Preface

- The composer of this document contributes his improved skills to
  - (a) The complete information displayed in D-Link Switch user manual, and
  - (b) The accumulated intelligence illustrated in D-Link D-Track System

- The composer’s humble wish: Helping Others Do the Same
MPLS Configuration Guide

- Multiprotocol Label Switching (MPLS)
- MPLS Terminology
- Label Distribution Protocol (LDP)
- Configuration Scenario #1
- Configuration Scenario #2
- Configuration Scenario #3
- Command Reference
MPLS Configuration Guide

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- Command Reference
Multiprotocol Label Switching (MPLS)

- Multi-Protocol Label Switching (MPLS) is a technology in which packets associated with a prefix-based Forwarding Equivalence Class (FEC) are encapsulated with a label stack and then switched along a label switched path (LSP) by sequence of label switch routers (LSRs). [RFC3031]
Multiprotocol Label Switching (MPLS)

- The word of “multiprotocol” describes that its techniques are applicable to ANY network layer protocol
  - For example: ATM, Frame Relay, and Ethernet
- “Label” is a short static length physically contiguous identifier which is used to identify a Forwarding Equivalence Class (FEC), with the characteristic of “local significance” in most of the situations
Multiprotocol Label Switching (MPLS)

- Specifies mechanisms to manage traffic flows of various granularities, such as flows between different hardware, machines, or even flows between different applications
- Remains independent of the layer-2 and layer-3 protocols
- Provides a means to map IP addresses to simple, fixed-length labels used by different packet-forwarding and packet-switching technologies
- Interfaces to existing routing protocols, such as Open Shortest PathFirst (OSPF)
Multiprotocol Label Switching (MPLS)

- Instead of forwarding packets on a hop-by-hop basis, paths (label-switched paths) are established for a specific source-destination pairs
- As a result of a preset path, individual routing nodes do not need to do a lookup forwarding on the packets as they enter the router (less CPU-intensive operations)
Multiprotocol Label Switching (MPLS)

- MPLS assigns short labels to network packets that describe how to forward them through the network.
- It offers two key functions:
  - (1) Partitions the entire set of possible packets into a set of "Forwarding Equivalence Classes (FECs)," and then
  - (2) Maps each FEC to a next hop.
Multiprotocol Label Switching (MPLS)

- The FEC to which the packet is assigned is encoded as a short fixed length value known as a "label"
- When a packet is forwarded to its next hop, the label is sent along with it; as such, the packets are "labeled"
Benefits of MPLS

- Network infrastructure scalability: many different types of traffic can be transferred via MPLS routing without regard to what type of traffic it is
- Operation cost decrease: with its capability of automatic configuration of the network and setting up of tunnels or label-switched paths
- Enriched reliability and predictability of traffic
Benefits of MPLS

- Supports multiple network layer protocols, such as IP, IPv6
- Compatible with noted link layer technologies, for example, ATM, frame relay, Ethernet
- Integrating with VPN and TE (Traffic Engineering) solves enterprise inter-connection issues, such as reducing congestion and ensuring QoS in network
RFC References

- RFC2547: BGP/MPLS VPNs
- RFC3031: Multiprotocol Label Switching Architecture
- RFC3036/5036: LDP Specification
- RFC3037: LDP Applicability
- RFC3107: Carrying Label Information in BGP-4
- RFC3209: RSVP-TE: Extensions to RSVP for LSP Tunnels
- RFC3443: Time To Live (TTL) Processing in MPLS Networks
- RFC3478: Graceful Restart Mechanism for Label Distribution Protocol
RFC References

- RFC4761: Virtual Private LAN Service (VPLS) using BGP for Auto-Discovery and Signaling
- RFC4762: Virtual Private LAN Service (VPLS) Using Label Distribution Protocol (LDP) Signaling
- RFC5085: Pseudowire Virtual Circuit Connectivity Verification (VCCV)
- RFC5462: Multiprotocol Label Switching (MPLS) Label Stack Entry: "EXP" Field Renamed to "Traffic Class" Field
- RFC5561: LDP Capabilities
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“Worldly wisdom teaches that it is better for reputation to fail conventionally than to succeed unconventionally.”

By John Maynard Keynes
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Basic MPLS Terminology

- The session of “Basic MPLS Terminology” explains essential MPLS terms. That should include
  - Label Switching Router (LSR)
  - Label-Switched Paths (LSP)
  - Forwarding Equivalence Class (FEC)
  - MPLS Label
  - MPLS Label CoS Values
  - MPLS Label Stack
  - Routers in an LSP
  - Label Distribution Protocol (LDP)
Label Switching Router (LSR)

- A LSR provides label switching and label distribution
- A router that supports MPLS and is capable of forwarding native Layer 3 packets

Quiz: How do we know whether MPLS has being activated in a D-Link switch?

Ans: With the command of “show mpls” as indicated here

```
DGS3630_SW1#show mpls
MPLS Status : Enabled
LSP Trap Status : Disabled
DGS3630_SW1#
```
Label Switching Edge Router (LER)

- A router that operates at the edge of an MPLS network and acts as the entry and exit points for the network
- It pushes an MPLS label onto an incoming packet and pops it off an outgoing packet
- Also known as “Edge LSR”
Forwarding Equivalence Class (FEC)

- Is a group of IP packets which are forwarded in the same manner (e.g., over the same path, with the same forwarding treatment)
- As described in RFC5036, each FEC is specified with one or more FEC elements
- A single FEC element identifies a set of packets that mapped to the corresponding LSP
- One route is corresponding to one specific FEC
- The packets belong to the same FEC are going to be processed in the same way in MPLS network
Forwarding Equivalence Class (FEC)

- The LSR (166.166.166.166) identifies “66.66.66.66” network in its FEC to another LSR (77.77.77.77)
Forwarding Equivalence Class (FEC)

- A label being put on a particular packet represents the Forwarding Equivalence Class to which that packet is assigned
Forwarding Equivalence Class (FEC)

- The label of “1003” is being put on a particular packet “77.77.77.77” represents the Forwarding Equivalence Class that the packet is assigned.
Forwarding Equivalence Class (FEC)

- In a Wireshark packet, a Forwarding Equivalence Class (FEC) shall consist of the following elements:
  - FEC Element Type
  - FEC Element address Type
  - FEC Element Length
  - Prefix

- A diagram, presented in next slide, illustrate an example of FEC elements
Forwarding Equivalence Class (FEC)

- Forwarding Equivalence Class (FEC) Elements

<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>VLAN_ID</th>
<th>MPLS Label</th>
<th>Length</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>404</td>
<td>2016-12-01 17:50:15.023834</td>
<td>77.77.77.77</td>
<td>55.55.57.55</td>
<td>LDP</td>
<td></td>
<td>397 Label Request Message</td>
<td></td>
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<td>405</td>
<td>2016-12-01 17:50:15.025115</td>
<td>55.55.57.55</td>
<td>77.77.77.77</td>
<td>LDP</td>
<td></td>
<td>474 Label Request Message</td>
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<td></td>
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<td>406</td>
<td>2016-12-01 17:50:15.044788</td>
<td>77.77.77.77</td>
<td>55.55.57.55</td>
<td>LDP</td>
<td></td>
<td>116 Label Mapping Message</td>
<td></td>
<td></td>
</tr>
<tr>
<td>407</td>
<td>2016-12-01 17:50:15.046097</td>
<td>55.55.57.55</td>
<td>77.77.77.77</td>
<td>LDP</td>
<td></td>
<td>348 Notification Message</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

PDU Length: 38  
LSR ID: 77.77.77.77  
Label Space ID: 0

- Label Mapping Message
  - 0... .... = U bit: Unknown bit not set
  - Message Type: Label Mapping Message (0x400)
  - Message Length: 28
  - Message ID: 0x00000000

- Forwarding Equivalence Classes TLV
  - 00... .... = TLV Unknown bits: Known TLV, do not Forward (0x0)
  - TLV Type: Forwarding Equivalence Classes TLV (0x100)
  - TLV Length: 7

- FEC Elements
  - FEC Element 1
    - FEC Element Type: Prefix FEC (2)
    - FEC Element Address Type: IPv4 (1)
    - FEC Element Length: 24
    - Prefix: 77.77.77.0
Forwarding Equivalence Class (FEC)

- FECs defines a single type of FEC element, the "Address Prefix FEC element"
- This element is an address prefix of any length from 0 to a full address (example: 166.166.166.0, as indicated here)

<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>VLAN_ID</th>
<th>MPLS Label</th>
<th>Length</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>730</td>
<td>2016-12-01 17:52:36.800066</td>
<td>55.55.57.55</td>
<td>77.77.77.77</td>
<td>LDP</td>
<td></td>
<td></td>
<td></td>
<td>108 Label Mapping Message</td>
</tr>
<tr>
<td>733</td>
<td>2016-12-01 17:52:36.940023</td>
<td>166.166.166.166</td>
<td>55.55.57.55</td>
<td>LDP</td>
<td></td>
<td></td>
<td></td>
<td>116 Label Mapping Message</td>
</tr>
<tr>
<td>736</td>
<td>2016-12-01 17:52:37.000028</td>
<td>55.55.57.55</td>
<td>77.77.77.77</td>
<td>LDP</td>
<td></td>
<td></td>
<td></td>
<td>192 Label Mapping Message</td>
</tr>
</tbody>
</table>

Frame 733: 116 bytes on wire (928 bits), 116 bytes captured (928 bits)
Internet Protocol Version 4, Src: 166.166.166.166, Dst: 55.55.57.55
Label Distribution Protocol
  Version: 1
  PDU Length: 46
  LSR ID: 166.166.166.166
  Label Space ID: 0
  Label Mapping Message
    0... .... = U bit: Unknown bit not set
    Message Type: Label Mapping Message (0x400)
    Message Length: 36
    Message ID: 0x00000019
  Forwarding Equivalence Classes TLV
    00... .... = TLV Unknown Bits: Known TLV, do not Forward (0x0)
    TLV Type: Forwarding Equivalence Classes TLV (0x100)
    TLV Length: 7
    FEC Elements
      FEC Element 1
        FEC Element Type: Prefix FEC (2)
        FEC Element Address Type: IPv4 (1)
        FEC Element Length: 24
        Prefix: 166.166.166.0
      Generic Label TLV
Uncovering Forwarding Equivalence Class (FEC)

- In D-Link switch, the command of “show mpls forwarding-table” is expected to display FECs at hand.
- D-Track DRU20150528000004/DRU20141126000001 disclose its (that command’s) capability during network troubleshooting stage.
- More details about FEC will be addressed in incoming slides in this documentation.
Layer 2 Frame Header

- In MPLS operation, a LSR modifies the layer 2 protocol identifier (PID) or EtherType value in the Layer 2 frame header to indicate that this packet is labeled.
- The below diagram presents an example.
MPLS Protocol Identifier (PID)

- An MPLS PID in the Layer 2 header is used to identify MPLS packet type
- These EtherType values are used to identify Layer 3 protocols with most Layer 2 encapsulations
  - Unlabeled IP Unicast, PID=0x0800
  - Labeled IP Unicast, PID=0x8847
  - Labeled IP multicast, PID=0x8848

- Quiz Session: which EtherType value being indicated in last slide?

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MPLS Label

- A short ID with fixed length and locally valid
- A length of 20 bits
- Unsigned integer in the range 0 through 1,048,575
- A label is only transmitted between two adjacent label switch router (LSR)
  - Of local significance
- Labels are used as lookup indexes for the label forwarding table, in other words, to identify a FEC for packet forwarding
- The “mpls forwarding-table” stores forwarding information for each label
MPLS Label

- When a packet is forwarded to its next hop, the label is sent along with it; that is, the packets are "labeled" before they are forwarded.
- The label is used as an index into a table which specifies the next hop, and a new label.
- The old label is replaced with the new label, and the packet is forwarded to its next hop (every LSR allocates a label for every destination in the IP routing table).
MPLS Label

- Labels are assigned by downstream routers relative to the flow of packets
- A router receiving labeled packets (the next-hop router) is responsible for assigning incoming labels
- A received packet containing a label that is unrecognized (unassigned) is dropped
- For unrecognized labels, the router does not attempt to unwrap the label to analyze the network layer header, nor does it generate an Internet Control Message Protocol (ICMP) destination unreachable message
MPLS Label

- A packet can carry a number of labels, organized as a last-in, first-out stack. This is referred to as a label stack. At a particular router, the decision about how to forward a labeled packet is based exclusively on the label at the top of the stack.

- MPLS label stack: the format of the MPLS label stack is shown in the following illustration.

![MPLS Label Stack Diagram](image-url)
MPLS Label Stack

- **MPLS Label Stack**
  - **Label**: The field contains the actual value for the label. This gives information on the protocol in the network layer and further information needed to forward the packet.
  - **CoS**: Class of Service. The setting of this field affects the scheduling and/or discard algorithms which are applied to the packet as it is transmitted through the network.
  - **S**: Bottom of the Stack, 1-bit field set to one for the last entry in the label stack and zero for all other label stack entries.
  - **TTL**: Time to Live, 8-bit field used to encode a time to live value.
MPLS Label

- An example of an MPLS Label shown in Wireshark
- Label: 1000

<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>MPLS Label</th>
<th>LSP Type</th>
<th>MPLS TTL</th>
<th>Length</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>953</td>
<td>2016-12-01 18:38:33.611810</td>
<td>77.77.77.77</td>
<td>127.0.0.127</td>
<td>MPLS ECHO</td>
<td>1000</td>
<td>1</td>
<td>122</td>
<td>MPLS Echo Request</td>
<td></td>
</tr>
<tr>
<td>959</td>
<td>2016-12-01 18:38:35.001791</td>
<td>77.77.77.77</td>
<td>127.0.0.127</td>
<td>MPLS ECHO</td>
<td>1000</td>
<td>2</td>
<td>126</td>
<td>MPLS Echo Request</td>
<td></td>
</tr>
<tr>
<td>960</td>
<td>2016-12-01 18:38:35.001794</td>
<td>77.77.77.77</td>
<td>127.0.0.127</td>
<td>MPLS ECHO</td>
<td>IPv4 Explicit...</td>
<td>1</td>
<td>130</td>
<td>MPLS Echo Request</td>
<td></td>
</tr>
<tr>
<td>961</td>
<td>2016-12-01 18:38:35.070081</td>
<td>166.166.166.166</td>
<td>77.77.77.77</td>
<td>MPLS ECHO</td>
<td>IPv4 Explicit...</td>
<td>254</td>
<td>118</td>
<td>MPLS Echo Reply</td>
<td></td>
</tr>
<tr>
<td>1264</td>
<td>2016-12-01 18:40:32.398238</td>
<td>166.166.166.166</td>
<td>127.0.0.127</td>
<td>MPLS ECHO</td>
<td>1003</td>
<td>255</td>
<td>98</td>
<td>MPLS Echo Request</td>
<td></td>
</tr>
<tr>
<td>1285</td>
<td>2016-12-01 18:40:32.398242</td>
<td>166.166.166.166</td>
<td>127.0.0.127</td>
<td>MPLS ECHO</td>
<td>IPv4 Explicit...</td>
<td>254</td>
<td>102</td>
<td>MPLS Echo Request</td>
<td></td>
</tr>
<tr>
<td>1266</td>
<td>2016-12-01 18:40:32.398873</td>
<td>166.166.166.166</td>
<td>127.0.0.127</td>
<td>MPLS ECHO</td>
<td>1003</td>
<td>255</td>
<td>98</td>
<td>MPLS Echo Request</td>
<td></td>
</tr>
</tbody>
</table>

Frame 953: 122 bytes on wire (976 bits), 122 bytes captured (976 bits)

MultiProtocol Label Switching Header, Label: 1000, Exp: 0, S: 1, TTL: 1

0000 0000 0011 1110 1000 .... .... .... = MPLS Label: 1000
.... .... .... .... .... = MPLS Experimental Bits: 0
.... .... .... .... .... = MPLS Bottom Of Label Stack: 1
.... .... .... .... .... = MPLS TTL: 1

Internet Protocol Version 4, Src: 77.77.77.77, Dst: 127.0.0.127
User Datagram Protocol, Src Port: 3503, Dst Port: 3503
MultiProtocol Label Switching Echo
Quiz Session: MPLS Label

- MPLS label
  - Another example of an MPLS Label shown in Wireshark
  - What is the Label number displayed in below screenshot?

![Wireshark Screenshot]

From 10: 72 bytes on wire (576 bits), 72 bytes captured (576 bits)
ethernet II, Src: D-LinkIn_31:1c:01 (6c:72120:31:1c:01), Dst: D-LinkIn_31:0c:01 (5c:72120:31:0c:01)
802.1Q Virtual LAN, PRI: 0, CFI: 0, ID: 100
MultiProtocol Label Switching Header, Label: 5001, Exp: 0, S: 1, TTL: 63
0000 0001 0011 1000 1000 ... ... ... = MPLS Label: 5001
... ... ... ... 000 ... ... = MPLS Experimental Bits: 0
... ... ... ... 1 ... ... = MPLS Bottom Of Label Stack: 1
... ... ... ... 0011 1111 = MPLS TTL: 63
Internet Control Message Protocol
Quiz Session: Construct a Label-value

- In D-Link Switch, are there any commands we could construct label value manually?
- Ans:
  - mpls static ftn NETWORK-PREFIX/PREFIX-LENGTH out-label **LABEL-VALUE** nexthop IP-ADDRESS
  - mpls static ilm in-label **LABEL-VALUE** forward-action {swap-label LABEL-VALUE | pop} nexthop IP-ADDRESS fec NETWORK-PREFIX/PREFIX-LENGTH
Relationship among LSRs, Labels, and FEC

- Router_A and Router_B are configured as LSR
- Router_A transmits a packet to Router_B. Router_A will label the packet with a label value (L) if and only if the packet is a member of a particular FEC (F)
- In other words, there is a "binding" between label (L) and FEC (F) for packets moving from Router_A and Router_B
Relationship among LSRs, Labels, and FEC

- L is an arbitrary value binding to F within Router_A and Router_B
  - Of local significance

- L in Router_A: "outgoing label"
  - Router_A is the "upstream LSR," since it sends out the packet

- L in Router_B: "incoming label"
  - Router_B is the "downstream LSR"
The Procedures for Advertising and Using labels

- The upstream LSR will perform
  - The Request Procedure
  - The NotAvailable Procedure
  - The Release Procedure
  - The labelUse Procedure

- The downstream LSR will perform
  - The Distribution Procedure
  - The Withdrawal Procedure
**Implicit NULL Label**

- Is a label with special semantics which an LSR can bind to an address prefix
- A (Penultimate) LSR pops the label stack, instead of replacing the value of the label, and then forwards the resulting (IP) packet
- It is expected to reduce the load on last hop router
- Is represented in LDP as a Generic Label TLV with a Label field value of 3 (this information is also indicated in DK1400739)
Implicit NULL Label (Wireshark Display Filter)

- The field name of “ldp.msg.tlv.generic.label” can be used on Wireshark LDP Display Filter
- As of Implicit NULL Label, we can apply ldp.msg.tlv.generic.label==3
Implicit NULL Label (Wireshark Display Filter)

- A diagram presents a list of ldp.msg.tlv.generic.label==3
- As indicated here, it exists in “Notification Message,” “Label Mapping Message,” as well as “Label Request Message”
Implicit NULL Label (Wireshark)

- Frame 78, Generic Label: 0x00003
Explicit NULL Label

- When an LSR receives an MPLS header where the label is set to 0, it (that LSR) always POPs the header (removes the label) (lessons learned from D-Track DK1400739)

- It is a mechanism for a packet’s FEC being determined only at the ingress to an LSP, and no where else along the path.
Explicit NULL Label

- As of the underneath diagram, frame 2586/2587 show “Explicit NULL (MPLS) Label”

<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>MPLS Label</th>
<th>Length</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>2583</td>
<td>2016-12-01 18:04:58.855005</td>
<td>166.166.166.166</td>
<td>77.77.77.77</td>
<td>MPLS ECHO</td>
<td></td>
<td>110</td>
<td>MPLS Echo Reply</td>
</tr>
<tr>
<td>2584</td>
<td>2016-12-01 18:04:59.46891</td>
<td>169.254.104.176</td>
<td>169.254.255.255</td>
<td>NBNS</td>
<td></td>
<td>92</td>
<td>Name query NB ACADEMY-PC1c&gt;</td>
</tr>
<tr>
<td>2585</td>
<td>2016-12-01 18:04:59.40713</td>
<td>77.77.77.77</td>
<td>127.0.0.127</td>
<td>MPLS ECHO</td>
<td>1003</td>
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<td>MPLS Echo Request</td>
</tr>
<tr>
<td>2586</td>
<td>2016-12-01 18:04:59.940717</td>
<td>77.77.77.77</td>
<td>127.0.0.127</td>
<td>MPLS ECHO</td>
<td>IPv4 Explicit-Null</td>
<td>102</td>
<td>MPLS Echo Request</td>
</tr>
<tr>
<td>2587</td>
<td>2016-12-01 18:05:00.008746</td>
<td>166.166.166.166</td>
<td>77.77.77.77</td>
<td>MPLS ECHO</td>
<td>IPv4 Explicit-Null</td>
<td>118</td>
<td>MPLS Echo Reply</td>
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<td>2588</td>
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<td>77.77.77.77</td>
<td>MPLS ECHO</td>
<td>IPv4 Explicit-Null</td>
<td>118</td>
<td>MPLS Echo Reply</td>
</tr>
<tr>
<td>2589</td>
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<td>169.254.104.176</td>
<td>169.254.255.255</td>
<td>NBNS</td>
<td></td>
<td>92</td>
<td>Name query NB ACADEMY-PC1c&gt;</td>
</tr>
</tbody>
</table>

- Note: 0 represents IPv4 Explicit Null label

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The MPLS experimental bits (EXP) field is a 3-bit field in the MPLS header that you can use to define the QoS treatment (per-hop behavior) that a node should give to a packet.

RFC 5462 also describes that "EXP field" is used as a traffic classification field.
### MPLS Experimental Bits (EXP) Field

- An example of MPLS experimental bits is demonstrated here

<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>Protocol</th>
<th>MPLS Label</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2017-02-07</td>
<td>192.168.100.2</td>
<td>7.7.7.7</td>
<td>ICMP</td>
<td>ICMP</td>
<td>1002</td>
</tr>
<tr>
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<td>2017-02-07</td>
<td>7.7.7.7</td>
<td>192.168.100.2</td>
<td>ICMP</td>
<td>IPv4</td>
<td>Explicit-Null</td>
</tr>
<tr>
<td>5</td>
<td>2017-02-07</td>
<td>192.168.100.2</td>
<td>77.77.77.77</td>
<td>ICMP</td>
<td>IPv4</td>
<td>Explicit-Null</td>
</tr>
<tr>
<td>7</td>
<td>2017-02-07</td>
<td>77.77.77.77</td>
<td>192.168.100.2</td>
<td>ICMP</td>
<td>IPv4</td>
<td>Explicit-Null</td>
</tr>
</tbody>
</table>

Frame 3: 78 bytes on wire (624 bits), 78 bytes captured (624 bits) on interface 0
MultiProtocol Label Switching Header, Label: 0 (IPv4 Explicit-Null), Exp: 0, S: 1, TTL: 254
0000 0000 0000 0000 0000 0000 ....... ....... = MPLS Label: IPv4 Explicit-Null (0)
.... .... .... .... .... .... = MPLS Experimental Bits: 0
.... .... .... .... .... .... = MPLS Bottom Of Label Stack: 1
.... .... .... .... .... .... = MPLS TTL: 254
Internet Protocol Version 4, Src: 7.7.7.7, Dst: 192.168.100.2
Internet Control Message Protocol
MPLS Experimental Bits configurations

- As stated in D-Track DRU201512290000003, configuration of binding MPLS Experimental Bits to class of service (CoS) can be achieved via underneath commands at D-Link switches:
  - configure terminal
  - mpls qos policy NAME
  - class map exp-cos EXP-LIST to COS-VALUE
  - match { ip NETWORK-PREFIX/PREFIX-LENGTH | vc IP-ADDRESS VC-ID }
  - trust exp
MPLS Experimental Bits (EXP) Field

- Another example of MPLS experimental bits, where 5 is being configured

![MPLS Experimental Bits Example](image-url)
Wireshark Display Filter on EXP

- The Field Name of “mpls.exp” in Wireshark packet represents MPLS Experimental Bits
- With the criteria of “mpls.exp==0,” a list of “Explicit NULL Label” is presented here
**TTL In MPLS Header**

- The TTL in MPLS header has a length of 8 bits
- During each label exchange activity, the TTL value of the outer layer label is reduced by “1”
MPLS Label Stack

- Is an ordered set of labels
- The LSR always swap the labels based on the label at the top
- When there are multiple labels, each label includes complete 32 bits
- The Label Stack supports one MPLS packet to carry multiple layers of labels
- It enables the MPLS technology to aid a hierarchical network system as well as MPLS tunnels
MPLS Label Stack Encoding

- MPLS Label Stack Encoding (RFC 3032)
- Reserved labels (in the 0 through 15 range)
  - 0: IPv4 Explicit Null label, this value is legal only when it is the sole label entry (no label stacking). It indicates that the label must be popped upon receipt.
  - 1: Router Alert label, when a packet is received with a top label value of 1, it is delivered to the local software module for processing.
  - 2: IPv6 Explicit Null label
  - 3: Implicit Null label, this label is used in the control protocol (LDP or RSVP) only to request label popping by the downstream router.
MPLS Label Stack Encoding

- MPLS Label Stack Encoding (RFC 3032)
- Reserved labels (in the 0 through 15 range)
  - 4 through 6: Unassigned
  - 7: Entropy label indicator, this label is used when an Entropy label is in the label stack and precedes the Entropy label
  - 8 through 15: Unassigned
MPLS Label Stack Encoding

- MPLS Label Stack Encoding (RFC 3032)
- Reserved labels (in the 0 through 15 range)
  - An example of “0, IPv4 Explicit Null label”

<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>MPLS Label</th>
<th>LSP Type</th>
<th>MPLS TTL</th>
<th>Length</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>2012-03-07 15:14:56.47571</td>
<td>212.1.254.14</td>
<td>212.1.254.60</td>
<td>TCP</td>
<td>IPv4 Explicit-Null</td>
<td>254</td>
<td>70</td>
<td>646+1650 [ACK] Seq=1 Ack=19 Win=16384 Len=0 TSval=...</td>
<td></td>
</tr>
<tr>
<td>84</td>
<td>2012-03-07 15:14:57.363306</td>
<td>212.1.254.14</td>
<td>212.1.254.60</td>
<td>TCP</td>
<td>IPv4 Explicit-Null</td>
<td>254</td>
<td>70</td>
<td>646+1650 [ACK] Seq=1 Ack=47 Win=16384 Len=0 TSval=...</td>
<td></td>
</tr>
<tr>
<td>126</td>
<td>2012-03-07 15:14:59.619713</td>
<td>212.1.254.21</td>
<td>212.1.254.60</td>
<td>LDP</td>
<td>IPv4 Explicit-Null</td>
<td>254</td>
<td>88</td>
<td>Hello Message</td>
<td></td>
</tr>
<tr>
<td>161</td>
<td>2012-03-07 15:15:03.851712</td>
<td>212.1.254.14</td>
<td>212.1.254.60</td>
<td>LDP</td>
<td>IPv4 Explicit-Null</td>
<td>254</td>
<td>88</td>
<td>Hello Message</td>
<td></td>
</tr>
<tr>
<td>168</td>
<td>2012-03-07 15:15:08.456526</td>
<td>212.1.254.24</td>
<td>212.1.254.60</td>
<td>LDP</td>
<td>IPv4 Explicit-Null</td>
<td>254</td>
<td>88</td>
<td>Keep Alive Message</td>
<td></td>
</tr>
</tbody>
</table>

- Multi-Protocol Label Switching Header, Label: 0 (IPv4 Explicit-Null), Exp: 6, St: 1, TTL: 254
  - 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 = MPLS Label: IPv4 Explicit-Null (0)
  - 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 = MPLS Experimental Bits: 6
  - 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 = MPLS Bottom Of Label Stack: 1
  - 1111 1111 1111 1111 1111 1111 1111 1111 1111 1111 1111 1111 1111 1111 1111 1111 = MPLS TTL: 254

- Internet Protocol Version 4, Src: 212.1.254.14, Dst: 212.1.254.60
- Label Distribution Protocol
MPLS Label-Stacked Packets

- Label-stacked packets
  - The egress router receives an MPLS label packet with its top label already popped by the penultimate router
  - The egress router cannot receive label-stacked packets that use label 0 or 2
  - It typically requests label 3 from the penultimate router
MPLS Label Stack

- Label Stack: Labels are processing in the FIFO basis
- The label close the L2 header is the value at the top of the label stack
- The label near the IP header is the means at the bottom-of-Stack bit implements an MPLS label stack

![MPLS Label Stack Example](image-url)
MPLS Label Stack

- According to RFC3031 (MPLS Architecture)
  - A labeled packet carries a number of labels, organized as a last-in, first-out stack
  - The label at the bottom of the stack as the level 1 label, to the label above it as the level 2 label
  - Level 1 label: 16; Level 2 label: 18
MPLS Label Class-of-Service (CoS) Value

- MPLS Label Class-of-Service (CoS) Value is used to prioritize packet forwarding
- A fixed CoS value means that all packets entering the LSP receive the same class of service
- The mapping between the CoS bit value and the output queue is hard-coded
MPLS Label CoS Values

- MPLS CoS Values (1st example)
  - MPLS CoS Value 0 (Transmit Queue: 0, Packet loss priority (PLP) Bit: Not Set)
MPLS Label CoS Values

- MPLS CoS Values (2nd example)
  - MPLS CoS Value 6 (Transmit Queue: 3, Packet loss priority (PLP) Bit: Not Set)
Routers in an LSP

- Depending upon the role a router is playing, it (a MPLS router) can be embedded with be one of the following three characters:
  - (1) Ingress router: The router at the beginning of an LSP
  - (2) Egress router: The router at the end of an LSP
  - (3) Transit router: Any intermediate router in the LSP between the ingress and egress routers
Routers in an LSP [Ingress Router]

- Ingress router, the router at the beginning of an LSP (managing traffic as it enters an MPLS domain)
- Ingress router will add the label (movement of PUSH)
- PUSH is the process to insert a label between L2 header and L3 header on the ingress router
- It (PUSH) can also be used by the intermediate LSR to add a new label to the label stack top of the MPLS packet
Routers in an LSP [Egress Router]

- Egress router, The router at the end of an LSP (operating traffic as it leaves an MPLS domain)
- Egress router will remove the label (movement of POP)
- POP manages the operation to remove all of the labels in the packets at the egress LSR
Routers in an LSP [Transit Router]

- Transit router, Any intermediate router in the LSP between the ingress and egress routers
- Transit router dispatch the label (movement of SWAP)
- SWAP replaces the stack top label in the packets according to the LSP in the forwarding table during packet forwarding activity
### Routers in an LSP (D-Link show command)

- The diagram attached here presents an example of a router’s role in LSP.
- This router serves the role of “Ingress” and “Transit” router for 7.7.7.0/24 and 77.77.77.0/24.

<table>
<thead>
<tr>
<th>LSP</th>
<th>Type</th>
<th>FEC</th>
<th>In Label</th>
<th>Next Hop</th>
<th>Status</th>
<th>Owner</th>
<th>Out Label</th>
<th>Out Interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ingress</td>
<td>7.7.7.0/24</td>
<td>-</td>
<td>192.168.57.7</td>
<td>Up</td>
<td>LDP</td>
<td>Push 0</td>
<td>VLAN 57</td>
</tr>
<tr>
<td>2</td>
<td>Ingress</td>
<td>77.77.77.0/24</td>
<td>-</td>
<td>192.168.57.7</td>
<td>Up</td>
<td>LDP</td>
<td>Push 0</td>
<td>VLAN 57</td>
</tr>
<tr>
<td>3</td>
<td>Transit</td>
<td>7.7.7.0/24</td>
<td>1000</td>
<td>192.168.57.7</td>
<td>Up</td>
<td>LDP</td>
<td>Push 0</td>
<td>VLAN 57</td>
</tr>
<tr>
<td>4</td>
<td>Transit</td>
<td>77.77.77.0/24</td>
<td>1001</td>
<td>192.168.57.7</td>
<td>Up</td>
<td>LDP</td>
<td>Push 0</td>
<td>VLAN 57</td>
</tr>
</tbody>
</table>

D-Link Certified Specialist

MPLS Configuration Guide
Quiz Session: MPLS Router Roles (1/2)

Q: Given the below diagram on “show mpls forwarding-table detail,” what is the MPLS Router Role(s) regarding FEC: 7.7.7.0/24?

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>LSP: 11</td>
<td>Type: Ingress</td>
<td>FEC: 7.7.7.0/24</td>
<td>In Label:</td>
<td>Next Hop: 192.168.57.7</td>
<td>Status: Up</td>
<td>Owner: LDP</td>
<td>Out Label: Push 0</td>
<td>Out Interface: VLAN 57</td>
</tr>
<tr>
<td>LSP: 9</td>
<td>Type: Transit</td>
<td>FEC: 7.7.7.0/24</td>
<td>In Label: 1003</td>
<td>Next Hop: 192.168.57.7</td>
<td>Status: Up</td>
<td>Owner: LDP</td>
<td>Out Label: Push 0</td>
<td>Out Interface: VLAN 57</td>
</tr>
</tbody>
</table>
Quiz Session: MPLS Router Roles (2/2)

- Ans: This router is acting as an “Ingress router” and “Transit router” as far as FEC: 7.7.7.0/24 is concerned

<table>
<thead>
<tr>
<th>LSP:13</th>
<th>Type: Transit</th>
<th>FEC: 66.66.66.0/24</th>
<th>Status: Up</th>
<th>Owner: LDP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>In Label: 1002</td>
<td>Out Label: Push 0</td>
<td>Out Interface: VLAN 56</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Next Hop: 192.168.56.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LSP:11</th>
<th>Type: Ingress</th>
<th>FEC: 7.7.7.0/24</th>
<th>Status: Up</th>
<th>Owner: LDP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>In Label: -</td>
<td>Out Label: Push 0</td>
<td>Out Interface: VLAN 57</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Next Hop: 192.168.57.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LSP:9</th>
<th>Type: Transit</th>
<th>FEC: 7.7.7.0/24</th>
<th>Status: Up</th>
<th>Owner: LDP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>In Label: 1003</td>
<td>Out Label: Push 0</td>
<td>Out Interface: VLAN 57</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Next Hop: 192.168.57.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
MPLS Domain

- Describes an integrated set of routing devices that operate MPLS routing and forwarding
- MPLS Node is the routing device inside a MPLS domain where the (MPLS) Node
  - (a) operates one or more L3 routing protocols, and
  - (b) are forwarding packets based on labels
Label Distribution Peers

- Two LSRs, configured with label distribution protocol to exchange label/FEC binding information, are recognized as "label distribution peers"
- In MPLS, two label distribution peers are required to engage in order to learn of each other's MPLS capabilities
- We also can describe that there is a "label distribution adjacency" between them
Label Retention Mode

- Inside the MPLS domain, one of the routers may receive a label binding for a particular FEC
- This router has two ways options as of Label Retention management
  - (a) keeps track of such bindings [defined as "Liberal Label Retention Mode"], or
  - (b) discards such bindings [described as "Conservative Label Retention Mode"]
Label Retention Mode

- Liberal Label Retention Mode
  - An LSR maintains the bindings between a label and a destination prefix
  - Resulting in "high memory usage" as the needs to maintain large number of labels

- Conservative Label Retention Mode
  - An LSR discards bindings that are received from downstream LSRs
  - LDP next-hop neighbors are required to maintained label

- D-Link switch command offers the option
  - label-retention-mode {liberal | conservative}
Label Retention Mode

- The right-hand side diagram indicates that this router is configured as "Liberal Label Retention Mode"
- This output is captured from a DGS-3630 switch
Methods Of Label Distribution

- "Downstream-on-demand" label distribution
  - Offers an LSR to explicitly request, from its next hop for a particular FEC, a label binding for that FEC
- "Unsolicited downstream" label distribution
  - Allows an LSR to distribute bindings to LSRs that have not explicitly requested them
Methods Of Label Distribution

- Label Distribution aims to speed up the setup of Label Switched Paths (LSPs) in case there is a change in the next hop.
- If the label distribution method is downstream-unsolicited and the label retention mode is conservative, once the LSR receives label bindings from LSRs which are not its next hop for that Forwarding Equivalence Class (FEC), it discards such bindings.
- If the label retention mode is liberal, it maintains such bindings.
Methods Of Label Distribution

- Downstream-on-demand means that MPLS devices do not signal a FEC-to-label binding until requested to do so by an upstream device.
- Upstream is the direction toward a packet’s source; the ingress node in an MPLS domain is the farthest possible upstream node.
- Downstream is the direction toward a packet’s destination; the egress node in an MPLS domain is the farthest possible downstream node. The egress node is sometime referred to as the tunnel endpoint.
Methods Of Label Distribution

- The underneath sketch shows that a router builds its MPLS peers with "Unsolicited downstream" label distribution settings

```
SW_Middle#show mpls ldp session

<table>
<thead>
<tr>
<th>Peer</th>
<th>Status</th>
<th>Role</th>
<th>Keep Alive</th>
<th>Distribution Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1.1.1:0</td>
<td>OPERATIONAL</td>
<td>Active</td>
<td>40(Sec)</td>
<td>DU</td>
</tr>
<tr>
<td>1.1.1.3:0</td>
<td>OPERATIONAL</td>
<td>Passive</td>
<td>40(Sec)</td>
<td>DU</td>
</tr>
</tbody>
</table>

Total Entries: 2
```

SW_Middle#_
Label Distribution And Label Retention

- If the label distribution method is **downstream-unsolicited** and the label retention mode is **conservative**, once the LSR receives label bindings from LSRs which are not its next hop for that Forwarding Equivalence Class (FEC), it discards such bindings.
- If the label retention mode is **liberal**, it maintains such bindings.
  - It helps to speed up the setup of Label Switched Paths (LSPs) in case there is a change in the next hop.
Quiz Session: Label Distribution and Retention

- Per last slide statement, what would be your interpretation with the screenshot shown in your right hand side?

```
#show mpls ldp information

Distribution Method: DU
LSP Control Mode: Independent
Label Retention: Liberal
```

D-Link Academy
Operations on MPLS Labels

- Operations on MPLS Labels
  - Push: Add a new label to the top of the packet
  - Pop: Remove the label from the beginning of the packet
  - Swap: Replace the label at the top of the label stack with a new label
  - Multiple Push: Add multiple labels (up to three) on top of existing packets
Operations on MPLS Labels

- Operations on MPLS Labels
  - Push: Add a new label to the top of the packet
    - The new top label in a label stack always initializes its TTL to 255, regardless of the TTL value of lower labels.
Operations on MPLS Labels

- Operations on MPLS Labels (2\textsuperscript{nd} example)
  - Push—Add a new label to the top of the packet

```
DGS3630_SW1#show mpls forwarding-table detail

LSP: 1
  Type: Ingress
  FEC: 7.7.7.0/24
  In Label: -
  Next Hop: 192.168.57.7

Status: Up
Owner: LDP
Out Label: Push 0
Out Interface: VLAN 57

LSP: 2
  Type: Ingress
  FEC: 77.77.77.0/24
  In Label: -
  Next Hop: 192.168.57.7

Status: Up
Owner: LDP
Out Label: Push 0
Out Interface: VLAN 57

LSP: 3
  Type: Transit
  FEC: 7.7.7.0/24
  In Label: 1000
  Next Hop: 192.168.57.7

Status: Up
Owner: LDP
Out Label: Push 0
Out Interface: VLAN 57

LSP: 4
  Type: Transit
  FEC: 77.77.77.0/24
  In Label: 1001
  Next Hop: 192.168.57.7

Status: Up
Owner: LDP
Out Label: Push 0
Out Interface: VLAN 57
```
Operations on MPLS Labels

- Operations on MPLS Labels (3rd example)
  - Pop—Remove the label from the beginning of the packet
Label-Switched Paths (LSPs)

- Data transmission occurs on Label-Switched Paths in MPLS.
- The data traffic of the same FEC passes the same LSP.
- In other words, LSP represents the path through one or more LSRs at one level of the hierarchy followed by a packets in a particular FECMPLS (Forwarding Equivalence Class MPLS).
Label-Switched Paths (LSPs)

- Is the virtual connection of MPLS
- The MPLS labels identify virtual links (paths) between distant nodes rather than (directly connected) endpoints
- MPLS directs data, inasmuch as, from one network node to the next based on short path labels rather than long network addresses, avoiding complex lookups in a routing table
Label-Switched Paths (LSPs)

- LSPs are a sequence of labels at each node along the path from the original source to the destination.
- The establishment of the LSP is the process to perform the FEC and label binding.
- LSPs are established either prior to data transmission (control-driven) or upon detection of a certain flow of data (data-driven).
Types of Label-Switched Paths (LSPs)

- Types of LSPs
  - Static LSPs: labels are manually assigned
  - LDP signaled LSPs
  - RSVP signaled LSPs: used to set up the path and dynamically assign labels
How a Packet Travels Along an LSP

- When an IP packet enters an LSP, the ingress router examines the packet and assigns it a label based on its destination.
- The packet is then forwarded to the next router in the LSP.
- When the packet reaches the egress router, the label is removed. Then, the packet again becomes a native IP packet and is again forwarded based on its IP routing information.
Mapping a Specific Packet to a Particular LSP

- Mapping a specific packet to a particular LSP is determined by
- (1) If a packet matches exactly one LSP, the packet is mapped to that LSP
- (2) If a packet matches several LSPs, the longest prefix gets the Crown
- (3) If a packet MUST connect to a specific egress router and a LSP has a /32 address of that router, inasmuch as, that packet is mapped to that LSP
Next Hop Label Forwarding Entry (NHLFE)

- NHLFE stores the next-hop information for forwarding MPLS packets
- A NHLFE should consist of
  - Next hop of the data packet
  - Link layer encapsulation used to forward the data packets
  - Code mode used to forward the packet label stack
Next Hop Label Forwarding Entry (NHLFE)

- NHLFE is used when forwarding a labeled packet
- The below screenshot is an example of “Forwarding Entry”

```
SP_SW2# show mpls forwarding-table
+-----------------+-----------------+-----------------+-----------------+-------------------+-------------------+
<table>
<thead>
<tr>
<th>LSP</th>
<th>FEC</th>
<th>In Label</th>
<th>Out Label</th>
<th>Out Interface</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>22.22.22.22/32</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>22.22.22.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>122.122.122.122/32</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>122.122.122.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>11.11.11.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 2</td>
<td>172.16.10.1</td>
</tr>
<tr>
<td>6</td>
<td>111.111.111.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 2</td>
<td>172.16.10.1</td>
</tr>
<tr>
<td>7</td>
<td>192.168.10.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 2</td>
<td>172.16.10.1</td>
</tr>
<tr>
<td>8</td>
<td>33.33.33.0/24</td>
<td>-</td>
<td>1000</td>
<td>VLAN 2</td>
<td>172.16.10.1</td>
</tr>
<tr>
<td>9</td>
<td>133.133.133.0/24</td>
<td>-</td>
<td>1001</td>
<td>VLAN 2</td>
<td>172.16.10.1</td>
</tr>
</tbody>
</table>
+-----------------+-----------------+----------+-----------+------------------+-------------------+
```

Total Entries: 9
Next Hop Label Forwarding Entry (NHLFE)

- Frame 1048 in underneath diagram demonstrates the network of 133.133.133.133, configured in vlan2, with MPLS label (1001), to harmonize the info shown in last slide.
**Incoming Label Map (ILM)**

- It (the Incoming Label Map) maps each incoming label to a set of NHLFE's
- ILM is used for forwarding packets that arrive as labeled packets
- Having the ILM map a label to a set containing more than one NHLFE may be useful if e.g. it is desired to do load balancing over multiple equal cost paths
- “mpls static ilm” is a D-Link switch command to add a static Incoming Label Map (ILM) entry
FEC-to-NHLFE Map (FTN)

- Should a packet arrived as “un-labeled”, in order to label this packet, the "FEC-to-NHLFE" (FTN) assists the LSR to map each FEC to a set of NHLFEs
- FTN maps each FEC to a series of NHLFEs
Label Swapping

- When forwarding a packet, there are two scenarios relating to Label Swapping
  - Forward a labeled packet
  - Forward an unlabeled packet
Label Swapping: Forward a Labeled Packet

- RFC 3031 states that “A LSR first examines the label at the top of the label stack”
- It (that LSR) uses the Incoming Label Map (ILM) to map this label to an The Next Hop Label Forwarding Entry (NHLFE)
- It then encodes the new label stack into the packet, and forwards the result
Label Swapping: Forward an Unlabeled Packet

- RFC 3031 defines that “A LSR analyzes the network layer header, to determine the packet's FEC”
- It then uses the FTN to map this to an NHLFE. Using the information in the NHLFE, it determines where to forward the packet, and performs an operation on the packet's label stack
- It then encodes the new label stack into the packet, and forwards the result
Virtual Routing and Forwarding (VRF)

- Is a technology that allows multiple instances of a routing table to co-exist within the same router at the same time.
- As the routing instances are independent, the same or overlapping IP addresses can be used without conflicting with each other.
- It aims to improve network performance since network paths can be segmented without requiring multiple routers.
- Deploys at small to medium enterprises and shared data centers.
- Can work independent with MPLS.
Virtual Routing and Forwarding (VRF)

- Types of Virtual Routing and Forwarding (VRF)
  - VRF Lite: when we use VRF without MPLS
  - VRF in MPLS network: when overlapped IP addressed is deployed in customer network

- A Power Point file on VRF can be retrieved from D-Track DEUR20100721000004
Virtual Routing and Forwarding (VRF) Lite

- When used inside a single router
- Each VRF instance is a separate router table
- By creating multiple route tables, we overcome the restrictions of multiple overlapping address spaces
- It also offers isolation to each tenant or area of the network
Virtual Private LAN Services (VPLS)

- Is a class of VPN that offers the connection of multiple sites in a single bridged domain over a managed IP/MPLS network.
- VPLS presents an Ethernet interface to customers, simplifying the LAN/WAN boundary for Service Providers and customers, and enabling rapid and flexible service provisioning, because the service bandwidth is not tied to the physical interface.
- The entire services in a VPLS appear to be on the same LAN, regardless of location.
- Also known as Transparent LAN Service.
Virtual Private LAN Services (VPLS)

- As stated in RFC 4762, the primary motivation behind Virtual Private LAN Services (VPLS) is to provide connectivity between geographically dispersed customer sites across MANs and WANs, as if they were connected using a LAN.
- The attachment circuit (AC) connected to the customer could be a physical Ethernet port, a logical (tagged) Ethernet port, an ATM PVC carrying Ethernet frames, etc., or even an Ethernet PW.
Virtual Private LAN Services (VPLS)

- VPLS is accomplished by incorporating MAC address learning, flooding, and forwarding functions in the context of pseudowires that connect these individual LANs across the packet switched network.
- Two types of addresses discovery:
  - Manual configuration
  - Auto-discovery procedure
VPLS Autodiscovery

- VPLS Autodiscovery activates individual Virtual Private LAN Service (VPLS) provider edge (PE) router to discover which other PE routers are part of the same VPLS domain.
- Automatically detects when PE routers are added to or removed from the VPLS domain.
- Works with Border Gateway Protocol (BGP) to discover the VPLS members and to set up and tear down pseudowires in the VPLS.
Virtual Private Wire Service (VPWS)

- Employs Layer 2 services over MPLS to build a topology of point-to-point connections that connect end customer sites in a VPN
- Is similar to Layer 2 services over MPLS, and employs a similar encapsulation scheme for forwarding traffic
Virtual Circuit Connectivity Verification (VCCV)

- As described in RFC5085, Virtual Circuit Connectivity Verification (VCCV) is designed for fault detection and diagnostic mechanisms that can be used for end-to-end fault detection and diagnostics for a Pseudowire.
- Also be used to verify and further diagnose the pseudowire forwarding path.
Virtual Circuit Connectivity Verification (VCCV)

- Wireshark example of Virtual Circuit Connectivity Verification (VCCV)

```
Frame 13: 108 bytes on wire (864 bits), 108 bytes captured (864 bits)
Ethernet II, Src: cc:01:0d:5c:00:10 (cc:01:0d:5c:00:10), Dst: cc:00:0d:5c:00:10 (cc:00:0d:5c:00:10)
MultiProtocol Label Switching Header, Label: 19, Exp: 5, S: 1, TTL: 254
Internet Protocol Version 4, Src: 1.1.2.1, Dst: 1.1.2.2

Label Distribution Protocol
  Version: 1
  PDU Length: 46
  LSR ID: 1.1.2.1
  Label Space ID: 0
  Label Mapping Message
    0...0... - U bit: Unknown bit not set
    Message Type: Label Mapping Message (0x400)
    Message Length: 36
    Message ID: 0x00000015
  Forwarding Equivalence Classes TLV
    00...0... - TLV Unknown bits: Known TLV, do not Forward (0x0)
    TLV Type: Forwarding Equivalence Classes TLV (0x100)
    TLV Length: 20

Interface Parameter: VCCV
  ID: VCCV (0x0c)
  Length: 4
  CC Type
    ...1 = PWE3 Control Word: True
    ...1. = MPLS Router Alert: True
    ...0. = MPLS Inner Label TTL = 1: False
  CV Type
    ...0 = ICMP Ping: False
    ...1. = LSP Ping: True
    ...0. = BFD IP/UDP-encapsulated, for PW Fault Detection only: False
```
MPLS Configuration Guide

- Multiprotocol Label Switching (MPLS)
- MPLS Terminology
- Label Distribution Protocol (LDP)
- Configuration Scenario #1
- Configuration Scenario #2
- Configuration Scenario #3
- Command Reference
Label Distribution Protocol (LDP)

- Is a signaling protocol for distributing labels in non-traffic-engineered applications
- Is responsible for the label binding information exchange activity
- Is to establish the LSP (Label Switch Path)
- Allows routing device to establish label-switched paths (LSPs) through a network by mapping network-layer routing information directly to data link layer-switched paths
- Once the connected interfaces of 2 routers being configured with “MPLP IP,” then, the LDP Neighboring relationship will be built up
Label Distribution Protocol (LDP)

- Is a protocol defined for distributing labels
- It is the set of procedures and messages by which Label Switched Routers (LSRs) establish Label Switched Paths (LSPs) through a network by mapping network-layer routing information directly to data-link layer switched paths
- It (LDP) associates a Forwarding Equivalence Class (FEC) with each LSP it creates
- The FEC associated with an LSP specifies which packets are "mapped" to that LSP. LSPs are extended through a network as each LSR "splices" incoming labels for a FEC to the outgoing label assigned to the next hop for the given FEC
Label Distribution Protocol (LDP)

- As characterized in RFC 5036, LDP defines messages, TLVs, and procedures in the following areas:
  - Peer discovery
  - Session management
  - Label distribution, and
  - Notification of errors and advisory information
- It (RFC 5036) also states that it (LDP) is the set of procedures and messages by which Label Switched Routers (LSRs) establish Label Switched Paths (LSPs) through a network by mapping network-layer routing information directly to data-link layer switched paths
Label Distribution Protocol (LDP)

- The LSR requests a label mapping from a neighboring LSR when it needs one, and advertises a label mapping to a neighboring LSR when it wishes the neighbor to use a label.
- LDP operation involves with the following messages:
  - Hello Message (UDP)
  - Session, Advertisement, and Notification messages (TCP)
- The UDP port for LDP Hello messages is 646
- The TCP port for establishing LDP session connections is 646
Quiz Session: Protocols in Frame (1/2)

According to underneath sketch, what “Protocols in Frame” are indicated from frame 314?

![Frame 314: 84 bytes on wire (672 bits), 84 bytes captured (672 bits) on interface 0](image)

- Interface id: 0 (\Device\NPF_3977636-707F-4015-A1CA-C3D63C9E28CC)
- Encapsulation type: Ethernet (1)
- [Time shift for this packet: 0.000000000 seconds]
- Epoch Time: 1486026870.618565000 seconds
- [Time delta from previous captured frame: 0.086561000 seconds]
- [Time delta from previous displayed frame: 1.000034000 seconds]
- [Time since reference or first frame: 448.807545000 seconds]
- Frame Number: 314
- Frame Length: 84 bytes (672 bits)
- Capture Length: 84 bytes (672 bits)
- [Frame is marked: False]
- [Frame is ignored: False]
- [Coloring Rule Name: UDP]
- [Coloring Rule String: udp]
Quiz Session: Protocols in Frame (2/2)

- Ans: eth, ethertype, ip, udp, ldp
Label Distribution Protocol (LDP) Identifier

- In D-Link switches, the LSR ID is recognized as the transport address.
- The transport address is used to establish an LDP TCP connection.
- Below sketch indicates the LSR with an ID of 77.77.77.77.
LDP Discovery

- A mechanism that enables an LSR to discover potential LDP peers
- An LSR periodically sends LDP Link Hellos out the interface
- They (LDP Link Hellos) are sent as UDP packets addressed to the well-known LDP discovery port for the "all routers on this subnet" group multicast address
LDP Discovery

- The “show mpls ldp discovery” D-Link switch command produces the information that the (55.55.57.55) interface of a DGS-3630 identifies 2 LDP neighbors, they are
  - 166.166.166.166, and
  - 77.77.77.77

```
DGS3630_SW1#show mpls ldp discovery

Local LDP Identifier: 55.55.57.55:0
Discovery Sources:
  Interfaces:
    VLAN 56 (LDP): xmit/recv
      LDP Id: 166.166.166.166:0
    VLAN 57 (LDP): xmit/recv
      LDP Id: 77.77.77.77:0

Targeted Hellos:

DGS3630_SW1#
```
LDP Sessions

- LDP sessions exist between LSRs to support label exchange between them
- LDP uses TCP as a reliable transport for sessions
- Under most of the circumstances, LDP sessions between LSRs that are directly connected at the link level
LDP Sessions

- By adapting the command of “show mpls ldp session,” it offers us an opportunity to view LDP session information from a specific LSR. Underneath sketch presents an example.

```
DGS3630_SW1# show mpls ldp session

<table>
<thead>
<tr>
<th>Peer</th>
<th>Status</th>
<th>Role</th>
<th>Keep Alive</th>
<th>Distribution Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>77.77.77.77:0</td>
<td>OPERATIONAL</td>
<td>Passive</td>
<td>40(Sec)</td>
<td>DU</td>
</tr>
<tr>
<td>166.166.166.166:0</td>
<td>OPERATIONAL</td>
<td>Passive</td>
<td>40(Sec)</td>
<td>DU</td>
</tr>
</tbody>
</table>

Total Entries: 2
```

D-Link Academy
Quiz Session: LDP sessions

- Q: In D-Link switches, what are the types of “LDP sessions” indicated via “show mpls ldp session” command?
Quiz Session: LDP sessions (Cont'd)

- Q: “LDP sessions” with “show mpls ldp session” command
- Ans: It starts with “NONEXISTENT” and arrives at “OPERATIONS” mode

```
DGS3630_Right_S#show mpls ldp session

+----------------+-----------+---------+---------------+---------------------+
<table>
<thead>
<tr>
<th>Peer</th>
<th>Status</th>
<th>Role</th>
<th>Keep Alive</th>
<th>Distribution Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>55.55.55.55:0</td>
<td>NONEXISTENT</td>
<td>Active</td>
<td>80(Sec)</td>
<td>DU</td>
</tr>
</tbody>
</table>
```

Total Entries: 1

```
DGS3630_Right_S#show mpls ldp session

+----------------+-----------+---------+---------------+---------------------+
<table>
<thead>
<tr>
<th>Peer</th>
<th>Status</th>
<th>Role</th>
<th>Keep Alive</th>
<th>Distribution Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>55.55.55.55:0</td>
<td>OPERATIONAL</td>
<td>Active</td>
<td>80(Sec)</td>
<td>DU</td>
</tr>
</tbody>
</table>
```

Total Entries: 1

DGS3630_Right_S#
Non-Directly Connected LDP Sessions (LSRs)

- Physical network connection: LSRa → LSR1 → LSR2 → LSRb
- A "traffic engineering" application requires LSRa sends traffic matching some criteria via an LSP to LSRb (non-directly connected LSP)
- As stated in RFC 5036: LSRa would apply two labels to traffic it forwards on the LSP to LSRb
  - A label learned from LSR1 to forward traffic along the LSP path from LSRa to LSRb, and
  - A label learned from LSRb to enable LSRb to label switch traffic arriving on the LSP
Non-Directly Connected LDP Sessions

- Nondirectly connected LSRs describes a LSR is more than one hop from its neighbor
- For these nondirectly connected neighbors, the LSR sends out a targeted Hello message as a UDP packet, but as a unicast message specifically addressed to that LSR
- The nondirectly connected LSR responds to the Hello message and the two routers begin to establish an LDP session
Type-Length-Value Encoding (1/3)

- Type-Length-Value (TLV)
  - All LDP messages have a common structure that uses a Type-Length-Value
  - Is used to encode much of the information carried in LDP messages
  - The Value part of a TLV-encoded object (TLV), may itself contain one or more TLVs
Type-Length-Value Encoding (2/3)

- There are several parameters used by more than one LDP message. For example
  - Forwarding Equivalence Classes (FECs) TLV
  - Generic Label TLV
  - Address List TLV, and
  - Hop Count TLV

- Given a diagram as attached in next slide presents the TLVs being described above
Type-Length-Value Encoding (3/3)

- Type-Length-Value Encoding

<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>VLAN_ID</th>
<th>MPLS Label</th>
<th>Length</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>168</td>
<td>2016-12-01</td>
<td>166.166.166.166</td>
<td>55.55.57.55</td>
<td>LDP</td>
<td></td>
<td></td>
<td></td>
<td>108 Label Mapping Message</td>
</tr>
<tr>
<td>170</td>
<td>2016-12-01</td>
<td>166.166.166.166</td>
<td>55.55.57.55</td>
<td>LDP</td>
<td></td>
<td></td>
<td></td>
<td>397 Label Request Message</td>
</tr>
<tr>
<td>171</td>
<td>2016-12-01</td>
<td>166.166.166.166</td>
<td>55.55.57.55</td>
<td>LDP</td>
<td></td>
<td></td>
<td></td>
<td>108 Label Mapping Message</td>
</tr>
</tbody>
</table>

- Frame 168: 108 bytes on wire (864 bits), 108 bytes captured (864 bits)
- Internet Protocol Version 4, Src: 166.166.166.166, Dst: 55.55.57.55
- Label Distribution Protocol
  - Version: 1
  - PDU Length: 58
  - LSR ID: 166.166.166.166
  - Label Space ID: 0
  - Label Mapping Message
    - 0...000 = U bit: Unknown bit not set
    - Message Type: Label Mapping Message (0x400)
    - Message Length: 28
    - Message ID: 0x00000000
  - Forwarding Equivalence Classes TLV
    - 00...000 = TLV Unknown bits: Known TLV, do not Forward (0x0)
    - TLV Type: Forwarding Equivalence Classes TLV (0x100)
    - TLV Length: 7
  - FEC Elements
  - Generic Label TLV
    - 00...000 = TLV Unknown bits: Known TLV, do not Forward (0x0)
    - TLV Type: Generic Label TLV (0x200)
    - TLV Length: 4
    - 0000 0000 0000 0000 0000 0000 0000 0000 - Generic Label: 0x0000
  - Hop Count TLV
    - 00...000 = TLV Unknown bits: Known TLV, do not Forward (0x0)
    - TLV Type: Hop Count TLV (0x103)
    - TLV Length: 1
    - Hop Count Value: 1
Forwarding Equivalence Classes (FECs) TLV

- FEC Element value: Wildcard or Prefix
- In “Prefix FEC Element,” the Prefix indicates the address being carried in this FEC

- Pop quiz: What is the prefix associated in Frame 168, as attached in next slide?
Forwarding Equivalence Classes (FECs) TLV

- **FEC Element value**: Wildcard or Prefix

```plaintext
Version: 1
PDU Length: 38
LSR ID: 166.166.166.166
Label Space ID: 0

Label Mapping Message
  0... .... = U bit: Unknown bit not set
  Message Type: Label Mapping Message (0x400)
  Message Length: 28
  Message ID: 0x00000008

Forwarding Equivalence Classes TLV
  00... .... = TLV Unknown bits: Known TLV, do not Forward (0x0)
  TLV Type: Forwarding Equivalence Classes TLV (0x100)
  TLV Length: 7

FEC Elements
  FEC Element 1
    FEC Element Type: Prefix FEC (2)
    FEC Element Address Type: IPv4 (1)
    FEC Element Length: 24
    Prefix: 66.66.66.0

Generic Label TLV
  00... .... = TLV Unknown bits: Known TLV, do not Forward (0x0)
```
Label TLVs

- Label TLVs encode labels
- Label TLVs are carried by the messages used to advertise, request, release, and withdraw label mappings
- Several different kinds of Label TLVs
  - Generic Label TLV
  - ATM Label TLV
  - Frame Relay Label TLV
Label TLVs (Generic Label TLV)

- Generic Label TLVs encode labels for use on links
- Label values are independent of the underlying link technology, such as PPP or Ethernet
- A label is a 20-bit label value represented as a 20-bit number in a 4 octet field
- Quiz: In Frame 172, displayed in next slide, what is the Generic Label being implemented here?
Label TLVs (Generic Label TLV)

- Generic Label TLVs

<table>
<thead>
<tr>
<th>No. ^</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>VLAN_ID</th>
<th>MPLS Label</th>
<th>Length</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>171</td>
<td>2016-12-01 18:35:13.137064</td>
<td>55.55.57.55</td>
<td>166.166.166.166</td>
<td>LDP</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>172</td>
<td>2016-12-01 18:35:13.138015</td>
<td>55.55.57.55</td>
<td>166.166.166.166</td>
<td>LDP</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>173</td>
<td>2016-12-01 18:35:13.159119</td>
<td>166.166.166.166</td>
<td>55.55.57.55</td>
<td>LDP</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Frame 172: 566 bytes on wire (4528 bits), 566 bytes captured (4528 bits)
- Internet Protocol Version 4, Src: 55.55.57.55, Dst: 166.166.166.166

- Label Distribution Protocol
  - Version: 1
  - PDU Length: 38
  - LSR ID: 55.55.57.55
  - Label Space ID: 0

- Label Mapping Message
  - 0... .... = U bit: Unknown bit not set
  - Message Type: Label Mapping Message (0x400)
  - Message Length: 28
  - Message ID: 0x000000017

- Forwarding Equivalence Classes TLV

- Generic Label TLV
  - 00... .... = TLV Unknown bits: Known TLV, do not Forward (0x0)
  - TLV Type: Generic Label TLV (0x200)
  - TLV Length: 4
  - .......... .... 0000 0000 0000 0000 0011 = Generic Label: 0x00003
Address List TLV

- The Address List TLV appears in Address and Address Withdraw messages.
- “Addresses” shows a list of addresses from the specified Address Family.
Address List TLV

- The below sketch displays the addresses being listed here: 192.168.57.7, 7.7.7.7, and 77.77.77.77

<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>Length</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>225</td>
<td>2016-12-01 18:35:20.5653817</td>
<td>55.55.57.55</td>
<td>77.77.77.77</td>
<td>LDP</td>
<td></td>
<td>04 Keep Alive Message</td>
</tr>
<tr>
<td>226</td>
<td>2016-12-01 18:35:20.565362</td>
<td>77.77.77.77</td>
<td>55.55.57.55</td>
<td>LDP</td>
<td></td>
<td>102 Address Message</td>
</tr>
<tr>
<td>227</td>
<td>2016-12-01 18:35:20.566542</td>
<td>55.55.57.55</td>
<td>77.77.77.77</td>
<td>LDP</td>
<td></td>
<td>114 Address Message</td>
</tr>
</tbody>
</table>

Frame 226: 102 bytes on wire (816 bits), 102 bytes captured (816 bits)
Internet Protocol Version 4, Src: 77.77.77.77, Dst: 55.55.57.55

Label Distribution Protocol
- Version: 1
- PDU Length: 32
- LSR ID: 77.77.77.77
- Label Space ID: 0

Address Message
- U bit: Unknown bit not set
- Message Type: Address Message (0x300)
- Message Length: 22
- Message ID: 0x00000004

Address List TLV
- TLV Unknown bits: Known TLV, do not Forward (0x0)
- TLV Type: Address List TLV (0x101)
- TLV Length: 14
- Address Family: IPv4 (1)

Addresses
- Address 1: 192.168.57.7
- Address 2: 7.7.7.7
- Address 3: 77.77.77.77
Address List TLV

- As stated, the Address List TLV also appears in Address Withdraw messages
- The Frame 1312 serves as an explanatory note
Quiz Session: Address List TLV

- Quiz: Does Address List TLV occupy any TLV parameter role in Label Withdrawal Message?

![Table and Frame Snippet]

- Frame 2296: 103 bytes on wire (824 bits), 103 bytes captured (824 bits)
- Internet Protocol Version 4, Src: 55.55.57.55, Dst: 77.77.77.77

- Label Distribution Protocol
  - Version: 1
  - PDU Length: 33
  - LSR ID: 55.55.57.55
  - Label Space ID: 0

- Label Withdrawal Message
  - U bit: Unknown bit not set
  - Message Type: Label Withdrawal Message (0x402)
  - Message Length: 23
  - Message ID: 0x000000197

- Forwarding Equivalence Classes TLV
- Generic Label TLV
Hop Count TLV

- Hop Count calculates the number of LSR hops along an LSP as the LSP is being set up

- When LSRa receives a “Label Mapping” or “Label Request” message with the Hop Count TLV, LSRa might propagate:
  - The Label Mapping message for the LSP to an upstream peer
    - If LSRa is a member of the edge set of an LSR domain: reset the hop count to 1
    - If not, LSRs MUST increment the received hop count
  - The Label Request message to a downstream peer to continue the LSP setup (LSRa MUST increment the received hop count)
Path Vector TLV

- Is used with the Hop Count TLV in Label Request and Label Mapping messages
- To implement the optional LDP Loop Detection mechanism
- In Label Mapping message, a Path Vector TLV records the path of LSRs a label advertisement has traversed to set up an LSP
Status TLV

- Status TLVs is displayed in Notification messages regarding specific events being signaled
- Status Code consists of
  - E-bit: Fatal error bit
    ✓ If set (=1), this is a fatal Error Notification
    ✓ If clear (=0), this is an Advisory Notification
  - F-bit: Forward bit
    ✓ If set (=1), the notification SHOULD be forwarded to the LSR for the next-hop or previous-hop for the LSP
    ✓ If clear (=0), the notification SHOULD NOT be forwarded
Status TLV

- Frame 2260, as indicated below, is an example of Status TLV
Type of LDP Messages

- Type of Messages
  - **Message Name**
  - Notification
  - Hello
  - Initialization
  - KeepAlive
  - Address
  - Address Withdraw
  - Label Mapping
  - Label Request
  - Label Abort Request
  - Label Withdraw
  - Label Release

- **Section Title**
  - "Notification Message"
  - "Hello Message"
  - "Initialization Message"
  - "KeepAlive Message"
  - "Address Message"
  - "Address Withdraw Message"
  - "Label Mapping Message"
  - "Label Request Message"
  - "Label Abort Request Message"
  - "Label Withdraw Message"
  - "Label Release Message"
LDP Messages (four categories)

- There are four categories of LDP messages (RFC5036)
- **Discovery messages**: to announce and maintain the presence of an LSR in a network
- **Session messages**: to establish, maintain, and terminate sessions between LDP peers
- **Advertisement messages**: to create, change, and delete label mappings for FECs
- **Notification messages**: to provide advisory information and to signal error information
LDP Messages between 2 LSRs (1/2)

- LDP Messages between Router_A and Router_B
- Router_A says: I am a MPLS enabled router (Hello Message, UDP)
- Router_B plans to establish a session with Router_A (Initialization Message, TCP)
- Router_A and Router_B become LDP peers (Advertisement Message, TCP)
LDP Messages between 2 LSRs (2/2)

- LDP Messages between Router_A and Router_B (Cont'd)
- To enable LSRs start mapping between a peer LDP Identifier and the peer's addresses, Router_A and Router_B advertise their addresses (LDP Address Message and LDP Withdraw Address Message, TCP)
- Router_A and Router_B become LDP peers (Advertisement Message, TCP)
- Router_B requests a label from Router_A (Label Request Message, TCP)
- Router_A advertises a label to its neighbor Router_B (Label Mapping Message, TCP)
Label Distribution Behavior

- Receive Label Request Message
- Receive Label Mapping Message
- Receive Label Abort Request Message
- Receive Label Release Message
- Receive Label Withdraw Message
- Recognize new FEC
- Detect change in FEC next hop
Label Distribution Behavior (Cont'd)

- Receive Notification Message / Label Request Aborted
- Receive Notification Message / No Label Resources
- Receive Notification Message / No Route
- Receive Notification Message / Loop Detected
- Receive Notification Message / Label Resources Available
- Detect local label resources have become available
- LSR decides to no longer label switch a FEC
- Timeout of deferred label request
LDP Message Exchange

- **Hello (Discovery) Message**
  - Announce and maintain the presence of a router in a network
  - Hello messages are transmitted as UDP packets to the LDP port at the group multicast address for all routers on the subnet
  - TLVs included in Hello Message
    - Common Hello Parameters TLV
    - Configuration Sequence Number TLV
    - IPv4 Transport Address TLV
    - IPv6 Transport Address TLV
Type-Length-Value (TLV) in Hello Message

- An example of TLVs included in a Hello Message?

<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>Length</th>
<th>Info</th>
</tr>
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<tbody>
<tr>
<td>3425</td>
<td>2016-12-01 18:49:51.889207</td>
<td>192.168.57.5</td>
<td>224.0.0.2</td>
<td>LDP</td>
<td>84</td>
<td>Hello Message</td>
</tr>
<tr>
<td>3424</td>
<td>2016-12-01 18:49:51.728939</td>
<td>192.168.57.7</td>
<td>224.0.0.2</td>
<td>LDP</td>
<td>84</td>
<td>Hello Message</td>
</tr>
<tr>
<td>3422</td>
<td>2016-12-01 18:49:51.195198</td>
<td>192.168.56.6</td>
<td>224.0.0.2</td>
<td>LDP</td>
<td>84</td>
<td>Hello Message</td>
</tr>
</tbody>
</table>

- Frame 3424: 84 bytes on wire (672 bits), 84 bytes captured (672 bits)
- Ethernet II, Src: D-LinkIn_39:94:01 (6c:72:20:39:94:01), Dst: IPv4mcast_02 (01:00:5e:00:00:02)
- Internet Protocol Version 4, Src: 192.168.57.7, Dst: 224.0.0.2
- User Datagram Protocol, Src Port: 646, Dst Port: 646

Label Distribution Protocol

Version: 1
PDU Length: 38
LSR ID: 77.77.77.77
Label Space ID: 0

Hello Message

- U bit: Unknown bit not set
- Message Type: Hello Message (0x100)
- Message Length: 28
- Message ID: 0x0000011b

- Common Hello Parameters TLV
- Configuration Sequence Number TLV
- IPv4 Transport Address TLV
LDP Message Exchange

- **Hello (Discovery) Message**
  - Announce and maintain the presence of a router in a network
  - Hello messages are transmitted as UDP packets to the LDP port at the group multicast address for all routers on the subnet

---

**Table:**

<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>MPLS Label</th>
<th>LSP Type</th>
<th>Length</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>35</td>
<td>2016-12-01 18:34:31.657537</td>
<td>192.168.56.5</td>
<td>224.0.0.2</td>
<td>LDP</td>
<td></td>
<td></td>
<td></td>
<td>84 Hello Message</td>
</tr>
<tr>
<td>36</td>
<td>2016-12-01 18:34:31.658548</td>
<td>192.168.57.5</td>
<td>224.0.0.2</td>
<td>LDP</td>
<td></td>
<td></td>
<td></td>
<td>84 Hello Message</td>
</tr>
<tr>
<td>55</td>
<td>2016-12-01 18:34:36.531844</td>
<td>192.168.56.5</td>
<td>224.0.0.2</td>
<td>LDP</td>
<td></td>
<td></td>
<td></td>
<td>84 Hello Message</td>
</tr>
<tr>
<td>56</td>
<td>2016-12-01 18:34:36.532707</td>
<td>192.168.57.5</td>
<td>224.0.0.2</td>
<td>LDP</td>
<td></td>
<td></td>
<td></td>
<td>84 Hello Message</td>
</tr>
</tbody>
</table>

Frame 35: 84 bytes on wire (672 bits), 84 bytes captured (672 bits)
Ethernet II, Src: D-LinkIn_3c:58:02 (6c:72:20:3c:58:02), Dst: IPv4mcast_02 (01:00:5e:00:00:02)
Internet Protocol Version 4, Src: 192.168.57.5, Dst: 224.0.0.2
User Datagram Protocol, Src Port: 646, Dst Port: 646

Source Port: 646
Destination Port: 646
Length: 50
Checksum: 0x328e [unverified]
[Checksum Status: Unverified]
[Stream index: 5]

Label Distribution Protocol
LDP Message Exchange

- **Hello (Discovery) Message**
  - Uses the UDP encapsulation with the destination port 646
  - The destination address is the multicast address (IP: 224.0.0.2)
  - After the LSR neighbor is discovered, LDP (Label Distribution Protocol) triggers the establishment of the LDP session
LDP Message Exchange

- **Hello (Discovery) Message**
  - Hello hold time (in seconds) specifies the time the sending LSR will maintain its record of Hellos from the receiving LSR without receipt of another Hello.
Case Study: Hello Message (1/2)

- In “Targeted Hello”
  - A value of 1 specifies that this Hello is a **Targeted Hello**, and
  - A value of 0 specifies that this Hello is a **Link Hello**

- LDP Targeted Hellos are sent as UDP packets addressed to the well-known LDP discovery port at the specific address

- A Targeted Hello is sent to a specific address rather than (Link Hello) to the "all routers" group multicast address for the outgoing interface

- An instance of “Link Hello” was presented in last slide
**Case Study: Hello Message (2/2)**

- Frame 43, as presented here, displays “Targeted Hello”

<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>Length</th>
<th>Info</th>
</tr>
</thead>
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<tr>
<td>43</td>
<td>2016-01-20</td>
<td>10.17.0.1</td>
<td>224.0.0.2</td>
<td>LDP</td>
<td>80</td>
<td>Hello Message</td>
</tr>
<tr>
<td>44</td>
<td>2016-01-20</td>
<td>10.17.0.2</td>
<td>10.15.0.3</td>
<td>LDP</td>
<td>88</td>
<td>Hello Message</td>
</tr>
<tr>
<td></td>
<td>2016-01-20</td>
<td>10.17.0.2</td>
<td>224.0.0.2</td>
<td>LDP</td>
<td>88</td>
<td>Hello Message</td>
</tr>
</tbody>
</table>

Frame 43: 88 bytes on wire (704 bits), 88 bytes captured (704 bits) on interface 0

Ethernet II, Src: D-LinkIn_ ae:08:00 (3c:1e:04:ae:08:00), Dst: CiscoInc_12:dc:00 (58:8d:09:12:dc:00)

802.1Q Virtual LAN, PRI: 0, CFI: 0, ID: 71

Internet Protocol Version 4, Src: 10.17.0.2, Dst: 10.15.0.3

User Datagram Protocol, Src Port: 646, Dst Port: 646

**Label Distribution Protocol**

Version: 1
PDU Length: 38
LSR ID: 10.15.0.4
Label Space ID: 0

**Hello Message**

0... .... = U bit: Unknown bit not set
Message Type: Hello Message (0x100)
Message Length: 28
Message ID: 0x0000dd7f2

**Common Hello Parameters TLV**

00... .... = TLV Unknown bits: Known TLV, do not Forward (0x0)
TLV Type: Common Hello Parameters TLV (0x400)
TLV Length: 4
Hold Time: 45

1... .... .... .... = Targeted Hello: Targeted Hello
0... .... .... .... = Hello Requested: Source does not request periodic hellos

0... .... .... .... = GTSM Flag: Not set

[Expert Info (Warning/Protocol): GTSM is not supported by the source, since basic discovery is not enabled]
LDP Message Exchange

- Initialization (Session) Message
  - The Initialization message carries both the LDP Identifier for the sender's (active LSR's) label space and the LDP Identifier for the receiver's (passive LSR's) label space
    - When routerB receives an Initialization message, it attempts to match the LDP Identifier carried by the message Protocol Data Units (PDU) with a Hello adjacency
    - Next routerB checks whether the session parameters proposed in the message are acceptable
    - If session parameters are acceptable, routerB replies with an Initialization message of its own to propose the parameters it wishes to use and a KeepAlive message to signal acceptance of routerA's parameters
LDP Message Exchange

- Initialization (Session) Message
  - TLVs included in Initialization Message
    - Common Session Parameters TLV
LDP Message Exchange

- Initialization (Session) Message
  - Router_A (55.55.57.55) establishes a session with Router_B (166.166.166.166) learned through the hello message, it uses the LDP initialization procedure over TCP transport.

<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source IP</th>
<th>Destination IP</th>
<th>Protocol</th>
<th>MPLS Label</th>
<th>LSP Type</th>
<th>Length</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>34</td>
<td>2016-12-01 18:49:52.059335</td>
<td>192.168.56.5</td>
<td>224.0.0.2</td>
<td>LDP</td>
<td></td>
<td></td>
<td></td>
<td>84 Hello Message</td>
</tr>
<tr>
<td>159</td>
<td>2016-12-01 18:35:11.129220</td>
<td>166.166.166.166</td>
<td>55.55.57.55</td>
<td>LDP</td>
<td></td>
<td></td>
<td></td>
<td>102 Initialization Message</td>
</tr>
<tr>
<td>160</td>
<td>2016-12-01 18:35:11.131017</td>
<td>55.55.57.55</td>
<td>166.166.166.166</td>
<td>LDP</td>
<td></td>
<td></td>
<td></td>
<td>102 Initialization Message</td>
</tr>
<tr>
<td>222</td>
<td>2016-12-01 18:35:20.550542</td>
<td>77.77.77.77</td>
<td>55.55.57.55</td>
<td>LDP</td>
<td></td>
<td></td>
<td></td>
<td>102 Initialization Message</td>
</tr>
<tr>
<td>223</td>
<td>2016-12-01 18:35:20.561406</td>
<td>55.55.57.55</td>
<td>77.77.77.77</td>
<td>LDP</td>
<td></td>
<td></td>
<td></td>
<td>102 Initialization Message</td>
</tr>
</tbody>
</table>

Frame 160: 102 bytes on wire (816 bits), 102 bytes captured (816 bits)
Internet Protocol Version 4, Src: 55.55.57.55, Dst: 166.166.166.166

Source Port: 646
Destination Port: 1026
Stream index: 2
[TCP Segment Len: 36]
Sequence number: 1 (relative sequence number)
[Next sequence number: 37 (relative sequence number)]
Acknowledgment number: 37 (relative ack number)
Header Length: 32 bytes
Flags: 0x018 (PSH, ACK)
Window size value: 8192
[Calculated window size: 8192]
LDP Message Exchange

- Initialization (Session) Message components
  - Message Type
  - Protocol Version: specifies LDP protocol version 1
  - Session Keep Alive Time: the receiving LSR MUST calculate the value of the KeepAlive Timer by using the smaller of its proposed KeepAlive Time and the KeepAlive Time received in the PDU. It means the maximum number of seconds that may elapse between the receipt of successive PDUs from the LDP peer on the session TCP connection
  - Loop Detection: discloses whether Loop Detection based on Path Vectors is enabled
LDP Message Exchange

- Initialization (Session) Message (Frame 393 as an example)
  - Message Type
  - Session Keep Alive Time
  - Session Max PDU (Protocol Data Units) Length

<table>
<thead>
<tr>
<th>No</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>VLAN_ID</th>
<th>MPLS Label</th>
<th>Length</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>387</td>
<td>2016-12-01 17:58:12.759281</td>
<td>192.168.56.5</td>
<td>224.0.0.2</td>
<td>LDP</td>
<td></td>
<td></td>
<td>84</td>
<td>Hello Message</td>
</tr>
<tr>
<td>388</td>
<td>2016-12-01 17:50:12.03432</td>
<td>192.160.57.5</td>
<td>224.0.0.2</td>
<td>LDP</td>
<td></td>
<td></td>
<td>84</td>
<td>Hello Message</td>
</tr>
<tr>
<td>393</td>
<td>2016-12-01 17:50:13.021414</td>
<td>77.77.77.77</td>
<td>55.55.52.55</td>
<td>LDP</td>
<td></td>
<td></td>
<td>102</td>
<td>Initialization Message</td>
</tr>
<tr>
<td>394</td>
<td>2016-12-01 17:50:13.021341</td>
<td>55.55.57.55</td>
<td>77.77.77.77</td>
<td>LDP</td>
<td></td>
<td></td>
<td>102</td>
<td>Initialization Message</td>
</tr>
<tr>
<td>395</td>
<td>2016-12-01 17:50:13.024380</td>
<td>77.77.77.77</td>
<td>55.55.57.55</td>
<td>LDP</td>
<td></td>
<td></td>
<td>102</td>
<td>Initialization Message</td>
</tr>
</tbody>
</table>

Frame 393: 182 bytes on wire (616 bits), 182 bytes captured (616 bits)
- Internet Protocol Version 4, Src: 77.77.77.77, Dst: 55.55.57.55

Label Distribution Protocol

Version: 1
PDU Length: 32
LSR ID: 77.77.77.77
Label Space ID: 0

Initialization Message
0... ... = U bit: Unknown bit not set

Message Type: Initialization Message (0x200)
Message Length: 22
Message ID: 0x00000004

Common Session Parameters TLV
0... ... = TLV Unknown bits: Known TLV, do not Forward (0x0)
TLV Type: Common Session Parameters TLV (0x500)
TLV Length: 14

Parameters
Session Protocol Version: 1
Session KeepAlive Time: 40
0... ... = Session Label Advertisement Discipline: Downstream Unsolicited proposed
0... ... = Session Loop Detection: Loop Detection Disabled
Session Path Vector Limit: 0
Session Max PDU Length: 1500
Session Receiver LSR Identifier: 55.55.57.55
LDP Message Exchange

- Frame 159 in the diagram displays the sender (166.166.166.166) and receiver (55.55.57.55).
LDP Message Exchange

- Initialization (Session) Message
  - Max PDU Length: A value of 255 or less specifies the default maximum length of 4096 octets
  - Receiver LDP Identifier: the receiver's label space

<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>VLAN_ID</th>
<th>MPLSLabel</th>
<th>Length</th>
<th>Info</th>
</tr>
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<tbody>
<tr>
<td>2001</td>
<td>2016-12-22 18:54:13.512443</td>
<td>192.168.10.1</td>
<td>224.0.0.2</td>
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<td>3</td>
<td></td>
<td></td>
<td>88 Hello Message</td>
</tr>
<tr>
<td>1368</td>
<td>2016-12-22 18:50:09.580996</td>
<td>133.133.133.133</td>
<td>111.111.111.111</td>
<td>LDP</td>
<td>3</td>
<td></td>
<td></td>
<td>100 Initialization Message</td>
</tr>
<tr>
<td>1369</td>
<td>2016-12-22 18:50:09.580949</td>
<td>111.111.111.111</td>
<td>111.111.111.111</td>
<td>LDP</td>
<td>3</td>
<td></td>
<td></td>
<td>100 Initialization Message</td>
</tr>
</tbody>
</table>

Frame 1368: 180 bytes on wire (048 bits), 106 bytes captured (048 bits)
802.1Q Virtual LAN, PRI: 0, CFI: 0, ID: 2
Internet Protocol Version 4, Src: 133.133.133.133, Dst: 111.111.111.111
Transmission Control Protocol, Src Port: 1027, Dst Port: 646, Seq: 1, Ack: 1, Len: 36

Label Distribution Protocol

Version: 1
PDU Length: 32
LSR ID: 133.133.133.133
Label Space ID: 0

Initialization Message

00000000 = U bit: Unknown bit not set
Message Type: Initialization Message (0x200)
Message Length: 22
Message ID: 0x00000007

Common Session Parameters TLV

00000000 = TLV Unknown bits: Known TLV, do not forward (0x0)
TLV Type: Common Session Parameters TLV (0x500)
TLV Length: 14

Parameters

- Session Protocol Version: 1
- Session KeepAlive Time: 40
- 00000000 = Session Label Advertisement Discipline: Downstream Unsolicited proposed
- 00000000 = Session Loop Detection: Loop Detection Disabled
- Session Path Vector Limit: 0
- Session Max PDU Length: 1580
- Session Receiver LSR Identifier: 111.111.111.111
- Session Receiver Label Space Identifier: 0
MPLS Session Loop Detection

- In MPLS Initialization Message, there is a parameter named: Session Loop Detection
- “Session loop detection” is located in “Common Session Parameters TLV” with two possible options:
  - A value of 0 means that Loop Detection is disabled
  - A value of 1 means that Loop Detection is enabled (indicating Loop Detection based on Path Vectors is enabled)
Quiz Session: MPLS Session Loop Detection

- In Frame 4900, what is the implemented Loop Detection status?

```
<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>Length</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>4896</td>
<td>2016-11-29 20:00:53.208259</td>
<td>192.168.56.6</td>
<td>192.168.56.5</td>
<td>LDP</td>
<td>84</td>
<td>Hello Message</td>
</tr>
<tr>
<td>4900</td>
<td>2016-11-29 20:00:54.619117</td>
<td>77.77.77.77</td>
<td>55.55.57.55</td>
<td>LDP</td>
<td>102</td>
<td>Initialization Message</td>
</tr>
<tr>
<td>4901</td>
<td>2016-11-29 20:00:54.620283</td>
<td>55.55.57.55</td>
<td>77.77.77.77</td>
<td>LDP</td>
<td>98</td>
<td>Notification Message</td>
</tr>
</tbody>
</table>

Frame 4900: 102 bytes on wire (816 bits), 102 bytes captured (816 bits)
Internet Protocol Version 4, Src: 77.77.77.77, Dst: 55.55.57.55
Transmission Control Protocol, Src Port: 1029, Dst Port: 646, Seq: 1, Ack: 1, Len: 36
Label Distribution Protocol

Version: 1
PDU Length: 32
LSR ID: 77.77.77.77
Label Space ID: 0

Initialization Message
0... .... - U bit: Unknown bit not set
Message Type: Initialization Message (0x200)
Message Length: 22
Message ID: 0x0000004d

Common Session Parameters TLV
00... .... - TLV Unknown bits: Known TLV, do not Forward (0x0)
TLV Type: Common Session Parameters TLV (0x500)
TLV Length: 14

Parameters
Session Protocol Version: 1
Session KeepAlive Time: 40
0... .... - Session Label Advertisement Discipline: Downstream Unsolicited proposed
0... .... - Session Loop Detection: Loop Detection Disabled
Session Path Vector Limit: 0
Session Max PDU Length: 1500
Session Receiver LSR Identifier: 55.55.57.55
Session Receiver Label Space Identification: 0
```
LDP Message Exchange

- Session Level Advertisement Discipline
  - Indicates the type of Label advertisement
  - A value of 0 means *Downstream Unsolicited Advertisement*
  - A value of 1 means *Downstream On Demand*
LDP Message Exchange

- Session Level Advertisement Discipline
  - Downstream on Demand Label Advertisement: the upstream LSR is responsible for requesting label mappings as needed
    ✓ It is used for a label-controlled ATM link or a label-controlled Frame Relay link
  - Downstream Unsolicited Label Advertisement: the downstream LSR is responsible for advertising a label mapping when it wants an upstream LSR to use the label
LDP Message Exchange

- Initialization (Session) Message
  - Frame 1396 is “Downstream-Unsolicited Distribution Mode”

```
<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>VLAN_ID</th>
<th>MPLS Label</th>
<th>Length</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>1396</td>
<td>2018-12-22 18:58:13.625216</td>
<td>111.111.111.111</td>
<td>122.122.122.122</td>
<td>LDP</td>
<td>2</td>
<td>166 Initialization Message</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1396</td>
<td>2018-12-22 18:58:13.625216</td>
<td>111.111.111.111</td>
<td>122.122.122.122</td>
<td>LDP</td>
<td>2</td>
<td>166 Initialization Message</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Frame 1396: 166 bytes on wire (448 bits), 166 bytes captured (448 bits)
```

- Ethernet II, Src: D-LinkIn_3c:58:01 (6c:72:20:3c:58:01), Dst: D-LinkIn_3c:58:01 (6c:72:20:3c:58:01)
- IPv4, Src: 111.111.111.111, Dst: 122.122.122.122
- Label Distribution Protocol
  - Version: 1
  - PDU Length: 32
  - LSR ID: 111.111.111.111
  - Label Space ID: 0
  - Initialization Message
    - 0... .... = 8 bit: Unknown bit not set
    - Message Type: Initialization Message (0x200)
    - Message Length: 22
    - Message ID: 0x000061c
  - Common Session Parameters TLV
    - 00... .... = TLV Unknown bits: Known TLV, do not Forward (0x0)
    - TLV Type: Common Session Parameters TLV (0x500)
    - TLV Length: 14
  - Parameters
    - Session Protocol Version: 1
    - Session KeepAlive Time: 40
    - 0... .... = Session Label Advertisement Discipline: Downstream Unsolicited proposed
    - 0... .... = Session Loop Detection: Loop Detection Disabled
    - Session Path Vector Limit: 0
    - Session Max PDU Length: 1500
LDP Message Exchange

- Initialization (Session) Message
  - Example of “Initialization message” and “KeepAlive message” with a logical sequence in below diagram

- The “Session Initialization Flows” in next four slides bring information in details
LDP Message Exchange

- KeepAlive Message
  - It is used as a mechanism that monitors the integrity of the LDP session transport connection
  - TLVs included in KeepAlive Message: None
Session Initialization Flows (1/4)

- Session Initialization Flows
  - Session Initialization Flows are going to be explained here using Frame 159 and Frame 162, as displayed here.

<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>VLAN ID</th>
<th>MPLS Label</th>
<th>Length</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>155</td>
<td>2016-12-01 18:35:10.701911</td>
<td>192.168.57.5</td>
<td>224.0.0.2</td>
<td>LDP</td>
<td></td>
<td></td>
<td>84</td>
<td>Hello Message</td>
</tr>
<tr>
<td>159</td>
<td>2016-12-01 18:35:11.129220</td>
<td>166.166.166.166</td>
<td>55.55.57.55</td>
<td>LDP</td>
<td></td>
<td></td>
<td></td>
<td>102 Initialization Message</td>
</tr>
<tr>
<td>160</td>
<td>2016-12-01 18:35:11.131017</td>
<td>55.55.57.5</td>
<td>166.166.166.166</td>
<td>LDP</td>
<td></td>
<td></td>
<td></td>
<td>102 Initialization Message</td>
</tr>
<tr>
<td>161</td>
<td>2016-12-01 18:35:11.132276</td>
<td>166.166.166.166</td>
<td>55.55.57.55</td>
<td>LDP</td>
<td></td>
<td></td>
<td></td>
<td>84 Keep Alive Message</td>
</tr>
<tr>
<td>162</td>
<td>2016-12-01 18:35:11.133394</td>
<td>55.55.57.5</td>
<td>166.166.166.166</td>
<td>LDP</td>
<td></td>
<td></td>
<td></td>
<td>84 Keep Alive Message</td>
</tr>
<tr>
<td>163</td>
<td>2016-12-01 18:35:11.135061</td>
<td>166.166.166.166</td>
<td>55.55.57.55</td>
<td>LDP</td>
<td></td>
<td></td>
<td></td>
<td>102 Address Message</td>
</tr>
</tbody>
</table>
Session Initialization Flows (2/4)

- Session Initialization Flows
  - Once matching Hello adjacency is generated, the adjacency specifies the local label space for the session
  - LSR (166.166.166.166) replies with an Initialization message of its own to propose the parameters it wishes to use to LSR (55.55.57.55)
  - The activity is stated in the diagram shown in next slide
Session Initialization Flows (3/4)

- Session Initialization Flows
  - Frame 159: What components indicated in “Parameters”?

```
<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>VLAN ID</th>
<th>MPLS Label</th>
<th>Length</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>155</td>
<td>2016-12-01 18:35:10.701911</td>
<td>192.168.57.5</td>
<td>224.6.8.2</td>
<td>LDP</td>
<td></td>
<td></td>
<td></td>
<td>84 Hello Message</td>
</tr>
<tr>
<td>159</td>
<td>2016-12-01 18:35:11.129220</td>
<td>166.166.166.166</td>
<td>55.55.57.55</td>
<td>LDP</td>
<td>55.55.57.55</td>
<td>166.166.166.166</td>
<td>102 Initialization Message</td>
<td></td>
</tr>
<tr>
<td>160</td>
<td>2016-12-01 18:35:11.131017</td>
<td>55.55.57.55</td>
<td>166.166.166.166</td>
<td>LDP</td>
<td></td>
<td></td>
<td></td>
<td>102 Initialization Message</td>
</tr>
<tr>
<td>160</td>
<td>2016-12-01 18:35:11.131017</td>
<td>166.166.166.166</td>
<td>55.55.57.55</td>
<td>LDP</td>
<td></td>
<td></td>
<td></td>
<td>102 Initialization Message</td>
</tr>
</tbody>
</table>

Frame 159: 102 bytes on wire (818 bits), 102 bytes captured (818 bits)
```

- Internet Protocol Version 4, Src: 166.166.166.166, Dst: 55.55.57.55
- Label Distribution Protocol
  - Version: 1
  - PDU Length: 32
  - LSR ID: 166.166.166.166
  - Label Space ID: 0
  - Initialization Message
    - 0...0... = U bit: Unknown bit not set
    - Message Type: Initialization Message (0x200)
    - Message Length: 22
    - Message ID: 0x00000005
  - Common Session Parameters TLV
    - 00... = TLV Unknown bits: Known TLV, do not Forward (0x0)
    - TLV Type: Common Session Parameters TLV (0x500)
    - TLV Length: 14
  - Parameters
    - Session Protocol Version: 1
    - Session KeepAlive Time: 40
    - 0...0... = Session Label Advertisement Discipline: Downstream Unsolicited proposed
    - Session Loop Detection: Loop Detection Disabled
    - Session Max PDU Length: 1500
    - Session Receiver LSR Identifier: 55.55.57.55
    - Session Receiver Label Space Identifier: 0
```
Session Initialization Flows (4/4)

- Session Initialization Flows
  - Frame 162: LSR (55.55.57.55) sends a KeepAlive message to signal acceptance of LSR2's parameters
Case Study: Initialization (Session) Message

- Distribution Mode info displayed with D-Link Switch show command

```plaintext
DGS3630_SW1#show mpls ldp information

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSR ID</td>
<td>55.55.57.55</td>
</tr>
<tr>
<td>LDP Version</td>
<td>1.0</td>
</tr>
<tr>
<td>LDP State</td>
<td>Enabled</td>
</tr>
<tr>
<td>TCP Port</td>
<td>646</td>
</tr>
<tr>
<td>UDP Port</td>
<td>646</td>
</tr>
<tr>
<td>Max PDU Length</td>
<td>1500</td>
</tr>
<tr>
<td>Initial Backoff</td>
<td>15 Seconds</td>
</tr>
<tr>
<td>Max Backoff</td>
<td>600 Seconds</td>
</tr>
<tr>
<td>Transport Address</td>
<td>55.55.57.55</td>
</tr>
<tr>
<td>Keep Alive Time</td>
<td>40 Seconds</td>
</tr>
<tr>
<td>Link Hello Holdtime</td>
<td>15 Seconds</td>
</tr>
<tr>
<td>Link Hello Interval</td>
<td>5 Seconds</td>
</tr>
<tr>
<td><strong>Distribution Method</strong></td>
<td><strong>DU</strong></td>
</tr>
<tr>
<td>LSP Control Mode</td>
<td>Independent</td>
</tr>
<tr>
<td>Label Retention</td>
<td>Liberal</td>
</tr>
<tr>
<td>Loop Detection</td>
<td>Disabled</td>
</tr>
<tr>
<td>Path Vector Limit</td>
<td>254</td>
</tr>
<tr>
<td>Hop Count Limit</td>
<td>254</td>
</tr>
<tr>
<td>Authentication</td>
<td>Disabled</td>
</tr>
<tr>
<td>PHP</td>
<td>Implicit null</td>
</tr>
<tr>
<td>Trap Status</td>
<td>Disabled</td>
</tr>
<tr>
<td>Graceful Restart</td>
<td>Disabled</td>
</tr>
<tr>
<td>Neighbor Liveness Time</td>
<td>120 Seconds</td>
</tr>
</tbody>
</table>
```
Quiz Session: Session Message

- Q: Are there any other types of Session Message?
Quiz Session: Session Message

- Q: Are there any other types of Session Message?
  - Ans: Session Rejected/No Hello Error Notification message
- The stated above messages were caused by either of the following possibilities:
  - When a LSR cannot find a matching Hello adjacency, or
  - If the parameters indicated in an Initialization message are not acceptable
LDP Message Exchange

- Initialization (Session) Message components
  - Path Vector Limit
  - If Loop Detection is disabled (D = 0), Path Vector Limit = 0
LDP Message Exchange

- Address Message
  - It is used to maintain a database for mapping between peer LDP Identifiers and next hop addresses
  - Two types of “Address” attached in the message
    - An LSR learned from other LSRs
    - An LSR’s interface address that would like to advertise
  - Address Message comes before “Label Mapping messages” or “Label Request messages”
  - TLVs included in Address Message
    - Address List TLV
LDP Message Exchange

- **Address Message**
  - LSR (166.166.166.166) sends an Address message to advertise its interface addresses to a peer (55.55.57.55)
Quiz Session: Address Message

- Address Message
  - As stated in RFC 5036, "Address List TLV" displays the list of interface addresses being advertised by the sending LSR
  - Question: In last slide, what are the "addresses" LSR (166.166.166.166) informs its peer (55.55.57.55)?
Quiz Session: Address Message

- Address Message
  - As stated in RFC 5036, “Address List TLV” displays the list of interface addresses being advertised by the sending LSR
  - Question: In last slide, what are the “addresses” LSR (166.166.166.166) informs its peer (55.55.57.55)?
  - Ans
    ✓ 192.168.56.6
    ✓ 166.166.166.166
    ✓ 66.66.66.66
Quiz Session: LDP Address Message (1/2)

Q: As indicated in below LDP Address Message, which FEC being advertised by (77.77.77.77) to (55.55.55.55)?
Quiz Session: LDP Address Message (2/2)

- Ans: that shall include
  - 192.168.200.254
  - 192.158.57.7
  - 7.7.7.7
  - 77.77.77.77
LDP Message Exchange

- Label Request Message
  - The “Label Request” activity is an action created by an upstream LSR
  - It is used to determine when to explicitly request that a downstream LSR bind a label to a FEC and send it the corresponding label mapping
  - The receiving LSR could
    - Respond to a Label Request message with a Label Mapping for the requested label, or
    - Reply with a Notification message indicating why it cannot comply with requirements
LDP Message Exchange

- Label Request Message
  - TLVs included in Label Request Message
    - FEC TLV
    - Generic Label TLV
    - Hop Count TLV
LDP Message Exchange

- **Label Request Message**
  - Below sketch displays a “Label Request Message”

```
<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>VLAN_ID</th>
<th>MPLS Label</th>
<th>Length</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1378 2016-12-22 18:50:11.568033</td>
<td>111.111.111.111</td>
<td>133.133.133.133</td>
<td>LDP</td>
<td>3</td>
<td>113 Label Mapping Message</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1379 2016-12-22 18:50:11.709927</td>
<td>133.133.133.133</td>
<td>111.111.111.111</td>
<td>LDP</td>
<td>3</td>
<td>98 Label Request Message</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1380 2016-12-22 18:50:11.709927</td>
<td>111.111.111.111</td>
<td>133.133.133.133</td>
<td>LDP</td>
<td>3</td>
<td>391 Label Mapping Message</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- 802.1Q Virtual LAN, PRI: 0, CFI: 0, ID: 3
- Internet Protocol Version 4, Src: 133.133.133.133, Dst: 111.111.111.111
- Label Distribution Protocol
- Label Distribution Protocol
- Label Distribution Protocol
- Label Distribution Protocol

- **Label Request Message**
  - 0... .... - U bit: Unknown bit not set
  - Message Type: Label Request Message (0x401)
  - Message Length: 20
  - Message ID: 0x000000be

- **Forwarding Equivalence Classes TLV**
  - 00... .... - TLV Unknown bits: Known TLV, do not Forward (0x0)
  - TLV Type: Forwarding Equivalence Classes TLV (0x100)
  - TLV Length: 7
  - FEC Elements
  - FEC Element 1

- **Hop Count TLV**
  - 00... .... - TLV Unknown bits: Known TLV, do not Forward (0x0)
  - TLV Type: Hop Count TLV (0x103)
  - TLV Length: 1
  - Hop Count Value: 0
```
LDP Message Exchange

- Label Abort Request Message
  - It may be used to abort an “Label Request Message”
  - As indicated in next slide, frame 13832, LSR (55.55.55.55) informs another LSR (66.66.66.66) that it will abort the FEC of 192.168.100.0
LDP Message Exchange

- An example of Label Abort Request Message

<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>MPLS Label</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>13831</td>
<td>2017-02-02 17:32:59.991016</td>
<td>55.55.55.55</td>
<td>77.77.77.77</td>
<td>LDP</td>
<td></td>
<td>Label Withdrawal Message</td>
</tr>
<tr>
<td>13832</td>
<td>2017-02-02 17:32:59.992923</td>
<td>55.55.55.55</td>
<td>66.66.66.66</td>
<td>LDP</td>
<td></td>
<td>Label Abort Request Message</td>
</tr>
<tr>
<td>13833</td>
<td>2017-02-02 17:32:59.993913</td>
<td>55.55.55.55</td>
<td>66.66.66.66</td>
<td>LDP</td>
<td></td>
<td>Notification Message</td>
</tr>
</tbody>
</table>

Frame 13832: 103 bytes on wire (824 bits), 103 bytes captured (824 bits) on interface 0
Internet Protocol Version 4, Src: 55.55.55.55, Dst: 66.66.66.66
Label Distribution Protocol

Version: 1
PDU Length: 33
LSR ID: 55.55.55.55
Label Space ID: 0

Label Abort Request Message

0...0... = U bit: Unknown bit not set
Message Type: Label Abort Request Message (0x404)
Message Length: 23
Message ID: 0x000000e0

Forwarding Equivalence Classes TLV

00...0... = TLV Unknown bits: Known TLV, do not Forward (0x0)
TLV Type: Forwarding Equivalence Classes TLV (0x100)
TLV Length: 7

FEC Elements

FEC Element 1

FEC Element Type: Prefix FEC (2)
FEC Element Address Type: IPv4 (1)
FEC Element Length: 24
Prefix: 192.168.100.0

Label Request Message ID TLV

00...0... = TLV Unknown bits: Known TLV, do not Forward (0x0)
TLV Type: Label Request Message ID TLV (0x600)
LDP Message Exchange

- Label Mapping Message
  - When an LSR receives a Label Mapping message from a next hop, the message is propagated upstream as specified below until an ingress LSR is reached or a loop is found
  - The use of the Path Vector TLV and Hop Count TLV in the Label Mapping message provide a mechanism to find and terminate looping LSPs
LDP Message Exchange

- TLVs included in Label Mapping Message
  - FEC TLV
    - FEC component of the FEC-Label mapping being advertised
  - (Generic) Label TLV
    - Displays the Label component of the FEC-Label mapping
  - Optional Parameters
    - Label Request Message ID TLV
      - If this Label Mapping message is a response to a Label Request message, it MUST be included
    - Hop Count TLV
      - Running total of the number of LSR hops along the LSP being set up by the Label message
Case Study: Label Mapping Message

- Frame 234 is an example of Label Mapping Message

<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>Length</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>234</td>
<td>2016-12-01 18:35:22.550639</td>
<td>55.55.57.55</td>
<td>77.77.77.77</td>
<td>LDP</td>
<td>490</td>
<td>Label Mapping Message</td>
</tr>
<tr>
<td>234</td>
<td>2016-12-01 18:35:22.548026</td>
<td>55.55.57.55</td>
<td>77.77.77.77</td>
<td>LDP</td>
<td>108</td>
<td>Label Mapping Message</td>
</tr>
<tr>
<td>234</td>
<td>2016-12-01 18:35:22.537490</td>
<td>77.77.77.77</td>
<td>55.55.57.55</td>
<td>LDP</td>
<td>108</td>
<td>Label Mapping Message</td>
</tr>
</tbody>
</table>

Frame 234: 108 bytes on wire (864 bits), 108 bytes captured (864 bits)
Internet Protocol Version 4, Src: 55.55.57.55, Dst: 77.77.77.77

Label Distribution Protocol

- Version: 1
- PDU Length: 38
- LSR ID: 55.55.57.55
- Label Space ID: 0

- Label Mapping Message
  - 0...0... = U bit: Unknown bit not set
  - Message Type: Label Mapping Message (0x400)
  - Message Length: 28
  - Message ID: 0x00000030

- Forwarding Equivalence Classes TLV
  - 00...0... = TLV Unknown bits: Known TLV, do not Forward (0x0)
  - TLV Type: Forwarding Equivalence Classes TLV (0x100)
  - TLV Length: 7

- FEC Elements

- Generic Label TLV
  - 00...0... = TLV Unknown bits: Known TLV, do not Forward (0x0)
  - TLV Type: Generic Label TLV (0x200)
  - TLV Length: 4
  - 0000 0000 0000 0000 0011 - Generic Label: 0x00003

- Hop Count TLV
  - 00...0... = TLV Unknown bits: Known TLV, do not Forward (0x0)
  - TLV Type: Hop Count TLV (0x103)
  - TLV Length: 1
  - Hop Count Value: 1
Case Study: Label Mapping Message

- The LSR (55.55.57.55), in Frame 234, distributes a label mapping (0x00003) for a FEC (5.5.5.0) to an LDP peer (77.77.77.77)

<table>
<thead>
<tr>
<th>Frame</th>
<th>LSR IP</th>
<th>Peer IP</th>
<th>Label</th>
<th>FEC</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>234</td>
<td>55.55.57.55</td>
<td>77.77.77.77</td>
<td>0x00003</td>
<td>5.5.5.0</td>
<td>Label Mapping Message</td>
</tr>
<tr>
<td>235</td>
<td>55.55.57.55</td>
<td>166.166.166.166</td>
<td>0x00003</td>
<td>5.5.5.0</td>
<td>Label Withdrawal Message</td>
</tr>
<tr>
<td>236</td>
<td>55.55.57.55</td>
<td>55.55.57.55</td>
<td>0x00003</td>
<td>5.5.5.0</td>
<td>Label Request Message</td>
</tr>
</tbody>
</table>

**Label Distribution Protocol**

```
Version: 1
PDU Length: 38
LSR ID: 55.55.57.55
Label Space ID: 0

Label Mapping Message
  Message Type: Label Mapping Message (0x400)
  Message Length: 28
  Message ID: 0:00000030

Forwarding Equivalence Classes TLV
  00... ... = TLV Unknown bits: Known TLV, do not Forward (0x0)
  TLV Type: Forwarding Equivalence Classes TLV (0x100)
  TLV Length: 7

FEC Elements
  FEC Element 1
    FEC Element Type: Prefix FEC (2)
    FEC Element Address Type: IPv4 (1)
    FEC Element Length: 24
    Prefix: 5.5.5.0

Generic Label TLV
  00... ... = TLV Unknown bits: Known TLV, do not Forward (0x0)
  TLV Type: Generic Label TLV (0x200)
  TLV Length: 4
```
Quiz Session: Label Mapping Message

- Frame 1383, as captured in next 2 slides, is a Label Mapping Message
- With the encoding for the message, could you share your thoughts on such observations?
Quiz Session: Label Mapping Message

- Label Mapping Message (Frame 1383)

```
Frame 1383:
120 bytes on wire (960 bits), 120 bytes captured (960 bits)
802.1Q VLAN, PRI: 0, CFI: 0, ID: 3
Internet Protocol Version 4, Src: 133.133.133.133, Dst: 111.111.111.111
Label Distribution Protocol
```

Version: 1
PDU Length: 46
LSR ID: 133.133.133.133
Label Space ID: 0

- Label Mapping Message
  - Message Type: Label Mapping Message (0x400)
  - Message Length: 36
  - Message ID: 0x000000c4

- Forwarding Equivalence Classes TLV
  - TLV Type: Forwarding Equivalence Classes TLV (0x100)
  - TLV Length: 7
    - FEC Elements
      - FEC Element 1
        - FEC Element Type: Prefix FEC (2)
        - FEC Element Address Type: IPv4 (1)
        - FEC Element Length: 24
        - Prefix: 133.133.133.0
      - Generic Label TLV
        - TLV Type: Generic Label TLV (0x200)
        - TLV Length: 4

- Label Request Message ID TLV
- Hop Count TLV
Quiz Session: Label Mapping Message

- Label Mapping Message (Frame 1383)

<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>Length</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>1382</td>
<td>2016-12-22 18:50:11.737348</td>
<td>111.111.111.111</td>
<td>133.133.133.133</td>
<td>LDP</td>
<td>320</td>
<td>Label Mapping Message</td>
</tr>
<tr>
<td>1383</td>
<td>2016-12-22 18:50:11.738102</td>
<td>133.133.133.133</td>
<td>111.111.111.111</td>
<td>LDP</td>
<td>120</td>
<td>Label Mapping Message</td>
</tr>
<tr>
<td>1390</td>
<td>2016-12-22 18:50:13.525163</td>
<td>172.16.10.1</td>
<td>224.0.0.2</td>
<td>LDP</td>
<td>88</td>
<td>Hello Message</td>
</tr>
</tbody>
</table>

Frame 1383: 120 bytes on wire (960 bits), 120 bytes captured (960 bits)
802.1Q Virtual LAN, PRI: 0, CFI: 0, ID: 3
Internet Protocol Version 4, Src: 133.133.133.133, Dst: 111.111.111.111

Label Distribution Protocol
- Version: 1
- PDU Length: 46
- LSR ID: 133.133.133.133
- Label Space ID: 0

- Label Mapping Message
  - 0... .... = U bit: Unknown bit not set
  - Message Type: Label Mapping Message (0x400)
  - Message Length: 36
  - Message ID: 0x000000c4

- Forwarding Equivalence Classes TLV

- Generic Label TLV

- Label Request Message ID TLV
  - 00... .... = TLV Unknown bits: Known TLV, do not Forward (0x0)
  - TLV Type: Label Request Message ID TLV (0x600)
  - TLV Length: 4
  - Label Request Message ID: 0x000000182

- Hop Count TLV
  - 00... .... = TLV Unknown bits: Known TLV, do not Forward (0x0)
  - TLV Type: Hop Count TLV (0x103)
  - TLV Length: 1
  - Hop Count Value: 1
Quiz Session: Label Request Mapping

- The collected Wireshark packets show Frame 1379 is a Label Request message and Frame 1380, Label Mapping message.

- Would you like to elaborate possible activities behind-the-scenes here?
Quiz Session: Label Request/Mapping (Cont'd)

- Frame 1379

```
Frame 1379: 367 bytes on wire (2936 bits), 367 bytes captured (2936 bits)
802.1Q Virtual LAN, PRI: 0, CFI: 0, ID: 3
Internet Protocol Version 4, Src: 133.133.133.133, Dst: 111.111.111.111
Label Distribution Protocol
Label Distribution Protocol
Label Distribution Protocol
Label Distribution Protocol
Label Distribution Protocol
Label Distribution Protocol
Label Distribution Protocol

Version: 1
PDU Length: 30
LSR ID: 133.133.133.133
Label Space ID: 0

Label Request Message
0... .... = U bit: Unknown bit not set
Message Type: Label Request Message (0x401)
Message Length: 20
Message ID: 0x000000be

Forwarding Equivalence Classes TLV
00... .... = TLV Unknown bits: Known TLV, do not Forward (0x0)
TLV Type: Forwarding Equivalence Classes TLV (0x100)
TLV Length: 7

FEC Elements

FEC Element 1
FEC Element Type: Prefix FEC (1)
FEC Element Address Type: IPV4 (1)
FEC Element Length: 24
Prefix: 22.22.22.0

Hop Count TLV
00... .... = TLV Unknown bits: Known TLV, do not Forward (0x0)
TLV Type: Hop Count TLV (0x103)
TLV Length: 1
Hop Count Value: 0
```
Quiz Session: Label Request/Mapping (Cont'd)

- Frame 1380

```
Frame 1380: 391 bytes on wire (3128 bits), 391 bytes captured (3128 bits)
802.1Q Virtual LAN, PRI: 0, CFI: 0, ID: 3
Internet Protocol Version 4, Src: 111.111.111.111, Dst: 133.133.133.133
Label Distribution Protocol
Label Distribution Protocol
Label Distribution Protocol
Label Distribution Protocol
Label Distribution Protocol
Label Distribution Protocol
Label Distribution Protocol
Label Distribution Protocol
Label Distribution Protocol
Label Distribution Protocol
Label Distribution Protocol

Version: 1
PDU Length: 38
LSR ID: 111.111.111.111
Label Space ID: 0
Label Mapping Message
0... .... = U bit: Unknown bit not set
```
Quiz Session: Label Request/Mapping (Cont'd)

- Frame 1380

Label Distribution Protocol
- Version: 1
- PDU Length: 38
- LSR ID: 111.111.111.111
- Label Space ID: 0

Label Mapping Message
- 0... ... = U bit: Unknown bit not set
- Message Type: Label Mapping Message (0x400)
- Message Length: 28
- Message ID: 0x000000184

Forwarding Equivalence Classes TLV
- 00... ... = TLV Unknown bits: Known TLV, do not Forward (0x0)
- TLV Type: Forwarding Equivalence Classes TLV (0x100)
- TLV Length: 7

FEC Elements
- FEC Element 1
  - FEC Element Type: Prefix FEC (2)
  - FEC Element Address Type: IPv4 (1)
  - FEC Element Length: 24
  - Prefix: 22.22.22.0

Generic Label TLV
- 00... ... = TLV Unknown bits: Known TLV, do not Forward (0x0)
- TLV Type: Generic Label TLV (0x200)
- TLV Length: 4
- .... ... ... 0000 0000 0000 0000 0000 = Generic Label: 0x00000
Quiz Session: Label Request/Mapping (Cont'd)

- Suggested response
- In Frame 1379, LSR (133.133.133.133) recognizes a new FEC (22.22.22.0) via the forwarding table and the LSR doesn't already have a mapping from the next hop (111.111.111.111) for the given FEC the request
- As such, a Request message had been transmitted by LSR (133.133.133.133)
- In Frame 1380, the receiving LSR (111.111.111.111) respond to a Label Request message with a Label Mapping
LDP Message Exchange

- Label Withdrawal Message
  - When an LSR sends a Label Withdraw Message to an LDP peer, it informs the peer that the peer may not continue to use specific FEC-label mappings the LSR had previously advertised.
  - The Label Withdrawal activity is performed by a downstream LSR to determine when to withdraw a FEC label mapping previously distributed to LDP peers.
LDP Message Exchange

- Label Withdrawal Message
  - As a matter of fact, as soon as an LSR tears down the binding between a label and a FEC, it shall withdraw the FEC label mapping from all LDP peers to which it has previously sent the mapping
  - As such, the mapping between the FECs and the labels is no longer exist
LDP Message Exchange

- Label Withdrawal Message
  - TLVs included in Label Withdrawal Message
    ✓ FEC TLV
    ✓ Generic TLV
  - The FEC TLV specifies the FEC for which labels are to be withdrawn
LDP Message Exchange

- **Label Withdraw Message**
  - An example of Label Withdrawal Message

---

### LDP Message Details

<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>MPLS Label</th>
<th>LSP Type</th>
<th>Length</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>2016-12-01 18:44:12.392682</td>
<td>77.77.77.77</td>
<td>55.55.57.55</td>
<td>LDP</td>
<td></td>
<td></td>
<td>363</td>
<td>Label Request Message</td>
</tr>
<tr>
<td>22</td>
<td>2016-12-01 18:44:17.428310</td>
<td>166.166.166.166</td>
<td>55.55.57.55</td>
<td>LDP</td>
<td></td>
<td></td>
<td>465</td>
<td>Label Request Message</td>
</tr>
<tr>
<td>22</td>
<td>2016-12-01 18:35:22.542765</td>
<td>55.55.57.55</td>
<td>166.166.166.166</td>
<td>LDP</td>
<td>103</td>
<td></td>
<td>103</td>
<td>Label Withdrawal Message</td>
</tr>
<tr>
<td>22</td>
<td>2016-12-01 18:35:22.542827</td>
<td>55.55.57.55</td>
<td>166.166.166.166</td>
<td>LDP</td>
<td>103</td>
<td></td>
<td>103</td>
<td>Label Withdrawal Message</td>
</tr>
<tr>
<td>22</td>
<td>2016-12-01 18:44:17.419701</td>
<td>55.55.57.55</td>
<td>77.77.77.77</td>
<td>LDP</td>
<td></td>
<td></td>
<td>103</td>
<td>Label Withdrawal Message</td>
</tr>
</tbody>
</table>

---

**Frame 235**: 103 bytes on wire (824 bits), 103 bytes captured (824 bits)

- Internet Protocol Version 4, Src: 55.55.57.55, Dst: 166.166.166.166
- Transmission Control Protocol, Src Port: 646, Dst Port: 1026

**Label Distribution Protocol**

- Version: 1
- PDU Length: 33
- LSR ID: 55.55.57.55
- Label Space ID: 0

**Label Withdrawal Message**

- 0... = U bit: Unknown bit not set
- Message Type: Label Withdrawal Message (0x402)
- Message Length: 23
- Message ID: 0x0000003b

- Forwarding Equivalence Classes TLV
- Generic Label TLV
LDP Message Exchange

- **Label Withdrawal Message**
  - The following diagram indicates that a “Label Withdrawal Message” to de-associate with the prefix of “192.168.10.0”
LDP Message Exchange

- Label Release Message
  - The “Label Release” behavior is took place by an upstream LSR
  - That upstream LSR takes the active role in determining when to release a previously received label mapping for a FEC
LDP Message Exchange

- Label Release Message
  - As stated in RFC 5036, an LSR sends a Label Release message to an LDP peer to signal the peer that the LSR no longer needs specific FEC-label mappings previously requested of and/or advertised by the peer.
  - An LSR transmits a Label Release message, after receiving a Label Withdraw message.
  - TLVs included in Label Release message:
    - FEC TLV
    - Generic Label TLV
LDP Message Exchange

- Label Release Message
  - The underneath diagram presents an example
LDP Message Exchange

- Address Withdraw Message
  - An LSR shall send out an “Address Withdraw Message” once it decides to "de-activate" a previously advertised address
  - TLVs included in Address Withdraw Message
    - Address List TLV
  - Address List TLV: The list of interface addresses being withdrawn by the sending LSR
Case Study: Address Withdraw Message

- Address Withdraw Message
  - In Frame 1312, the LSR_1 (111.111.111.111) informs another LSR_2 (122.122.122.122) that it (LSR_1) decides to "de-activate" the address of 192.168.10.1

---

<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>Length</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>1311</td>
<td>2016-12-22 18:49:55.547684</td>
<td>122.122.122.122</td>
<td>111.111.111.111</td>
<td>LDP</td>
<td>107</td>
<td>Label Release Message</td>
</tr>
<tr>
<td>1312</td>
<td>2016-12-22 18:49:55.549207</td>
<td>111.111.111.111</td>
<td>122.122.122.122</td>
<td>LDP</td>
<td>172</td>
<td>Address Withdrawal Message</td>
</tr>
<tr>
<td>1313</td>
<td>2016-12-22 18:49:55.550317</td>
<td>122.122.122.122</td>
<td>111.111.111.111</td>
<td>LDP</td>
<td>107</td>
<td>Label Release Message</td>
</tr>
</tbody>
</table>

Frame 1312: 172 bytes on wire (1376 bits), 172 bytes captured (1376 bits)
- 802.1Q Virtual LAN, PRI: 0, CFI: 0, ID: 2
- Internet Protocol Version 4, Src: 111.111.111.111, Dst: 122.122.122.122
- Label Distribution Protocol
- Label Distribution Protocol
- Label Distribution Protocol

> Version: 1
> PDU Length: 24
> LSR ID: 111.111.111.111
> Label Space ID: 0

> Address Withdrawal Message
> 0... .... = U bit: Unknown bit not set
> Message Type: Address Withdrawal Message (0x301)
> Message Length: 14
> Message ID: 0x00000016c

> Address List TLV
> 00... .... = TLV Unknown bits: Known TLV, do not Forward (0x03)
> TLV Type: Address List TLV (0x101)
> TLV Length: 6
> Address Family: IPv4 (1)

> Addresses
> Address 1: 192.168.10.1
LDP Message Exchange

- Notification Message
  - LDP sends notification messages to report errors and other events of interest
  - Example of an event: a fatal error or LDP session advisory information
  - Once the last Hello adjacency for an LDP session is deleted, the LSR deactivates the LDP session by sending a Notification message, discarding label mapping (as shown in next slide) and then closing the transport connection
  - TLVs included in Notification Message
    ✓ Status TLV
LDP Message Exchange

- Notification Message
  - An example of “notification message”

<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>MPLS Label</th>
<th>LSP Type</th>
<th>Length</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>2266</td>
<td>2016-12-01 18:44:14.207592</td>
<td>55.55.57.55</td>
<td>77.77.77.77</td>
<td>LDP</td>
<td></td>
<td></td>
<td></td>
<td>276 Notification Message</td>
</tr>
<tr>
<td>2272</td>
<td>2016-12-01 18:44:14.223593</td>
<td>166.166.166.166</td>
<td>55.55.57.55</td>
<td>LDP</td>
<td></td>
<td></td>
<td></td>
<td>73 Notification Message</td>
</tr>
</tbody>
</table>

Frame 2267: 276 bytes on wire (2208 bits), 276 bytes captured (2208 bits)


Internet Protocol Version 4, Src: 55.55.57.55, Dst: 77.77.77.77


Label Distribution Protocol

- Version: 1
- PDU Length: 24
- LSR ID: 55.55.57.55
- Label Space ID: 0

Address Withdrawal Message

Label Distribution Protocol

- Version: 1
- PDU Length: 23
- LSR ID: 55.55.57.55
- Label Space ID: 0

Label Release Message
LDP Message Exchange

- Notification Message
  - This “notification message” indicates a “Fatal Error Notification” status, as a result of power-off one of the routers.
Quiz Session: Notification Message (1/4)

- Frame 158 carries with Two Notification Messages, could you look into the details and offer some insight?

<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>Length</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>156</td>
<td>2016-01-20 18:07:00.969682</td>
<td>10.17.0.2</td>
<td>224.0.0.2</td>
<td>LDP</td>
<td>88</td>
<td>Hello Message</td>
</tr>
<tr>
<td>157</td>
<td>2016-01-20 18:07:01.129655</td>
<td>10.17.0.1</td>
<td>224.0.0.2</td>
<td>LDP</td>
<td>88</td>
<td>Hello Message</td>
</tr>
<tr>
<td>158</td>
<td>2016-01-20 18:07:01.197646</td>
<td>10.15.0.3</td>
<td>10.15.0.4</td>
<td>LDP</td>
<td>112</td>
<td>Notification Message</td>
</tr>
<tr>
<td>160</td>
<td>2016-01-20 18:07:01.800117</td>
<td>10.15.0.4</td>
<td>10.15.0.3</td>
<td>LDP</td>
<td>101</td>
<td>Label Mapping Message</td>
</tr>
</tbody>
</table>

Frame 158: 112 bytes on wire (896 bits), 112 bytes captured (896 bits) on interface 0
Ethernet II, Src: CiscoInc_12:dc:00 (58:8d:09:12:dc:00), Dst: D-LinkIn_1e:04:ae:08:00
802.1Q Virtual LAN, PRI: 6, CFI: 0, ID: 71
Internet Protocol Version 4, Src: 10.15.0.3, Dst: 10.15.0.4
Label Distribution Protocol
  Version: 1
  PDU Length: 50
  LSR ID: 10.15.0.3
  Label Space ID: 0
  Notification Message
  Notification Message
Quiz Session: Notification Message (2/4)

- 1st Notification Message in Frame 158

<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>Length</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>163</td>
<td>2016-01-20 18:07:01.998903</td>
<td>10.15.0.4</td>
<td>10.15.0.3</td>
<td>LDP</td>
<td>91</td>
<td>91 Label Request Message</td>
</tr>
<tr>
<td>164</td>
<td>2016-01-20 18:07:02.009565</td>
<td>10.15.0.3</td>
<td>10.15.0.4</td>
<td>LDP</td>
<td>90</td>
<td>90 Notification Message</td>
</tr>
<tr>
<td></td>
<td>2016-01-20 18:07:01.197646</td>
<td>10.15.0.3</td>
<td>10.15.0.4</td>
<td>LDP</td>
<td>112</td>
<td>112 Notification Message Notification Message</td>
</tr>
</tbody>
</table>

Label Distribution Protocol
- Version: 1
- PDU Length: 50
- LSR ID: 10.15.0.3
- Label Space ID: 0

Notification Message
- 0... .... = U bit: Unknown bit not set
- Message Type: Notification Message (0x1)
- Message Length: 18
- Message ID: 0x0002904d

Status TLV
- 00... .... = TLV Unknown bits: Known TLV, do not Forward (0x0)
- TLV Type: Status TLV (0x300)
- TLV Length: 10

Status
- 1... .... = E Bit: Fatal Error Notification
- 0... .... = F Bit: Notification should NOT be Forwarded
- 00 0000 0000 0000 0000 0000 0000 0000 0001 = Status Data: Hold Timer Expired (0x9)
- Message ID: 0x00000000
- Message Type: Unknown (0x0000)
Quiz Session: Notification Message (3/4)

- 2nd Notification Message in Frame 158

<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>Length</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>163</td>
<td>2016-01-20 18:07:01.098003</td>
<td>10.15.0.4</td>
<td>10.15.0.3</td>
<td>LDP</td>
<td>91</td>
<td>Label Request Message</td>
</tr>
<tr>
<td>164</td>
<td>2016-01-20 18:07:02.005005</td>
<td>10.15.0.3</td>
<td>10.15.0.4</td>
<td>LDP</td>
<td>90</td>
<td>Notification Message</td>
</tr>
<tr>
<td>158</td>
<td>2016-01-20 18:07:01.197646</td>
<td>10.15.0.3</td>
<td>10.15.0.4</td>
<td>LDP</td>
<td>112</td>
<td>112 Notification Message Notification Message</td>
</tr>
</tbody>
</table>

Frame 158: 112 bytes on wire (896 bits), 112 bytes captured (896 bits) on interface 0
Ethernet II, Src: Ciscolnc_12:dc:00 (58:8d:09:12:dc:00), Dst: D-link_lan_e:08:00 (3c:1e:04:ae:08:00)
802.1Q Virtual LAN, PRI: 6, CFI: 0, ID: 71
Internet Protocol Version 4, Src: 10.15.0.3, Dst: 10.15.0.4
Label Distribution Protocol
Version: 1
PDU Length: 50
LSR ID: 10.15.0.3
Label Space ID: 0
Notification Message
Message Type: Notification Message (0x1)
Message Length: 18
Message ID: 0x00002004e
Status TLV
00... = TLV Unknown bits: Known TLV, do not Forward (0x0)
TLV Type: Status TLV (0x300)
TLV Length: 10
Status
1... = F Bit: Fatal Error Notification
.0... = F Bit: Notification should NOT be Forwarded
1010 = Status Data: Shutdown (0xA)
Message ID: 0x00000000
Message Type: Unknown (0x0000)
Quiz Session: Notification Message (4/4)

- The possible situation is..........
- The LSR experiences a condition of “fatal error” as it is stated in the “Status Code”
- Since the Message Type is unknown, this LDP message is malformed
- Nevertheless, the first fatal error was caused by “Hold Timer Expired (0x9)” Status Code and the second one, “Shutdown” Status Code
- After sending the Notification message the LSR is going to terminate the LDP session by closing the session TCP connection and discard all state associated with the session
Message Type Display Filter

- Display Filter Reference: Label Distribution Protocol
- Message Type: ldp.msg.type
  - Notification Message: 0x0001
  - Hello Message: 0x0100
  - Initialization Message: 0x0200
  - KeepAlive Message: 0x0201
  - Address Message: 0x0300
  - Address Withdraw Message: 0x0301
  - Label Mapping Message: 0x0400
  - Label Request Message: 0x0401
  - Label Withdraw Message: 0x0402
  - Label Release Message: 0x0403
Message Type Display Filter

- The below diagram indicates an example of `ldp.msg.type == 0x0100` with a result of all “Hello Message”
Penultimate hop popping (PHP)

- Describes the process whereby the outermost label of an MPLS tagged packet is removed by a Label Switch Router (LSR) before that (MPLS tagged) packet is delivered to an adjacent Label Edge Router (LER)
- As described in RFC 3031, this PHP technique allows the egress to do a single lookup, and also requires only a single lookup by the penultimate node
- In a statement presented in RFC2547, PHP reduces the load on the Label Edge Router (LER) in a Layer 3 MPLS VPN environment
Penultimate hop popping (PHP)

- The right-hand side diagram indicates that this LSR (111.111.111.111) is a penultimate hop carrying an explicit null (MPLS) label value.

- This is a show command output from DGS-3630 switch.
MPLS Loop

- As stated in RFC 3031, if the upstream LSR thinks a label is bound to an explicit route, and the downstream LSR doesn't think that label is bound to anything, and if the hop by hop routing of the unlabeled IP packet brings the packet back to the upstream LSR, then a loop is formed.
Time-to-Live (TTL)

- Each packet carries a "Time To Live" (TTL) value in its header.
- The TTL gets deducted by 1, whenever a packet passes through a router.
- Once the TTL reaches 0 before the packet has reached its destination, the packet shall be discarded.
- In conventional IP forwarding, TTL offers some level of protection against forwarding loops.
MPLS Loop Detection

- We can adapt the command of “loop-detection” to enable loop detection capability.
- It (loop-detection) performs below functions:
  - Finding looping LSPs, and
  - Preventing Label Request messages from looping in the presence of non-merge capable LSRs.
- As explained in D-Link switch user manual, LDP loop detection makes use of the Path Vector TLVs and Hop Count TLVs carried by the label request and label mapping messages to prevent looping of LDP messages.
MPLS Loop Detection

- Path Vector TLV
  - Contains a list of the LSRs
  - Each LSR has its identical LSR Identifier (ID)
  - When a LSR receives a message with a Path Vector TLV including its LSR ID, there is a MPLS loop
  - The “path-vector maxlength” D-Link switch command manually adjusts the maximum path vector length
MPLS Loop Detection

- Hop Count TLV
  - The Hop Count in the egress router, it is set as “1”
  - The count number increases by 1 for every LSR pass-through
  - Once an LSR detects a Hop Count has reached a configured maximum value, there is a MPLS loop
  - A D-Link switch command “maxhops” offers the convenience to configure the maximum number of hops permitted in the LSP setup
MPLS Loop Detection

- Frame 1379, a label mapping message, indicates in below diagram, is an example that LSR (133.133.133.133) holds a position of “egress router” with the hop count of 1.
MPLS Loop Detection

- As described in RFC 3037: Use of the optional path vector based loop detection mechanism imposes additional memory and processing requirements on an LSR, as well as additional LDP traffic
- RFC 3036, page 24, also offers additional information on this subject
MPLS Loop Detection

- Activates LOOP DETECTION function in D-Link switch
  - Switch# configure terminal
  - Switch(config)# mpls ldp configuration
  - Switch(config-ldp)# loop-detection
- The Loop Detection TLV can be seen at
  - Label Request Message
  - Label Mapping Message
LSP Control Mode

- As defined in RFC 3031, there are two types of LSP Control Mode: Ordered versus Independent
  
  - Ordered LSP Control: an LSR only binds a label to a particular FEC if it is the egress LSR for that FEC, or if it has already received a label binding for that FEC from its next hop for that FEC
  
  - Independent LSP Control: each LSR, upon noting that it recognizes a particular FEC, makes an independent decision to bind a label to that FEC and to distribute that binding to its label distribution peers

- D-Link Switch command “lsp-control-mode” serves the purpose of configuration
Quiz Session: LSP Control Mode

- As presented in the right-hand side diagram, what is the LSP Control Mode being deployed?

```
DGS3630_SW1#show mpls ldp information

<table>
<thead>
<tr>
<th>LSR ID</th>
<th>55.55.57.55</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDP Version</td>
<td>1.0</td>
</tr>
<tr>
<td>LDP State</td>
<td>Enabled</td>
</tr>
<tr>
<td>TCP Port</td>
<td>646</td>
</tr>
<tr>
<td>UDP Port</td>
<td>646</td>
</tr>
<tr>
<td>Max PDU Length</td>
<td>1500</td>
</tr>
<tr>
<td>Initial Backoff</td>
<td>15 Seconds</td>
</tr>
<tr>
<td>Max Backoff</td>
<td>600 Seconds</td>
</tr>
<tr>
<td>Transport Address</td>
<td>55.55.57.55</td>
</tr>
<tr>
<td>Keep Alive Time</td>
<td>40 Seconds</td>
</tr>
<tr>
<td>Link Hello Holdtime</td>
<td>15 Seconds</td>
</tr>
<tr>
<td>Link Hello Interval</td>
<td>5 Seconds</td>
</tr>
<tr>
<td>Distribution Method</td>
<td>DL</td>
</tr>
</tbody>
</table>

**LSP Control Mode**: Independent

Label Retention: Liberal
Loop Detection: Disabled
Path Vector Limit: 254
Hop Count Limit: 254
Authentication: Disabled
PHP: Implicit null
Trap Status: Disabled
Graceful Restart: Disabled
Neighbor Liveness Time: 120 Seconds
```
Route Selection

- [RFC 3031] Deals with the method used for selecting the LSP for a particular FEC. Two type of options
  - (1) Hop by hop routing, and
  - (2) Explicit routing [deployment examples: policy routing or traffic engineering]
- “Strictly" explicitly routed: when a single LSR specifies the entire LSP
- “Loosely" explicitly routed: when a single LSR specifies only some of the LSP, the LSP is "loosely" explicitly routed.
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Proverb

“Tell me and I forget, teach me and I may remember, involve me and I learn.”

By Benjamin Franklin
MPLS Configuration Guide

- Multiprotocol Label Switching (MPLS)
- MPLS Terminology
- Label Distribution Protocol (LDP)
- Configuration Scenario #1
- Configuration Scenario #2
- Configuration Scenario #3
- Command Reference
MPLS Configuration Lab

- We are going to conduct lab practice on MPLS.
- It is suggested that three MPLS-enabled switches are available in your lab facility (MI Mode).
- The use of D-Track DK1300509 has originated many other reforms. This lab practice is only one of the examples.
MPLS Configuration Lab: Topology

- Three DGS-3630-28TC (MI Mode) with MPLS configurations

prompt DGS3630_Hub
int. loopback 1: 5.5.5.5/24
int. loopback 2: 55.55.55.55/24
int. vlan56: 192.168.56.5/24
int. vlan57: 192.168.57.5/24
Router BGP 5

Router BGP 5

prompt DGS3630_Left
int. loopback 1: 6.6.6.6/24
int. loopback 2: 66.66.66.66/24
int. vlan56: 192.168.56.6/24
int. vlan100: 192.168.100.254/24
Router BGP 6

prompt DGS3630_Right
int. loopback 1: 7.7.7.7/24
int. loopback 2: 77.77.77.77/24
int. vlan57: 192.168.57.7/24
int. vlan200: 192.168.200.254/24
Router BGP 7
MPLS Configuration Lab: LSR Settings

- **DGS3630_Hub**
  - configure terminal
  - prompt DGS3630_Hub
  - monitor session 1 destination interface ethernet 1/0/1
  - monitor session 1 source interface ethernet 1/0/5-7
  - interface loopback 1
  - ip address 5.5.5.5 255.255.255.0
  - exit
  - interface loopback 2
  - ip address 55.55.55.55 255.255.255.0
  - exit
MPLS Configuration Lab: LSR Settings

- **DGS3630_Hub**
  - mpls ldp configuration
  - router-id 55.55.55.55
  - explicit-null
  - exit
  - mpls ip
  - mpls label protocol ldp
  - vlan 56
  - exit
MPLS Configuration Lab: LSR Settings

- **DGS3630_Hub**
  - interface vlan 56
  - ip address 192.168.56.5 255.255.255.0
  - mpls ip
  - mpls label protocol ldp
  - exit
  - interface eth 1/0/5
  - switchport mode access
  - switchport access vlan 56
  - exit
MPLS Configuration Lab: LSR Settings

- **DGS3630_Hub**
  - vlan 57
  - exit
  - interface vlan 57
  - ip address 192.168.57.5 255.255.255.0
  - mpls ip
  - mpls label protocol ldp
  - exit
  - interface eth 1/0/7
  - switchport mode access
  - switchport access vlan 57
  - exit
  - no int vlan 1
MPLS Configuration Lab: LSR Settings

- **DGS3630_Hub**
  - router bgp 5
  - bgp router-id 5.5.5.5
  - neighbor 192.168.57.7 remote-as 7
  - neighbor 192.168.57.7 activate
  - neighbor 192.168.57.7 description DGS-3630-28TC(SW3)
  - neighbor 192.168.56.6 remote-as 6
  - neighbor 192.168.56.6 activate
  - neighbor 192.168.56.6 description DGS-3630-28TC(SW2)
  - network 5.5.5.0/24
  - network 55.55.55.0/24
  - network 192.168.56.0/24
  - network 192.168.57.0/24
  - exit
MPLS Configuration Lab: LSR Settings

- **DGS3630_Left**
  - configure terminal
  - monitor session 1 destination interface ethernet 1/0/1
  - monitor session 1 source interface ethernet 1/0/5-8
  - interface loopback 1
  - ip address 6.6.6.6 255.255.255.0
  - exit
  - interface loopback 2
  - ip address 66.66.66.66 255.255.255.0
  - exit
MPLS Configuration Lab: LSR Settings

- **DGS3630_Left**
  - mpls ldp configuration
  - router-id 66.66.66.66
  - explicit-null
  - exit
  - mpls ip
  - mpls label protocol ldp
  - no int vlan 1
  - vlan 100
  - exit
MPLS Configuration Lab: LSR Settings

- **DGS3630_Left**
  - `int vlan 100`
  - `ip address 192.168.100.254 255.255.255.0`
  - `mpls ip`
  - `mpls label protocol ldp`
  - `exit`
  - `interface eth 1/0/8`
  - `switchport mode access`
  - `switchport access vlan 66`
  - `exit`
MPLS Configuration Lab: LSR Settings

- **DGS3630_Left**
  - vlan 56
  - exit
  - interface vlan 56
  - ip address 192.168.56.6 255.255.255.0
  - mpls ip
  - mpls label protocol ldp
  - exit
  - interface eth 1/0/5
  - switchport mode access
  - switchport access vlan 56
  - exit
MPLS Configuration Lab: LSR Settings

- **DGS3630_Left**
  - router bgp 6
  - bgp router-id 6.6.6.6
  - neighbor 192.168.56.5 remote-as 5
  - neighbor 192.168.56.5 activate
  - neighbor 192.168.56.5 description DGS-3630-28TC(SW1)
  - network 6.6.6.0/24
  - network 66.66.66.0/24
  - network 192.168.56.0/24
  - network 192.168.100.0/24
MPLS Configuration Lab: LSR Settings

- **DGS3630_Right**
  - configure terminal
  - prompt DGS3630_Right
  - monitor session 1 destination interface ethernet 1/0/1
  - monitor session 1 source interface ethernet 1/0/7-8
  - interface loopback 1
  - ip address 7.7.7.7 255.255.255.0
  - exit
  - interface loopback 2
  - ip address 77.77.77.77 255.255.255.0
  - exit
MPLS Configuration Lab: LSR Settings

- **DGS3630_Right**
  - mpls ldp configuration
  - router-id 77.77.77.77
  - explicit-null
  - exit
  - mpls ip
  - mpls label protocol ldp
  - no int vlan 1
  - vlan 200
  - exit
MPLS Configuration Lab: LSR Settings

- **DGS3630_Right**
  - int vlan 200
  - ip address 192.168.200.254 255.255.255.0
  - mpls ip
  - mpls label protocol ldp
  - exit
  - interface eth 1/0/8
  - switchport mode access
  - switchport access vlan 200
  - exit
MPLS Configuration Lab: LSR Settings

- **DGS3630_Right**
  - vlan 57
  - exit
  - interface vlan 57
  - ip address 192.168.57.7 255.255.255.0
  - mpls ip
  - mpls label protocol ldp
  - exit
  - interface eth 1/0/7
  - switchport mode access
  - switchport access vlan 57
  - exit
MPLS Configuration Lab: LSR Settings

- **DGS3630_Right**
  - router bgp 7
  - bgp router-id 7.7.7.7
  - neighbor 192.168.57.5 remote-as 5
  - neighbor 192.168.57.5 activate
  - neighbor 192.168.57.5 description DGS-3630-28TC(SW1)
  - network 7.7.7.0/24
  - network 77.77.77.0/24
  - network 192.168.57.0/24
  - network 192.168.200.0/24
MPLS Configuration Lab: MPLS interface status

- With the command of “show mpls interface” you are able to view MPLS interface status. Take DGS3630_Hub as an example, how many MPLS interface(s) being configured?

```
DGS3630_Hub#show mpls interface

<table>
<thead>
<tr>
<th>Interface</th>
<th>IP Address</th>
<th>Oper Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>vlan56</td>
<td>192.168.56.5/24</td>
<td>Up</td>
</tr>
<tr>
<td>vlan57</td>
<td>192.168.57.5/24</td>
<td>Up</td>
</tr>
</tbody>
</table>

Total Entries: 2
```

- The D-Track DI20160401000003 generates positive image of this command as far as individual’s troubleshooting skill is concerned.
MPLS Configuration Lab: MPLS LDP interface

- This command of “show mpls ldp interface” is used to display LDP interface information.
- The right-hand side diagram shall offer adequate visual understandings.

```
DGS3630_SW1#show mpls ldp interface

Interface : vlan56

Admin State : Enabled
Oper State : Enabled
Targeted Hello Accept : Acceptable
Hello Interval : 5(Sec)
Hello Hold Time : 15(Sec)
Distribution Method : DU

Interface : vlan57

Admin State : Enabled
Oper State : Enabled
Targeted Hello Accept : Acceptable
Hello Interval : 5(Sec)
Hello Hold Time : 15(Sec)
Distribution Method : DU

Total Entries: 2
DGS3630_SW1#_
```
Quiz Session: Output from show commands

- The “Hello Interval” and “Hello Hold Time” parameters also being carried out with “show mpls ldp interface” command, how do you interpret on that?
Quiz Session: Output from show commands

- We just had an opportunity to display the output of “show mpls interface” and “show mpls ldp interface,” are you able to distinguish outcome differences between these two commands?
MPLS Lab Note: Interface settings with MPLS

- Even you plan to deploy DGS3630_Left and DGS3630_Right as the PE router, the laptop connected interface also require MPLS configurations. As such, two laptops are able to ping each other.

- The lesson is learned from DI20160401000003, avoiding irreversible damages in the field work.
MPLS Lab Note: Check the connectivity

- The command of “ping mpls ipv4” is used to check the connectivity of the LSP for the specified FEC
- For example, in DGS3630_Right, you can exercise
  - Ping mpls ipv4 6.6.6.6/24, or
  - Ping mpls ipv4 66.66.66.66/24

- A D-Track case, HQ20090211000002, also describes the technical capabilities of this command
MPLS Configuration Lab: LDP Peers (1/2)

- As stated in RFC 5035, “Two LSRs that use LDP to exchange label/FEC mapping information are known as "LDP Peers" with respect to that information”

- Quiz Session: Can D-Link switch show command offer the convenience of such feasibility?
**MPLS Configuration Lab: LDP Peers (2/2)**

- Quiz Session: LDP Peers message with D-Link switch command?
  - Ans: `show mpls ldp neighbor`

- Note: The maximum allowable PDU Length is negotiable when an LDP session is initialized.
MPLS Configuration Lab: distribution-mode (1/2)

- Quiz Session: The “distribution-mode” command makes suitable to configure the label distribution mode. How do we know the parameters being set up on the same subject in our neighboring LSR?
MPLS Configuration Lab: distribution-mode (2/2)

- Quiz Session: “distribution-mode” in neighboring LSR
- Ans: Employ the command of “show mpls ldp neighbor” shall fulfill the requirements

```
DGS3630_Hub#show mpls ldp neighbor

Peer : 66.66.66.66:0
-----------------------
Protocol Version : 1.0
Transport Address : 66.66.66.66
Keep Alive Time   : 60 seconds
Distribution Method : DU
Loop Detect       : Disabled
Path Vector Limit : 0
Max PDU Length    : 1500
Graceful Restart  : Disabled
Reconnection Time : 0 Seconds
Recovery Time     : 0 Seconds
```
MPLS Configuration Lab: Distribution Method

- The following list of commands display the information on “Distribution Method”
  - show mpls ldp information
  - show mpls ldp interface
  - show mpls ldp neighbor
  - show mpls ldp session
  - show mpls ldp session peer 77.77.77.77 detail
Quiz Session: mpls ldp discovery (1/2)

- Quiz: We would like to obtain LDP neighboring information in DGS3630_Hub, what could be a fitting show command to reach our goal?
Quiz Session: mpls ldp discovery (2/2)

- Quiz: LDP neighboring information in DGS3630_Hub
- Ans: It is suggested to take advantage of “show mpls ldp discovery.” Please refer the below sketch for detail outputs

```
DGS3630_Hub#show mpls ldp discovery
Local LDP Identifier: 55.55.55.55:0
Discovery Sources:
   Interfaces:
   VLAN 56 (LDP): xmit/recv
       LDP Id: 66.66.66.66:0
   VLAN 57 (LDP): xmit/recv
       LDP Id: 77.77.77.77:0
Targeted Hellos:
DGS3630_Hub#
```
Quiz Session: mpls ldp session (1/2)

- Quiz: How to verify the “mpls ldp session” in DGS3630_Hub?
Quiz Session: mpls ldp session (2/2)

- Quiz: How to verify the “mpls ldp session” in DGS3630_Hub
- Ans: With the command of “show mpls ldp session”

```
DGS3630_Hub#show mpls ldp session

<table>
<thead>
<tr>
<th>Peer</th>
<th>Status</th>
<th>Role</th>
<th>Keep Alive</th>
<th>Distribution Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>66.66.66.66:0</td>
<td>OPERATIONAL</td>
<td>Passive</td>
<td>40(Sec)</td>
<td>DU</td>
</tr>
<tr>
<td>77.77.77.77:0</td>
<td>OPERATIONAL</td>
<td>Passive</td>
<td>40(Sec)</td>
<td>DU</td>
</tr>
</tbody>
</table>

Total Entries: 2
```

- **LSR determines whether it will play the active or passive role in session establishment by comparing addresses. In this example, “DGS3630_Right” and “DGS3630_Left” take the responsibility of “active role”**
Quiz Session: mpls forwarding-table (1/3)

- Quiz: In DGS3630_Hub, what is the total mpls forwarding-table entries?

- This is a common question being claimed in the field. D-Track DI20160401000003, DI20160407000005, DRU20150203000005, as well others, justify the command’s mighty power in customer service.
Quiz Session: mpls forwarding-table (2/3)

- Quiz: Total mpls forwarding-table entries in DGS3630_Hub
- Ans: With the command of “show mpls forwarding-table,” it offers the answer of 18

```plaintext
DGS3630_Hub#show mpls forwarding-table

<table>
<thead>
<tr>
<th>LSP</th>
<th>FEC</th>
<th>In Label</th>
<th>Out Label</th>
<th>Out Interface</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.5.5.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>55.55.55.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>5.5.5.5/32</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>55.55.55.55/32</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>192.168.57.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>6.6.6.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 56</td>
<td>192.168.56.6</td>
</tr>
<tr>
<td>13</td>
<td>6.6.6.0/24</td>
<td>1000</td>
<td>0</td>
<td>VLAN 56</td>
<td>192.168.56.6</td>
</tr>
<tr>
<td>7</td>
<td>66.66.66.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 56</td>
<td>192.168.56.6</td>
</tr>
<tr>
<td>15</td>
<td>66.66.66.0/24</td>
<td>1002</td>
<td>0</td>
<td>VLAN 56</td>
<td>192.168.56.6</td>
</tr>
</tbody>
</table>
```
Quiz Session: mpls forwarding-table (3/3)

- Quiz: mpls forwarding-table entries in DGS3630_Hub

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.5.5.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>55.55.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>5.5.5/32</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>55.55.55/32</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>192.168.57.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>6.6.6.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 56</td>
</tr>
<tr>
<td>13</td>
<td>6.6.6.0/24</td>
<td>1000</td>
<td>0</td>
<td>VLAN 56</td>
</tr>
<tr>
<td>7</td>
<td>66.66.66.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 56</td>
</tr>
<tr>
<td>15</td>
<td>66.66.66.0/24</td>
<td>1002</td>
<td>0</td>
<td>VLAN 56</td>
</tr>
<tr>
<td>8</td>
<td>192.168.100.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 56</td>
</tr>
<tr>
<td>14</td>
<td>192.168.100.0/24</td>
<td>1001</td>
<td>0</td>
<td>VLAN 56</td>
</tr>
<tr>
<td>12</td>
<td>7.7.7.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 57</td>
</tr>
<tr>
<td>10</td>
<td>7.7.7.0/24</td>
<td>1003</td>
<td>0</td>
<td>VLAN 57</td>
</tr>
<tr>
<td>11</td>
<td>77.77.77.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 57</td>
</tr>
<tr>
<td>18</td>
<td>77.77.77.0/24</td>
<td>1005</td>
<td>0</td>
<td>VLAN 57</td>
</tr>
<tr>
<td>16</td>
<td>192.168.200.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 57</td>
</tr>
<tr>
<td>17</td>
<td>192.168.200.0/24</td>
<td>1004</td>
<td>0</td>
<td>VLAN 57</td>
</tr>
<tr>
<td>9</td>
<td>192.168.56.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Total Entries: 18
Quiz Session: Forwarding-table entries

- Quiz: Are you able to tell the total number of Forwarding-table entries in the rest of two LSRs?
  - DGS3630_Left:
  - DGS3630_Right:
Quiz Session: Forwarding-table entries

- Quiz: Are you able to tell the total number of Forwarding-table entries in the rest of two LSRs?
- DGS3630_Left: 11 (please see next slide for identical records)
- DGS3630_Right: 11
Quiz Session: Forwarding-table entries

- 11 forwarding-table entries from DGS3630_Left

```
DGS3630_Left#>show mpls forwarding-table

<table>
<thead>
<tr>
<th>LSP</th>
<th>FEC</th>
<th>In Label</th>
<th>Out Label</th>
<th>Out Interface</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.6.6.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>66.66.66.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>6.6.6.6/32</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>66.66.66.66/32</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>192.168.100.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>5.5.5.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 56</td>
<td>192.168.56.5</td>
</tr>
<tr>
<td>7</td>
<td>55.55.55.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 56</td>
<td>192.168.56.5</td>
</tr>
<tr>
<td>8</td>
<td>192.168.57.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 56</td>
<td>192.168.56.5</td>
</tr>
<tr>
<td>9</td>
<td>7.7.7.0/24</td>
<td>-</td>
<td>1003</td>
<td>VLAN 56</td>
<td>192.168.56.5</td>
</tr>
<tr>
<td>10</td>
<td>77.77.70.0/24</td>
<td>-</td>
<td>1005</td>
<td>VLAN 56</td>
<td>192.168.56.5</td>
</tr>
<tr>
<td>11</td>
<td>192.168.200.0/24</td>
<td>-</td>
<td>1004</td>
<td>VLAN 56</td>
<td>192.168.56.5</td>
</tr>
</tbody>
</table>

Total Entries: 11
```
Quiz Session: Forwarding-table entries

- 11 forwarding-table entries from DGS3630_Right

```
DGS3630_Right# show mpls forwarding-table

<table>
<thead>
<tr>
<th>LSP</th>
<th>FEC</th>
<th>In Label</th>
<th>Out Label</th>
<th>Out Interface</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.7.7.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>77.77.7.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>7.7.7.7/32</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>77.77.77.77/32</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>192.168.200.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>5.5.5.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 57</td>
<td>192.168.57.5</td>
</tr>
<tr>
<td>7</td>
<td>55.55.5.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 57</td>
<td>192.168.57.5</td>
</tr>
<tr>
<td>8</td>
<td>192.168.56.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 57</td>
<td>192.168.57.5</td>
</tr>
<tr>
<td>9</td>
<td>6.6.6.0/24</td>
<td>-</td>
<td>1000</td>
<td>VLAN 57</td>
<td>192.168.57.5</td>
</tr>
<tr>
<td>10</td>
<td>192.168.100.0/24</td>
<td>-</td>
<td>1001</td>
<td>VLAN 57</td>
<td>192.168.57.5</td>
</tr>
<tr>
<td>11</td>
<td>66.66.66.0/24</td>
<td>-</td>
<td>1002</td>
<td>VLAN 57</td>
<td>192.168.57.5</td>
</tr>
</tbody>
</table>

Total Entries: 11
```
Quiz Session: Label Retention Mode (1/2)

- Quiz: Which D-Link command can present Label Retention status of “DGS3630_Right”?
Quiz Session: Label Retention Mode (2/2)

- Quiz: Label Retention status in “DGS3630_Right”
- Ans: Please refer to “show mpls ldp information.”

- Liberal Label Retention Mode: Every label mappings received from a peer LSR is retained regardless of whether the LSR is the next hop for the advertised mapping.
Quiz Session: mpls forwarding-table (1/4)

- Quiz: In the position of “DGS3630_Left,” what would be the forwarding-table on the prefix of 77.77.77.0/24?
Quiz Session: mpls forwarding-table (2/4)

- Quiz: MPLS forwarding-table on “77.77.77.0/24”
- Ans: From “show mpls forwarding-table detail” it indicates it is an “Ingress router” on that prefix (77.77.77.0/24) where it would take the action of “Push 1005” in managing that label

- Please refer the following two slides for detail information
Quiz Session: mpls forwarding-table (3/4)

- The below sketch shall display the MPLS label forwarding path info.

```
DGS3630_Left#
DGS3630_Left# show mpls forwarding-table

<table>
<thead>
<tr>
<th>LSP</th>
<th>FEC</th>
<th>In Label</th>
<th>Out Label</th>
<th>Out Interface</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.6.6.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>66.66.66.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>6.6.6.6/32</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>66.66.66.66/32</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>192.168.100.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>5.5.5.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 56</td>
<td>192.168.56.5</td>
</tr>
<tr>
<td>7</td>
<td>55.55.55.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 56</td>
<td>192.168.56.5</td>
</tr>
<tr>
<td>8</td>
<td>192.168.57.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 56</td>
<td>192.168.56.5</td>
</tr>
<tr>
<td>9</td>
<td>7.7.7.0/24</td>
<td>-</td>
<td>1003</td>
<td>VLAN 56</td>
<td>192.168.56.5</td>
</tr>
<tr>
<td>10</td>
<td>77.77.77.0/24</td>
<td>-</td>
<td>1005</td>
<td>VLAN 56</td>
<td>192.168.56.5</td>
</tr>
<tr>
<td>11</td>
<td>192.168.200.0/24</td>
<td>-</td>
<td>1004</td>
<td>VLAN 56</td>
<td>192.168.56.5</td>
</tr>
</tbody>
</table>

Total Entries: 11
```

D-Link Academy
Quiz Session: mpls forwarding-table (4/4)

- Itemized LSP illustration

```
DGS3630_Left#show mpls forwarding-table detail

<table>
<thead>
<tr>
<th>LSP:1</th>
<th>Status:Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type:Egress</td>
<td>Owner:LDP</td>
</tr>
<tr>
<td>FEC:6.6.6.0/24</td>
<td>Out Label:Pop</td>
</tr>
<tr>
<td>In Label:0</td>
<td>Out Interface:-</td>
</tr>
<tr>
<td>Next Hop:-</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LSP:2</th>
<th>Status:Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type:Egress</td>
<td>Owner:LDP</td>
</tr>
<tr>
<td>FEC:66.66.66.0/24</td>
<td>Out Label:Pop</td>
</tr>
<tr>
<td>In Label:0</td>
<td>Out Interface:-</td>
</tr>
<tr>
<td>Next Hop:-</td>
<td></td>
</tr>
</tbody>
</table>
```
Quiz Session: mpls forwarding-table (4/4)

- Itemized LSP illustration

```
DGS3630_Left#show mpls forwarding-table detail

LSP:1
Type:Egress
FEC:6.6.6.0/24
In Label:0
Next Hop:-

LSP:2
Type:Egress
FEC:66.66.66.0/24
In Label:0
Next Hop:-

LSP:9
Type:Ingress
FEC:7.7.7.0/24
In Label:-
Next Hop:192.168.56.5

LSP:10
Type:Ingress
FEC:77.77.77.0/24
In Label:-
Next Hop:192.168.56.5

LSP:11
Type:Ingress
FEC:192.168.200.0/24
In Label:-
Next Hop:192.168.56.5

Total Entries: 11
```

D-Link Certified Specialist
- MPLS Configuration Guide

D-Link Academy
Quiz Session: Penultimate Hop Popping (1/2)

- Quiz: We are interested in learning the “Penultimate Hop Popping” behavior in DGS3630_Hub, what would be a proper approach to divide and conquer?
Quiz Session: Penultimate Hop Popping (2/2)

- Quiz: “Penultimate Hop Popping” behavior in DGS3630_Hub
- Ans: “show mpls ldp information” shall bring noticeable results
MPLS Configuration Lab: LDP label binding info.

- The command of “show mpls ldp bindings” illustrates all LDP label binding information.
- In DGS3630_Hub, this command informs us that 192.168.100.0/24 comes from the downstream LSR (66.66.66.66) and is requested by upstream LSR (77.77.77.77).

- The acting abilities of this command is also revealed in D-Track DRU20150408000005.
MPLS Lab Note: LDP label binding info.

- Should the upstream / downstream output of a specific FEC is “NONE,” after executing “show mpls ldp bindings” command. You might be experiencing incorrect configurations.
- It is recommended to immediately review the settings.

- D-Track DRU20150408000005 endeavors on this subject to streamline our productivity.
LSR's forwarding table entries (1/4)

- “explicit-null” is the command to advertise the explicit null label to the penultimate hop
- The above three LSRs come with “explicit-null” and our lab brings the number of forwarding table entries:
  - DGS3630_Hub: 18
  - DGS3630_Right: 11
  - DGS3630_Left: 11

- Quiz Session: Should the changes of label advertisement cause any impact to the forwarding-table entries?
LSR's forwarding table entries (2/4)

- Network Topology / Configuration remains the same
- DGS3630_Hub: being modified to implicit null
- The number of forwarding table entries
  - DGS3630_Hub: 12
  - DGS3630_Right: 11 (remains the same)
  - DGS3630_Left: 11 (remains the same)

- Findings: There are no DGS3630_Hub interface prefix(s) in its DGS3630_Hub’s mpls forwarding table entries
LSR's forwarding table entries (3/4)

- Network Topology / Configuration remains the same
- All three switches shift to implicit null mode
- The number of forwarding table entries
  - DGS3630_Hub: 12
  - DGS3630_Right: 6
  - DGS3630_Left: 6

- Findings: Each LSR’s interfaces would not be presented in its own MPLS forwarding table entries
LSR's forwarding table entries (4/4)

- Our lab findings correspond to D-Track KM “DK1400739” where it clearly states “The implicit NULL should be used, as the PHP reduces the amount of lookup required on the last hop of an LSP.”

- Additional short statements in D-Track HQ20150409000008, captured below, have instructed us a similar concept
  - The LDP is “Implicit-Null” on both switches and the two switches are connected directly. So there is no LSP between the two switches.
Penultimate Hop Popping (PHP) Behavior

- As DGS-3630 CLI Reference Guide indicates in page 963:
- Use this (explicit-null) command on the egress router to configure the Penultimate Hop Popping (PHP) behavior of the upstream router.
- If the egress router advertises the explicit null label, the upstream router will keep the outer label without popping.
- If the egress router advertises the implicit null label, the upstream router will do Penultimate Hop Popping.
Penultimate Hop Popping (PHP) Behavior

- As DGS-3630 CLI Reference Guide indicates in page 963:
  - Use this (explicit-null) command on the egress router to configure the Penultimate Hop Popping (PHP) behavior of the upstream router.

- If the egress router advertises the explicit null label, the upstream router will keep the outer label without popping.

- If the egress router advertises the implicit null label, the upstream router will do Penultimate Hop Popping.

- In Plain English, please.
PHP Behavior Verification: explicit-null (1/5)

- Network Topology / Configuration remains the same
- **All three switches are implemented with “explicit-null”**
  - Switch(config)# mpls ldp configuration
  - Switch(config-ldp)# explicit-null

- We are taking 66.66.66.0/24, from DGS3630_Left, as an example, and corresponding lab outcomes by adapting the command of “show mpls forwarding-table detail” in each LSR as a means to confirm associated label advertisement action
PHP Behavior Verification: explicit-null (2/5)

- In DGS3630_Left
- One MPLS forwarding table entry
  - As an Egress router, In label: 0, Out label: Pop

```
DGS3630_Left: #show mpls forwarding-table detail

LSP: 1
  Type: Ingress
  FEC: 7.7.7.0/24
  In Label: -
  Next Hop: 192.168.56.5
  Status: Up
  Owner: LDP
  Out Label: Push 1003
  Out Interface: VLAN 56

LSP: 2
  Type: Ingress
  FEC: 7.7.77.0/24
  In Label: -
  Next Hop: 192.168.56.5
  Status: Up
  Owner: LDP
  Out Label: Push 1004
  Out Interface: VLAN 56
```
**PHP Behavior Verification: explicit-null (2/5)**

- **In DGS3630_Left**
- **One MPLS forwarding table entry**
  - As an Egress router, In label: 0, Out label: Pop

```bash
DGS3630_Left#show mpls forwarding-table detail
```

<table>
<thead>
<tr>
<th>LSP:1</th>
<th>LSP:5</th>
<th>LSP:6</th>
<th>LSP:7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type: Ingress</td>
<td>Type: Egress</td>
<td>Type: Egress</td>
<td>Type: Egress</td>
</tr>
<tr>
<td>FEC: 7.7.7.0/24</td>
<td>FEC: 66.66.66.0/24</td>
<td>FEC: 6.6.6.6/32</td>
<td>FEC: 66.66.66.66/32</td>
</tr>
<tr>
<td>In Label: -</td>
<td>In Label: 0</td>
<td>In Label: 0</td>
<td>In Label: 0</td>
</tr>
<tr>
<td>Next Hop: 192.168.56.5</td>
<td>Out Label: Pop</td>
<td>Out Label: Pop</td>
<td>Out Label: Pop</td>
</tr>
<tr>
<td></td>
<td>Status: Up</td>
<td>Status: Up</td>
<td>Status: Up</td>
</tr>
<tr>
<td></td>
<td>Owner: LDP</td>
<td>Owner: LDP</td>
<td>Owner: LDP</td>
</tr>
<tr>
<td></td>
<td>Out Interface: -</td>
<td>Out Interface: -</td>
<td>Out Interface: -</td>
</tr>
</tbody>
</table>

D-Link Academy
PHP Behavior Verification: explicit-null (3/5)

- In **DGS3630_Hub**

- Two forwarding table entries
  - As an Ingress router, In label: -, Out label: Push 0
  - As a Transit router, In label: 1002, out label: Push 0

```
DGS3630_Hub# show mpls forwarding-table detail

LSP:1
  Type:Egress
  FEC:5.5.5.0/24
  In Label:0
  Next Hop:-
  Status:Up
  Owner:LDP
  Out Label:Pop
  Out Interface:-

LSP:2
  Type:Egress
  FEC:55.55.55.0/24
  In Label:0
  Next Hop:-
  Status:Up
  Owner:LDP
  Out Label:Pop
  Out Interface:-
```
PHP Behavior Verification: explicit-null (3/5)

- **In DGS3630_Hub**

- **Two forwarding table entries**
  - As an Ingress router, In label: -, Out label: Push 0
  - As a Transit router, In label: 1002, out label: Push 0

```
DGS3630_Hub# show mpls forwarding-table detail
```

<table>
<thead>
<tr>
<th>LSP:1</th>
<th>Type: Egress</th>
<th>Status: Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEC: 5.5.5.0/24</td>
<td>Owner: LDP</td>
<td></td>
</tr>
<tr>
<td>In Label: 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Next Hop: -</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LSP:2</th>
<th>Type: Egress</th>
<th>Status: Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEC: 55.55.55.0/24</td>
<td>Owner: LDP</td>
<td></td>
</tr>
<tr>
<td>In Label: 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Next Hop: -</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LSP:15</th>
<th>Type: Ingress</th>
<th>Status: Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEC: 66.66.66.0/24</td>
<td>Owner: LDP</td>
<td></td>
</tr>
<tr>
<td>In Label: -</td>
<td>Out Label: Push 0</td>
<td></td>
</tr>
<tr>
<td>Next Hop: 192.168.56.6</td>
<td>Out Interface: VLAN 56</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LSP:16</th>
<th>Type: Transit</th>
<th>Status: Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEC: 66.66.66.0/24</td>
<td>Owner: LDP</td>
<td></td>
</tr>
<tr>
<td>In Label: 1002</td>
<td>Out Label: Push 0</td>
<td></td>
</tr>
<tr>
<td>Next Hop: 192.168.56.6</td>
<td>Out Interface: VLAN 56</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LSP:17</th>
<th>Type: Ingress</th>
<th>Status: Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEC: 192.168.100.0/24</td>
<td>Owner: LDP</td>
<td></td>
</tr>
<tr>
<td>In Label: -</td>
<td>Out Label: Push 0</td>
<td></td>
</tr>
<tr>
<td>Next Hop: 192.168.56.6</td>
<td>Out Interface: VLAN 56</td>
<td></td>
</tr>
</tbody>
</table>
PHP Behavior Verification: explicit-null (4/5)

- In DGS3630_Right
- One MPLS forwarding table entry
  - As an Egress router, In label: -, Out label: Push 1002

```
DGS3630_Right(show mpls forwarding-table detail)

LSP:1
  Type:Egress
  FEC:7.7.7.0/24
  In Label:0
  Next Hop: -
  Status:Up
  Owner:LDP
  Out Label:Pop
  Out Interface: -

LSP:2
  Type:Egress
  FEC:77.77.77.0/24
  In Label:0
  Next Hop: -
  Status:Up
  Owner:LDP
  Out Label:Pop
  Out Interface: -
```
PHP Behavior Verification: explicit-null (4/5)

- In DGS3630_Right
- One MPLS forwarding table entry
  - As an Ingress router, In label: -, Out label: Push 1002

```
DGS3630_Right # show mpls forwarding-table detail
```

<table>
<thead>
<tr>
<th>LSP</th>
<th>Type: Egress</th>
<th>FEC: 7.7.7.0/24</th>
<th>In Label: 0</th>
<th>Next Hop: -</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSP</td>
<td>Type: Egress</td>
<td>FEC: 6.6.6.0/24</td>
<td>In Label: -</td>
<td>Next Hop: 192.168.57.5</td>
</tr>
<tr>
<td>LSP</td>
<td>Type: Ingress</td>
<td>FEC: 66.66.66.0/24</td>
<td>In Label: -</td>
<td>Out Label: Push 1002</td>
</tr>
<tr>
<td>LSP</td>
<td>Type: Ingress</td>
<td>FEC: 192.168.100.0/24</td>
<td>In Label: -</td>
<td>Out Label: Push 1001</td>
</tr>
</tbody>
</table>

Total Entries: 11
If the egress router advertises the explicit null label, the upstream router will keep the outer label without popping.

DGS3630_Hub is DGS3630_Right’s upstream router

Since the egress router is configured with explicit null label, thus, DGS3630_Hub keeps the outer label without popping.

<table>
<thead>
<tr>
<th>LSP: 15</th>
<th>Status: Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type: Ingress</td>
<td>Owner: LDP</td>
</tr>
<tr>
<td>FEC: 66.66.66.0/24</td>
<td>Out Label: Push 0</td>
</tr>
<tr>
<td>In Label: -</td>
<td>Out Interface: VLAN 56</td>
</tr>
<tr>
<td>Next Hop: 192.168.56.6</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LSP: 16</th>
<th>Status: Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type: Transit</td>
<td>Owner: LDP</td>
</tr>
<tr>
<td>FEC: 66.66.66.0/24</td>
<td>Out Label: Push 0</td>
</tr>
<tr>
<td>In Label: 1002</td>
<td>Out Interface: VLAN 56</td>
</tr>
<tr>
<td>Next Hop: 192.168.56.6</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LSP: 17</th>
<th>Status: Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type: Ingress</td>
<td>Owner: LDP</td>
</tr>
<tr>
<td>FEC: 192.168.100.0/24</td>
<td>Out Label: Push 0</td>
</tr>
<tr>
<td>In Label: -</td>
<td>Out Interface: VLAN 56</td>
</tr>
<tr>
<td>Next Hop: 192.168.56.6</td>
<td></td>
</tr>
</tbody>
</table>
PHP Behavior Verification: implicit null (1/5)

- Network Topology / Configuration remains the same
- **All three switches are implemented with “implicit null”**
  - Switch(config)# mpls ldp configuration
  - Switch(config-ldp)# no explicit-null

- We continue our interests on 66.66.66.0/24, from DGS3630_Left, and corresponding our findings with the command of “show mpls forwarding-table detail” in each LSR to confirm associated label advertisement action
PHP Behavior Verification: implicit null (2/5)

- **In DGS3630_Left**
- There is NO MPLS forwarding table entry on its own interface(s)

```bash
DGS3630_Left#show mpls forwarding-table
```

<table>
<thead>
<tr>
<th>LSP</th>
<th>FEC</th>
<th>In Label</th>
<th>Out Label</th>
<th>Out Interface</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.5.5.0/24</td>
<td>-</td>
<td>-</td>
<td>VLAN 56</td>
<td>192.168.56.5</td>
</tr>
<tr>
<td>2</td>
<td>55.55.55.0/24</td>
<td>-</td>
<td>-</td>
<td>VLAN 56</td>
<td>192.168.56.5</td>
</tr>
<tr>
<td>3</td>
<td>192.168.57.0/24</td>
<td>-</td>
<td>-</td>
<td>VLAN 56</td>
<td>192.168.56.5</td>
</tr>
<tr>
<td>4</td>
<td>7.7.7.0/24</td>
<td>-</td>
<td>1003</td>
<td>VLAN 56</td>
<td>192.168.56.5</td>
</tr>
<tr>
<td>5</td>
<td>192.168.200.0/24</td>
<td>-</td>
<td>1004</td>
<td>VLAN 56</td>
<td>192.168.56.5</td>
</tr>
<tr>
<td>6</td>
<td>77.77.77.0/24</td>
<td>-</td>
<td>1005</td>
<td>VLAN 56</td>
<td>192.168.56.5</td>
</tr>
</tbody>
</table>

Total Entries: 6
PHP Behavior Verification: implicit null (3/5)

- In DGS3630_Hub
- Two forwarding table entries
  - As an Ingress router, In label: -, Out label: Php
  - As a Transit router, In label: 1002, out label: Pop

```
DGS3630_Hub#show mpls forwarding-table detail
```

<table>
<thead>
<tr>
<th>LSP: 5</th>
<th>Ingress</th>
<th>Status: Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEC: 7.7.7.0/24</td>
<td>Owner:LDP</td>
<td></td>
</tr>
<tr>
<td>In Label: -</td>
<td>Out Label: Php</td>
<td></td>
</tr>
<tr>
<td>Next Hop: 192.168.57.7</td>
<td>Out Interface: VLAN 57</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LSP: 6</th>
<th>Transit</th>
<th>Status: Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEC: 7.7.7.0/24</td>
<td>Owner:LDP</td>
<td></td>
</tr>
<tr>
<td>In Label: 1003</td>
<td>Out Label: Pop</td>
<td></td>
</tr>
<tr>
<td>Next Hop: 192.168.57.7</td>
<td>Out Interface: VLAN 57</td>
<td></td>
</tr>
</tbody>
</table>

PHP Behavior Verification: implicit null (3/5)

- **In DGS3630_Hub**
- **Two forwarding table entries**
  - As an Ingress router, In label: -, Out label: Php
  - As a Transit router, In label: 1002, out label: Pop

DGS3630_Hub#show mpls forwarding-table detail

<table>
<thead>
<tr>
<th>LSP:5</th>
<th>Type:Ingress</th>
<th>FEC:7.7.7.0/24</th>
<th>In Label:</th>
<th>Next Hop:192.168.57.7</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSP:6</td>
<td>Type:Transit</td>
<td>FEC:7.7.7.0/24</td>
<td>In Label:1003</td>
<td>Next Hop:192.168.57.7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LSP:9</th>
<th>Type:Ingress</th>
<th>FEC:66.66.66.0/24</th>
<th>Status:Up</th>
<th>Owner:LDP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In Label:-</td>
<td>Out Label:Php</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Next Hop:192.168.56.6</td>
<td>Out Interface:VLAN 56</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LSP:3</th>
<th>Type:Transit</th>
<th>FEC:66.66.66.0/24</th>
<th>Status:Up</th>
<th>Owner:LDP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In Label:1002</td>
<td>Out Label:Pop</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Next Hop:192.168.56.6</td>
<td>Out Interface:VLAN 56</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LSP:10</th>
<th>Type:Ingress</th>
<th>FEC:192.168.100.0/24</th>
<th>Status:Up</th>
<th>Owner:LDP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In Label:-</td>
<td>Out Label:Php</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
PHP Behavior Verification: implicit null (4/5)

- In **DGS3630_Right**
- One MPLS forwarding table entry
  - As an Egress router, In label: -, Out label: Push 1002

```
DGS3630_Right#show mpls forwarding-table detail
```

<table>
<thead>
<tr>
<th>LSP: 1</th>
<th>Status: Up</th>
<th>Owner: LDP</th>
<th>Out Label: Php</th>
<th>Out Interface: VLAN 57</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type: Ingress</td>
<td>FEC: 5.5.5.0/24</td>
<td>In Label: -</td>
<td>Next Hop: 192.168.57.5</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LSP: 2</th>
<th>Status: Up</th>
<th>Owner: LDP</th>
<th>Out Label: Php</th>
<th>Out Interface: VLAN 57</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type: Ingress</td>
<td>FEC: 55.55.55.0/24</td>
<td>In Label: -</td>
<td>Next Hop: 192.168.57.5</td>
<td></td>
</tr>
</tbody>
</table>
PHP Behavior Verification: implicit null (4/5)

- In DGS3630_Right
- One MPLS forwarding table entry
  - As an Egress router, In label: -, Out label: Push 1002

```
DGS3630_Right#show mpls forwarding-table detail

LSP: 1
  Type: Ingress
  FEC: 5.5.5.0/24
  In Label: -
  Next Hop: 192.168.57.5

LSP: 2
  Type: Ingress
  FEC: 55.55.55.0/24
  In Label: -
  Next Hop: 192.168.57.5

LSP: 5
  Type: Ingress
  FEC: 192.168.100.0/24
  In Label: -
  Next Hop: 192.168.57.5

  Status: Up
  Owner: LDP

LSP: 6
  Type: Ingress
  FEC: 66.66.66.0/24
  In Label: -
  Next Hop: 192.168.57.5

  Status: Up
  Owner: LDP

  Out Label: Push 1002
  Out Interface: VLAN 57

Total Entries: 6
DGS3630_Right#
```
PHP Behavior Verification: implicit null (5/5)

- If the egress router advertises the implicit null label, the upstream router will do Penultimate Hop Popping.
- DGS3630_Hub is DGS3630_Right’s upstream router
- Since the egress router is configured with implicit null label, thus, DGS3630_Hub performs Penultimate Hop Popping

<table>
<thead>
<tr>
<th>LSP: 9</th>
<th>Type: Ingress</th>
<th>Status: Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEC: 66.66.66.0/24</td>
<td>Owner: LDP</td>
<td>Out Label: Php</td>
</tr>
<tr>
<td>In Label: --</td>
<td>Out Label: Php</td>
<td></td>
</tr>
<tr>
<td>Next Hop: 192.168.56.6</td>
<td>Out Interface: VLAN 56</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LSP: 3</th>
<th>Type: Transit</th>
<th>Status: Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEC: 66.66.66.0/24</td>
<td>Owner: LDP</td>
<td>Out Label: Php</td>
</tr>
<tr>
<td>In Label: 1002</td>
<td>Out Label: Pop</td>
<td></td>
</tr>
<tr>
<td>Next Hop: 192.168.56.6</td>
<td>Out Interface: VLAN 56</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LSP: 10</th>
<th>Type: Ingress</th>
<th>Status: Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEC: 192.168.100.0/24</td>
<td>Owner: LDP</td>
<td>Out Label: Php</td>
</tr>
<tr>
<td>In Label: --</td>
<td>Out Label: Php</td>
<td></td>
</tr>
</tbody>
</table>

D-Link Academy
Brainstorming on PHP (Wireshark collect data)

- Port 1 in each switch is reserved for network monitoring
  - monitor session 1 destination interface ethernet 1/0/1
  - monitor session 1 source interface ethernet 1/0/5-7
- When explicit-null is configured in DGS3630_Right, it shows “IPv4 Explicit-Null” as MPLS Label in specific frames

### Table: mpls

<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>MPLS Label</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2017-02-07 18:09:21.334458</td>
<td>192.168.100.2</td>
<td>7.7.7.7</td>
<td>ICMP</td>
<td>IPv4 Explicit-Null</td>
</tr>
<tr>
<td>8</td>
<td>2017-02-07 18:09:21.498305</td>
<td>192.168.200.3</td>
<td>6.6.6.6</td>
<td>ICMP</td>
<td>1000</td>
</tr>
<tr>
<td>16</td>
<td>2017-02-07 18:09:21.529694</td>
<td>192.168.200.3</td>
<td>66.66.66.66</td>
<td>ICMP</td>
<td>1002</td>
</tr>
</tbody>
</table>

- Quiz Session: if implicit-null is implemented, do you see the same?
Brainstorming on PHP (Wireshark collect data)

- Quiz Session: if implicit-null is implemented, do you see “IPv4 Explicit-Null” as MPLS Label in specific frames?
- Ans: Real time data collection as indicated below
Brainstorming on Distribution-Mode (1/4)

- D-Link switches offer two type of MPLS distribution-mode settings
  - dod: downstream-on-demand distribution mode
  - du: downstream-unsolicited distribution mode
- By default, the distribution mode is downstream unsolicited

- Quiz Session: Would modifiability being realized in LSR’s mpls forwarding table entries?
Brainstorming on Distribution-Mode (2/4)

- Observation: mpls forwarding-table entries in DGS3630_Hub (in du mode)

<table>
<thead>
<tr>
<th></th>
<th>10.5.5.0/24</th>
<th>0</th>
<th>-</th>
<th>-</th>
<th>-</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>10.5.5.5/32</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>10.5.5.55/32</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>10.5.5.55/32</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>10.168.157.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>66.66.6.0/24</td>
<td>0</td>
<td>0</td>
<td>VLAN 56</td>
<td>192.168.56.6</td>
</tr>
<tr>
<td>13</td>
<td>66.66.6.0/24</td>
<td>1000</td>
<td>0</td>
<td>VLAN 56</td>
<td>192.168.56.6</td>
</tr>
<tr>
<td>7</td>
<td>66.66.66.0/24</td>
<td>0</td>
<td>0</td>
<td>VLAN 56</td>
<td>192.168.56.6</td>
</tr>
<tr>
<td>15</td>
<td>66.66.66.0/24</td>
<td>1002</td>
<td>0</td>
<td>VLAN 56</td>
<td>192.168.56.6</td>
</tr>
<tr>
<td>8</td>
<td>192.168.100.0/24</td>
<td>0</td>
<td>0</td>
<td>VLAN 56</td>
<td>192.168.56.6</td>
</tr>
<tr>
<td>14</td>
<td>192.168.100.0/24</td>
<td>1001</td>
<td>0</td>
<td>VLAN 56</td>
<td>192.168.56.6</td>
</tr>
<tr>
<td>12</td>
<td>7.7.7.0/24</td>
<td>0</td>
<td>0</td>
<td>VLAN 57</td>
<td>192.168.57.7</td>
</tr>
<tr>
<td>10</td>
<td>7.7.7.0/24</td>
<td>1003</td>
<td>0</td>
<td>VLAN 57</td>
<td>192.168.57.7</td>
</tr>
<tr>
<td>11</td>
<td>7.7.7.77.0/24</td>
<td>0</td>
<td>0</td>
<td>VLAN 57</td>
<td>192.168.57.7</td>
</tr>
<tr>
<td>18</td>
<td>7.7.77.0/24</td>
<td>1005</td>
<td>0</td>
<td>VLAN 57</td>
<td>192.168.57.7</td>
</tr>
<tr>
<td>16</td>
<td>192.168.200.0/24</td>
<td>0</td>
<td>0</td>
<td>VLAN 57</td>
<td>192.168.57.7</td>
</tr>
<tr>
<td>17</td>
<td>192.168.200.0/24</td>
<td>1004</td>
<td>0</td>
<td>VLAN 57</td>
<td>192.168.57.7</td>
</tr>
<tr>
<td>9</td>
<td>192.168.56.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Total Entries: 18
Brainstorming on Distribution-Mode (3/4)

- Observation: mpls forwarding-table entries in DGS3630_Hub (in dod mode)

![Table of mpls forwarding-table entries in DGS3630_Hub]

```
<table>
<thead>
<tr>
<th>LSP</th>
<th>FEC</th>
<th>In Label</th>
<th>Out Label</th>
<th>Out Interface</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.5.5.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>192.168.57.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>55.55.55.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>6.6.6.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 56</td>
<td>192.168.56.6</td>
</tr>
<tr>
<td>7</td>
<td>6.6.6.0/24</td>
<td>1000</td>
<td>0</td>
<td>VLAN 56</td>
<td>192.168.56.6</td>
</tr>
<tr>
<td>5</td>
<td>192.168.100.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 56</td>
<td>192.168.56.6</td>
</tr>
<tr>
<td>8</td>
<td>192.168.100.0/24</td>
<td>1001</td>
<td>0</td>
<td>VLAN 56</td>
<td>192.168.56.6</td>
</tr>
<tr>
<td>6</td>
<td>66.66.66.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 56</td>
<td>192.168.56.6</td>
</tr>
<tr>
<td>9</td>
<td>66.66.66.0/24</td>
<td>1002</td>
<td>0</td>
<td>VLAN 56</td>
<td>192.168.56.6</td>
</tr>
<tr>
<td>10</td>
<td>192.168.56.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>11</td>
<td>7.7.7.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 57</td>
<td>192.168.57.7</td>
</tr>
<tr>
<td>14</td>
<td>7.7.7.0/24</td>
<td>1003</td>
<td>0</td>
<td>VLAN 57</td>
<td>192.168.57.7</td>
</tr>
<tr>
<td>12</td>
<td>192.168.200.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 57</td>
<td>192.168.57.7</td>
</tr>
<tr>
<td>16</td>
<td>192.168.200.0/24</td>
<td>1005</td>
<td>0</td>
<td>VLAN 57</td>
<td>192.168.57.7</td>
</tr>
<tr>
<td>13</td>
<td>77.77.77.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 57</td>
<td>192.168.57.7</td>
</tr>
<tr>
<td>15</td>
<td>77.77.77.0/24</td>
<td>1004</td>
<td>0</td>
<td>VLAN 57</td>
<td>192.168.57.7</td>
</tr>
</tbody>
</table>
```

Total Entries: 16
Brainstorming on Distribution-Mode (4/4)

- Quiz Session: it was 18 in du mode, but 16 in dod mode. Which two entries are jumping off the stage?

- Quiz Session: With your “Divide and Conquer” strategy, do DGS3630_Left and DGS3630_Right look very much alike?
Static FEC–To-NHLFE Map (FTN) entry (1/8)

- According to our labe configuration, we have identified that 192.168.200.0/24 prefix label value, as well as others, is auto created by LSR
- Although a MPLS label has a character of local significance, is there any way we are given the feasibility to manually set up MPLS Value?

- In fact, “mpls static ftn” is the command used to add a static FEC–To-NHLFE Map (FTN) entry
Static FEC–To-NHLFE Map (FTN) entry (2/8)

- Let’s resume our configuration lab where the network topology and configuration remains exactly the same
- Make sure all LSRs ARE deployed with explicit-null label advertisement
- The 192.168.200.0/24 is expected to be chosen for general practice
Static FEC–To-NHLFE Map (FTN) entry (3/8)

- Do “show mpls forwarding-table” command in GS3630_Right

```
DGS3630_Right#show mpls forwarding-table

<table>
<thead>
<tr>
<th>LSP</th>
<th>FEC</th>
<th>In Label</th>
<th>Out Label</th>
<th>Out Interface</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.7.7.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>77.77.77.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>7.7.7.7/32</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>77.77.77.77/32</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>192.168.200.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>5.5.5.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 57</td>
<td>192.168.57.5</td>
</tr>
<tr>
<td>7</td>
<td>55.55.55.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 57</td>
<td>192.168.57.5</td>
</tr>
<tr>
<td>8</td>
<td>192.168.56.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 57</td>
<td>192.168.57.5</td>
</tr>
<tr>
<td>9</td>
<td>6.6.6.0/24</td>
<td>-</td>
<td>1000</td>
<td>VLAN 57</td>
<td>192.168.57.5</td>
</tr>
<tr>
<td>10</td>
<td>66.66.66.0/24</td>
<td>-</td>
<td>1002</td>
<td>VLAN 57</td>
<td>192.168.57.5</td>
</tr>
<tr>
<td>11</td>
<td>192.168.100.0/24</td>
<td>-</td>
<td>1001</td>
<td>VLAN 57</td>
<td>192.168.57.5</td>
</tr>
</tbody>
</table>

Total Entries: 11
DGS3630_Right#
```
Static FEC–To-NHLFE Map (FTN) entry (4/8)

- Input “mpls static ftn 192.168.200.0/24 out-label 17 nexthop 192.168.57.5” command and exercise “show mpls forwarding-table” command in DGS3630_Right.

- As indicated in next slide, you shall see total 12 forwarding table entries, comparing 11 entries earlier, where 192.168.200.0/24 comes with the label value of “17”.
Static FEC–To-NHLFE Map (FTN) entry (5/8)

- The underneath sketch justifies the statements as addressed in last slide

```
# show mpls forwarding-table

<table>
<thead>
<tr>
<th>LSP</th>
<th>FEC</th>
<th>In Label</th>
<th>Out Label</th>
<th>Out Interface</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.7.7.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>77.77.77.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>7.7.7.7/32</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>77.77.77.77/32</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>12</td>
<td>192.168.200.0/24</td>
<td>-</td>
<td>17</td>
<td>VLAN 57</td>
<td>192.168.57.5</td>
</tr>
<tr>
<td>5</td>
<td>192.168.200.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>5.5.5.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 57</td>
<td>192.168.57.5</td>
</tr>
<tr>
<td>7</td>
<td>55.55.55.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 57</td>
<td>192.168.57.5</td>
</tr>
<tr>
<td>8</td>
<td>192.168.56.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 57</td>
<td>192.168.57.5</td>
</tr>
<tr>
<td>9</td>
<td>6.6.6.0/24</td>
<td>-</td>
<td>1001</td>
<td>VLAN 57</td>
<td>192.168.57.5</td>
</tr>
<tr>
<td>10</td>
<td>192.168.100.0/24</td>
<td>-</td>
<td>1002</td>
<td>VLAN 57</td>
<td>192.168.57.5</td>
</tr>
<tr>
<td>11</td>
<td>66.66.66.0/24</td>
<td>-</td>
<td>1003</td>
<td>VLAN 57</td>
<td>192.168.57.5</td>
</tr>
</tbody>
</table>

Total Entries: 12
DGS3630_Right#_```
Static FEC–To-NHLFE Map (FTN) entry (6/8)

- Our sense of vision is clearly not without certain limitations

- Let’s continue our exploration to see 192.168.200.0/24 in the MPLS forwarding table entries both DGS3630_Hub and DGS3630_Left
**Static FEC–To-NHLFE Map (FTN) entry (7/8)**

- In DGS3630_Hub

<table>
<thead>
<tr>
<th>LSP</th>
<th>FEC</th>
<th>In Label</th>
<th>Out Label</th>
<th>Out Interface</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.7.7.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 57</td>
<td>192.168.57.7</td>
</tr>
<tr>
<td>2</td>
<td>7.7.7.0/24</td>
<td>1000</td>
<td>0</td>
<td>VLAN 57</td>
<td>192.168.57.7</td>
</tr>
<tr>
<td>3</td>
<td>5.5.5.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>55.55.55.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>5.5.5.5/32</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>55.55.55.55/32</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>192.168.56.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>77.77.77.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 57</td>
<td>192.168.57.7</td>
</tr>
<tr>
<td>9</td>
<td>77.77.77.0/24</td>
<td>1004</td>
<td>0</td>
<td>VLAN 57</td>
<td>192.168.57.7</td>
</tr>
<tr>
<td>10</td>
<td>192.168.200.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 57</td>
<td>192.168.57.7</td>
</tr>
<tr>
<td>11</td>
<td>192.168.200.0/24</td>
<td>1005</td>
<td>0</td>
<td>VLAN 57</td>
<td>192.168.57.7</td>
</tr>
</tbody>
</table>
### Static FEC–To-NHLFE Map (FTN) entry (8/8)

- In DGS3630_Left

```
DGS3630_Left# show mpls forwarding-table

<table>
<thead>
<tr>
<th>LSP</th>
<th>FEC</th>
<th>In Label</th>
<th>Out Label</th>
<th>Out Interface</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.6.6.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>192.168.100.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>66.66.66.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>6.6.6.6/32</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>66.66.66.66/32</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>5.5.5.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 56</td>
<td>192.168.56.5</td>
</tr>
<tr>
<td>7</td>
<td>55.55.55.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 56</td>
<td>192.168.56.5</td>
</tr>
<tr>
<td>8</td>
<td>192.168.57.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 56</td>
<td>192.168.56.5</td>
</tr>
<tr>
<td>9</td>
<td>7.7.7.0/24</td>
<td>-</td>
<td>1000</td>
<td>VLAN 56</td>
<td>192.168.56.5</td>
</tr>
<tr>
<td>10</td>
<td>77.77.77.0/24</td>
<td>-</td>
<td>1004</td>
<td>VLAN 56</td>
<td>192.168.56.5</td>
</tr>
<tr>
<td>11</td>
<td>192.168.200.0/24</td>
<td>-</td>
<td>1005</td>
<td>VLAN 56</td>
<td>192.168.56.5</td>
</tr>
</tbody>
</table>
```

Total Entries: 11

DGS3630_Left#_
The Journey of one MPLS Label

- As elaborated from our exercise, the prefix of 192.168.200.0/24 is one of the interfaces configured in DGS3630_Right
- This Quiz Session expects to starts obtaining Label Value of 192.168.200.0/24 at DGS3630_Hub and DGS3630_Left
- It followed by specific mark to distinguish the impact of “Explicit-null value” and “Implicit Null value”
- At last, we shall expose to manual set label value horizon by adapting “mpls static ftn” command
Configuration Parameter Summary

- Activate LDP protocol
- Enable the MPLS function on the interfaces
- Empower the LDP in the interface mode
MPLS Configuration Guide

- Multiprotocol Label Switching (MPLS)
- MPLS Terminology
- Label Distribution Protocol (LDP)
- Configuration Scenario #1
- Configuration Scenario #2
- Configuration Scenario #3
- Command Reference
MPLS Configuration Lab #2

- Layer 3 VPN serves the main function of this configuration lab
- Computing devices involved in testbed are similar to the ones in our first lab

- The spirit of D-Track DK1400261 and DK1400240 yields essential outcome of this lab practice
MPLS Configuration Lab #2: Topology

- DGS-3630-28TC (MI Mode) with MPLS Layer 3 VPNs configurations

DGS3630_P_Node
int. loopback 1: 5.5.5.5/24
int. vlan56: 192.168.56.5/24
int. vlan57: 192.168.57.5/24
OSPF

DGS3630_PE_Left
int. loopback 1: 6.6.6.6/24
int. vlan56: 192.168.56.6/24
int. vlan100: 192.168.100.254/24
OSPF/BGP 100

DGS3630_PE_Right
int. loopback 1: 7.7.7.7/24
int. vlan57: 192.168.57.7/24
int. vlan200: 192.168.200.254/24
OSPF/BGP 100

Laptop: 192.168.100.2/24

Laptop: 192.168.200.3/24
MPLS Configuration Lab #2

- DGS3630_P_Node configurations
  - configure terminal
  - prompt DGS3630_P_Node
  - monitor session 1 destination interface ethernet 1/0/1
  - monitor session 1 source interface ethernet 1/0/5-7
  - mpls ip
  - mpls label protocol ldp
  - interface loopback 1
  - ip address 5.5.5.5 255.255.255.0
  - exit
  - vlan 56
  - exit
MPLS Configuration Lab #2

- DGS3630_P_Node configurations
  - configure terminal
  - interface vlan 56
  - mpls ip
  - mpls label protocol ldp
  - ip address 192.168.56.5 255.255.255.0
  - exit
  - interface eth 1/0/5
  - switchport mode access
  - switchport access vlan 56
  - exit
  - vlan 57
  - exit
MPLS Configuration Lab #2

- DGS3630_P_Node configurations
- configure terminal
- interface vlan 57
- mpls ip
- mpls label protocol ldp
- ip address 192.168.57.5 255.255.255.0
- exit
- interface eth 1/0/7
- switchport mode access
- switchport access vlan 57
- exit
- no int vlan 1
MPLS Configuration Lab #2

- DGS3630_P_Node configurations
  - configure terminal
  - mpls ldp configuration
  - router-id 5.5.5.5
  - explicit-null
  - discovery hello holdtime 15
  - discovery hello interval 5
  - exit
- router ospf
  - router-id 5.5.5.5
  - network 5.5.5.0 255.255.255.0 area 0.0.0.0
  - network 192.168.56.0 255.255.255.0 area 0.0.0.0
  - network 192.168.57.0 255.255.255.0 area 0.0.0.0
  - exit

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MPLS Configuration Lab #2

- DGS3630_PE_Left configurations
  - configure terminal
  - monitor session 1 destination interface ethernet 1/0/1
  - monitor session 1 source interface ethernet 1/0/5-8
  - no int vlan 1
  - ip vrf L3VPN
  - rd 100:1
  - route-target export 100:1
  - route-target import 100:1
  - exit
  - interface loopback 1
  - ip address 6.6.6.6 255.255.255.0
  - exit
MPLS Configuration Lab #2

- DGS3630_PE_Left configurations
  - configure terminal
  - mpls ip
  - mpls label protocol ldp
  - mpls ldp configuration
  - router-id 6.6.6.6
  - neighbor 7.7.7.7 targeted
  - exit
  - explicit-null
  - discovery hello holdtime 15
  - discovery hello interval 5
  - exit
  - vlan 100
  - exit
MPLS Configuration Lab #2

- DGS3630_PE_Left configurations
  - configure terminal
  - interface vlan 100
  - ip vrf forwarding L3VPN
  - ip address 192.168.100.254 255.255.255.0
  - exit
  - interface eth 1/0/8
  - switchport mode access
  - switchport access vlan 100
  - exit
  - vlan 56
  - exit
MPLS Configuration Lab #2

- DGS3630_PE_Left configurations
- configure terminal
- interface vlan 56
- mpls ip
- mpls label protocol ldp
- ip address 192.168.56.6 255.255.255.0
- exit
- interface eth 1/0/5
- switchport mode access
- switchport access vlan 56
- exit
MPLS Configuration Lab #2

- DGS3630_PE_Left configurations
- configure terminal
- router bgp 100
- neighbor 7.7.7.7 remote-as 100
- neighbor 7.7.7.7 update-source loopback 1
- address-family vpnv4
- neighbor 7.7.7.7 activate
- neighbor 7.7.7.7 send-community both
- exit
- address-family ipv4 vrf L3VPN
- network 192.168.100.0/24
- exit
- exit
MPLS Configuration Lab #2

- DGS3630_PE_Left configurations
- configure terminal
- router ospf
- router-id 6.6.6.6
- network 6.6.6.0 255.255.255.0 area 0.0.0.0
- network 192.168.56.0 255.255.255.0 area 0.0.0.0
- Exit

- Incorrect OSPF configuration could lead the breakdown of OSPF neighbor relationships, which is also described in D-Track DEUR20150307000001

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MPLS Configuration Lab #2

- DGS3630_PE_Right configurations
- configure terminal
- monitor session 1 destination interface ethernet 1/0/1
- monitor session 1 source interface ethernet 1/0/7-8
- no int vlan 1
- ip vrf L3VPN
- rd 100:1
- route-target export 100:1
- route-target import 100:1
- exit
MPLS Configuration Lab #2

- DGS3630_PE_Right configurations
- configure terminal
- mpls ip
- mpls label protocol ldp

- interface loopback 1
- ip address 7.7.7.7 255.255.255.0
- exit
MPLS Configuration Lab #2

- DGS3630_PE_Right configurations
- configure terminal
- mpls ldp configuration
- router-id 7.7.7.7
- neighbor 6.6.6.6 targeted
- exit
- explicit-null
- discovery hello holdtime 15
- discovery hello interval 5
- exit
- vlan 200
- exit
MPLS Configuration Lab #2

- DGS3630_PE_Right configurations
  - configure terminal
  - interface vlan 200
  - ip vrf forwarding L3VPN
  - ip address 192.168.200.254 255.255.255.0
  - exit
- interface eth 1/0/8
  - switchport mode access
  - switchport access vlan 200
  - exit
MPLS Configuration Lab #2

- DGS3630 PE Right configurations
- configure terminal
- vlan 57
- exit
- interface vlan 57
- mpls ip
- mpls label protocol ldp
- ip address 192.168.57.7 255.255.255.0
- exit
- interface eth 1/0/7
- switchport mode access
- switchport access vlan 57
- exit
MPLS Configuration Lab #2

- DGS3630_PE_Right configurations
  - configure terminal
  - router bgp 100
  - neighbor 6.6.6.6 remote-as 100
  - neighbor 6.6.6.6 update-source loopback 1
  - address-family vpnv4
  - neighbor 6.6.6.6 activate
  - neighbor 6.6.6.6 send-community both
  - exit

- address-family ipv4 vrf L3VPN
  - network 192.168.200.0/24
  - exit
  - exit

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MPLS Configuration Lab #2

- DGS3630_PE_Right configurations
- configure terminal
- router ospf
- router-id 7.7.7.7
- network 7.7.7.0 255.255.255.0 area 0.0.0.0
- network 192.168.57.0 255.255.255.0 area 0.0.0.0
- exit
Quiz Session: MPLS LDP Session

- How many LDP session entries are shown in our routing devices?
Quiz Session: MPLS LDP Session (Cont'd)

- How many LDP session entries are shown in our routing devices?

```
DGS3630_PE_Left#show mpls ldp session

<table>
<thead>
<tr>
<th>Peer</th>
<th>Status</th>
<th>Role</th>
<th>Keep Alive</th>
<th>Distribution Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.5.5.5:0</td>
<td>OPERATIONAL</td>
<td>Active</td>
<td>40(Sec)</td>
<td>DU</td>
</tr>
<tr>
<td>7.7.7.7:0</td>
<td>OPERATIONAL</td>
<td>Passive</td>
<td>40(Sec)</td>
<td>DU</td>
</tr>
</tbody>
</table>
```

Total Entries: 2

```
DGS3630_PE_Righ#show mpls ldp session

<table>
<thead>
<tr>
<th>Peer</th>
<th>Status</th>
<th>Role</th>
<th>Keep Alive</th>
<th>Distribution Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.5.5.5:0</td>
<td>OPERATIONAL</td>
<td>Active</td>
<td>40(Sec)</td>
<td>DU</td>
</tr>
<tr>
<td>6.6.6.6:0</td>
<td>OPERATIONAL</td>
<td>Active</td>
<td>40(Sec)</td>
<td>DU</td>
</tr>
</tbody>
</table>
```

Total Entries: 2
MPLS LDP Discovery

- It is suggested relying on “show mpls ldp discovery” to exhibit LDP discovery information
- In DGS3630_PE_Left, there are two entries
  - Directly connected interface to its neighbor (5.5.5.5)
  - LDP over non-directly connected links (7.7.7.7)

```
DGS3630_PE_Left# show mpls ldp discovery

Local LDP Identifier: 6.6.6.6:0
Discovery Sources:
  Interfaces:
    VLAN 36 (LDP): xmit/recv
    LDP Id: 5.5.5.5:0
  Targeted Hellos:
    192.168.56.6 -> 192.168.57.7 (LDP): passive, xmit/recv
    LDP Id: 7.7.7.7:0
```

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MPLS LDP Discovery (Wireshark frame)

- A wireshark frame displays DGS3630 PE Left waives its “Targeted Hello” hand to DGS3630 PE Right
Quiz Session: LDP Discovery (DGS3630_P_Node)

Quiz: What would be the LDP Discovery information in DGS3630_P_Node? Are there any distinct messages being delivered in “Target Hellos” via switch show command?
Quiz Session: LDP Discovery (DGS3630_P_Node)

- As of our configuration, the “Target Hellos” of DGS3630_P_Node shall appear blank

```
DGS3630_P_Node# show mpls ldp discovery

Local LDP Identifier: 5.5.5.5:0
Discovery Sources:
  Interfaces:
    VLAN 56 (LDP): xmit/recv
    LDP Id: 6.6.6.6:0
    VLAN 57 (LDP): xmit/recv
    LDP Id: 7.7.7.7:0
Targeted Hellos:
```

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Quiz Session: MPLS LDP Discovery (1/2)

- The underneath diagram shows TWO Targeted Hellos entries in “DGS3630_PE_Left”

```
DGS3630_PE_Left#sh mpls ldp discovery

Local LDP Identifier: 6.6.6.6:0
Discovery Sources:
  Interfaces:
    VLAN 56 (LDP): xmit/recv
    LDP Id: 5.5.5.5:0
Targeted Hellos:
  6.6.6.6 -> 7.7.7.7 (LDP): active
  6.6.6.6 -> 192.168.57.7 (LDP): active
```

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- MPLS Configuration Guide
Quiz Session: MPLS LDP Discovery (1/2)

- The underneath diagram shows TWO Targeted Hellos entries in “DGS3630_PE_Left”

```bash
DGS3630_PE_Left#(sh mpls ldp discovery
Local LDP Identifier: 6.6.6.6:0
Discovery Sources:
  Interfaces:
    VLAN 56 (LDP): xmit/recv
    LDP Id: 5.5.5.5:0
Targeted Hellos:
  6.6.6.6 -> 7.7.7.7 (LDP): active
  6.6.6.6 -> 192.168.57.7 (LDP): active
```

- What bring the honor of such creativity?
Quiz Session: MPLS LDP Discovery (2/2)

- Switch configuration is displayed in right hand side diagram
- A duplicate “mpls ldp configuration” configuration turns the unintentional mis-typing into (virtual) reality

- *Learning offers a way of error prevention*
Standing VRF settings (1/3)

- “show ip vrf” command presents latest VRF settings
- With the parameter of “interfaces,” you are able to view interfaces associated with one or more VRFs
- The underneath sketch clearly informs us relevant message

<table>
<thead>
<tr>
<th>Interfaces</th>
<th>IP Address</th>
<th>VRF</th>
</tr>
</thead>
<tbody>
<tr>
<td>vlan100</td>
<td>192.168.100.254/24</td>
<td>L3VPN</td>
</tr>
</tbody>
</table>

DGS3630 PE_Left#show ip vrf interfaces

<table>
<thead>
<tr>
<th>Interfaces</th>
<th>IP Address</th>
<th>VRF</th>
</tr>
</thead>
<tbody>
<tr>
<td>vlan200</td>
<td>192.168.200.254/24</td>
<td>L3VPN</td>
</tr>
</tbody>
</table>
Standing VRF settings (2/3)

- Incorrect BGP configuration was created in composer’s lab, bringing malformed Layer 3 VPN
- This “show ip vrf interfaces” command DOES NOT match any proper IP address, as clearly described below

<table>
<thead>
<tr>
<th>Interfaces</th>
<th>IP Address</th>
<th>VRF</th>
</tr>
</thead>
<tbody>
<tr>
<td>vlan100</td>
<td>0.0.0.0/0</td>
<td>L3VPN</td>
</tr>
</tbody>
</table>

D-Link Certified Specialist
- MPLS Configuration Guide

D-Link Academy
Standing VRF settings (3/3)

- Working on D-Link switch lab could look into as an art, not just science
- The composer of this document once learned that “an art reproduction represents the progress of democracy”
Standing VRF settings (3/3)

- Working on D-Link switch lab could look into as an art, not just science
- The composer of this document once learned that “an art reproduction represents the progress of democracy”
- How long will take you to REPRODUCE IP address (0.0.0.0) in the VRF interface via your TESTBED facility?
MPLS Forwarding-Table (1/2)

- The MPLS label forwarding path information on DGS3630 PE_Left is described here

```bash
DGS3630_PE_Left#show mpls forwarding-table
```

<table>
<thead>
<tr>
<th>LSP</th>
<th>FEC</th>
<th>In Label</th>
<th>Out Label</th>
<th>Out Interface</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.6.6.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>6.6.6.6/32</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>5.5.5.5/32</td>
<td>-</td>
<td>0</td>
<td>VLAN 56</td>
<td>192.168.56.5</td>
</tr>
<tr>
<td>4</td>
<td>192.168.57.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 56</td>
<td>192.168.56.5</td>
</tr>
<tr>
<td>5</td>
<td>7.7.7.7/32</td>
<td>-</td>
<td>1001</td>
<td>VLAN 56</td>
<td>192.168.56.5</td>
</tr>
</tbody>
</table>

Total Entries: 5
MPLS Forwarding-Table (2/2)

- What would be the DGS3630_PE_Right’s MPLS label forwarding path?
### MPLS Forwarding-Table (2/2)

- Does your switch yield alike result?

```bash
DGS3630_PE_Righ#show mpls forwarding-table
```

<table>
<thead>
<tr>
<th>LSP</th>
<th>FEC</th>
<th>In Label</th>
<th>Out Label</th>
<th>Out Interface</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.7.7.7/32</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>7.7.7.0/24</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>5.5.5.5/32</td>
<td>-</td>
<td>0</td>
<td>VLAN 57</td>
<td>192.168.57.5</td>
</tr>
<tr>
<td>4</td>
<td>192.168.56.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 57</td>
<td>192.168.57.5</td>
</tr>
<tr>
<td>5</td>
<td>6.6.6.6/32</td>
<td>-</td>
<td>1000</td>
<td>VLAN 57</td>
<td>192.168.57.5</td>
</tr>
</tbody>
</table>

Total Entries: 5

DGS3630_PE_Righ#_
Route Distinguisher (RD) (1/4)

- In DGS3630_PE_Right, we had deployed Route Distinguisher configurations, as illustrated here
  - ip vrf L3VPN
  - rd 100:1
  - route-target export 100:1
  - route-target import 100:1

- Quiz Session: Where does this setting being presented in collected Wireshark frame of DGS3630_PE_Right?
Route Distinguisher (RD) (2/4)

- Quiz Session: Where does this setting being presented in collected Wireshark frame of DGS3630_PE_Right?
- From collected frames, locate a BGP UPDATE Message, frame 907 as indicated below

<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>MPLS Label</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>903</td>
<td>2017-02-15 19:28:13.905858</td>
<td>7.7.7.7</td>
<td>6.6.6.6</td>
<td>BGP</td>
<td>UPDATE Message</td>
<td></td>
</tr>
<tr>
<td>1154</td>
<td>2017-02-15 19:29:12.904226</td>
<td>7.7.7.7</td>
<td>6.6.6.6</td>
<td>BGP</td>
<td>KEEPALIVE Message</td>
<td></td>
</tr>
<tr>
<td>1161</td>
<td>2017-02-15 19:29:13.159240</td>
<td>6.6.6.6</td>
<td>7.7.7.7</td>
<td>BGP</td>
<td>IPv4 Explicit-Null</td>
<td>KEEPALIVE Message</td>
</tr>
<tr>
<td>1393</td>
<td>2017-02-15 19:30:11.902919</td>
<td>7.7.7.7</td>
<td>6.6.6.6</td>
<td>BGP</td>
<td>KEEPALIVE Message</td>
<td>KEEPALIVE Message</td>
</tr>
<tr>
<td>1495</td>
<td>2017-02-15 19:30:13.155370</td>
<td>6.6.6.6</td>
<td>7.7.7.7</td>
<td>BGP</td>
<td>IPv4 Explicit-Null</td>
<td>KEEPALIVE Message</td>
</tr>
</tbody>
</table>
Route Distinguisher (RD) (3/4)

- In “Path Attribute” “EXTENDED_COMMUNITIES”.

<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>MPLS Label</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>903</td>
<td>2017-02-15 19:28:13.905858</td>
<td>7.7.7.7</td>
<td>6.6.6.6</td>
<td>BGP</td>
<td></td>
<td>UPDATE Message</td>
</tr>
<tr>
<td>1154</td>
<td>2017-02-15 19:29:12.904226</td>
<td>7.7.7.7</td>
<td>6.6.6.6</td>
<td>BGP</td>
<td></td>
<td>KEEPALIVE Message</td>
</tr>
</tbody>
</table>

- Frame 907: 161 bytes on wire (1288 bits), 161 bytes captured (1288 bits) on interface 0
- MultiProtocol Label Switching Header, Label: 0 (IPv4 Explicit-Null), Exp: 0, S: 1, TTL: 254
- Internet Protocol Version 4, Src: 6.6.6.6, Dst: 7.7.7.7
- Border Gateway Protocol - UPDATE Message
  - Marker: ffffffff
  - Type: UPDATE Message (2)
  - Withdrawn Routes Length: 0
  - Total Path Attribute Length: 68
  - Path attributes
    - Path Attribute - ORIGIN: IGP
    - Path Attribute - AS_PATH: empty
    - Path Attribute - MULTI_EXIT_DISC: 0
    - Path Attribute - LOCAL_PREF: 100
    - Path Attribute - EXTENDED_COMMUNITIES
      - Flags: 0x0, Optional, Transitive: Optional, Transitive, Complete Type Code: EXTENDED_COMMUNITIES (16)
      - Length: 8
      - Carried extended communities: (1 community)
        - Community Transitive Two-Octet AS Route Target: 100:1
          - Community type high: Transitive Two-Octet AS (0x00)
          - Subtype as2: Route Target (0x02)
          - Two octets AS specific: 100
          - Four octets AN specific: 1
Route Distinguisher (RD) (4/4)

- Also in “Path Attribute,” MP_REACH_NLRI

```
Border Gateway Protocol - UPDATE Message
  Marker: fffffffffffffffffffffffffffffffff
  Length: 91
  Type: UPDATE Message (2)
  Withdrawn Routes Length: 0
  Total Path Attribute Length: 68

Path attributes
  Path Attribute - ORIGIN: IGP
  Path Attribute - AS_PATH: empty
  Path Attribute - MULTI_EXIT_DISC: 0
  Path Attribute - LOCAL_PREF: 100
  Path Attribute - EXTENDED_COMMUNITIES
  Path Attribute - MP_REACH_NLRI
    Flags: 0x90, Optional, Length: Optional, Non-transitive, Complete, Extended Length
    Type Code: MP_REACH_NLRI (14)
    Length: 32
    Address family identifier (AFI): IPv4 (1)
    Subsequent address family identifier (SAFI): Labeled VPN Unicast (128)
    Next hop network address (12 bytes)
    Number of Subnetwork points of attachment (SNPA): 0

Network layer reachability information (15 bytes)
  BGP Prefix
    Prefix Length: 112
    Label Stack: 5001 (bottom)
    Route Distinguisher: 100:1
    MP Reach NLRI IPv4 prefix: 192.168.100.0
```
Quiz Session: BGP RD (2/1)

- Quiz Session: “bgp.rd” is a display filter on BGP Route Distinguisher. What types of messages would show BGP RD information in Wireshark frames?
Quiz Session: BGP RD (2/2)

- As displayed here, only UPDATE Message offers such feasibility
Routing Table Entry

- We have configured OSPF/BGP among these three routing devices. What are the Routing Table Entry indicated from DGS3630_PE_Left?

```
DGS3630_PE_Left#show ip route
Code: C - connected, S - static, R - RIP, B - BGP, I - IS-IS, O - OSPF,
     IA - OSPF inter area,
     N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2,
     E1 - OSPF external type 1, E2 - OSPF external type 2,
     * - candidate default

Gateway of last resort is not set

0      5.5.5.5/32 [80/2] via 192.168.56.5, vlan56
C      6.6.6.0/24 is directly connected, loopback1
0      7.7.7.7/32 [80/3] via 192.168.56.5, vlan56
C      192.168.56.0/24 is directly connected, vlan56
0      192.168.57.0/24 [80/2] via 192.168.56.5, vlan56

Total Entries: 5
```

D-Link Academy
Routing Table Entry

- In DGS3630_P_Node, what would be associated Routing Table Entry?

```plaintext
DGS3630_P_Node#show ip route
Code: C - connected, S - static, R - RIP, B - BGP, I - IS-IS, O - OSPF,
     IA - OSPF inter area,
     N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2,
     E1 - OSPF external type 1, E2 - OSPF external type 2,
     * - candidate default

Gateway of last resort is not set

C  5.5.5.0/24 is directly connected, loopback1
O  6.6.6.6/32 [80/2] via 192.168.56.6, vlan56
O  7.7.7.7/32 [80/2] via 192.168.57.7, vlan57
C  192.168.56.0/24 is directly connected, vlan56
C  192.168.57.0/24 is directly connected, vlan57

Total Entries: 5
```

D-Link Academy
VPN Routing and Forwarding (VRF) entry

- The command of “show ip route [vrf VRF-NAME]” displays VPN Routing and Forwarding (VRF) entry in the routing table.
- We obtain 192.168.200.0/24 info from DGS3630_PE_Left

```
DGS3630 PE_Left#show ip route vrf L3VPN
VRF: L3VPN Code: C - connected, S - static, R - RIP, B - BGP, I - IS-IS, O - O SPF,
     IA - OSPF inter area,
     N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2, 
     E1 - OSPF external type 1, E2 - OSPF external type 2, 
     * - candidate default

Gateway of last resort is not set

C 192.168.100.0/24 is directly connected, vlan100
B 192.168.200.0/24 [130/1] via 192.168.56.5,

Total Entries: 2
```

D-Link Academy
Quiz Session: VRF entry (1/2)

- What would be the VRF entry results being generated from DGS3630_PE_Right?

- A sys log file, attached in DK1400240, brings essential know-how to VRF troubleshooting technique
Quiz Session: VRF entry (2/2)

- What VRF entry results would have been generated from DGS3630_PE_Right?
- Please review below diagram for your reference

```
DGS3630_PE_Righ# show ip route vrf L3VPN
VRF: L3VPN Code: C - connected, S - static, R - RIP, B - BGP, I - IS-IS, 0 - 0 SPF,
     IA - OSPF inter area,
     N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2,
     E1 - OSPF external type 1, E2 - OSPF external type 2,
     * - candidate default

Gateway of last resort is not set
B  192.168.100.0/24 [130/1] via 192.168.57.5
C  192.168.200.0/24 is directly connected, vlan200

Total Entries: 2
```

D-Link Academy
Working Routing Entries

- To display some brief information for the working routing entries, we can adapt the command of “show ip route summary”

```
DGS3630_PE_Left# show ip route summary
Route Source    Networks
Connected       2
Static          0
RIP              0
OSPF            3
BGP              0
ISIS            0
Total           5
Multi-path      0

DGS3630_PE_Left#
```

```
DGS3630_PE_Right# show ip route summary
Route Source    Networks
Connected       2
Static          0
RIP              0
OSPF            3
BGP              0
ISIS            0
Total           5
Multi-path      0

DGS3630_PE_Right#
```
Working Routing Entries

- In this simulation environment, the “show ip route bgp” shall not produce any entries, as displayed below

```
DGS3630_PE_Left#show ip route bgp

Total Entries: 0

DGS3630_PE_Left#_
```
Quiz Session: Working Routing Entries

- Are you able to identify the differences between these two alike commands?

DGS3630_PE_Left# show ip route summary

<table>
<thead>
<tr>
<th>Route Source</th>
<th>Networks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connected</td>
<td>2</td>
</tr>
<tr>
<td>Static</td>
<td>0</td>
</tr>
<tr>
<td>RIP</td>
<td>0</td>
</tr>
<tr>
<td>OSPF</td>
<td>3</td>
</tr>
<tr>
<td>BGP</td>
<td>0</td>
</tr>
<tr>
<td>ISIS</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>5</td>
</tr>
<tr>
<td>Multi-path</td>
<td>0</td>
</tr>
</tbody>
</table>

DGS3630_PE_Left# show ip route summary vrf L3VPN

<table>
<thead>
<tr>
<th>Route Source</th>
<th>Networks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connected</td>
<td>1</td>
</tr>
<tr>
<td>Static</td>
<td>0</td>
</tr>
<tr>
<td>RIP</td>
<td>0</td>
</tr>
<tr>
<td>OSPF</td>
<td>0</td>
</tr>
<tr>
<td>BGP</td>
<td>1</td>
</tr>
<tr>
<td>ISIS</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>2</td>
</tr>
<tr>
<td>Multi-path</td>
<td>0</td>
</tr>
</tbody>
</table>

DGS3630_PE_Left#_
MPLS Label Stack

- According to RFC3031, the label at the bottom of the stack as the level 1 label, to the label above it as the level 2 label.
- We obtain the below frame from DGS3630 PE_Right.

```
No. | Time        | Source      | Destination | Protocol | MPLS Label
--- | ----------- | ----------- | ----------- |---------- |-------------
514 | 2017-02-15 | 19:24:02.870349 | 192.168.100.2 | ICMP     | IPv4 Explicit-Null,5001
516 | 2017-02-15 | 19:24:03.228933 | 192.168.200.3 | ICMP     | 1001,5001
```

Frame 516: 82 bytes on wire (656 bits), 82 bytes captured (656 bits) on interface 0

MultiProtocol Label Switching Header, Label: 1001, Exp: 0, S: 0, TTL: 255
000 0000 0011 1110 1001 ... ... ... = MPLS Label: 1001
... ... ... ... ... = MPLS Experimental Bits: 0
... ... ... ... ... ... ... = MPLS Bottom Of Label Stack: 0
... ... ... ... ... ... ... = MPLS TTL: 255

MultiProtocol Label Switching Header, Label: 5001, Exp: 0, S: 1, TTL: 127
000 0001 0011 1000 1001 ... ... ... = MPLS Label: 5001
... ... ... ... ... ... ... = MPLS Experimental Bits: 0
... ... ... ... ... ... ... = MPLS Bottom Of Label Stack: 1
... ... ... ... ... ... ... = MPLS TTL: 127

Internet Control Message Protocol
Quiz Session: MPLS Label Stack

- From the diagram displayed in last slide, what is the value of
  - Level 1 label
  - Level 2 label
- What are the correlation between your examination and MPLS Forwarding-Table information?
Quiz Session: Ping in MPLS (1/3)

- The laptop (192.168.100.2) attempts to ping the interface of (192.168.200.254) in DGS3630_PE_Right
- Collected Wireshark frames are displayed below

<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>MPLS Label</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2017-02-15 18:21:37.199202</td>
<td>192.168.100.2</td>
<td>192.168.200.254</td>
<td>ICMP</td>
<td>1001,5001</td>
<td>Echo (ping) request id=0x0001, seq=15166/15931, ttl=127 (no response found)</td>
</tr>
<tr>
<td>2</td>
<td>2017-02-15 18:21:37.199203</td>
<td>192.168.100.2</td>
<td>192.168.200.254</td>
<td>ICMP</td>
<td>1001,5001</td>
<td>Echo (ping) request id=0x0001, seq=15166/15931, ttl=128 (reply in 3)</td>
</tr>
<tr>
<td>3</td>
<td>2017-02-15 18:21:37.223808</td>
<td>192.168.100.2</td>
<td>192.168.200.254</td>
<td>ICMP</td>
<td>1001,5001</td>
<td>Echo (ping) request id=0x0001, seq=15166/15931, ttl=123 (reply in 3)</td>
</tr>
<tr>
<td>4</td>
<td>2017-02-15 18:21:37.223805</td>
<td>192.168.100.2</td>
<td>192.168.200.254</td>
<td>ICMP</td>
<td>1001,5001</td>
<td>Echo (ping) request id=0x0001, seq=15166/15931, ttl=255 (request in 2)</td>
</tr>
<tr>
<td>5</td>
<td>2017-02-15 18:21:37.224579</td>
<td>192.168.100.2</td>
<td>192.168.200.254</td>
<td>ICMP</td>
<td>1001,5001</td>
<td>Echo (ping) request id=0x0001, seq=15167/16187, ttl=127 (no response found)</td>
</tr>
</tbody>
</table>

Frame 2: 74 bytes on wire (592 bits), 74 bytes captured (592 bits) on interface 0

Internet Control Message Protocol

- Type: 0 (echo (ping) request)
- Code: 0
- Checksum: 0x121d [correct]
- Checksum Status: Good
- Identifier (16): 1 (0x0001)
- Identifier (Le): 256 (0x100)
- Sequence number (16): 15166 (0x3b5e)
- Sequence number (Le): 15931 (0x3e3b)
- [Response frame: ]

Data: 6162636465666768696a6b6c6d6e6f7871727374757677761... [Length: 32]
Quiz Session: Ping in MPLS (2/3)

- The laptop (192.168.100.2) attempts to ping the interface of (192.168.200.254) in DGS3630_PE_Right

- Collected Wireshark frames are displayed below

<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>MPLS Label</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2017-02-15</td>
<td>192.168.100.2</td>
<td>192.168.200.254</td>
<td>ICMP</td>
<td>1001,5001</td>
<td>Echo (ping) request id=0x0001, seq=15166/15931, ttl=127 (no response fou</td>
</tr>
<tr>
<td>2</td>
<td>2017-02-15</td>
<td>192.168.100.2</td>
<td>192.168.200.254</td>
<td>ICMP</td>
<td>1001,5001</td>
<td>Echo (ping) request id=0x0001, seq=15166/15931, ttl=128 (reply in 3)</td>
</tr>
<tr>
<td>3</td>
<td>2017-02-15</td>
<td>192.168.200.254</td>
<td>192.168.100.2</td>
<td>ICMP</td>
<td>IPv4 Explicit-Null</td>
<td>Echo (ping) reply id=0x0001, seq=15166/15931, ttl=255 (request in 2)</td>
</tr>
<tr>
<td>4</td>
<td>2017-02-15</td>
<td>192.168.200.254</td>
<td>192.168.100.2</td>
<td>ICMP</td>
<td>IPv4 Explicit-Null</td>
<td>Echo (ping) reply id=0x0001, seq=15166/15931, ttl=254</td>
</tr>
<tr>
<td>5</td>
<td>2017-02-15</td>
<td>192.168.200.254</td>
<td>192.168.200.254</td>
<td>ICMP</td>
<td>IPv4 Explicit-Null</td>
<td>Echo (ping) request id=0x0001, seq=15167/15187, ttl=127 (no response fou</td>
</tr>
</tbody>
</table>

Frame 3: 82 bytes on wire (656 bits), 82 bytes captured (656 bits) on interface 0


- MultiProtocol Label Switching Header, Label: 0 (IPv4 Explicit-Null), Exp: 0, S: 0, TTL: 254
  - MultiProtocol Label Switching Header, Label: 0 (IPv4 Explicit-Null) (0)
    - MultiProtocol Label Switching Header, Label: 5001, Exp: 0, S: 1, TTL: 255
      - MultiProtocol Label Switching Header, Label: 5001 (5001)
        - MultiProtocol Label Switching Header, Label: 1001, TTL: 255
          - MultiProtocol Label Switching Header, Label: 1001 (1001)
              - Internet Control Message Protocol
Quiz Session: Ping in MPLS (3/3)

- Let’s expand your general knowledge and share your thoughts on any possible network interactions?
### MAC Address Table (1/4)

- This command “show mac-address-table” is used to display a specific MAC address entry or the MAC address entries.

#### DGS3630_PE_Left

<table>
<thead>
<tr>
<th>VLAN</th>
<th>MAC Address</th>
<th>Type</th>
<th>Ports</th>
</tr>
</thead>
<tbody>
<tr>
<td>56</td>
<td>6C-72-20-3C-58-01</td>
<td>Dynamic</td>
<td>eth1/0/5</td>
</tr>
<tr>
<td>56</td>
<td>6C-72-20-3C-62-01</td>
<td>Static</td>
<td>CPU</td>
</tr>
<tr>
<td>100</td>
<td>00-1C-23-2F-64-D7</td>
<td>Dynamic</td>
<td>eth1/0/8</td>
</tr>
<tr>
<td>100</td>
<td>6C-72-20-3C-62-00</td>
<td>Static</td>
<td>CPU</td>
</tr>
</tbody>
</table>

Total Entries: 4

#### DGS3630_PE_Right

<table>
<thead>
<tr>
<th>VLAN</th>
<th>MAC Address</th>
<th>Type</th>
<th>Ports</th>
</tr>
</thead>
<tbody>
<tr>
<td>57</td>
<td>6C-72-20-39-94-01</td>
<td>Static</td>
<td>CPU</td>
</tr>
<tr>
<td>57</td>
<td>6C-72-20-3C-58-02</td>
<td>Dynamic</td>
<td>eth1/0/7</td>
</tr>
<tr>
<td>200</td>
<td>00-1C-23-32-B1-33</td>
<td>Dynamic</td>
<td>eth1/0/8</td>
</tr>
<tr>
<td>200</td>
<td>6C-72-20-39-94-00</td>
<td>Static</td>
<td>CPU</td>
</tr>
</tbody>
</table>

Total Entries: 4
MAC Address Table (2/4)

- Although BGP is not configured in DGS3630_P_Node, nevertheless, we do encounter BGP traffic in collected wireshark frames.
MAC Address Table (3/4)

- Is the source and destination mac in frame 1143 corresponding to "show mac-address-table" information?
MAC Address Table (4/4)

- Is the source and destination mac in frame 1145 corresponding to “show mac-address-table” information?

```
DGS3630_Pe_left#sh mac-address-table

<table>
<thead>
<tr>
<th>VLAN</th>
<th>MAC Address</th>
<th>Type</th>
<th>Ports</th>
</tr>
</thead>
<tbody>
<tr>
<td>56</td>
<td>6C-72-20-3C-58-01</td>
<td>Dynamic</td>
<td>eth1/0/5</td>
</tr>
<tr>
<td>56</td>
<td>6C-72-20-3C-62-01</td>
<td>Static</td>
<td>CPU</td>
</tr>
<tr>
<td>100</td>
<td>00-1C-23-2F-64-07</td>
<td>Dynamic</td>
<td>eth1/0/8</td>
</tr>
<tr>
<td>100</td>
<td>6C-72-20-3C-62-00</td>
<td>Static</td>
<td>CPU</td>
</tr>
</tbody>
</table>

Total Entries: 4
```

D-Link Academy
MPLS LDP address-message (1/2)

- The default IP address for VLAN 1 is 10.90.90.90/8 in DGS-3630
- Within our testbed, “no int vlan 1” was deployed in DGS3630_PE_Right in the first place
- If we decide to enable int vlan 1 while the rest of the config remains the same, then a question you should ask yourself:
MPLS LDP address-message (1/2)

- The default IP address for VLAN 1 is 10.90.90.90/8 in DGS-3630
- Within our testbed, “no int vlan 1” was deployed in DGS3630_PE_Right in the first place
- If we decide to enable int vlan 1 while the rest of the config remains the same, then a question you should ask yourself:
  - Do we see “10.90.90.90” in LDP address message?
MPLS LDP address-message (2/2)

- Frame 3, an address message, indicates that DGS3630_PE_Right (7.7.7.7) informs DGS3630_P_Node (5.5.5.5) on a specific IP address.
MPLS Configuration Guide

- Multiprotocol Label Switching (MPLS)
- MPLS Terminology
- Label Distribution Protocol (LDP)
- Configuration Scenario #1
- Configuration Scenario #2
- Configuration Scenario #3
- Command Reference
MPLS Configuration Lab #3

- This exercise details the functions needed to offer Virtual Private LAN Services (VPLS) where we build a MPLS tunnel between two PE (Provider Edge) routers.
- The same equipment shall discover your true potential in our journey.

- The D-Track DRU20170206000001/HQ20130626000013 serve the “transport address” in this protocol exercise.
MPLS Configuration Lab #3 : Topology

- DGS-3630-28TC with MPLS Virtual Private LAN Service (VPLS)

```
prompt DGS3630_P_Node
int. loopback 1: 5.5.5.5/24
int. vlan4001: 192.168.56.5/24
int. vlan4002: 192.168.57.5/24
OSPF

Laptop connects to int. eth 1/0/3
```

```
prompt DGS3630_PE_Left
int. loopback 1: 6.6.6.6/24
int. vlan4001: 192.168.56.6/24
OSPF

Laptop connects to int. eth 1/0/3
```

```
prompt DGS3630_PE_Right
int. loopback 1: 7.7.7.7/24
int. vlan4002: 192.168.57.7/24
OSPF

Laptop connects to int. eth 1/0/3
```
MPLS Configuration Lab #3

- The goal of this lab is setting up transport tunnels to other PEs (DGS3630_PE_Left & DGS3630_PE_Right) and delivering traffic over PWs.
MPLS Configuration Lab #3

- DGS3630_P_Node configurations
  - configure terminal
  - prompt DGS3630_P_Node
  - vlan 2-5,4001,4002
  - interface ethernet 1/0/5
  - switchport mode access
  - switchport access vlan 4001
  - interface ethernet 1/0/7
  - switchport mode access
  - switchport access vlan 4002
MPLS Configuration Lab #3

- DGS3630_P_Node configurations
  - interface vlan 1
  - no ip address 10.90.90.90 255.0.0.0
  - interface vlan 4001
  - ip address 192.168.56.5 255.255.255.0
  - interface vlan 4002
  - ip address 192.168.57.5 255.255.255.0
  - interface loopback 1
  - ip address 5.5.5.5 255.255.255.0
  - exit
MPLS Configuration Lab #3

- DGS3630_P_Node configurations
- mpls ip
- interface vlan 4001
- mpls ip
- exit
- mpls ip
- interface vlan 4002
- mpls ip
MPLS Configuration Lab #3

- DGS3630_P_Node configurations
  - mpls label protocol ldp
  - interface vlan 1
  - exit
- interface vlan 4001
  - mpls label protocol ldp
  - exit
- interface vlan 4002
  - mpls label protocol ldp
  - exit
MPLS Configuration Lab #3

- DGS3630_P_Node configurations
  - router ospf
  - router-id 5.5.5.5
  - network 192.168.56.0 255.255.255.0 area 0.0.0.0
  - network 192.168.57.0 255.255.255.0 area 0.0.0.0
  - network 5.5.5.5 255.255.255.0 area 0.0.0.0
  - exit
MPLS Configuration Lab #3

- DGS3630_PE_Left configurations
  - configure terminal
  - prompt DGS3630_PE_Left
  - monitor session 1 destination interface ethernet 1/0/1
  - monitor session 1 source interface ethernet 1/0/3-8
  - vlan 2-5,4001
  - interface ethernet 1/0/3
  - switchport mode trunk
  - interface ethernet 1/0/4
  - switchport mode trunk
  - interface ethernet 1/0/5
  - switchport mode access
  - switchport access vlan 4001
MPLS Configuration Lab #3

- DGS3630_PE_Left configurations
- configure terminal
- interface vlan 1
- no ip address 10.90.90.90 255.0.0.0
- interface vlan 4001
- ip address 192.168.56.6 255.255.255.0
- interface loopback 1
- ip address 6.6.6.6 255.255.255.0
MPLS Configuration Lab #3

- DGS3630_PE_Left configurations
- configure terminal
- mpls ip
- interface vlan 4001
- mpls ip
- exit
- mpls label protocol ldp
- interface vlan 4001
- mpls label protocol ldp
- exit
MPLS Configuration Lab #3

- DGS3630_PE_Left configurations
  - configure terminal
  - l2 vfi vpls manual
  - vpn id 100
  - pw-type raw
  - neighbor remote 7.7.7.7 encapsulation mpls
  - exit
  - exit
  - interface ethernet 1/0/3
  - xconnect vfi vpls
  - end
  - configure terminal
  - interface ethernet 1/0/4
  - xconnect vfi vpls
  - end
MPLS Configuration Lab #3

- DGS3630_PE_Left configurations
- router ospf
- router-id 6.6.6.6
- network 6.6.6.0 255.255.255.0 area 0.0.0.0
- network 192.168.56.0 255.255.255.0 area 0.0.0.0
- exit
MPLS Configuration Lab #3

- DGS3630_PE_Right configurations
- configure terminal
- prompt DGS3630_PE_Right
- monitor session 1 destination interface ethernet 1/0/1
- monitor session 1 source interface ethernet 1/0/3-8
- vlan 2-5,4002
- interface ethernet 1/0/3
- switchport mode trunk
- interface ethernet 1/0/4
- switchport mode trunk
- interface ethernet 1/0/7
- switchport mode access
- switchport access vlan 4002
MPLS Configuration Lab #3

- DGS3630_PE_Right configurations
  - configure terminal
  - interface vlan 1
  - no ip address 10.90.90.90 255.0.0.0
  - exit
  - interface vlan 4002
  - ip address 192.168.57.7 255.255.255.0
  - exit
  - interface loopback 1
  - ip address 7.7.7.7 255.255.255.0
  - exit
MPLS Configuration Lab #3

- DGS3630_PE_Right configurations
  - configure terminal
  - mpls ip
  - interface vlan 4002
  - mpls ip
  - exit
  - configure terminal
  - mpls label protocol ldp
  - interface vlan 4002
  - mpls label protocol ldp
  - exit
MPLS Configuration Lab #3

- DGS3630_PE_Right configurations
- # VPLS
- configure terminal
- l2 vfi vpls manual
- vpn id 100
- pw-type raw
- neighbor remote 6.6.6.6 encapsulation mpls
- interface ethernet 1/0/3
- xconnect vfi vpls
- interface ethernet 1/0/4
- xconnect vfi vpls
- end
MPLS Configuration Lab #3

- DGS3630_PE_Right configurations
- router ospf
- router-id 7.7.7.7
- network 7.7.7.0 255.255.255.0 area 0.0.0.0
- network 192.168.57.0 255.255.255.0 area 0.0.0.0
- exit
Learn from Practice Settings

- In VPLS, discovery refers to the process of finding all the PEs (Provider Edge routers) that participate in a given VPLS instance.
- A PE either can be configured with the identities of all the other PEs in a given VPLS [manual-discovery] or can use some protocol to discover the other PEs [auto-discovery].

Quiz Session: Did we adapt “manual-discovery” or “auto-discovery” in this lab exercise?
show vplts

- This command (show vplts) is used to display VPLS information. The underneath diagrams build the exhibits.

```
DGS3630_PE_Left#show vplts

<table>
<thead>
<tr>
<th>VPLS Name</th>
<th>VPLS ID</th>
<th>Peers/ACs</th>
<th>Oper Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>vplts</td>
<td>100</td>
<td>1/2</td>
<td>Up</td>
</tr>
</tbody>
</table>

Total Entries: 1
```

```
DGS3630_PE_Right#show vplts

<table>
<thead>
<tr>
<th>VPLS Name</th>
<th>VPLS ID</th>
<th>Peers/ACs</th>
<th>Oper Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>vplts</td>
<td>100</td>
<td>1/2</td>
<td>Up</td>
</tr>
</tbody>
</table>

Total Entries: 1
```
show vpls detail

- “show vpls detail” elaborates VPLS messages
- Quiz Session: Could you share your thoughts why an identical local AC Operation Status exist here?

```
DGS3630_PE_Left#show vpls detail

VPLS Name: vpls, Operate Status: Up, Type: Manual
VPLS ID: 100, Service Type: Raw, MTU: 1500, MAC Limit: 0
Egress VLAN mode: Default
Peers via Pseudowires:
  VC ID   Peer    Type   Oper Status
  ------- ------ ------ --------
  100     7.7.7.7 Network Up

Local ACs:
  Local AC Oper Status
  Eth1/0/3  Up
  Eth1/0/4  Down

Total Entries: 1
DGS3630_PE_Left#_```
VCID

- VCID is used to identify an emulated LAN segment
- It (VCID) can be obtained in FEC TLV via Wireshark frame

```
Frame 729: 122 bytes on wire (976 bits), 122 bytes captured (976 bits) on interface 0
Internet Protocol Version 4, Src: 6.6.6.6, Dst: 7.7.7.7
Label Distribution Protocol
  Version: 1
  PDU Length: 52
  LSR ID: 6.6.6.6
  Label Space ID: 0
  Notification Message
    0... .... = U bit: Unknown bit not set
    Message Type: Notification Message (0x1)
    Message Length: 42
    Message ID: 0x00000355
  Status TLV
  PW Status TLV
  Forwarding Equivalence Classes TLV
    00... .... = TLV Unknown bits: Known TLV, do not Forward (0x0)
    TLV Type: Forwarding Equivalence Classes TLV (0x100)
    TLV Length: 12
  FEC Elements
    FEC Element 1 [VCID: 100]
      FEC Element Type: Virtual Circuit FEC (128)
      0... .... = C-bit: Control Word NOT Present
      .000 0000 0000 0001 = VC Type: Ethernet (0x0005)
      VC Info length: 4
      Group ID: 0
      VC ID: 100
```
Pseudowire Type

- The allowed PW types are Ethernet (0x0005) and Ethernet tagged mode (0x004). The example displayed below is Ethernet (0x0005)

| Frame 1124: 122 bytes on wire (976 bits), 122 bytes captured (976 bits) on interface 0 |
| Ethernet II, Src: D-LinkIn.39:94:01 (6c:72:39:94:01), Dst: D-LinkIn.3c:58:02 (6c:72:3c:58:02) |
| Internet Protocol Version 4, Src: 7.7.7.7, Dst: 6.6.6.6 |
| Label Distribution Protocol |
| Version: 1 |
| PDU Length: 52 |
| LSR ID: 7.7.7.7 |
| Label Space ID: 0 |
| Notification Message |
| 0... = U bit: Unknown bit not set |
| Message Type: Notification Message (0x1) |
| Message Length: 42 |
| Message ID: 0x00000400 |
| Status TLV |
| PW Status TLV |
| Forwarding Equivalence Classes TLV |
| 00... = TLV Unknown bits: Known TLV, do not Forward (0x0) |
| TLV Type: Forwarding Equivalence Classes TLV (0x100) |
| TLV Length: 12 |
| FEC Elements |
| FEC Element 1 VCID: 100 |
| FEC Element Type: Virtual Circuit FEC (128) |
| 0... = C-bit: Control Word NOT Present |
| 000 0000 0000 0101 = VC Type: Ethernet (0x0005) |
| VC Info Length: 4 |
| Group ID: 0 |
| VC ID: 100 |
Topological Model for VPLS

- Each PE will form remote MAC address to PW associations and associate directly attached MAC addresses to local customer facing ports.
- This is modeled on standard IEEE 802.1 MAC address learning.
- The reachability on Address Learning is obtained by standard learning bridge functions in the data plane.
show mac-address-table vpls

- This command (show mac-address-table vpls) is used to display VPLS MAC address information.
- From DGS3630_PE_Left, we have obtained the below two addresses:
  - “00-1C-23-2F-64-D7” and
  - “00-1c-23-32-B1-33”

```bash
DGS3630_PE_Left# show mac-address-table vpls

<table>
<thead>
<tr>
<th>VPLS Name</th>
<th>MAC Address</th>
<th>Peer (VC ID/IP) or AC</th>
</tr>
</thead>
<tbody>
<tr>
<td>vpls</td>
<td>00-1C-23-2F-64-D7</td>
<td>Eth1/0/3</td>
</tr>
<tr>
<td>vpls</td>
<td>00-1C-23-32-B1-33</td>
<td>100/7.7.7.7</td>
</tr>
</tbody>
</table>

Total Entries: 2
```

D-Link Academy
show mac-address-table vpls

- From DGS3630_PE_Left, we had retrieved a similar result

```
DGS3630_PE_Right# show mac-address-table vpls

<table>
<thead>
<tr>
<th>VPLS Name</th>
<th>MAC Address</th>
<th>Peer (VC ID/IP) or AC</th>
</tr>
</thead>
<tbody>
<tr>
<td>vpls</td>
<td>00-1C-23-2F-64-D7</td>
<td>100/6.6.6.6</td>
</tr>
<tr>
<td>vpls</td>
<td>00-1C-23-32-B1-33</td>
<td>Eth1/0/0/3</td>
</tr>
</tbody>
</table>

Total Entries: 2
```

- Quiz Session: who should claim as the owner(s) of?
  - “00-1C-23-2F-64-D7” and
  - “00-1c-23-32-B1-33”
Quiz Session: mac-address-table vplsls

- “00-1C-23-2F-64-D7” is the laptop connects to DGS3630_PE_Left
Quiz Session: mac-address-table vpls

- “00-1c-23-32-B1-33” is the laptop connects to DGS3630_PE_Right
show mpls l2transport vc

- “show mpls l2transport vc” yields VC information for VPLS

- DRU20170206000001 also carries the output of this command for reference
show mpls forwarding-table

- What is the 6.6.6.6 label value in MPLS label forwarding path information? (also confirm your answers to the messages indicated in last slide)

```
DGS3630_PE_Righ#show mpls forwarding-table

<table>
<thead>
<tr>
<th>LSP</th>
<th>FEC</th>
<th>In Label</th>
<th>Out Label</th>
<th>Out Interface</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.5.5.5/32</td>
<td></td>
<td></td>
<td>VLAN 4002</td>
<td>192.168.57.5</td>
</tr>
<tr>
<td>2</td>
<td>6.6.6.6/32</td>
<td></td>
<td>1000</td>
<td>VLAN 4002</td>
<td>192.168.57.5</td>
</tr>
<tr>
<td>2946</td>
<td>VC 100/6.6.6.6</td>
<td></td>
<td>1000/1000</td>
<td>VLAN 4002</td>
<td>192.168.57.5</td>
</tr>
<tr>
<td>2945</td>
<td>VC 100/6.6.6.6</td>
<td>1000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total Entries: 4

DGS3630_PE_Righ#
```

- This command is also described in DRU20170206000001
show mpls ldp discovery

- To display LDP discovery information, you can rely on the command of “show mpls ldp discovery”

```
DGS3630 PE_Left#show mpls ldp discovery

Local LDP Identifier: 6.6.6.6:0
Discovery Sources:
   Interfaces:
      VLAN 4001 (LDP): xmit/recv
         LDP Id: 5.5.5.5:0
   Targeted Hellos:
      192.168.56.6 -> 192.168.57.7 (LDP): passive, xmit/recv
         LDP Id: 7.7.7.7:0
```

DGS3630 PE_Left#_
Quiz Session: LDP Session

- As of DGS3630_PE_Left, what are the expected total LDP session?
Quiz Session: LDP Session

- As of DGS3630_PE_Left, what are the expected total LDP session?

```
DGS3630_PE_Left#show mpls ldp session

<table>
<thead>
<tr>
<th>Peer</th>
<th>Status</th>
<th>Role</th>
<th>Keep Alive</th>
<th>Distribution Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.5.5.5:0</td>
<td>OPERATIONAL</td>
<td>Active</td>
<td>40(Sec)</td>
<td>DU</td>
</tr>
<tr>
<td>7.7.7.7:0</td>
<td>OPERATIONAL</td>
<td>Passive</td>
<td>40(Sec)</td>
<td>DU</td>
</tr>
</tbody>
</table>

Total Entries: 2
```

- Note: A full mesh of LDP sessions is used to establish the mesh of PWs, resulting a large number of targeted LDP sessions
MPLS Configuration Guide

- Multiprotocol Label Switching (MPLS)
- MPLS Terminology
- Label Distribution Protocol (LDP)
- Configuration Scenario #1
- Configuration Scenario #2
- Configuration Scenario #3
- Command Reference
D-Link Switch MPLS Command

- Global Configuration Mode
- Interface Configuration Mode
- LDP Configuration Mode
- LDP Target Peer Mode
- MPLS QoS Configuration Mode
- Privileged EXEC Mode
D-Link Switch MPLS Command

- Global Configuration Mode
- Interface Configuration Mode
- LDP Configuration Mode
- LDP Target Peer Mode
- MPLS QoS Configuration Mode
- Privileged EXEC Mode
Global Configuration Mode (List of Commands)

- Switch# configure terminal
  - Switch(config)# mpls ip
  - Switch(config)# mpls label protocol ldp
  - Switch(config)# mpls ldp configuration
  - Switch(config)# mpls qos policy policy1
  - Switch(config)# snmp-server enable traps mpls ldp
  - Switch(config)# mpls static ftn 172.18.10.0/24 out-label 100 nexthop 110.1.1.2
  - Switch(config)# mpls static ilm in-label 100 forward-action swap-label 200 nexthop 120.1.1.3 fec 172.18.10.0/24
  - Switch(config)# mpls static ilm in-label 100 forward-action pop nexthop 120.1.1.3 fec 172.18.10.0/24
D-Link Switch **MPLS Command**

- **Command:** mpls ip
- **Description:** This command is used to enable MPLS forwarding globally in the Global Configuration mode, or MPLS forwarding on an interface in the Interface Configuration mode.
- **Example:** This example shows how to enable MPLS globally and enable MPLS on VLAN 200.
  - Switch(config)# mpls ip
  - Switch(config)# interface vlan200
  - Switch(config-if)# mpls ip

- The empowerment of this command is described in detail at D-Track (DI20160401000003/DRU20120307000006)
D-Link Switch **MPLS/LDP Command**

- **Command:** mpls label protocol ldp (1/2)
- **Description:** This command is used to enable
  - LDP globally in the Global Configuration mode, and/or
  - LDP on this interface in the Interface Configuration mode
- **Example:** This example shows how to enable LDP globally and enable LDP on VLAN 100.
  - Switch# configure terminal
  - Switch(config)# mpls label protocol ldp
  - Switch(config)# interface vlan 100
  - Switch(config-if)# mpls label protocol ldp
  - Switch(config-if)#
D-Link Switch **MPLS/LDP Command**

- **Command:** `mpls label protocol ldp` (2/2)
- **Usage Guideline:** LDP is running on an interface only when
  - MPLS and LDP are globally enabled, or
  - MPLS and LDP are enabled on this interface

- In D-Track system, DI20160401000003 complies with the efforts of this command
D-Link Switch MPLS/LDP Command

- Command: mpls ldp configuration
- Description: This command is used to enter the LDP Configuration mode to configure LDP related settings
- Example: This example shows how to enter the LDP configuration mode.
  
  - Switch# configure terminal
  - Switch(config)# mpls ldp configuration
  - Switch(config-ldp)#
D-Link Switch **MPLS** Command

- Command: mpls static ftn (1/2)
- Description: This command is used to add a static FEC-To-NHLFE Map (FTN) entry. (NHLFE stands for Next Hop Label Forwarding Entry.)
- Usage Guideline: Use this command to add a static FTN entry. At the ingress Label Edge Router (LER), the incoming IP packets that are classified to FEC will be pushed with the MPLS label and forwarded to the next hop according to the FTN.
D-Link Switch **MPLS Command**

- **Command:** mpls static ftn (2/2)
- **Example:** This example shows how to configure a static FTN that pushes with the label ‘100’ for prefix FEC 172.18.10.0/24.
  - Switch# configure terminal
  - Switch(config)# mpls static ftn 172.18.10.0/24 out-label 100 nexthop 110.1.1.2
  - Switch(config)#
D-Link Switch **MPLS** Command

- **Command:** mpls static ilm (1/2)
- **Description:** This command is used to add a static Incoming Label Map (ILM) entry.
- **Usage Guideline:** Use this command to add a static ILM entry. At LSR, the incoming MPLS packets that are matched to the incoming label will be processed according configured ILM action. The label operation is either
  - swapping the incoming top label to the configured outgoing label, or
  - popping the top label and then forwarding the packet to the next hop.
D-Link Switch **MPLS Command**

- Command: `mpls static ilm (2/2)`
- Example: This command is used to add a static Incoming Label Map (ILM) entry.
- Usage Guideline: This example shows how to configure a static ILM that swaps the label from 100 to 200 for the prefix `FEC 172.18.10.0/24` at the transit LSR
  - Switch# configure terminal
  - Switch(config)# mpls static ilm in-label 100 forward-action swap-label 200 nexthop 120.1.1.3 fec 172.18.10.0/24
  - Switch(config)#

D-Link Academy
Quiz Session: MPLS Incoming Label Map (1/2)

- Q: Could you elaborate “MPLS Incoming Label Map” regarding FEC 192.168.200.0/24 and FEC 192.168.100.0/24 here?

<table>
<thead>
<tr>
<th>LSP:15</th>
<th>Type: Transit</th>
<th>FEC: 192.168.200.0/24</th>
<th>Status: Up</th>
<th>Owner: Static</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>In Label: 17</td>
<td></td>
<td>Out Label: Push 333</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Next Hop: 192.168.57.7</td>
<td></td>
<td>Out Interface: VLAN 57</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LSP:8</th>
<th>Type: Egress</th>
<th>FEC: 192.168.56.0/24</th>
<th>Status: Up</th>
<th>Owner: LDP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>In Label: 0</td>
<td></td>
<td>Out Label: Pop</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Next Hop: -</td>
<td></td>
<td>Out Interface: -</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LSP:16</th>
<th>Type: Transit</th>
<th>FEC: 192.168.100.0/24</th>
<th>Status: Up</th>
<th>Owner: Static</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>In Label: 16</td>
<td></td>
<td>Out Label: Push 222</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Next Hop: 192.168.56.6</td>
<td></td>
<td>Out Interface: VLAN 56</td>
</tr>
</tbody>
</table>
Quiz Session: MPLS Incoming Label Map (2/2)

- Ans: The incoming label of FEC 192.168.200.0/24 is 17 and swap with 333 when sending it out. As of FEC 192.168.100.0/24, in label of 16 and out label with 222

<table>
<thead>
<tr>
<th>LSP:15</th>
<th>Status:Up</th>
<th>Owner:Static</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type: Transit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FEC: 192.168.200.0/24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In Label: 17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Next Hop: 192.168.57.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Out Label: Push 333</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Out Interface: VLAN 57</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LSP:8</th>
<th>Status:Up</th>
<th>Owner:LDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type: Egress</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FEC: 192.168.56.0/24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In Label: 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Next Hop: -</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Out Label: Pop</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Out Interface: -</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LSP:16</th>
<th>Status:Up</th>
<th>Owner:Static</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type: Transit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FEC: 192.168.100.0/24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In Label: 16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Next Hop: 192.168.56.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Out Label: Push 222</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Out Interface: VLAN 56</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
D-Link Switch MPLS Command

- Global Configuration Mode
- Interface Configuration Mode
- LDP Configuration Mode
- LDP Target Peer Mode
- MPLS QoS Configuration Mode
- Privileged EXEC Mode
Interface Configuration Mode (List of Commands)

- Switch# configure terminal
- Switch(config)# interface vlan 10
  - Switch(config-if)# mpls label protocol ldp
  - Switch(config-if)# mpls ip
  - Switch(config-if)# discovery targeted-hello accept

- “mpls label protocol ldp” is adapted to enable LDP on this interface in the Interface
- “discovery targeted-hello accept” is used to enable the targeted hello message acceptance
D-Link Switch MPLS Command

- Global Configuration Mode
- Interface Configuration Mode
- LDP Configuration Mode
- LDP Target Peer Mode
- MPLS QoS Configuration Mode
- Privileged EXEC Mode
LDP Configuration Mode (List of Commands)

- Switch(config)# mpls ldp configuration
  - Switch(config-ldp)# router-id 110.10.10.30
  - Switch(config-ldp)# keepalive-holdtime 60
  - Switch(config-ldp)# path-vector maxlen 30
  - Switch(config-ldp)# backoff 100 200
  - Switch(config-ldp)# explicit-null
  - Switch(config-ldp)# loop-detection
  - Switch(config-ldp)# maxhops 30
LDP Configuration Mode (List of Commands)

- Switch(config)# mpls ldp configuration
  - Switch(config-ldp)# neighbor 110.10.10.1 targeted
  - Switch(config-ldp)# md5 authentication
  - Switch(config-ldp)# neighbor 10.90.90.12 password DLINK
  - Switch(config-ldp)# discovery hello holdtime 30
  - Switch(config-ldp)# discovery hello hello interval 10
  - Switch(config-ldp)# discovery transport-address 192.168.0.1
  - Switch(config-ldp)# distribution-mode du
LDP Configuration Mode (List of Commands)

- `Switch(config)# mpls ldp configuration`
  - `Switch(config-ldp)# graceful-restart`
  - `Switch(config-ldp)# graceful-restart recovery timer 500`
  - `Switch(config-ldp)# graceful-restart neighbor-liveness timer 180`
  - `Switch(config-ldp)# label-retention-mode conservative`
  - `Switch(config-ldp)# lsp-control-mode ordered`
  - `Switch(config-ldp)# lsp trigger 10 permit ip 192.1.1.0/24`
  - `Switch(config-ldp)# lsp trigger 20 deny any`
D-Link Switch LDP Command

- **Command:** router-id (1/2)
- **Description:** This command is used to configure the LSR ID of the LDP
  - The LSR ID is used to identify the LSR in the MPLS network
  - It is recommended to set the LSR ID to the IP address of a loopback interface
- **Example:** This example shows how to configure the LDP LSR ID to 110.10.10.30
  - Switch# configure terminal
  - Switch(config)# mpls ldp configuration
  - Switch(config-ldp)# router-id 110.10.10.30
D-Link Switch LDP Command

- Command: router-id (2/2)
- Frame 36 in the following Wireshark sketch presents an LSR ID (55.55.57.55) in the LSR (192.168.57.5)

```
<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>MPLS Label</th>
<th>LSP Type</th>
<th>MPLS TTL</th>
<th>Length</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>35</td>
<td>2016-12-01 18:34:31.657537</td>
<td>192.168.56.5</td>
<td>224.0.0.2</td>
<td>LDP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>84 Hello Message</td>
</tr>
<tr>
<td>36</td>
<td>2016-12-01 18:34:31.658548</td>
<td>192.168.57.5</td>
<td>224.0.0.2</td>
<td>LDP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>84 Hello Message</td>
</tr>
<tr>
<td>55</td>
<td>2016-12-01 18:34:36.331844</td>
<td>192.168.56.5</td>
<td>224.0.0.2</td>
<td>LDP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>84 Hello Message</td>
</tr>
</tbody>
</table>
```

- Frame 36: 84 bytes on wire (672 bits), 84 bytes captured (672 bits)
- Ethernet II, Src: D-LinkIn_3c:50:02 (6c:72:20:3c:50:02), Dst: IPv4mcast_02 (01:00:5e:00:00:02)
- Internet Protocol Version 4, Src: 192.168.57.5, Dst: 224.0.0.2
- User Datagram Protocol, Src Port: 646, Dst Port: 646

```
Label Distribution Protocol
Version: 1
PDU Length: 30
LSR ID: 55.55.57.55
Label Space ID: 0
```

- Hello Message
D-Link Switch LDP Command

- Command: discovery hello (1/4)
  - discovery hello {holdtime SECONDS | interval SECONDS}
- Description: This command is used to configure the LDP link hello hold-time and hello interval
- LDP sends link hello messages at the configured interval to discover the neighbor
- For a discovered neighbor, LDP maintains a hold-timer
D-Link Switch **LDP Command**

- **Command**: discovery hello (2/4)
  - discovery hello {holdtime SECONDS | interval SECONDS}
- **Example**: This example shows how to configure the hello hold-time to 30 seconds and the hello interval to 10 seconds
  - Switch# configure terminal
  - Switch(config)# mpls ldp configuration
  - Switch(config-ldp)# discovery hello holdtime 30
  - Switch(config-ldp)# discovery hello interval 10
  - Switch(config-ldp)#
**D-Link Switch LDP Command**

- **Command:** discovery hello (3/4)
- **With below diagram, you shall see LSR (192.168.56.5) sends out Hello Message every 5 seconds (frame 35/55), with hold time of 15 seconds**

```
DGS3630_SW1#show mpls ldp interface

Interface : vlan56

Admin State          : Enabled
Oper State           : Enabled
Targeted Hello Accept : Acceptable
Hello Interval       : 5(Sec)
Hello Hold Time      : 15(Sec)
Distribution Method  : DU

Interface : vlan57

Admin State          : Enabled
Oper State           : Enabled
Targeted Hello Accept : Acceptable
Hello Interval       : 5(Sec)
Hello Hold Time      : 15(Sec)
Distribution Method  : DU

Total Entries: 2
```

D-Link Academy
D-Link Switch **LDP Command**

- **Command**: discovery hello (4/4)
- With below diagram, you shall see LSR (192.168.56.5) sends out Hello Message every 5 seconds (frame 35/55), with hold time of 15 seconds

![Diagram of LDP message exchange]

- **Frame 35**: 84 bytes on wire (672 bits), 84 bytes captured (672 bits)
- Ethernet II, Src: D-LinkIn_3c:58:02 (6c:72:20:3c:58:02), Dst: IPv4mcast_02 (01:00:5e:00:00:02)
- Internet Protocol Version 4, Src: 192.168.57.5, Dst: 224.0.0.2
- User Datagram Protocol, Src Port: 646, Dst Port: 646

**Label Distribution Protocol**

- **Version**: 1
- **PDU Length**: 38
- **LSR ID**: 55:55:57.55
- **Label Space ID**: 0

**Hello Message**

- **Message Type**: Hello Message (0x100)
- **Message Length**: 28

**Common Hello Parameters TLV**

- **Hold Time**: 15
- **Targeted Hello**: Link Hello
- **Hello Requested**: Source does not request periodic hellos
- **DTSM Flag**: Not set
- **Sequence Number TLV**

D-Link Academy
D-Link Switch LDP Command

- Command: discovery transport-address (1/3)
  - discovery transport-address {interface | IP-ADDRESS}
- Description: By default, the LSR ID is used as the transport address for all interfaces
- This command is used to configure the LDP transport address, in establishing an LDP TCP connection
  - If configured as interface, the IP address of each interface is used as the transport address
  - If configured as a specified IP address, this address is used as transport address by all interfaces
D-Link Switch LDP Command

- Command: discovery transport-address (2/3)
  - discovery transport-address {interface | IP-ADDRESS}
- Example: This example shows how to configure the transport address to 192.168.0.1
  - Switch# configure terminal
  - Switch(config)# mpls ldp configuration
  - Switch(config-ldp)# discovery transport-address 192.168.0.1
  - Warning: The configuring will lead to LDP sessions restart.
  - Switch(config-ldp)#
D-Link Switch LDP Command

- Command: discovery transport-address (3/3)
- Frame 2048, a Hello message, indicates transport-address (55.55.57.55) for the LSR (192.168.56.5)

<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>VLAN_ID</th>
<th>MPLS Label</th>
<th>Length</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>2049</td>
<td>2016-12-01 18:42:59.249404</td>
<td>192.168.57.5</td>
<td>224.0.0.2</td>
<td>LDP</td>
<td></td>
<td></td>
<td></td>
<td>84 Hello Message</td>
</tr>
<tr>
<td>2048</td>
<td>2016-12-01 18:42:59.169395</td>
<td>192.168.56.5</td>
<td>224.0.0.2</td>
<td>LDP</td>
<td></td>
<td></td>
<td></td>
<td>84 Hello Message</td>
</tr>
<tr>
<td>2046</td>
<td>2016-12-01 18:42:58.484593</td>
<td>192.168.56.6</td>
<td>224.0.0.2</td>
<td>LDP</td>
<td></td>
<td></td>
<td></td>
<td>84 Hello Message</td>
</tr>
</tbody>
</table>

Frame 2048: 84 bytes on wire (672 bits), 84 bytes captured (672 bits)
Ethernet II, Src: D-LinkIn_3c:58:01 (6c:72:20:3c:58:01), Dst: IPv4mcast_02 (01:00:5e:00:00:02)
Internet Protocol Version 4, Src: 192.168.56.5, Dst: 224.0.0.2
User Datagram Protocol, Src Port: 646, Dst Port: 646

Label Distribution Protocol

Version: 1
PDU Length: 38
LSR ID: 55.55.57.55
Label Space ID: 0

Hello Message
0... ..... = U bit: Unknown bit not set
Message Type: Hello Message (0x100)
Message Length: 28
Message ID: 0x00000145

Common Hello Parameters TLV
Configuration Sequence Number TLV
IPv4 Transport Address TLV
00... ..... = TLV Unknown bits: Known TLV, do not Forward (0x0)
TLV Type: IPv4 Transport Address TLV (0x401)
TLV Length: 4
IPv4 Transport Address: 55.55.57.55
D-Link Switch LDP Command

- Command: keepalive-holdtime SECONDS (15 ~ 65535) (1/6)
- Description: This command is used to configure the keep-alive hold-time for LDP sessions.
  - LDP maintains a keep-alive hold timer for each peer session.
  - If the keep-alive hold timer expires without receipt of an LDP PDU from the peer, LDP terminates the LDP session.
  - Each LSR sends keep-alive messages at regular intervals to its LDP peers to keep the sessions active.
  - The keep-alive interval is one third of the keep-alive hold-time
D-Link Switch **LDP Command**

- Command: `keepalive-holdtime SECONDS (15 ~ 65535)` *(2/6)*
- Example: This example shows how to configure the keep-alive hold-time to 60 seconds
  - Switch# configure terminal
  - Switch(config)# mpls ldp configuration
  - Switch(config-ldp)# keepalive-holdtime 60
  - Warning: The configuring will lead to LDP sessions restart.
  - Switch(config-ldp)#
D-Link Switch **LDP** Command

- **Command**: `keepalive`-`holdtime` SECONDS (15 ~ 65535) (3/6)
- The following describe keep Alive message from 166.166.166.155 to 55.55.57.55. What would be hold-time in seconds being set via “keepalive-holdtime” command?
D-Link Switch LDP Command

- Command: keepalive-holdtime SECONDS (15 ~ 65535) (4/6)
- 1st packet: (#252), 12/1, 18:35:24
- 2nd packet: (#294), 12/1, 18:35:37
- Time period between them: 37-24=13 seconds.
- Since The keep-alive interval is one third of the keep-alive hold-time, as such it could be 40 seconds (13*3)
D-Link Switch LDP Command

- Command: keepalive-holdtime SECONDS (15 ~ 65535) (5/6)
- Use “show mpls ldp information” to verify latest status

```
DGS3630_SW1#show mpls ldp information

<table>
<thead>
<tr>
<th>LSR ID</th>
<th>55.55.57.55</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDP Version</td>
<td>1.0</td>
</tr>
<tr>
<td>LDP State</td>
<td>Enabled</td>
</tr>
<tr>
<td>TCP Port</td>
<td>646</td>
</tr>
<tr>
<td>UDP Port</td>
<td>646</td>
</tr>
<tr>
<td>Max PDU Length</td>
<td>1500</td>
</tr>
<tr>
<td>Initial Backoff</td>
<td>15 Seconds</td>
</tr>
<tr>
<td>Max Backoff</td>
<td>600 Seconds</td>
</tr>
<tr>
<td>Transport Address</td>
<td>55.55.57.55</td>
</tr>
<tr>
<td>Keep Alive Time</td>
<td>40 Seconds</td>
</tr>
<tr>
<td>Link Hello Holdtime</td>
<td>15 Seconds</td>
</tr>
<tr>
<td>Link Hello Interval</td>
<td>5 Seconds</td>
</tr>
<tr>
<td>Distribution Method</td>
<td>DU</td>
</tr>
<tr>
<td>LSP Control Mode</td>
<td>Independent</td>
</tr>
<tr>
<td>Label Retention</td>
<td>Liberal</td>
</tr>
<tr>
<td>Loop Detection</td>
<td>Disabled</td>
</tr>
<tr>
<td>Path Vector Limit</td>
<td>254</td>
</tr>
<tr>
<td>Hop Count Limit</td>
<td>254</td>
</tr>
<tr>
<td>Authentication</td>
<td>Disabled</td>
</tr>
<tr>
<td>PHP</td>
<td>Implicit null</td>
</tr>
<tr>
<td>Trap Status</td>
<td>Disabled</td>
</tr>
<tr>
<td>Graceful Restart</td>
<td>Disabled</td>
</tr>
<tr>
<td>Neighbor Liveness Time</td>
<td>120 Seconds</td>
</tr>
</tbody>
</table>
```
D-Link Certified Specialist

MPLS Configuration Guide

D-Link Switch LDP Command

- Command: keepalive-holdtime SECONDS (15 ~ 65535) (6/6)
- The below sketch, frame 2284, shows Session KeepAlive Time is set as “40” seconds
D-Link Switch LDP Command

- **Command**: explicit-null (1/4)
- **Description**: This command is used to advertise the explicit null label to the penultimate hop.
  - Use this command on the **egress router** to configure the Penultimate Hop Popping (PHP) behavior of the upstream router.
  - If the **egress router** advertises the **implicit null label**, the upstream router will do Penultimate Hop Popping.
  - If the **egress router** advertises the **explicit null label**, the upstream router will keep the outer label without popping.
D-Link Switch **LDP** Command

- **Command**: explicit-null (2/4)
- **Example**: This example shows how to configure the egress LSR advertise Explicit NULL label.
  - Switch# configure terminal
  - Switch(config)# mpls ldp configuration
  - Switch(config-ldp)# explicit-null
  - Warning: The configuring will lead to LDP sessions restart.
  - Switch(config-ldp)#
D-Link Switch LDP Command

- Command: explicit-null (3/4)
- Use “show mpls ldp information” indicates this router (DGS3630_SW1) carries with PHP setting of “Implicit null”

```
DGS3630_SW1#show mpls ldp information

LSR ID : 55.55.57.55
LDP Version : 1.0
LDP State : Enabled
TCP Port : 646
UDP Port : 646
Max PDU Length : 1500
Initial Backoff : 15 Seconds
Max Backoff : 600 Seconds
Transport Address : 55.55.57.55
Keep Alive Time : 40 Seconds
Link Hello Holdtime : 15 Seconds
Link Hello Interval : 5 Seconds
Distribution Method : DU
LSP Control Mode : Independent
Label Retention : Liberal
Loop Detection : Disabled
Path Vector Limit : 254
Hop Count Limit : 254
Authentication : Disabled
PHP : Implicit null
Trap Status : Disabled
Graceful Restart : Disabled
Neighbor Liveness Time : 120 Seconds
```
D-Link Switch **LDP Command**

- Command: explicit-null (4/4)
- On the other hand, this router (DGS3630_SW3) carries with PHP setting of “Explicit null”
D-Link Switch LDP Command

- Command: loop-detection (1/2)
- Description: This command is used to enable loop detection.
  - Use this command to enable LDP loop detection. LDP loop detection makes use of the Path Vector and Hop Count TLVs carried by the label request and label mapping messages to prevent looping of LDP messages.
  - If enabled, LDP does not send the LDP message that violates the path vector check or hop count check to the next hop.
D-Link Switch **LDP Command**

- **Command**: loop-detection (2/2)
- **Example**: This example shows how to enable LDP loop detection
  - Switch# configure terminal
  - Switch(config)# mpls ldp configuration
  - Switch(config-ldp)# loop-detection
  - Warning: The configuring will lead to LDP sessions restart.
  - Switch(config-ldp)#
D-Link Switch **LDP Command**

- **Command**: maxhops (1/3)
- **Description**: This command is used to configure the maximum number of hops permitted in the LSP setup
  - Use the maximum hop count limitation command to prevent looping of the LDP mapping message or label of request message during routing transitions.
  - If loop detection is enabled, LDP does not send the LDP message that violates the maximum hop limitation to the next hop
  - The range of maximum number of hops is from 1 to 255
D-Link Switch **LDP Command**

- **Command**: `maxhops (2/3)`
- **Example**: This example shows how to configure the maximum hop count to 30.
  - Switch# configure terminal
  - Switch(config)# mpls ldp configuration
  - Switch(config-ldp)# maxhops 30
  - Warning: The configuring will lead to LDP sessions restart.
  - Switch(config-ldp)#
D-Link Switch LDP Command

- Command: maxhops (3/3)
- In D-Link switches, by default, this value is 254
- With the command of “show mpls ldp information” offers an opportunity to view “Hop Count Limit” settings, as presented in the righthand side diagram
D-Link Switch LDP Command

- Command: path-vector maxlength (1/3)
- Description: This command is used to configure the maximum path vector length
  - If loop detection is enabled, a path vector TLV will be included in the label request or label mapping message.
  - A loop is detected when an LSR receives a message that includes a path vector TLV and an LSR ID that matches its own ID, or when the path vector length in the received message is greater than the maximum length defined in the path-vector maxlength command.
D-Link Switch **LDP Command**

- **Command**: path-vector maxlength (2/3)
- **Example**: This example shows how to configure the maximum path vector to 30.
  - Switch# configure terminal
  - Switch(config)# mpls ldp configuration
  - Switch(config-ldp)# path-vector maxlength 30
  - Warning: The configuring will lead to LDP sessions restart.
  - Switch(config-ldp)#
D-Link Switch LDP Command

- Command: path-vector maxlength (3/3)
- In D-Link switches, by default, this value is 254.
D-Link Switch **LDP Command**

- Command: distribution-mode (1/3)
- Description: This command is used to configure the label distribution mode.
  
  - distribution-mode \{dod \mid du\}
  
  - dod: Specifies to use the downstream-on-demand distribution mode
  
  - Du: Specifies to use the downstream-unsolicited distribution mode

- Note: By default, the distribution mode is downstream unsolicited.
D-Link Switch LDP Command

- Command: distribution-mode (2/3)
- Usage Guideline
  - Downstream-on-demand mode (dod): the downstream LSR advertises a label mapping when an upstream connection makes an explicit request
  - Downstream-unsolicited mode (du): the downstream LSR advertises a label mapping when a label is learned in the routing table
- Example: This example shows how to configure the label distribution mode to the downstream-unsolicited mode
  - Switch# configure terminal
  - Switch(config)# mpls ldp configuration
  - Switch(config-ldp)# distribution-mode du
D-Link Switch **LDP Command**

- **Command:** distribution-mode (3/3)
- **Configuration Example**
  - The below sketch displays that this device is configured as downstream-unsolicited distribution mode (du)

```
DGS3630_SW1#show mpls ldp interface

<table>
<thead>
<tr>
<th>Interface</th>
<th>vlan56</th>
</tr>
</thead>
<tbody>
<tr>
<td>Admin State</td>
<td>Enabled</td>
</tr>
<tr>
<td>Oper State</td>
<td>Enabled</td>
</tr>
<tr>
<td>Targeted Hello Accept</td>
<td>Acceptable</td>
</tr>
<tr>
<td>Hello Interval</td>
<td>5(Sec)</td>
</tr>
<tr>
<td>Hello Hold Time</td>
<td>15(Sec)</td>
</tr>
<tr>
<td>Distribution Method</td>
<td>DU</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Interface</th>
<th>vlan57</th>
</tr>
</thead>
<tbody>
<tr>
<td>Admin State</td>
<td>Enabled</td>
</tr>
<tr>
<td>Oper State</td>
<td>Enabled</td>
</tr>
<tr>
<td>Targeted Hello Accept</td>
<td>Acceptable</td>
</tr>
<tr>
<td>Hello Interval</td>
<td>5(Sec)</td>
</tr>
<tr>
<td>Hello Hold Time</td>
<td>15(Sec)</td>
</tr>
<tr>
<td>Distribution Method</td>
<td>DU</td>
</tr>
</tbody>
</table>
```

D-Link Academy
D-Link Switch LDP Command

- Command: backoff (1/3)
- Description: The Label Distribution Protocol (LDP) back-off delay time is a mechanism to prevent an endless sequence of session setup failures that occur between two Label Switched Routers (LSRs) with incompatible settings.
- This command is used to configure the initial and maximum back-off delay time.
D-Link Switch **LDP** Command

- **Command**: backoff (2/3)
- **Example**: This example shows how to configure the initial and maximum back-off delay time to 100 and 200 seconds.
  - Switch# configure terminal
  - Switch(config)# mpls ldp configuration
  - Switch(config-ldp)# backoff 100 200
    - backoff INIT-TIME MAX-TIME (seconds)
  - Switch(config-ldp)#
D-Link Switch **LDP Command**

- Command: `backoff (3/3)`
- The command of "show mpls ldp information" releases Backoff configurations.
D-Link Switch LDP Command

- Command: lsp-control-mode (1/2)
  - lsp-control-mode {independent | ordered}

- Description
  - In Independent LSP Control, each Label Switching Router (LSR) independently binds a label to a Forwarding Equivalence Class (FEC) and distributes the binding to its label distribution peers.
  - In Ordered LSP Control, an LSR only binds a label to a FEC if it is the egress LSR for that FEC, or if it has already received a label binding for that FEC from its next hop for that FEC.
D-Link Switch LDP Command

- Command: lsp-control-mode (2/2)
  - lsp-control-mode {independent | ordered}
- Example: This example shows how to configure the LSP control mode to ordered.
  - Switch# configure terminal
  - Switch(config)# mpls ldp configuration
  - Switch(config-ldp)# lsp-control-mode ordered
  - Warning: The configuring will lead to LDP sessions restart.
  - Switch(config-ldp)#
D-Link Switch MPLS Command

- Global Configuration Mode
- Interface Configuration Mode
- LDP Configuration Mode
- LDP Target Peer Mode
- MPLS QoS Configuration Mode
- Privileged EXEC Mode
LDP Target Peer Mode (List of Commands)

- Switch# configure terminal
- Switch(config)# mpls ldp configuration
- Switch(config-ldp)# neighbor 110.10.10.1 targeted
  - Switch(config-ldp-targeted-peer)# discovery targeted-hello holdtime 90
  - Switch(config-ldp-targeted-peer)# discovery targeted-hello interval 30
D-Link Switch MPLS Command

- Global Configuration Mode
- Interface Configuration Mode
- LDP Configuration Mode
- LDP Target Peer Mode
- MPLS QoS Configuration Mode
- Privileged EXEC Mode
MPLS QoS Configuration Mode (List of Commands)

- Switch# configure terminal
- Switch(config)# mpls qos policy policy1
- Switch(config-mpls-qos)# class map cos-exp 0 to 0
- Switch(config-mpls-qos)# class map cos-exp 1 to 1
- Switch(config-mpls-qos)# class map cos-exp 2 to 2
- Switch(config-mpls-qos)# class map cos-exp 3 to 3
- Switch(config-mpls-qos)# class map cos-exp 4 to 4
- Switch(config-mpls-qos)# class map cos-exp 5 to 5
- Switch(config-mpls-qos)# class map cos-exp 6,7 to 6
- Switch(config-mpls-qos)#

D-Link Academy
MPLS QoS Configuration Mode (List of Commands)

- Switch# configure terminal
- Switch(config)# mpls qos policy policy1
  - Switch(config-mpls-qos)# class map cos-exp 0 to 0
- Switch(config)# mpls qos policy policy1
  - Switch(config-mpls-qos)# class map exp-cos 0,2-7 to 3
- Switch(config)# mpls qos policy policy1
  - Switch(config-mpls-qos)# match ip 172.18.1.0/24
- Switch(config)# mpls qos policy policy1
  - Switch(config-mpls-qos)# trust exp
D-Link Switch MPLS Command

- Global Configuration Mode
- Interface Configuration Mode
- LDP Configuration Mode
- LDP Target Peer Mode
- MPLS QoS Configuration Mode
- Privileged EXEC Mode
Privileged EXEC Mode (List of Commands)

- Switch# show mpls interface
- Switch# show mpls forwarding-table
- Switch# show mpls lsp trigger
- Switch# show mpls qos policy
- Switch# ping mpls ipv4 192.1.1.0/24
- Switch# traceroute mpls ipv4 192.1.1.0/24
- Switch# clear mpls ldp neighbor all
Privileged EXEC Mode (List of Commands)

- Switch# show mpls ldp neighbor
- Switch# show mpls ldp neighbor password
- Switch# show mpls ldp bindings
- Switch# show mpls ldp discovery
- Switch# show mpls ldp neighbor targeted
- Switch# show mpls ldp information
- Switch# show mpls ldp session
- Switch# show mpls ldp statistic
D-Link Switch MPLS Command

- The MPLS LSP Ping/Traceroute for LDP/TE, and LSP Ping for VCCV feature helps service providers monitor label switched paths (LSPs) and quickly isolate Multiprotocol Label Switching (MPLS) forwarding problems.
D-Link Switch MPLS Command

- MPLS LSP Ping to test LSP connectivity for IPv4 Label Distribution Protocol (LDP) prefixes, Resource Reservation Protocol (RSVP) traffic engineering (TE), and Any Transport over MPLS (AToM) forwarding equivalence classes (FECs).
D-Link Switch MPLS Command

- MPLS LSP ping uses MPLS echo request and reply packets to validate an LSP. You can use MPLS LSP ping to validate IPv4 LDP, AToM, and IPv4 RSVP FECs by using appropriate keywords and arguments with the ping mpls command.

- The destination IP address of the MPLS echo request packet is different from the address used to select the label stack. The destination IP address is defined as a 127.x.y.z/8 address. The 127.x.y.z/8 address prevents the IP packet from being IP switched to its destination if the LSP is broken.
D-Link Certified Specialist

MPLS Configuration Guide

D-Link Switch MPLS Command

- An example of MPLS Echo Request

<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>MPLS Label</th>
<th>LSP Type</th>
<th>Length</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>2453</td>
<td>2016-12-01 18:04:11.021581</td>
<td>77.77.77.77</td>
<td>127.0.0.127</td>
<td>MPLS ECHO</td>
<td>1003</td>
<td>122</td>
<td>128 NPS Echo Request</td>
<td></td>
</tr>
<tr>
<td>2459</td>
<td>2016-12-01 18:04:12.171538</td>
<td>77.77.77.77</td>
<td>127.0.0.127</td>
<td>MPLS ECHO</td>
<td>1003</td>
<td>126</td>
<td>126 NPS Echo Request</td>
<td></td>
</tr>
<tr>
<td>2460</td>
<td>2016-12-01 18:04:12.171542</td>
<td>77.77.77.77</td>
<td>127.0.0.127</td>
<td>MPLS ECHO</td>
<td>1003</td>
<td>130</td>
<td>130 NPS Echo Request</td>
<td></td>
</tr>
<tr>
<td>2463</td>
<td>2016-12-01 18:04:12.259074</td>
<td>106.166.166.166</td>
<td>77.77.77.77</td>
<td>MPLS ECHO</td>
<td>103</td>
<td>118</td>
<td>118 NPS Echo Request</td>
<td></td>
</tr>
<tr>
<td>2481</td>
<td>2016-12-01 18:04:19.802107</td>
<td>77.77.77.77</td>
<td>127.0.0.127</td>
<td>MPLS ECHO</td>
<td>1003</td>
<td>122</td>
<td>122 NPS Echo Request</td>
<td></td>
</tr>
<tr>
<td>2487</td>
<td>2016-12-01 18:04:21.021386</td>
<td>77.77.77.77</td>
<td>127.0.0.127</td>
<td>MPLS ECHO</td>
<td>1003</td>
<td>126</td>
<td>126 NPS Echo Request</td>
<td></td>
</tr>
</tbody>
</table>

> Frame 2453: 122 bytes on wire (976 bits), 122 bytes captured (976 bits)
> Internet Protocol Version 4, Src: 77.77.77.77, Dst: 127.0.0.127
> User Datagram Protocol, Src Port: 3503, Dst Port: 3503
> Multiprotocol Label Switching Echo
  > Global Flags: 0x0000
  > Message Type: MPLS Echo Request (1)
  > Reply Mode: Reply via an IPv4/IPv6 UDP packet (2)
  > Return Code: No return code (0)
  > Return Subcode: 0
  > Sender’s Handle: 0x00000000
  > Sequence Number: 1
  > Timestamp Sent: Feb 7, 2036 11:88:45.000000000 UTC
  > Timestamp Received: Jan 1, 1970 00:00:00.000000000 UTC
  > Target FEC Stack
  > Downstream Mapping

D-Link Academy
D-Link Switch MPLS Command

- An MPLS echo reply is sent in response to an MPLS echo request. The reply is sent as an IP packet and it is forwarded using IP, MPLS, or a combination of both types of switching. The source address of the MPLS echo reply packet is an address obtained from the router generating the echo reply. The destination address is the source address of the router that originated the MPLS echo request packet.

- The MPLS echo reply destination port is set to the echo request source port.
D-Link Switch MPLS Command

- An example of MPLS Echo Reply

<table>
<thead>
<tr>
<th>No.</th>
<th>Time</th>
<th>Source</th>
<th>Destination</th>
<th>Protocol</th>
<th>MPLS Label</th>
<th>LSP Type</th>
<th>Length</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>2453</td>
<td>2016-12-01 18:04:11.021381</td>
<td>77.77.77.77</td>
<td>127.0.0.127</td>
<td>MPLS ECHO</td>
<td>1003</td>
<td>122</td>
<td>2463.122 MPLS Echo Request</td>
<td></td>
</tr>
<tr>
<td>2459</td>
<td>2016-12-01 18:04:12.171538</td>
<td>77.77.77.77</td>
<td>127.0.0.127</td>
<td>MPLS ECHO</td>
<td>1003</td>
<td>126</td>
<td>2469.126 MPLS Echo Request</td>
<td></td>
</tr>
<tr>
<td>2460</td>
<td>2016-12-01 18:04:12.171542</td>
<td>77.77.77.77</td>
<td>127.0.0.127</td>
<td>MPLS ECHO</td>
<td>1003</td>
<td>130</td>
<td>2460.130 MPLS Echo Request</td>
<td></td>
</tr>
<tr>
<td>2463</td>
<td>2016-12-01 18:04:12.259874</td>
<td>166.166.166.166</td>
<td>77.77.77.77</td>
<td>MPLS ECHO</td>
<td>1003</td>
<td>118</td>
<td>2463.118 MPLS Echo Request</td>
<td></td>
</tr>
<tr>
<td>2481</td>
<td>2016-12-01 18:04:19.982197</td>
<td>77.77.77.77</td>
<td>127.0.0.127</td>
<td>MPLS ECHO</td>
<td>1003</td>
<td>122</td>
<td>2481.122 MPLS Echo Request</td>
<td></td>
</tr>
<tr>
<td>2487</td>
<td>2016-12-01 18:04:21.021385</td>
<td>77.77.77.77</td>
<td>127.0.0.127</td>
<td>MPLS ECHO</td>
<td>1003</td>
<td>126</td>
<td>2487.126 MPLS Echo Request</td>
<td></td>
</tr>
</tbody>
</table>

Frame 2463: 118 bytes on wire (944 bits), 118 bytes captured (944 bits)
802.1Q Virtual LAN, PRI: 0, CFI: 0, ID: 57
MultiProtocol Label Switching Header, Label: 0 (IPv4 Explicit-Null), Exp: 0, S: 1, TTL: 254
Internet Protocol Version 4, Src: 166.166.166.166, Dst: 77.77.77.77
User Datagram Protocol, Src Port: 3503, Dst Port: 3503
MultiProtocol Label Switching Echo

- Global Flags: 0x0000
- Message Type: MPLS Echo Reply (2)
- Reply Mode: Reply via an IPv4/IPv6 UDP packet (2)
- Return Code: Replying router is an egress for the FEC at stack depth RSC (3)
- Return Subcode: 1
- Sender’s Handle: 0x00000000
- Sequence Number: 2
- Timestamp Sent: Feb 7, 2036 11:08:46.000000000 UTC
- Timestamp Received: Feb 7, 2036 17:18:42.000000000 UTC
- Target FEC Stack
- IPv4 Interface and Label Stack Object
D-Link Switch MPLS Command

- MPLS echo request
  - An MPLS echo request packet cannot be forwarded via IP because IP TTL is set to 1 and the IP destination address field is set to a 127/8 address.
  - The FEC being checked is not stored in the IP destination address field (as is the case of ICMP)
D-Link Switch MPLS Command

- MPLS LSP Traceroute to trace the LSPs for IPv4 LDP prefixes and RSVP TE prefixes.
D-Link Switch MPLS Command

- Command: show mpls forwarding-table
- This command is used to display the MPLS label forwarding path info.

```
DGS3630_SW1#show mpls forwarding-table

+-------+----------+--------+----------+----------------+-------------------+
<table>
<thead>
<tr>
<th>LSP</th>
<th>FEC</th>
<th>In Label</th>
<th>Out Label</th>
<th>Out Interface</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.7.7.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 57</td>
<td>192.168.57.7</td>
</tr>
<tr>
<td>3</td>
<td>7.7.7.0/24</td>
<td>1000</td>
<td>0</td>
<td>VLAN 57</td>
<td>192.168.57.7</td>
</tr>
<tr>
<td>2</td>
<td>77.77.77.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 57</td>
<td>192.168.57.7</td>
</tr>
<tr>
<td>4</td>
<td>77.77.77.0/24</td>
<td>1001</td>
<td>0</td>
<td>VLAN 57</td>
<td>192.168.57.7</td>
</tr>
<tr>
<td>5</td>
<td>66.66.66.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 56</td>
<td>192.168.56.6</td>
</tr>
<tr>
<td>6</td>
<td>66.66.66.0/24</td>
<td>1002</td>
<td>0</td>
<td>VLAN 56</td>
<td>192.168.56.6</td>
</tr>
<tr>
<td>7</td>
<td>166.166.166.0/24</td>
<td>-</td>
<td>0</td>
<td>VLAN 56</td>
<td>192.168.56.6</td>
</tr>
<tr>
<td>8</td>
<td>166.166.166.0/24</td>
<td>1003</td>
<td>0</td>
<td>VLAN 56</td>
<td>192.168.56.6</td>
</tr>
</tbody>
</table>
+-------+----------+--------+----------+----------------+-------------------+
Total Entries: 8
DGS3630_SW1#_
Quiz Session: Bind MPLS Exp To Cos

- Quiz Session: how can I bind MPLS Exp to Cos?
Quiz Session: Bind MPLS Exp To Cos (Cont'd)

- Quiz Session: how can I bind MPLS Exp to Cos?
- Ans:
  - mpls qos policy NAME
  - class map exp-cos EXP-LIST to COS-VALUE
  - match {ip NETWORK-PREFIX/PREFIX-LENGTH | vc IP-ADDRESS VC-ID
  - trust exp

- The D-Track HQ20151230000001 identifies user needs on this topic

D-Link Academy
D-Link (VRF-lite) Commands

- Virtual Routing and Forwarding Lite (VRF-lite)
- Command Mode
  - Global Configuration Mode
  - Interface Configuration Mode
  - Router Configuration Mode
  - VRF Configuration Mode
  - User/Privileged EXEC Mode
D-Link (VRF-lite) Commands

- Virtual Routing and Forwarding Lite (VRF-lite)
- Global Configuration Mode
- Commands: ip vrf (1/2)
- Description:
  - This command is used to create a new VRF instance and enter the VRF Configuration Mode.
  - After a new VRF instance is created, a new VRF routing table will be created
  - All IP interfaces associated to this VRF will be restored to the global routing instance
D-Link (VRF-lite) Commands

- Virtual Routing and Forwarding Lite (VRF-lite)
- Global Configuration Mode
- Commands: ip vrf (2/2)
- Example: this example shows how to create and delete a VRF instance
  - Switch# configure terminal
  - Switch(config)# ip vrf VPN-A
  - Switch(config-vrf)# exit
  - Switch(config)# no ip vrf VPN-A
  - Switch(config)#
D-Link (VRF-lite) Commands

- Virtual Routing and Forwarding Lite (VRF-lite)
- Interface Configuration Mode
- Commands: ip vrf forwarding (1/2)
- Description:
  - This command is used to associate an interface to one VRF instance.
  - By associating interfaces to different VRFs, the interfaces in different VRFs can be configured with the same IP address.
  - The IP address space in one VRF is individual and can overlap among different VRFs.
D-Link (VRF-lite) Commands

- Virtual Routing and Forwarding Lite (VRF-lite)
- Interface Configuration Mode
- Commands: ip vrf forwarding (2/2)
- Example: this example shows how to associate the VLAN 100 interface to the VRF VPN-A
  - Switch# configure terminal
  - Switch(config)# int vlan 100
  - Switch(config-if)# ip vrf forwarding VPN-A
  - Switch(config-if)# ip address 100.1.1.1 255.255.255.0
  - Switch(config-if)#
D-Link (VRF-lite) Commands

- Virtual Routing and Forwarding Lite (VRF-lite)
- Router Configuration Mode
- Commands: address-family ipv4 vrf (1/3)
- Description:
  - This command is used to enter the VRF address family configuration mode
  - This command is used for configuring the routing instances such as BGP or RIP
D-Link (VRF-lite) Commands

- Virtual Routing and Forwarding Lite (VRF-lite)
- Router Configuration Mode
- Commands: address-family ipv4 vrf (2/3)
- Example: this example shows how to create a new RIP routing instance of VRF VPN-A.
  - Switch# configure terminal
  - Switch(config)# ip vrf VPN-A
  - Switch(config-vrf)# exit
  - Switch(config)# router rip
  - Switch(config-router)# address-family ipv4 vrf VPN-A
  - Switch(config-router-af)#
D-Link (VRF-lite) Commands

- Virtual Routing and Forwarding Lite (VRF-lite)
- Router Configuration Mode
- Commands: address-family ipv4 vrf (3/3)
- Example: this example shows how to create a new BGP routing instance of VRF VPN-BGP.
  - Switch# configure terminal
  - Switch(config)# ip vrf VPN-BGP
  - Switch(config-vrf)# exit
  - Switch(config)# router bgp 65000
  - Switch(config-router)# address-family ipv4 vrf VPN-BGP
  - Switch(config-router-af)#
D-Link (VRF-lite) Commands

- Virtual Routing and Forwarding Lite (VRF-lite)
- VRF Configuration Mode
- Commands: import map (1/2)

Description:

- This command is used to configure the import route map of one VRF
- This is used by the routing protocol to filter the routes imported to the routing table associated with a VRF instance
- One VRF only has one import route map. The new import route map will overwrite the value set before
D-Link (VRF-lite) Commands

- Virtual Routing and Forwarding Lite (VRF-lite)
- VRF Configuration Mode
- Commands: import map (2/2)
- Example: this example shows how to create a VRF VPN-A and set its import route map.
  - Switch# configure terminal
  - Switch(config)# ip vrf VPN-A
  - Switch(config-vrf)# import map rmap1
  - Switch(config-vrf)#
D-Link (VRF-lite) Commands

- Virtual Routing and Forwarding Lite (VRF-lite)
- VRF Configuration Mode
- Commands: maximum routes (1/2)

Description:
- This command is used to limit how many routes can be allowed within the VRF.
- This limit only applies to the active route. To only get a notification, set the warning-only option.
D-Link (VRF-lite) Commands

- Virtual Routing and Forwarding Lite (VRF-lite)
- VRF Configuration Mode
- Commands: maximum routes (2/2)
- Example: this example shows how to configure the VRF VPN-A’s routes limit to 100
  - Switch# configure terminal
  - Switch(config)# ip vrf VPN-A
  - Switch(config-vrf)# maximum routes 100 warning-only
  - Switch(config-vrf)#
D-Link (VRF-lite) Commands

- Virtual Routing and Forwarding Lite (VRF-lite)
- VRF Configuration Mode
- Commands: rd (1/2)
- Description:
  - This command is used to configure the Route Distinguisher (RD) of one VRF
  - One VRF has only one route distinguisher and cannot be changed if it has been set to one value
D-Link (VRF-lite) Commands

- Virtual Routing and Forwarding Lite (VRF-lite)
- VRF Configuration Mode
- Commands: rd (2/2)
- Example: this example shows how to configure the VRF VPN-A’s routes limit to 100
  - Switch# configure terminal
  - Switch(config)# ip vrf VPN-A
  - Switch(config-vrf)# rd 100:1
  - Switch(config-vrf)#
D-Link (VRF-lite) Commands

- Virtual Routing and Forwarding Lite (VRF-lite)
- VRF Configuration Mode
- Commands: route-target (1/2)
  - route-target \{import | export | both\} ROUTE-TARGET
- Description:
  - This command is used to add one route target of a VRF
  - The route target is a useful VPN application. One VRF can have multiple route targets
D-Link (VRF-lite) Commands

- Virtual Routing and Forwarding Lite (VRF-lite)
- VRF Configuration Mode
- Commands: route-target (2/2)
- Example: This example shows how to create a VRF instance VPN-A and add import and export targets
  - Switch# configure terminal
  - Switch(config)# ip vrf VPN-A
  - Switch(config-vrf)# route-target import 100:1
  - Switch(config-vrf)# route-target export 100:1
  - Switch(config-vrf)#
D-Link (VRF-lite) Commands

- Virtual Routing and Forwarding Lite (VRF-lite)
- User/Privileged EXEC Mode
- Commands: `show ip vrf`
- Description:
  - This command is used to check the settings of VRF instances
Thank You