Provisioning gives devices initial addresses, credentials, etc. on boot/restart.

3. Background

L3DL is primarily designed for a Clos type datacenter scale and topology, but can accommodate richer topologies which contain potential cycles.

While L3DL is designed for the MDC, there are no inherent reasons it could not run on a WAN. The authentication and authorization needed to run safely on a WAN need to be considered, and the appropriate level of security options chosen.

L3DL assumes a new IEEE assigned EtherType (TBD).

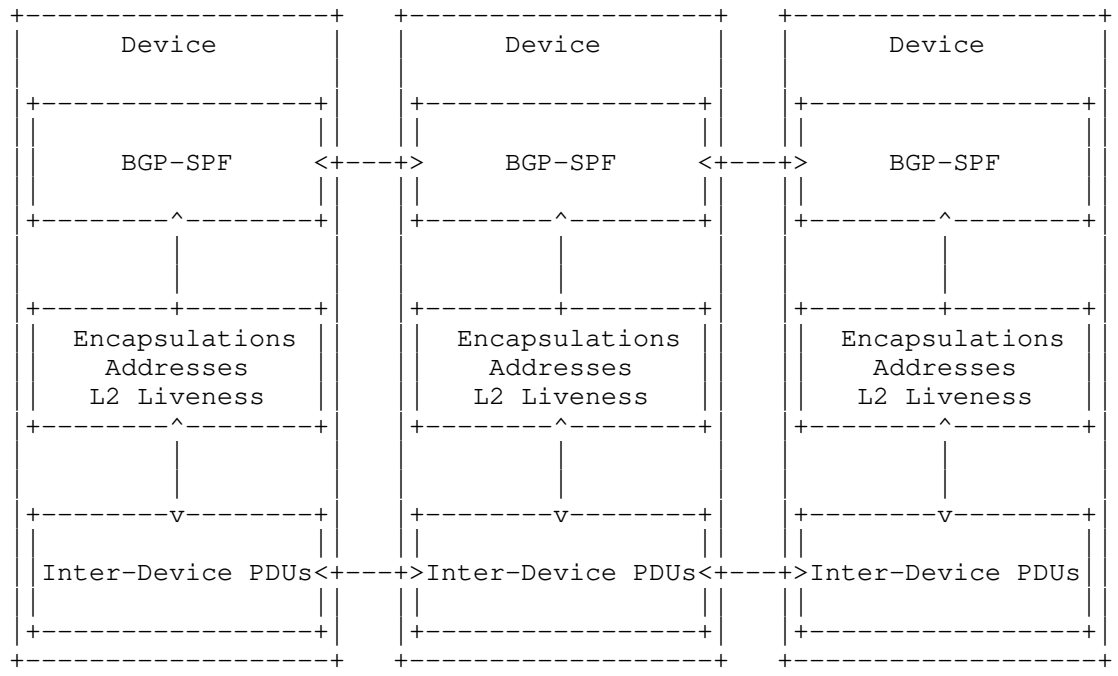
The number of addresses of one Encapsulation type on an interface link may be quite large given a TOR with tens of servers, each server having a few hundred micro-services, resulting in an inordinate number of addresses. And highly automated micro-service migration can cause serious address prefix disaggregation, resulting in interfaces with thousands of disaggregated prefixes.

Therefore the L3DL protocol is session oriented and uses incremental announcement and withdrawal with session restart, a la BGP ([RFC4271]).

4. Top Level Overview

- Devices discover each other on logical links
- Logical Link Endpoint Identifiers (LLEIs) are exchanged
- Layer 2 Liveness checks may be started
- Encapsulation data are exchanged and IP-Level Liveness checks enabled

- A BGP-like upper layer protocol is assumed to use the identiiers and encapsulation data to discover and build a topology database



There are two protocols, the inter-device (left-right in the diagram) per-link layer 3 discovery and the API to the upper level BGP-like routing prototol (up-down in the above diagram):

- Inter-device PDUs are used to exchange device and logical link identities and layer 2.5 (MPLS) and 3 identifiers (not payloads), e.g. device IDs, port identities, VLAN IDs, Encapsulations, and IP addresses.

- A Link Layer to BGP API presents these data up the stack to a BGP protocol or an other device-spanning upper layer protocol, presenting them using the BGP-LS BGP-like data format.

The upper layer BGP family routing protocols cross all the devices, though they are not part of these L3DL protocols.

To simplify this document, Layer 2 framing is not shown. L3DL is about layer 3.

5. Inter-Link Protocol Overview

Two devices discover each other and their respective identities by sending multicast HELLO PDUs (Section 10). To assure discovery of new devices coming up on a multi-link topology, devices on such a topology, and only on a multi-link topology, send periodic HELLOs forever, see Section 18.1.

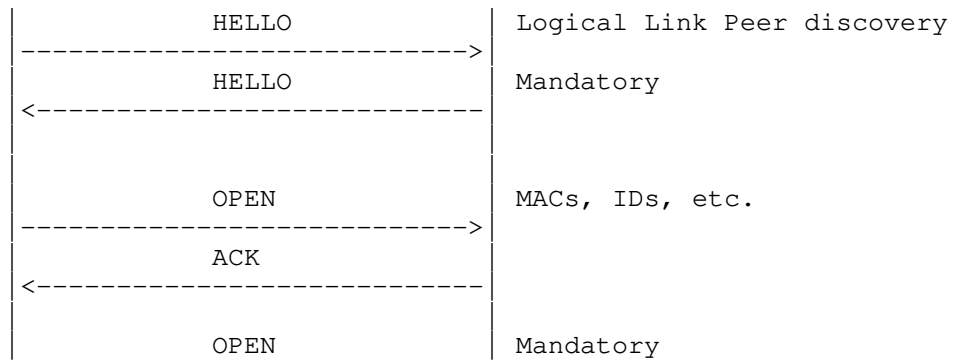
Once a new device is recognized, both devices attempt to negotiate and establish a session by sending unicast OPEN PDUs (Section 11) to the source MAC addresses (plus VIDs if VLANs) of the received HELLOs. Once a session is established through the OPEN exchange, the Encapsulations (Section 13) configured on an end point may be announced and modified. Note that these are only the encapsuation and addresses configured on the announcing interface; though a device's loopback and overlay interface(s) may also be announced. When two devices on a link have compatible Encapsulations and addresses, i.e. the same AFI/SAFI and the same subnet, the link is announced via the BGP-LS API.

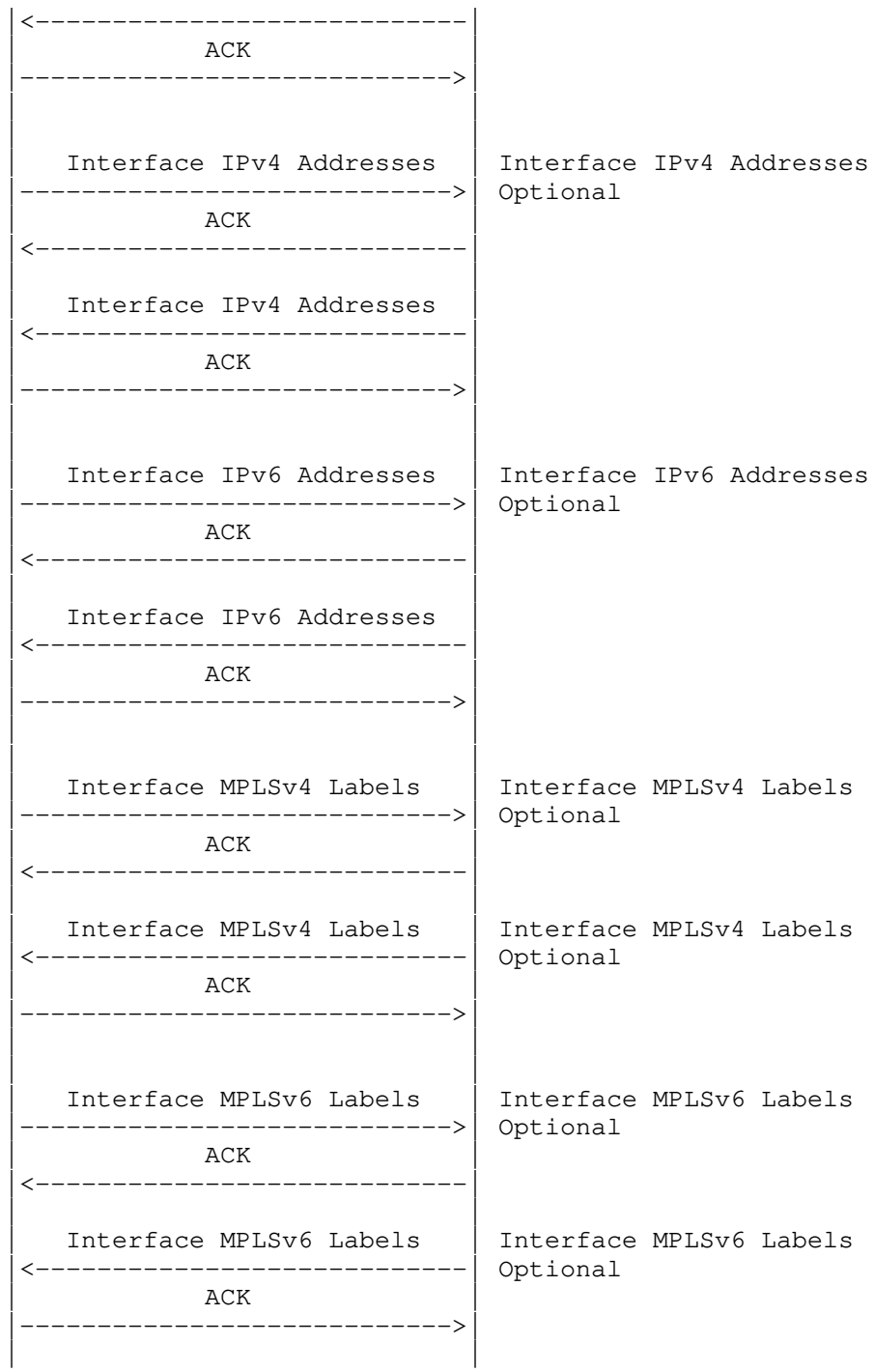
5.1. L3DL Ladder Diagram

The HELLO, Section 10, is a priming message sent on all configured logical links. It is a small L3DL PDU encapsulated in an Ethernet multicast frame with the simple goal of discovering the identities of logical link endpoint(s) reachable from a Logical Link Endpoint, Section 9.

The HELLO and OPEN, Section 11, PDUs, which are used to discover and exchange detailed Logical Link Endpoint Identifiers, LLEIs, and the ACK/ERROR PDU, are mandatory; other PDUs are optional; though at least one encapsulation SHOULD be agreed at some point.

The following is a ladder-style diagram of the L3DL protocol exchanges:




ACK
Interface IPv4 Addresses
Interface IPv4 Addresses
Optional
ACK
Interface IPv4 Addresses
ACK
Interface IPv6 Addresses
Interface IPv6 Addresses
Optional
ACK
Interface IPv6 Addresses
ACK
Interface MPLSv4 Labels
Interface MPLSv4 Labels
Optional
ACK
Interface MPLSv4 Labels
Interface MPLSv4 Labels
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Interface MPLSv6 Labels
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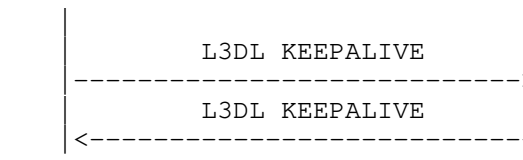
ACK



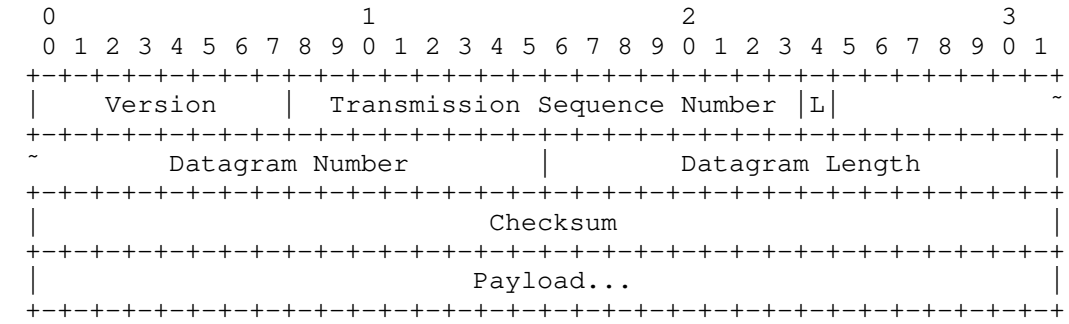
6. Transport Layer

L3DL PDUs are carried by a simple transport layer which allows long PDUs to occupy many Ethernet frames. The L3DL content of a single Ethernet frame, exclusive of Ethernet framing data, is referred to as a Datagram.

The L3DL Transport Layer encapsulates each Datagram using a common transport header.

If a PDU does not fit in a single datagram, it is broken into multiple Datagrams and reassembled by the receiver a la [RFC0791] Section 2.3 Fragmentation.

Should a PDU need to be retransmitted, it MUST BE sent as the identical Datagram set as the original transmission. The Transmission Sequence Number informs the receiver that it is the same PDU.



The fields of the L3DL Transport Header are as follows:

Version: Seven-bit Version number of the protocol, currently 0. Values other than 0 MUST BE treated as an error. The protocol version needs to be in one and only one place, so it is in the datagram as opposed to, for example, the PDU header.

L: A bit that set to one if this Datagram is the last Datagram of the PDU. For a PDU which fits in only one Datagram, it is set to one. Note that this is the inverse of the marking technique used by [RFC0791].

Transmission Sequence Number: A 16-bit strictly increasing unsigned integer identifying this PDU, possibly across retransmissions, that wraps from 2^16-1 to 0. The initial value is arbitrary. See [RFC1982] on DNS Serial Number Arithmetic for too much detail on comparison and incrementing a wrapping sequence number.

Datagram Number: A monotonically increasing 24-bit value which starts at zero for each PDU. This is used to reassemble frames into PDUs a la [RFC0791] Section 2.3. Note that this limits an L3DL PDU to 2^24 frames.

Datagram Length: Total number of octets in the Datagram including all payloads and fields. Note that this limits a datagram to 2^16 octets; though Ethernet framing is likely to impose a smaller limit.

Checksum: A 32 bit hash over the Datagram to detect bit flips, see Section 7.

If a Datagram fails checksum verification, the datagram is invalid and should be silently discarded. The sender will retransmit the PDU, and the receiver can assmble it.

Payload: The PDU being transported or a fragment thereof.

To avoid the need for a receiver to reassemble two PDUs at the same time, a sender MUST NOT send a subsequent PDU when a PDU is already in flight and not yet acknowledged; assuming it is an ACKed PDU Type.

7. The Checksum

There is a reason conservative folk use a checksum in UDP. And as many operators stretch to jumbo frames (over 1,500 octets) longer checksums are the prudent approach.

For the purpose of computing a checksum, the checksum field itself is assumed to be zero.

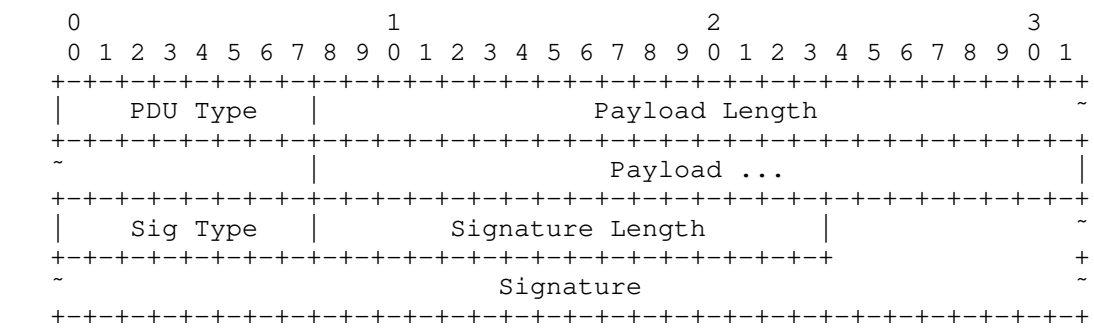
The following code describes the suggested algorithm.

Sum up 32-bit unsigned ints in a 64-bit long, then take the high-order section, shift it right, rotate, add it in, repeat until zero.

```
<CODE BEGINS>
#include <stddef.h>
#include <stdint.h>

/* The F table from Skipjack, and it would work for the S-Box. */
static const uint8_t sbox[256] = {
0xa3,0xd7,0x09,0x83,0xf8,0x48,0xf6,0xf4,0xb3,0x21,0x15,0x78,
0x99,0xb1,0xaf,0xf9,0xe7,0x2d,0x4d,0x8a,0xce,0x4c,0xca,0x2e,
0x52,0x95,0xd9,0x1e,0x4e,0x38,0x44,0x28,0x0a,0xdf,0x02,0xa0,
0x17,0xf1,0x60,0x68,0x12,0xb7,0x7a,0xc3,0xe9,0xfa,0x3d,0x53,
0x96,0x84,0x6b,0xba,0xf2,0x63,0x9a,0x19,0x7c,0xae,0xe5,0xf5,
0xf7,0x16,0x6a,0xa2,0x39,0xb6,0x7b,0x0f,0xc1,0x93,0x81,0x1b,
0xee,0xb4,0x1a,0xea,0xd0,0x91,0x2f,0xb8,0x55,0xb9,0xda,0x85,
0x3f,0x41,0xbf,0xe0,0x5a,0x58,0x80,0x5f,0x66,0x0b,0xd8,0x90,
0x35,0xd5,0xc0,0xa7,0x33,0x06,0x65,0x69,0x45,0x00,0x94,0x56,
0x6d,0x98,0x9b,0x76,0x97,0xfc,0xb2,0xc2,0xb0,0xfe,0xdb,0x20,
0xe1,0xeb,0xd6,0xe4,0xdd,0x47,0x4a,0x1d,0x42,0xed,0x9e,0x6e,
0x49,0x3c,0xcd,0x43,0x27,0xd2,0x07,0xd4,0xde,0xc7,0x67,0x18,
0x89,0xcb,0x30,0x1f,0x8d,0xc6,0x8f,0xaa,0xc8,0x74,0xdc,0xc9,
0x5d,0x5c,0x31,0xa4,0x70,0x88,0x61,0x2c,0x9f,0x0d,0x2b,0x87,
0x50,0x82,0x54,0x64,0x26,0x7d,0x03,0x40,0x34,0x4b,0x1c,0x73,
0xd1,0xc4,0xfd,0x3b,0xcc,0xfb,0x7f,0xab,0xe6,0x3e,0x5b,0xa5,
0xad,0x04,0x23,0x9c,0x14,0x51,0x22,0xf0,0x29,0x79,0x71,0x7e,
0xff,0x8c,0x0e,0xe2,0x0c,0xef,0xbc,0x72,0x75,0x6f,0x37,0xa1,
0xec,0xd3,0x8e,0x62,0x8b,0x86,0x10,0xe8,0x08,0x77,0x11,0xbe,
0x92,0x4f,0x24,0xc5,0x32,0x36,0x9d,0xcf,0xf3,0xa6,0xbb,0xac,
0x5e,0x6c,0xa9,0x13,0x57,0x25,0xb5,0xe3,0xbd,0xa8,0x3a,0x01,
0x05,0x59,0x2a,0x46
};

/* non-normative example C code, constant time even */

uint32_t sbox_checksum_32(const uint8_t *b, const size_t n)
{
  uint32_t sum[4] = {0, 0, 0, 0};
  uint64_t result = 0;
  for (size_t i = 0; i < n; i++)
    sum[i & 3] += sbox[*b++];
  for (int i = 0; i < sizeof(sum)/sizeof(*sum); i++)
    result = (result << 8) + sum[i];
  result = (result >> 32) + (result & 0xFFFFFFFF);
  result = (result >> 32) + (result & 0xFFFFFFFF);
  return (uint32_t) result;
}
<CODE ENDS>
```

8. TLV PDUs

The basic L3DL application layer PDU is a typical TLV (Type Length Value) PDU. It includes a signature to provide optional integrity and authentication. It may be broken into multiple Datagrams, see Section 6.



The fields of the basic L3DL header are as follows:

PDU Type: An integer differentiating PDU payload types. See Section 22.1.

Payload Length: Total number of octets in the Payload field.

Payload: The application layer content of the L3DL PDU.

Sig Type: The type of the Signature, see Section 22.2. Type 0, a null signature, is defined in this document.

Sig Type 0 indicates a null Signature. For a trivial PDU such as KEEPALIVE, the underlying Datagram checksum may be sufficient for integrity, though it lacks authenticity.

Other Sig Types may be defined in other documents, cf. [I-D.ymbk-lsvr-l3dl-signing].

Signature Length: The length of the Signature, possibly including padding, in octets. If Sig Type is 0, Signature Length MUST BE 0.

Signature: The result of running the signature algorithm specified in Sig Type over all octets of the PDU except for the Signature itself.

9. Logical Link Endpoint Identifier

L3DL discovers neighbors on logical links and establishes sessions between the two ends of all consenting discovered logical links. A logical link is described by a pair of Logical Link Endpoint Identifiers, LLEIs.

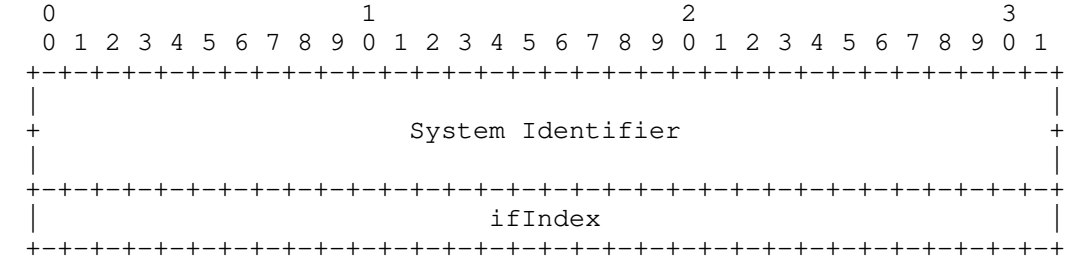
An LLEI is a variable length descriptor which could be an ASN, a classic RouterID, a catenation of the two, an eight octet ISO System Identifier [RFC1629], or any other identifier unique to a single logical link endpoint in the topology.

An L3DL deployment will choose and define an LLEI which suits its needs, simple or complex. Examples of two extremes follow:

A simplistic view of a link between two devices is two ports, identified by unique MAC addresses, carrying a layer 3 protocol conversation. In this case, the MAC addresses might suffice for the LLEIs.

Unfortunately, things can get more complex. Multiple VLANs can run between those two MAC addresses. In practice, many real devices use the same MAC address on multiple ports and/or sub-interfaces.

Therefore, in the general circumstance, a fully described LLEI might be as follows:



System Identifier, a la [RFC1629], is an eight octet identifier unique in the entire operational space. Routers and switches usually have internal MAC Addresses which can be padded with high order zeros and used if no System ID exists on the device. If no unique identifier is burned into a device, the local L3DL configuration SHOULD create and assign a unique one, likely by configuration.

ifIndex is the SNMP identifier of the (sub-)interface, see [RFC1213]. This uniquely identifies the port.

For a layer 3 tagged sub-interface or a VLAN/SVI interface, Ifindex is that of the logical sub-interface, so no further disambiguation is needed.

L3DL PDUs learned over VLAN-ports may be interpreted by upper layer-3 routing protocols as being learned on the corresponding layer-3 SVI interface for the VLAN.

LLEIs are big-endian.

10. HELLO

The HELLO PDU is unique in that it is encapsulated in a multicast Ethernet frame. It solicits response(s) from other LLEI(s) on the link. See Section 18.1 for why multicast is used. The destination multicast MAC Addressees to be used MUST be one of the following, See Clause 9.2.2 of [IEEE802-2014]:

01-80-C2-00-00-0E: Nearest Bridge = Propagation constrained to a single physical link; stopped by all types of bridges (including MPRs (media converters)). This SHOULD BE used when the link is known to be a simple point to point link.

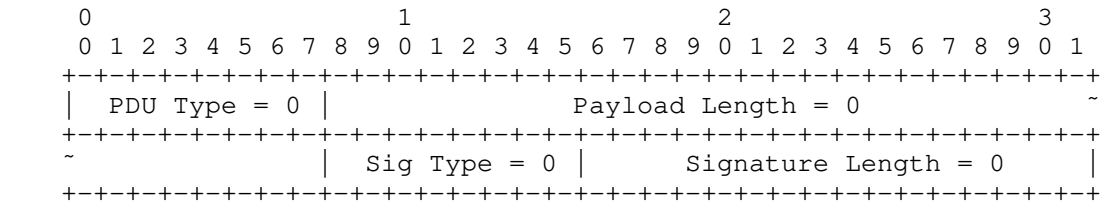
To Be Assigned: When a switch receives a frame with a multicast destination MAC it does not recognize, it forwards to all ports. This destination MAC is to be sent when the interface is known to be connected to a switch. See Section 23. This SHOULD BE used when the link may be a multi-point link.

All other L3DL PDUs are encapsulated in unicast frames, as the peer's destination MAC address is known after the HELLO exchange.

When an interface is turned up on a device, it SHOULD issue a HELLO if it is to participate in L3DL sessions.

If a constrained Nearest Bridge destination address has been configured for a point-to-point interface, see above, then the HELLO SHOULD NOT be repeated once a session has been created by an exchange of OPENs.

If the configured destination address is one that is propagated by switches, the HELLO SHOULD be repeated at a configured interval, with a default of 60 seconds. This allows discovery by new devices which come up on the layer-2 mesh.



If more than one device responds, one adjacency is formed for each unique source LLEI response. L3DL treats each adjacency as a separate logical link.

When a HELLO is received from a source MAC address (plus VID if VLAN) with which there is no established L3DL session, the receiver SHOULD respond by sending an OPEN PDU to the source MAC address (plus VID). The two devices establish an L3DL session by exchanging OPEN PDUs.

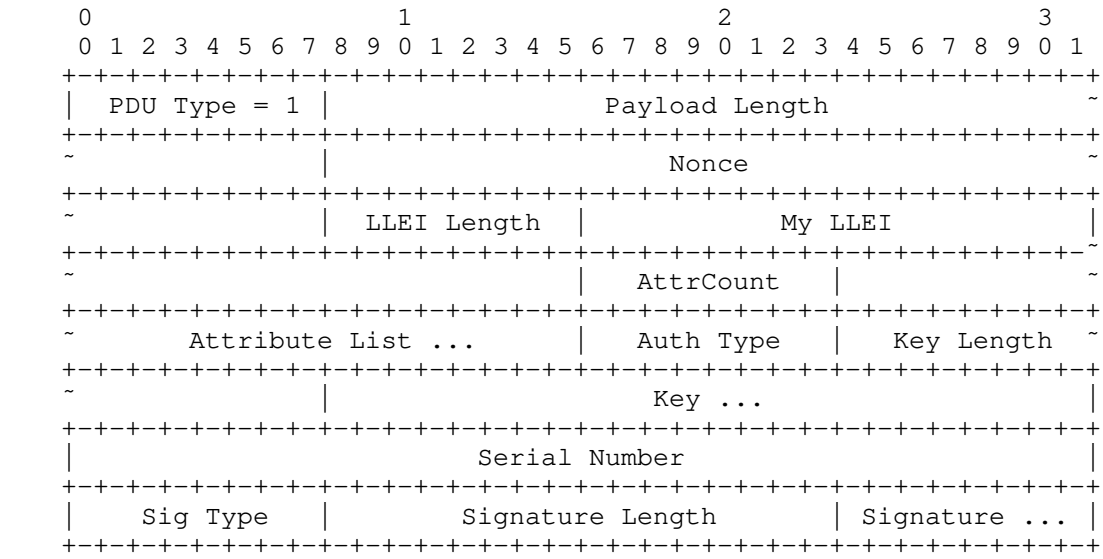
If a HELLO is received from a MAC address with which there is an established session, the HELLO should be dropped.

The Payload Length is zero as there is no payload.

HELLO PDUs can not be signed as keying material has yet to be exchanged. Hence the signature MUST always be the null type.

11. OPEN

Each device has learned the other's MAC Address from the HELLO exchange, see Section 10. Therefore the OPEN and all subsequent PDUs MUST BE unicast, as opposed to the HELLO's multicast frame.



The Payload Length is the number of octets in all fields of the PDU from the Nonce through the Serial Number, not including the three final signature fields.

The Nonce enables detection of a duplicate OPEN PDU. It SHOULD be either a random number or a high resolution timestamp. It is needed to prevent session closure due to a repeated OPEN caused by a race or a dropped or delayed ACK.

My LLEI is the sender's LLEI, see Section 9.

AttrCount is the number of attributes in the Attribute List. Attributes are single octets the semantics of which are operator-defined.

A node may have zero or more operator-defined attributes, e.g.: spine, leaf, backbone, route reflector, arabica, ...

Attribute syntax and semantics are local to an operator or datacenter; hence there is no global registry. Nodes exchange their attributes only in the OPEN PDU.

Auth Type is the Signature algorithm suite, see Section 8.

Key Length is a 16-bit field denoting the length in octets of the Key itself, not including the Auth Type or the Key Length. If the Auth Type is zero, then the Key Length MUST also be zero, and there MUST BE no Key data.

The Key is specific to the operational environment. A failure to authenticate is a failure to start the L3DL session, an ERROR PDU MUST BE sent (Error Code 3), and HELLOs MUST be restarted.

The Serial Number is that of the last received and processed PDU. This allows a receiver sending an OPEN to tell the sender that the receiver wants to resume a session and the sender only needs to send data more recent than the Serial Number. If this OPEN is not trying to restart a lost session, the Serial Number MUST BE set to zero.

The Signature fields are described in Section 8 and in an asymmetric key environment serve as a proof of possession of the signing auth data by the sender.

Once two logical link endpoints know each other, and have ACKed each other's OPEN PDUs, Layer 2 KEEPALIVEs (see Section 15) MAY be started to ensure Layer 2 liveness and keep the session semantics alive. The timing and acceptable drop of KEEPALIVE PDUs are discussed in Section 15.

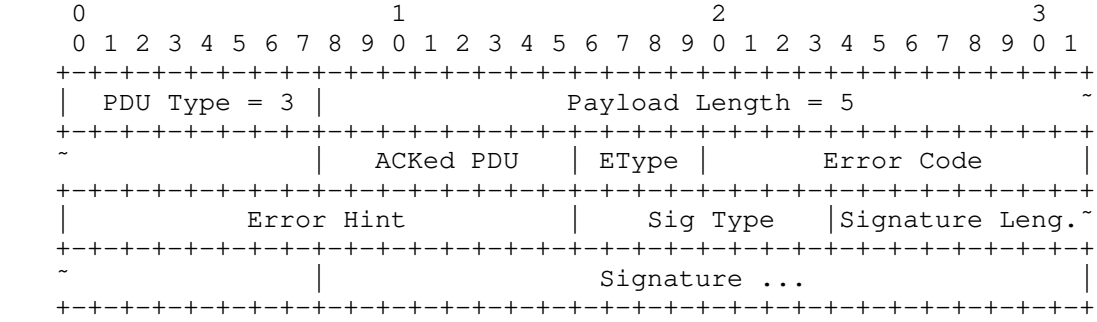
If a sender of OPEN does not receive an ACK of the OPEN PDU, then they MUST resend the same OPEN PDU, with the same Nonce. Resending an unacknowledged OPEN PDU, like other ACKed PDUs, SHOULD use exponential back-off, see [RFC1122].

If a properly authenticated OPEN arrives with a new Nonce from an LLEI with which the receiving logical link endpoint believes it already has an L3DL session (OPENs have already been exchanged), and the Serial Number in the OPEN is non-zero, the receiver SHOULD establish a new session by sending an OPEN with the Serial Number of the last data it received. Each party MUST resume sending encapsulations etc. subsequent to the other party's Sequence Number. And each MUST retain all previously discovered encapsulation and other data.

If a properly authenticated OPEN arrives with a new Nonce from an LLEI with which the receiving logical link endpoint believes it already has an L3DL session (OPENs have already been exchanged), and the Serial Number in the OPEN is zero, then the receiver MUST assume that the sending LLEI or entire device has been reset. All previously discovered encapsulation data MUST NOT be kept and MUST BE withdrawn via the BGP-LS API and the recipient MUST respond with a new OPEN.

12. ACK

The ACK PDU acknowledges receipt of a PDU and reports any error condition which might have been raised.



The ACK acknowledges receipt of an OPEN, Encapsulation, VENDOR PDU, etc.

The ACKed PDU is the PDU Type of the PDU being acknowledged, e.g., OPEN, one of the Encapsulations, etc.

If there was an error processing the received PDU, then the EType is non-zero. If the EType is zero, Error Code and Error Hint MUST also be zero.

A non-zero EType is the receiver's way of telling the PDU's sender that the receiver had problems processing the PDU. The Error Code and Error Hint will tell the sender more detail about the error.

The decimal value of EType gives a strong hint how the receiver sending the ACK believes things should proceed:

- 0 - No Error, Error Code and Error Hint MUST be zero
- 1 - Warning, something not too serious happened, continue
- 2 - Session should not be continued, try to restart
- 3 - Restart is hopeless, call the operator
- 4-15 - Reserved

The Error Codes, noting protocol failures, are listed in Section 22.4. Someone stuck in the 1990s might think the catenation of EType and Error Code as an echo of 0x1zzz, 0x2zzz, etc. They might be right; or not.

The Error Hint, an arbitrary 16 bits, is any additional data the sender of the error PDU thinks will help the recipient or the debugger with the particular error.

The Signature fields are described in Section 8.

12.1. Retransmission

If a PDU sender expects an ACK, e.g. for an OPEN, an Encapsulation, a VENDOR PDU, etc., and does not receive the ACK for a configurable time (default one second), and the interface is live at layer 2, the sender resends the PDU using exponential back-off, see [RFC1122]. This cycle MAY be repeated a configurable number of times (default three) before it is considered a failure. The session MAY BE considered closed in case of this ACK failure.

If the link is broken at layer 2, retransmission MAY BE retried when the link is restored.

13. The Encapsulations

Once the devices know each other's LLEIs, know each other's upper layer (L2.5 and L3) identities, have means to ensure link state, etc., the L3DL session is considered established, and the devices SHOULD exchange L3 interface encapsulations, L3 addresses, and L2.5 labels.

The Encapsulation types the peers exchange may be IPv4 (Section 13.3), IPv6 (Section 13.4), MPLS IPv4 (Section 13.6), MPLS IPv6 (Section 13.7), and/or possibly others not defined here.

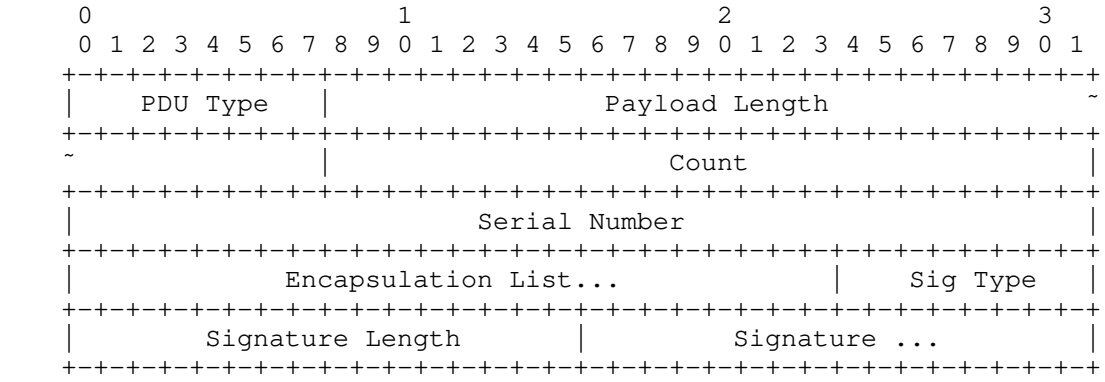
The sender of an Encapsulation PDU MUST NOT assume that the peer is capable of the same Encapsulation Type. An ACK (Section 12) merely acknowledges receipt. Only if both peers have sent the same Encapsulation Type is it safe for Layer 3 protocols to assume that they are compatible for that type.

A receiver of an encapsulation might recognize an addressing conflict, such as both ends of the link trying to use the same address. In this case, the receiver SHOULD respond with an error (Error Code 2) ACK. As there may be other usable addresses or encapsulations, this error might log and continue, letting an upper layer topology builder deal with what works.

Further, to consider a logical link of a type to formally be established so that it may be pushed up to upper layer protocols, the addressing for the type must be compatible, e.g. on the same IP subnet.

13.1. The Encapsulation PDU Skeleton

The header for all encapsulation PDUs is as follows:



An Encapsulation PDU describes zero or more addresses of the encapsulation type.

The 24-bit Count is the number of Encapsulations in the Encapsulation list.

The Serial Number is a monotonically increasing 32-bit value representing the sender's state in time. It may be an integer, a timestamp, etc. On session restart (new OPEN), a receiver MAY send the last received Session Number to tell the sender to only send newer data.

If a sender has multiple links on the same interface, separate state: data, ACKs, etc. must be kept for each peer session.

Over time, multiple Encapsulation PDUs may be sent for an interface as configuration changes.

If the length of an Encapsulation PDU exceeds the Datagram size limit on media, the PDU is broken into multiple Datagrams. See Section 8.

The Signature fields are described in Section 8.

The Receiver MUST acknowledge the Encapsulation PDU with a Type=3, ACK PDU (Section 12) with the Encapsulation Type being that of the encapsulation being announced, see Section 12.

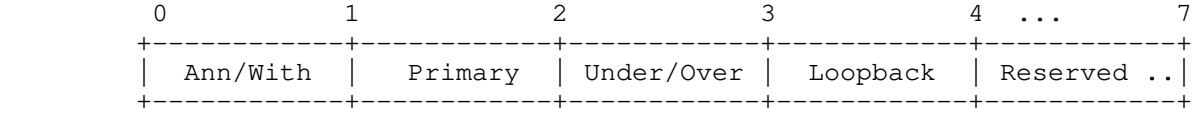
If the Sender does not receive an ACK in a configurable interval (default one second), and the interface is live at layer 2, they SHOULD retransmit. After a user configurable number of failures

(default three), the L3DL session should be considered dead and the OPEN process SHOULD be restarted.

If the link is broken at layer 2, retransmission MAY BE retried if data have not changed in the interim.

13.2. Encapsulaion Flags

The Encapsulation Flags are a sequence of bit fields as follows:



Each encapsulation in an Encapsulation PDU of Type T may announce new and/or withdraw old encapsulations of Type T. It indicates this with the Ann/With Encapsulation Flag, Announce == 1, Withdraw == 0.

Each Encapsulation interface address in an Encapsulation PDU is either a new encapsulation be announced (Ann/With == 1) (yes, a la BGP) or requests one be withdrawn (Ann/With == 0). Adding an encapsulation which already exists SHOULD raise an Announce/Withdraw Error (see Section 22.4); the EType SHOULD be 2, suggesting a session restart (see Section 12 so all encapsulations will be resent.

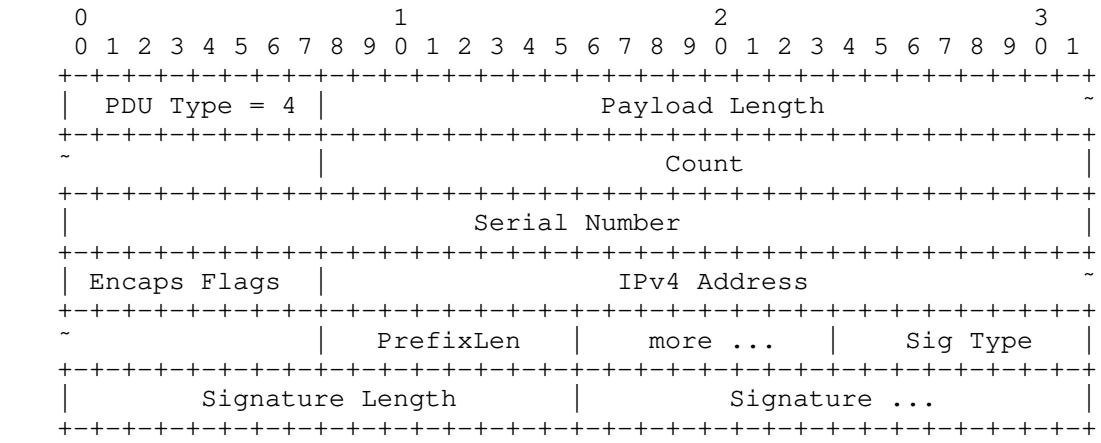
If an LLEI has multiple addresses for an encapsulation type, one and only one address MAY be marked as primary (Primary Flag == 1) for that Encapsulation Type.

An Encapsulation interface address in an Encapsulation PDU MAY be marked as a loopback, in which case the Loopback bit is set. Loopback addresses are generally not seen directly on an external interface. One or more loopback addresses MAY be exposed by configuration on one or more L3DL speaking external interfaces, e.g. for iBGP peering. They SHOULD be marked as such, Loopback Flag == 1.

Each Encapsulation interface address in an Encapsulation PDU is that of the direct 'underlay interface (Under/Over == 1), or an 'overlay' address (Under/Over == 0), likely that of a VM or container guest bridged or configured on to the interface already having an underlay address.

13.3. IPv4 Encapsulation

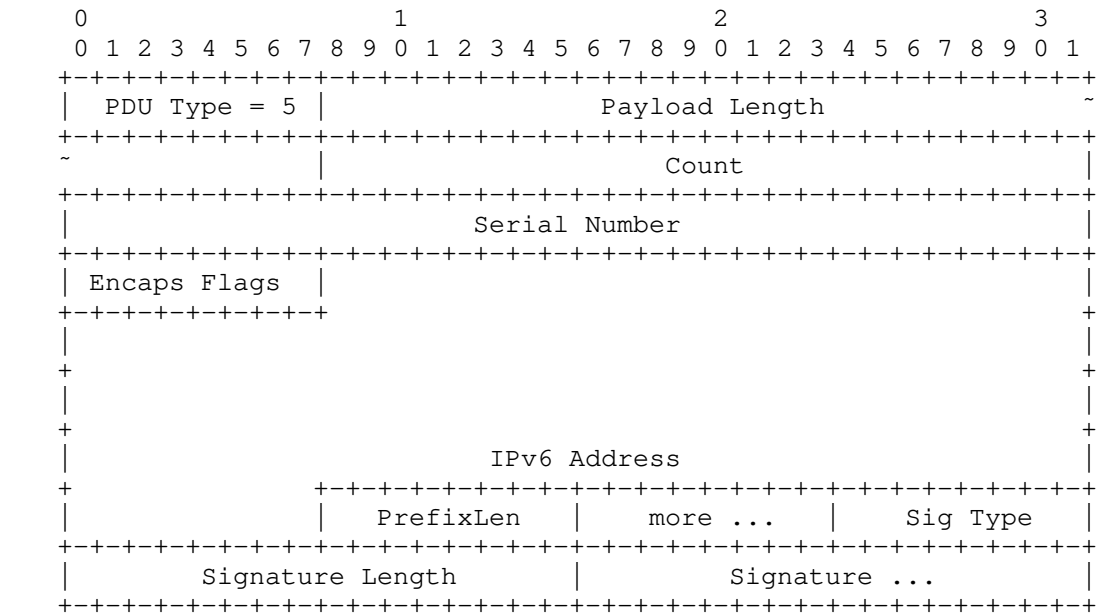
The IPv4 Encapsulation describes a device's ability to exchange IPv4 packets on one or more subnets. It does so by stating the interface's addresses and the corresponding prefix lengths.



The 24-bit Count is the sum of the number of IPv4 Encapsulations being announced and/or withdrawn.

13.4. IPv6 Encapsulation

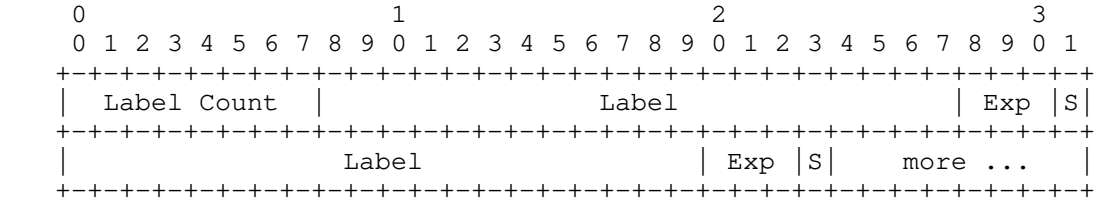
The IPv6 Encapsulation describes a logical link's ability to exchange IPv6 packets on one or more subnets. It does so by stating the interface's addresses and the corresponding prefix lengths.



The 24-bit Count is the sum of the number of IPv6 Encapsulations being announced and/or withdrawn.

13.5. MPLS Label List

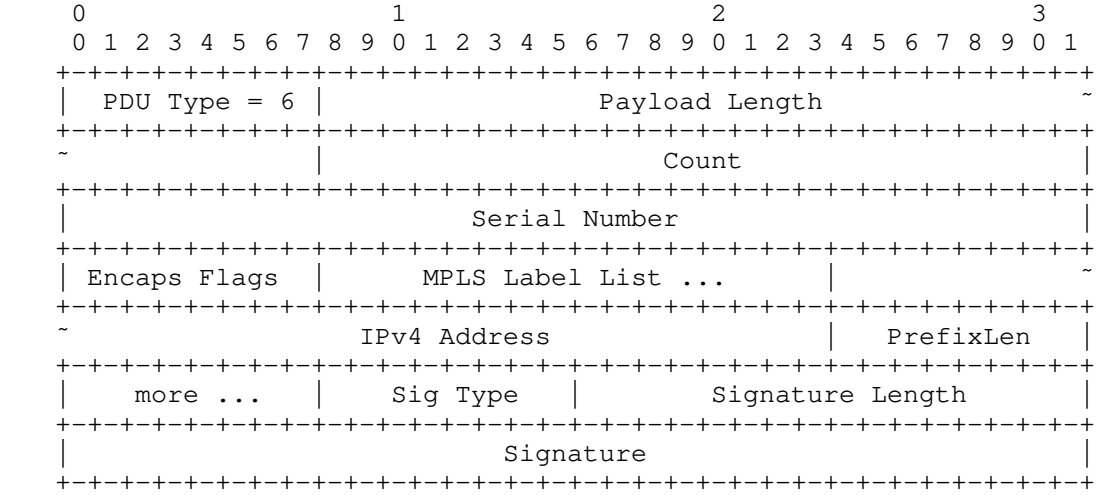
As an MPLS enabled interface may have a label stack, see [RFC3032], a variable length list of labels is needed. These are the labels the sender will accept for the prefix to which the list is attached.



A Label Count of zero is an implicit withdraw of all labels for that prefix on that interface.

13.6. MPLS IPv4 Encapsulation

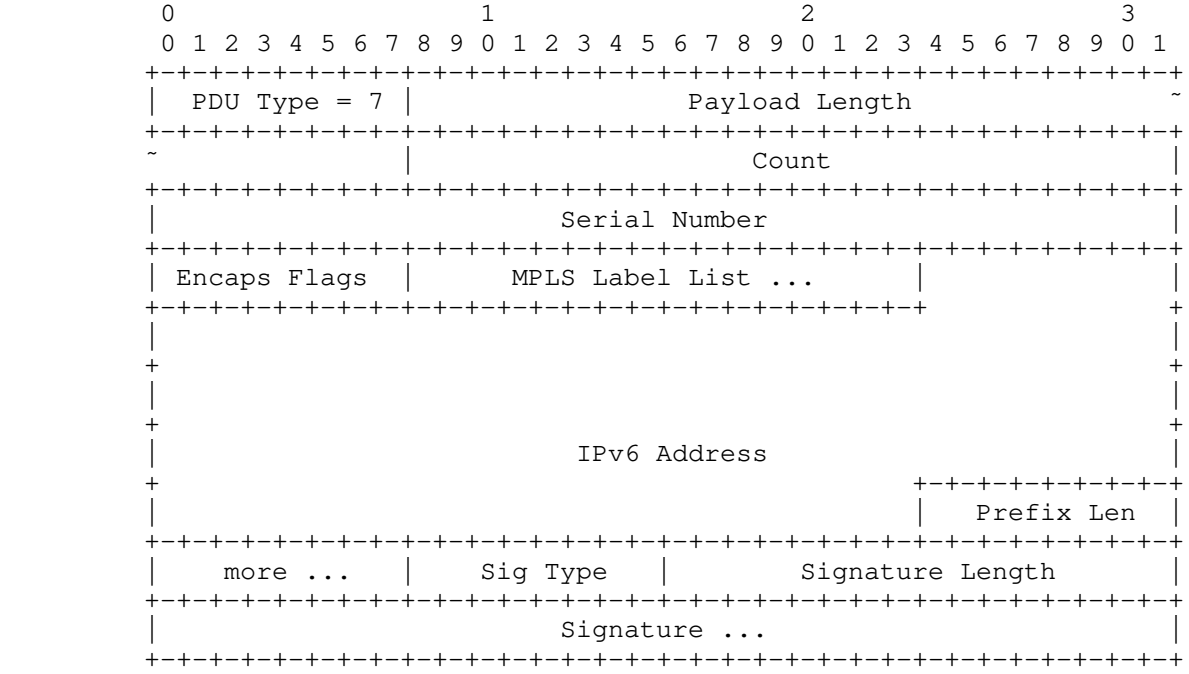
The MPLS IPv4 Encapsulation describes a logical link's ability to exchange labeled IPv4 packets on one or more subnets. It does so by stating the interface's addresses the corresponding prefix lengths, and the corresponding labels which will be accepted fpr each address.



The 24-bit Count is the sum of the number of MPLSv4 Encapsulation being announced and/or withdrawns.

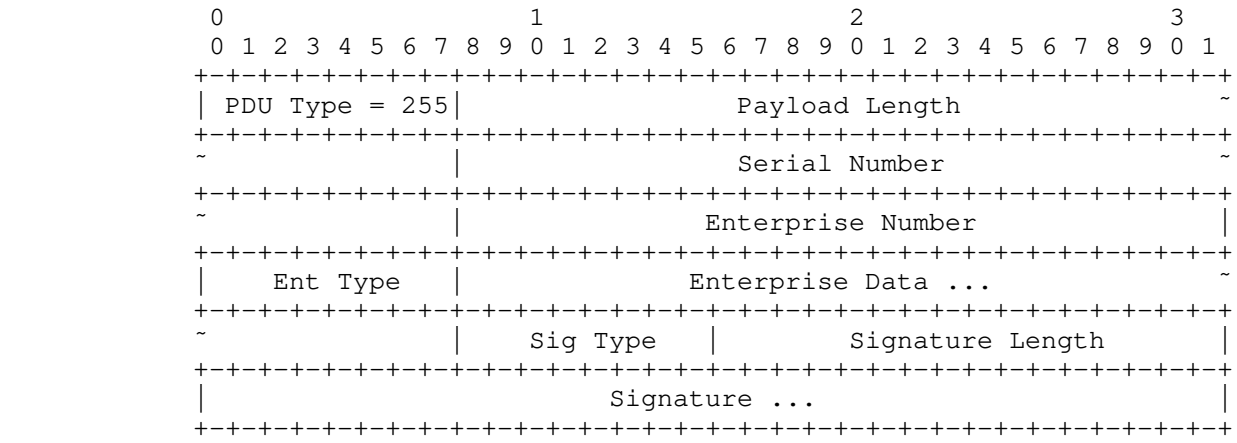
13.7. MPLS IPv6 Encapsulation

The MPLS IPv6 Encapsulation describes a logical link's ability to exchange labeled IPv6 packets on one or more subnets. It does so by stating the interface's addresses, the corresponding prefix lengths, and the corresponding labels which will be accepted for each address.



The 24-bit Count is the sum of the number of MPLSv6 Encapsulations being announced and/or withdrawn.

14. VENDOR - Vendor Extensions

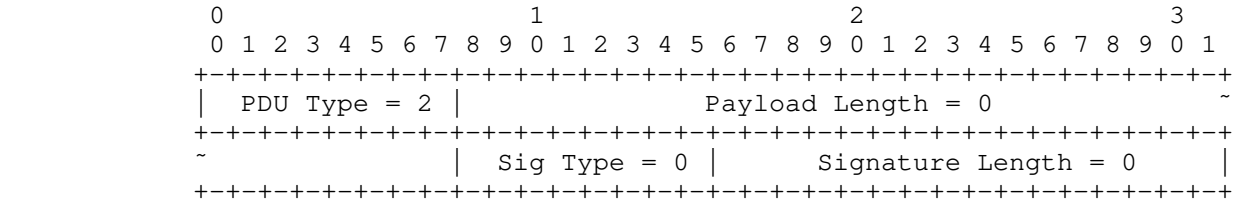


Vendors or enterprises may define TLVs beyond the scope of L3DL standards. This is done using a Private Enterprise Number [IANA-PEN] followed by Enterprise Data in a format defined for that Enterprise Number and Ent Type.

Ent Type allows a VENDOR PDU to be sub-typed in the event that the vendor/enterprise needs multiple PDU types.

As with Encapsulation PDUs, a receiver of a VENDOR PDU MUST respond with an ACK or an ERROR PDU. Similarly, a VENDOR PDU MUST only be sent over an open session.

15. KEEPALIVE - Layer 2 Liveness



L3DL devices SHOULD beacon frequent Layer 2 KEEPALIVE PDUs to ensure session continuity. The inter-KEEPALIVE interval is configurable, with a default of ten seconds. A receiver may choose to ignore KEEPALIVE PDUs.

An operational deployment MUST BE configured whether to use KEEPALIVEs or not, either globally, or as finely as to per-link granularity. Disagreement MAY result in repeated session failure and reestablishment.

KEEPALIVEs SHOULD be beaconed at a configured frequency. One per second is the default. Layer 3 liveness, such as BFD, may be more (or less) aggressive.

When a sender transmits a PDU which is not a KEEPALIVE, the sender SHOULD reset the KEEPALIVE timer. I.e. sending any PDU acts as a keepalive. Once the last fragment has been sent, the KEEPALIVE timer SHOULD BE restarted. Do not wait for the ACK.

If a KEEPALIVE or other PDUs have not been received from a peer with which a receiver has an open session for a configurable time (default 30 seconds), the link SHOULD BE presumed down. The devices MAY keep configuration state and restore it without retransmission if no data have changed. Otherwise, a new session SHOULD BE established and new Encapsulation PDUs exchanged.

16. Layers 2.5 and 3 Liveness

Layer 2 liveness may be continuously tested by KEEPALIVE PDUs, see Section 15. As layer 2.5 or layer 3 connectivity could still break, liveness above layer 2 MAY be frequently tested using BFD ([RFC5880]) or a similar technique.

This protocol assumes that one or more Encapsulation addresses may be used to ping, run BFD, or whatever the operator configures.

17. The North/South Protocol

Thus far, a one-hop point-to-point logical link discovery protocol has been defined.

The devices know their unique LLEIs and know the unique peer LLEIs and Encapsulations on each logical link interface.

Full topology discovery is not appropriate at the L3DL layer, so Dijkstra a la IS-IS etc. is assumed to be done by higher level protocols such as BGP-SPF.

Therefore the LLEIs, link Encapsulations, and state changes are pushed North via a small subset of the BGP-LS API. The upper layer routing protocol(s), e.g. BGP-SPF, learn and maintain the topology, run Dijkstra, and build the routing database(s).

For example, if a neighbor’s IPv4 Encapsulation address changes, the devices seeing the change push that change Northbound.

17.1. Use BGP-LS as Much as Possible

BGP-LS [RFC7752] defines BGP-like Datagrams describing logical link state (links, nodes, link prefixes, and many other things), and a new BGP path attribute providing Northbound transport, all of which can be ingested by upper layer protocols such as BGP-SPF; see Section 4 of [I-D.ietf-lsvr-bgp-spf].

For IPv4 links, TLVs 259 and 260 are used. For IPv6 links, TLVs 261 and 262. If there are multiple addresses on a link, multiple TLV pairs are pushed North, having the same ID pairs.

17.2. Extensions to BGP-LS

The Northbound protocol needs a few minor extensions to BGP-LS. Luckily, others have needed the same extensions.

Similarly to BGP-SPF, the BGP protocol is used in the Protocol-ID field specified in table 1 of [I-D.ietf-idr-bgpls-segment-routing-epe]. The local and remote node descriptors for all NLRI are the IDs described in Section 11. This is equivalent to an adjacency SID or a node SID if the address is a loopback address.

Label Sub-TLVs from [I-D.ietf-idr-bgp-ls-segment-routing-ext] Section 2.1.1, are used to associate one or more MPLS Labels with a link.

18. Discussion

This section explores some trade-offs taken and some considerations.

18.1. HELLO Discussion

A device with multiple Layer 2 interfaces, traditionally called a switch, may be used to forward frames and therefore packets from multiple devices to one logical interface (LLEI), I, on an L3DL speaking device. Interface I could discover a peer J across the switch. Later, a prospective peer K could come up across the switch. If I was not still sending and listening for HELLOs, the potential peering with K could not be discovered. Therefore, on multi-link interfaces, L3DL MUST continue to send HELLOs as long as they are turned up.

18.2. HELLO versus KEEPALIVE

Both HELLO and KEEPALIVE are periodic. KEEPALIVE might be eliminated in favor of keeping only HELLOs. But KEEPALIVEs are unicast, and thus less noisy on the network, especially if HELLO is configured to transit layer-2-only switches, see Section 18.1.

19. VLANs/SVIs/Sub-interfaces

One can think of the protocol as an instance (i.e. state machine) which runs on each logical link of a device.

As the upper routing layer must view VLAN topologies as separate graphs, L3DL treats VLAN ports as separate links.

L3DL PDUs learned over VLAN-ports may be interpreted by upper layer-3 routing protocols as being learned on the corresponding layer-3 SVI interface for the VLAN.

As Sub-Interfaces each have their own LLIEs, they act as separate interfaces, forming their own links.

20. Implementation Considerations

An implementation SHOULD provide the ability to configure each logical interface as L3DL speaking or not.

An implementation SHOULD provide the ability to configure whether HELLOs on an L3DL enabled interface send Nearest Bridge or the MAC which is propagated by switches from that interface; see Section 10.

An implementation SHOULD provide the ability to distribute one or more loopback addresses or interfaces into L3DL on an external L3DL speaking interface.

An implementation SHOULD provide the ability to distribute one or more overlay and/or underlay addresses or interfaces into L3DL on an external L3DL speaking interface.

An implementation SHOULD provide the ability to configure one of the addresses of an encapsulation as primary on an L3DL speaking interface. If there is only one address for a particular encapsulation, the implementation MAY mark it as primary by default.

An implementation MAY allow optional configuration which updates the local forwarding table with overlay and underlay data both learned from L3DL peers and configured locally.

21. Security Considerations

The protocol as is MUST NOT be used outside a datacenter or similarly closed environment without authentication ans authorisation mechanisms such as [I-D.ymbk-lsvr-l3dl-signing].

Many MDC operators have a strange belief that physical walls and firewalls provide sufficient security. This is not credible. All MDC protocols need to be examined for exposure and attack surface. In the case of L3DL, Authentication and Integrity as provided in [I-D.ymbk-lsvr-l3dl-signing] is strongly recommended.

It is generally unwise to assume that on the wire Layer 2 is secure. Strange/unauthorized devices may plug into a port. Mis-wiring is very common in datacenter installations. A poisoned laptop might be plugged into a device's port, form malicious sessions, etc. to divert, intercept, or drop traffic.

Similarly, malicious nodes/devices could mis-announce addressing.

If OPENs are not being authenticated, an attacker could forge an OPEN for an existing session and cause the session to be reset.

For these reasons, the OPEN PDU's authentication data exchange SHOULD be used.

If the KEEPALIVE PDU is not signed (as suggested in Section 8) to save computation, then a MITM could fake a session being alive.

22. IANA Considerations

22.1. PDU Types

This document requests the IANA create a registry for L3DL PDU Type, which may range from 0 to 255. The name of the registry should be L3DL-PDU-Type. The policy for adding to the registry is RFC Required per [RFC5226], either standards track or experimental. The initial entries should be the following:

PDU Code	PDU Name
0	HELLO
1	OPEN
2	KEEPALIVE
3	ACK
4	IPv4 Announcement
5	IPv6 Announcement
6	MPLS IPv4 Announcement
7	MPLS IPv6 Announcement
8-254	Reserved
255	VENDOR

22.2. Signature Type

This document requests the IANA create a registry for L3DL Signature Type, AKA Sig Type, which may range from 0 to 255. The name of the registry should be L3DL-Signature-Type. The policy for adding to the registry is RFC Required per [RFC5226], either standards track or experimental. The initial entries should be the following:

Number	Name
0	Null
1-255	Reserved

22.3. Flag Bits

This document requests the IANA create a registry for L3DL PL Flag Bits, which may range from 0 to 7. The name of the registry should be L3DL-PL-Flag-Bits. The policy for adding to the registry is RFC Required per [RFC5226], either standards track or experimental. The initial entries should be the following:

Bit	Bit Name
0	Announce/Withdraw (ann == 0)
1	Primary
2	Underlay/Overlay (under == 0)
3	Loopback
4-7	Reserved

22.4. Error Codes

This document requests the IANA create a registry for L3DL Error Codes, a 16 bit integer. The name of the registry should be L3DL-Error-Codes. The policy for adding to the registry is RFC Required

per [RFC5226], either standards track or experimental. The initial entries should be the following:

Error Code	Error Name
0	No Error
1	Checksum Error
2	Logical Link Addressing Conflict
3	Authorization Failure
4	Announce/Withdraw Error

23. IEEE Considerations

This document requires a new EtherType.

This document requires a new multicast MAC address that will be broadcast through a switch.

24. Acknowledgments

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