MPLS: The Global Label Maker

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Who’s this guy?

- I am Nick Allgood
- Currently live in Baltimore, MD
- Work as a Network Architect for the past several years.
- Working on PhD in Computer Science at UMBC.

    Research Interests: Quantum Computation and Wireless Sensor Networks.

MPLS History

- Multi-Protocol Label Switching (MPLS) is a way to label traffic with a 20-bit label to be used for packet forwarding decisions instead of a network address.

- Defined in RFC 3031 on January 2001.

- Created as a scalable solution as the internet began exploding in connected nodes.

- Much less resource intensive than doing many recursive route lookups and computations.

- Often called “Layer 2.5” in the OSI reference model or a “shim” layer.

MPLS Basics

- Uses a stack data structure to store the labels (LIFO) for forwarding packets.

- When transmitting labeled traffic, only three operations are *PUSH*, *POP*, *SWAP*

- Relies on TCP 646 for neighbor establishment, but MPLS itself is fairly agnostic and designed to carry many different protocols.

- At a very, very high-level you could think of MPLS being a tunnel for traffic (though it's not a tunnel).

- Pronounced "Em Pee Ell Ess" **NOT** "Mipples"

MPLS Header

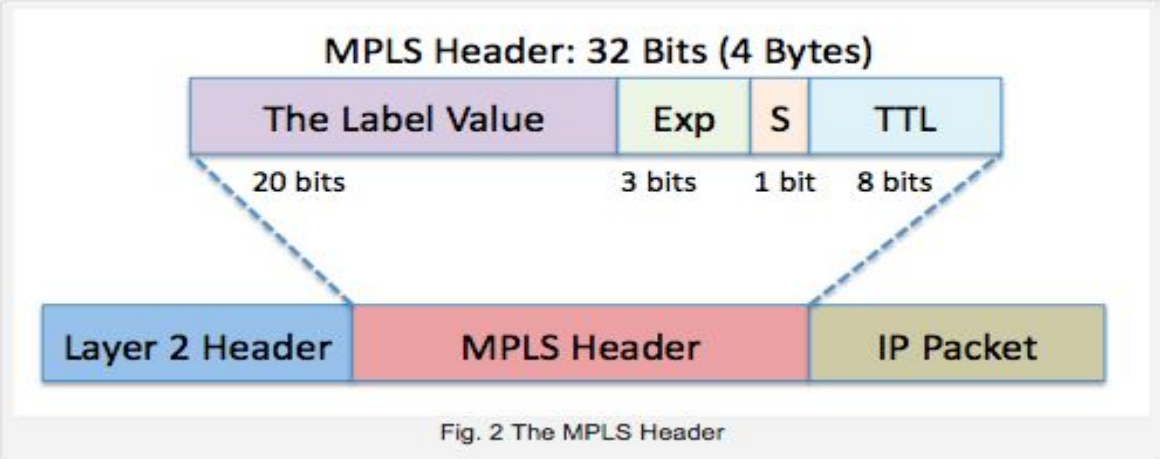

Fig. 2 The MPLS Header

- http://blog.ine.com/2010/02/21/the-mpls-forwarding-plane/

MPLS Terms

- Label Switch Router (LSR): Router that performs forwarding of labeled packets. Also known as “P” or “Provider” router.

- Label Edge Router (LER): Router that sits at the edge of an MPLS provider’s and provides connectivity to the customer network. Also known as the “PE” or “Provider Edge” router.

- Customer Edge Router (CER): Router that exists within the customers network and connects to the MPLS provider. Also called “CE” router.

- Forwarding Equivalence Class (FEC): Name given to labeled traffic that behaves and flows in a certain way. Default every prefix is it’s own FEC but this can be changed.

MPLS Traffic Flow

CE -> PE -> P -> P -> P -> PE -> CE

MPLS Label Types

- 15 different label types for MPLS, though only 8 are assigned. Each have a different effect on traffic flow.

- Implicit-Null: Default setting in most software. Instructs the penultimate LSR to pop the MPLS label off before forwarding (PHP).

    - IPv4 / IPv6 Value: 3

- Explicit-Null: Leaves the top most label on until the final LSR is reached.

    - IPv4 Value: 0

    - IPv6 Value: 2

The MPLS Databases

- MPLS maintains multiple databases that contain the bindings for labels to IPv4, IPv6, etc addresses.

- Label Information Base (LIB): This contains the direct label to network address bindings. Does not contain routes!

- Label Forwarding Information Base (LFIB): This contains the forwarding information that is created from the LIB above. This is what is uses to forward labeled traffic.

- All lookups should be done from the LFIB.

- The LFIB is typically implemented like a cache in the forwarding asics of the hardware.

Label Distribution Protocol

- MPLS typically uses the label distribution protocol (LDP) which connects on TCP 646.

- LDP is how neighbor devices communicate and form consistent label switching paths (LSPs)

- Typically LDP neighbors are formed on directly connected devices, but can be done with nodes that are not directly connected (known as targeted LDP)

MPLS Software

- All major network vendors support this (Cisco, Juniper, Force10, Alcatel, etc) and have for many years.

- Linux supports MPLS but requires LWT and specific kernel modules to be added. In addition iproute2 is required for manually adding static MPLS routes.

- You can also use Quagga which has full support for LDP (via LDPD), MPLS, and about nearly any other industry standard routing protocol. (Quagga configuration is nearly identical to Cisco).

Adding / Showing MPLS Routes

Cisco (IOS / IOS-XE)

```
interface Gig0/0
 mpls ip
```

Linux (Quagga)

```
mpls ldp
!
 router-id 1.1.1.1
!
address-family ipv4
  interface eth0
```

Cisco (IOS / IOS-XE)

```
show mpls ldp bindings
```

Linux (Quagga)

```
show mpls ldp binding
```

** Labels are typically dynamically assigned via LDP but you have the option of specifying labels manually if you wish.

** The Linux example above shows using static label assignments

Metro Ethernet Forum (MEF)

- MEF is a non-profit consortium to promote the adoption of Metro Ethernet Standards.

- They provide information and suggestions to existing standards to utilize metro ethernet.

- The big push was to get many carriers off of legacly ATM/Frame-Relay networks and start utilizing ethernet as a standard for access.

- Many of the L2VPN types were expanded and improved thanks to MEF.

Layer 2 VPNs

- Uses MPLS to provide a “flat” network topology, so you can have an office across the globe appear to be directly connected (because it is!).

- Under the hood, MPLS uses the concept of virtual circuits or pseudowires to form the direct connection between customer facing interfaces.

- For virtual circuits to work, there must be an MPLS label switched between the two connecting routers. In addition, they must be running LDP.

- As the name states, it’s operating at Layer 2 of the OSI model, so it carries all the woes that layer 2 switching networks have (broadcast storms, bridging loops, etc).

L2VPN Types

- **E-Line:** **Point-to-point service**
  - EPL: Port-based. Virtual circuit connect physical ports
  - EVPL: VLAN-based. Virtual circuit connect between VLAN interfaces.
- **E-LAN:** **Multipoint service (VPLS)**
  - EPLAN: Port-based. Virtual circuit connects between ports.
  - EVPLAN: VLAN-based. Virtual circuit connects between VLAN interfaces.

L2TPv3

- Also known as “poor man’s” MPLS
- IETF standard.
- RFC 5641 (Updated RFC 3931)

More L2TPV3

Benefits

- No MPLS network required, runs directly over IP and existing hardware.
- Well supported

Drawbacks

- Much larger overhead compared to MPLS
- Loss of many features MPLS provides (such as traffic engineering).
- Only supports point-to-point services

L2VPN Diagram

C > CE > PE > P > P > P > PE > CE > C

Layer 3 VPNs

- Provide a similar type of service to Layer 2 VPNs, however as the name states, they operate at Layer 3 of the OSI model.

- Uses virtual routing tables (Cisco calls them VRF's)

- Requires MPBGP (Multi-protocol BGP) which is just BGP.

- MPBGP acts as the carrier protocol which carries the routes.

More L3VPNs

- The virtual routing tables are configured with a Route Distinguisher (RD) and a Route Target (RT)

- RD’s are what uniquely identify a VPN across a transit network.

    Side bonus of able to use overlapping IP’s.

    Accomplish this by encoding the RD as a BGP extended community

- RT’s are what are used to control the importing and exporting of routes into a virtual routing table.

L3VPN Diagram

C > CE > PE > P > P > P > PE > CE > C

Basic MPLS Traffic Engineering

- MPLS Traffic Engineering (TE) is used to route across the best MPLS path to the destination.

- Uses another protocol called RSVP which is used for MPLS path signalling.

- You set a desired bandwidth to not be exceeded on a specific MPLS path.

- Estimated bandwidth statistics are reported up through existing routing protocols (through the use of traffic engineering extensions).

More TE

- MPLS traffic engineering operates using GRE tunnels
- Two options for traffic flow:
    - Autoroute: Let the IGP metrics decide which is the best path
    - Explicit: Specify every node in the MPLS path
- RSVP uses what is known as Constrained Shortest Path First (CSPF) to determine the most optimal labeled path.

MPLS TE Diagram

PE1 - <MESH OF P1 - P5> - PE2

- Label bandwidth on links
- Separate P’s a few into diff cities/countries
- Label RSVP Bandwidth
- Show at least one TE tunnel configured

Questions?

Thanks!

- Hope you all learned something useful and fun.
- Feel free to ask me any questions!
- Email me anytime @ nick.allgood@gmail.com
- Slides will be up (eventually) at https://github.com/nallg00d/fosscon2018

References

MPLS RFC: https://tools.ietf.org/html/rfc3031

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MPLS on Linux Tutorial:
https://www.netdevconf.org/1.1/proceedings/slides/prabhu-mpls-tutorial.pdf

LDP Test on Quagga: https://github.com/rwestphal/quagga-ldpd/wiki/ldpd-basic-test-setup

Metro Ethernet Forum: https://www.mef.net/

Layer 2 VPN Concepts:
https://www.cisco.com/c/en/us/td/docs/net_mgmt/prime/fulfillment/6-2/theory/operations/guide/theory/l2ce.pdf

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MPLS Traffic Engineering:
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