MPLS LDP

Nurul Islam Roman (nurul@apnic.net)

BUILT FOR THE HUMAN NETWORK

CISCO

Agenda

- LDP Overview
- LDP Protocol Details
- LDP Configuration and Monitoring

Label Distribution Protocol

Overview

- MPLS nodes need to exchange label information with each other
  - Ingress PE node (Push operation)

    Needs to know what label to use for a given FEC to send packet to neighbor
  - Core P node (Swap operation)

    Needs to know what label to use for swap operation for incoming labeled packets
  - Egress PE node (Pop operation)

    Needs to tell upstream neighbor what label to use for specific FEC type LDP used for exchange of label (mapping) information
- Label Distribution Protocol (LDP)
  - Defined in RFC 3035 and RFC3036; updated by RFC5036
  - LDP is a superset of the Cisco-specific Tag Distribution Protocol
- Note that, in addition LDP, also other protocols are being used for label information exchange
  - Will be discussed later

Label Distribution Protocol

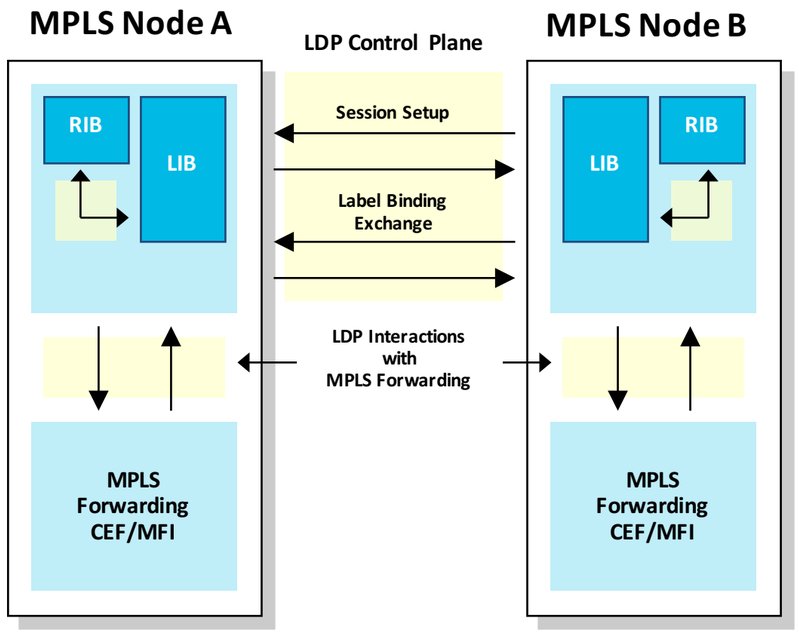
Some More Details

- Assigns, distributes, and installs (in forwarding) labels for prefixes advertised by unicast routing protocols
  - OSPF, IS-IS, EIGRP, etc.
- Also used for Pseudowire/PW (VC) signaling
  - Used for L2VPN control plane signaling
- Uses UDP (port 646) for session discovery and TCP (port 646) for exchange of LDP messages
- LDP operations
  - LDP Peer Discovery
  - LDP Session Establishment
  - MPLS Label Allocation, Distribution, and Updating MPLS forwarding
- Information repositories used by LDP
  - LIB: Label Information Database (read/write)
  - RIB: Routing Information Database/routing table (read-only)

Label Distribution Protocol

Operations Details

- LDP startup
  - Local labels assigned to RIB prefixes and stored in LIB
  - Peer discovery and session setup
  - Exchange of MPLS label bindings
- Programming of MPLS forwarding
  - Based on LIB info
  - CEF/MFI updates



Agenda LDP Protocol Details

- LDP Concepts
- LDP Identifier
- LDP PDU
- LDP Messages
- LDP Session Establishment
- LDP Sessions between ATM LSRs
- Targeted LDP sessions
- Summary

LDP Concepts

- Label Distribution Protocol
  - LDP works between adjacent/non-adjacent peers
  - LDP sessions are established between peers
  - LDP messages sent in the form of TLVs

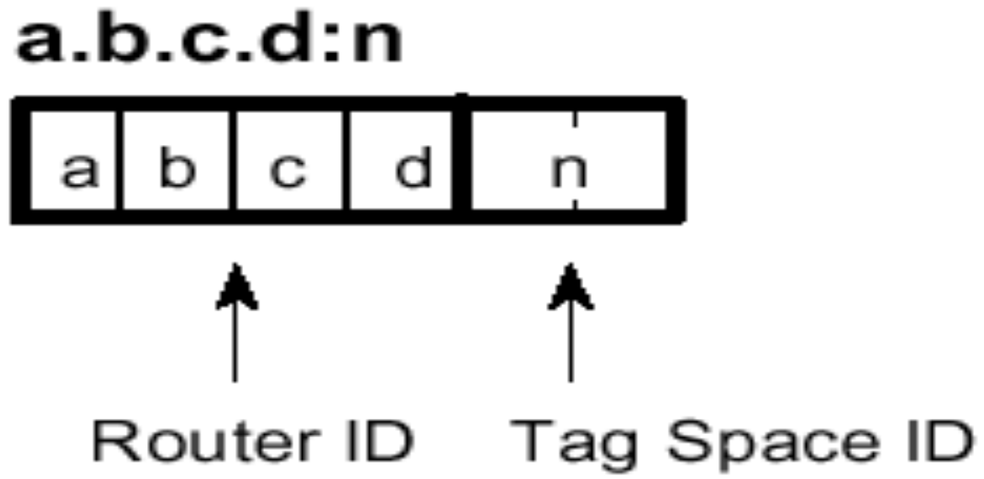
    <Type, Length, Value>
- Standardized via RFC 3036 (Updated by RFC 5036)

TDP/LDP Transport

- Uses TCP for reliable transport
- Well-known TCP port
  - *LDP (port 646)*
  - ~~*TDP (port 711)*~~
- LSR with higher LDP router-id opens a connection to port 646 of other LSR
- Design Choice:
  - *One TDP/LDP session per TCP connection*

LDP Identifier

- Identifies tag space
- 6 bytes (4 bytes =>IP address, 2 bytes =>Label space ID)

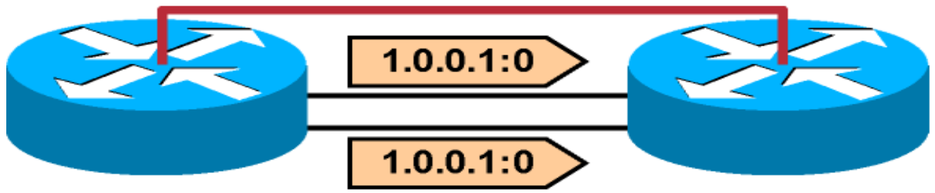


LDP Identifier: Label Space

- LSRs establish one LDP session per label space.
  - Per-platform label space requires only one LDP session, even if there are multiple parallel links between a pair of LSRs.
- Per-platform label space is announced by setting the label space ID to 0, for example:
  - LDP ID = 1.0.0.1:0
- A combination of frame-mode and cell-mode MPLS, or multiple cell-mode links, results in multiple LDP sessions.

Label Space and number of LDP sessions

Frame Mode



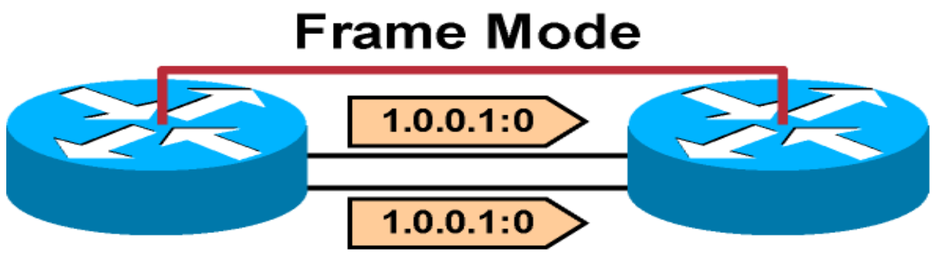
Cell Mode

Frame Mode

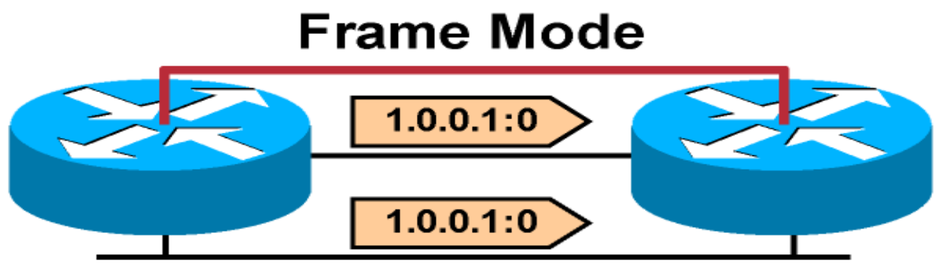
Mixed Mode

020G_318

Label Space and number of LDP sessions (Cont.)



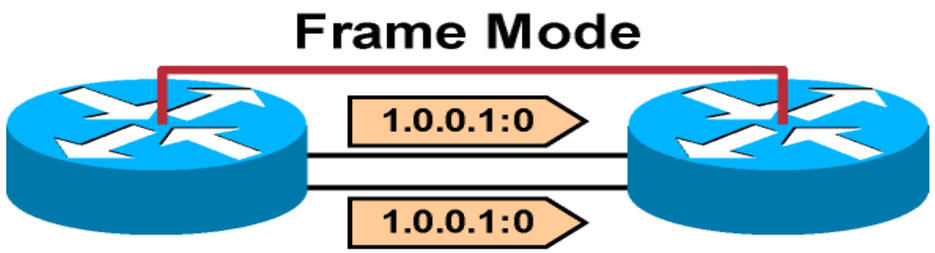
Cell Mode

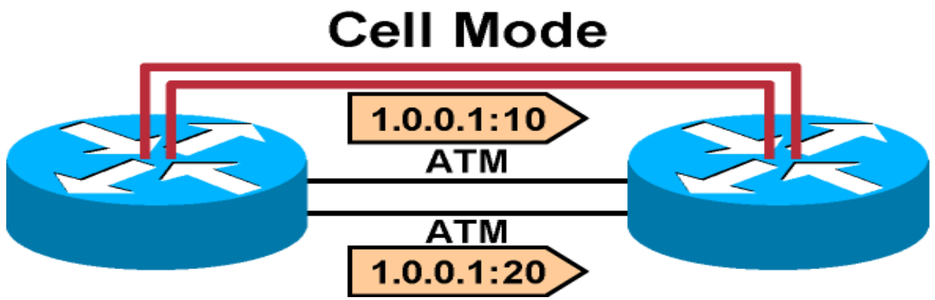


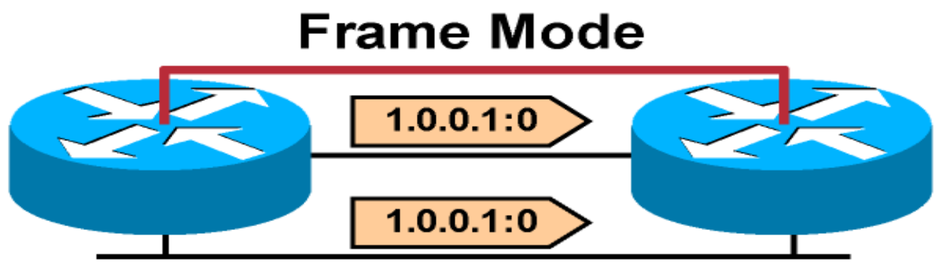
Mixed Mode

020G_317

Label Space and number of LDP sessions (Cont.)



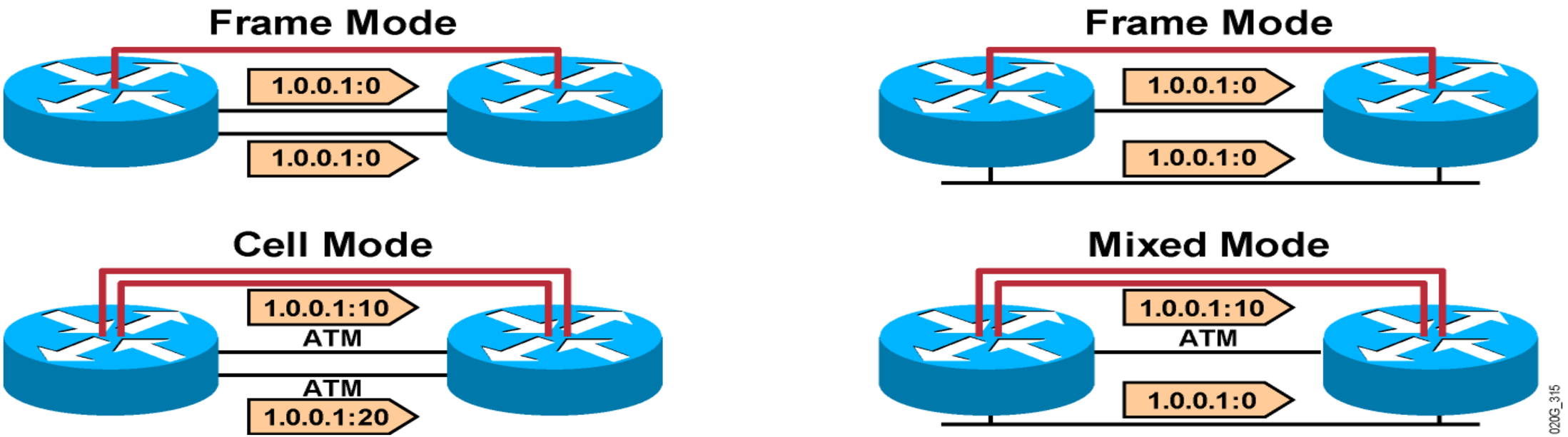




Mixed Mode

020G_316

Label Space and number of LDP sessions (Cont.)



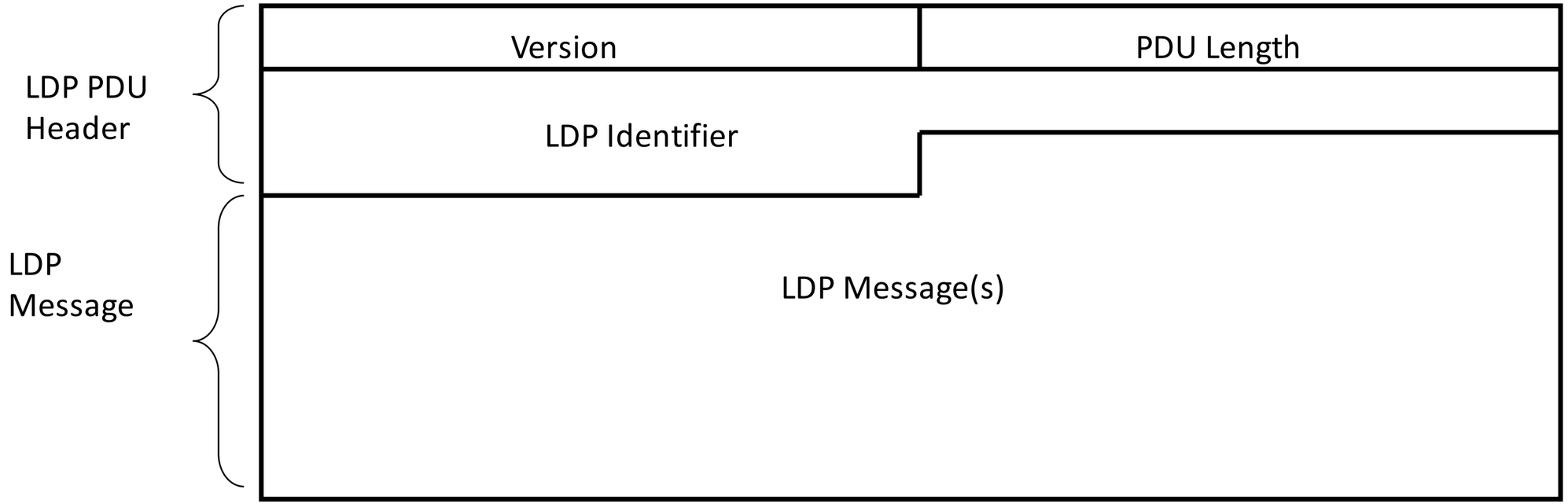
–One LDP session is established for each announced LDP identifier (router ID + label space).

–The number of LDP sessions is determined by the number of different label spaces.

–The bottom right example is not common, because ATM LSRs do not use Ethernet for packet forwarding, and frame-mode MPLS across ATM uses per-platform label space.

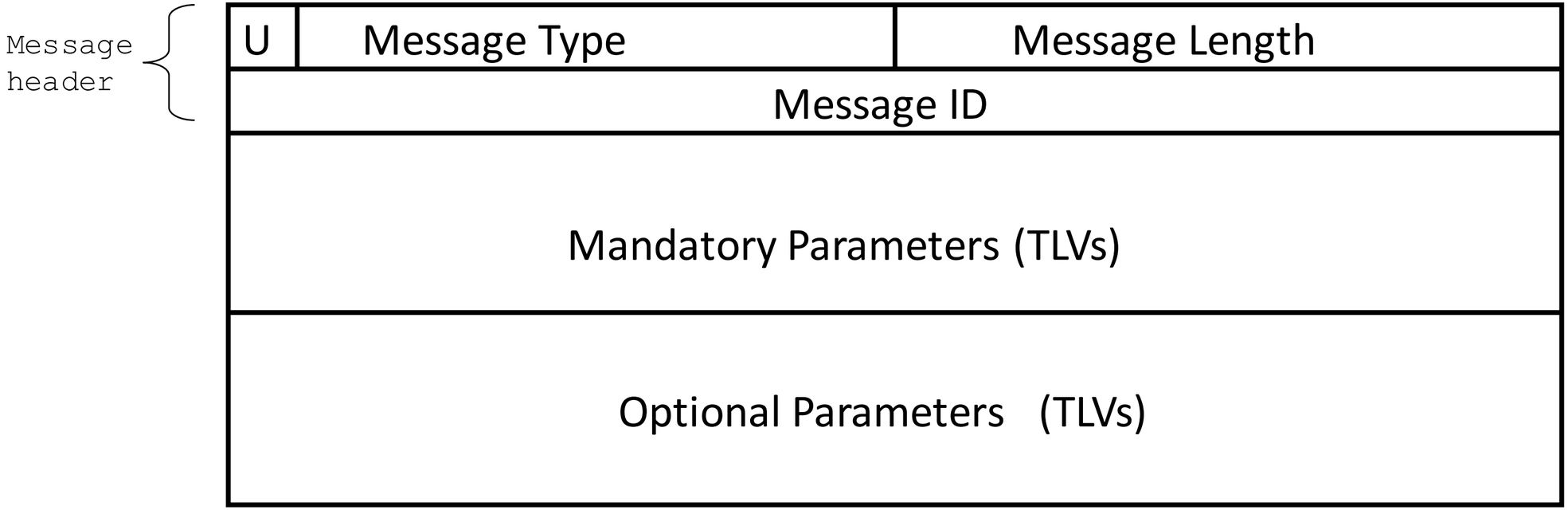
LDP Protocol Data Units

- All LDP information is sent in the form of PDUs over the TCP connection



Version => LDP version. Current LDP version is 1
PDU Length (excludes Version and PDU Length fields) => total length of PDU in bytes.
LDP Identifier => discussed earlier
LDP Messages => one or more LDP messages

LDP Message

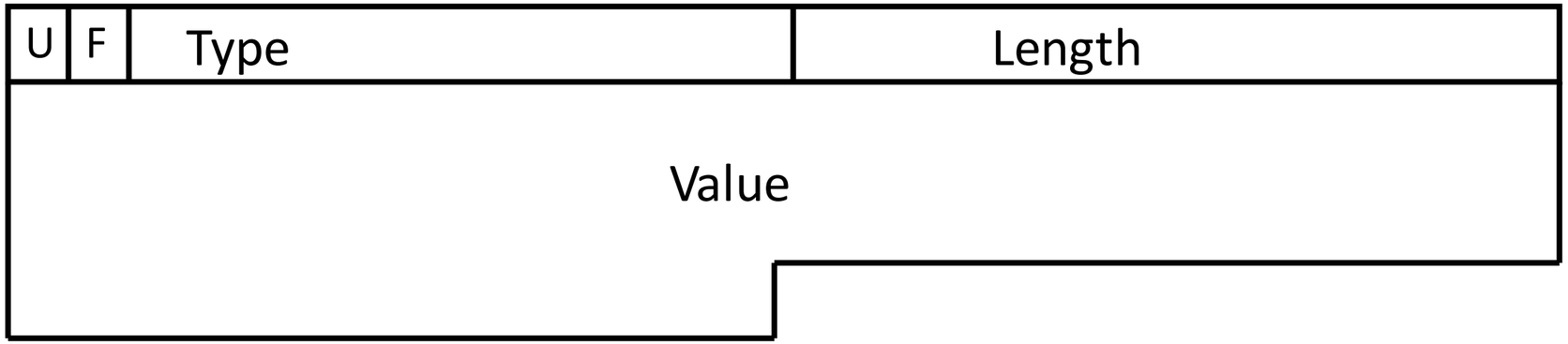


U bit is the Unknown Message bit. If the received message is of unknown type, then if:

U=0, send Notification Message to the originator of this message

U=1, silently ignore the unknown message

LDP Message TLVs



U bit is the Unknown TLV bit. If the received TLV is of unknown type, then if:

U=0, send Notification Message to the originator of this message and ignore the entire message

U=1, silently ignore the unknown TLV and process the rest of the message

F bit is the Forward unknown TLV bit. F bit is only applicable when the U=1

F=0,the unknown TLV is not forwarded with its LDP message

F=1,the unknown TLV is forwarded with its LDP message

LDP Messages Types

DISCOVERY messages

ADJACENCY messages deal with initialization, keepalive & shutdown of sessions

LABEL ADVERTISEMENT messages deal with label binding, requests, withdrawal & release

NOTIFICATION messages provide advisory information & signal errors

Discovery Message

- Used to discover and maintain the presence of new peers using HELLO messages
- Hello packets (UDP) sent to all-routers multicast address (224.0.0.2)
- Direct unicast hello is sent to non-adjacent neighbors
- Once session is established, HELLO messages serve as link integrity messages
- Session is bi-directional

Adjacency Messages

INITIALIZATION

Two LSRs negotiate on various parameters & options

These include keepalive timer values, Label ranges, Unsolicited vs. On-demand label advertisement, Ordered vs. Independent mode, Liberal vs. Conservative Label retention

KEEPALIVE

LDP message that indicates that neighbor is alive

Label Advertisement related messages

- LABEL RELEASE

  An LSR releases a Label Binding that it previously got from it's LDP peer. Used in Conservative Label Retention mode

- LABEL REQUEST

  Used by an upstream LSR to request a Label binding for a prefix from the downstream LDP peer. Used in downstream on-demand mode

- LABEL ABORT REQUEST

  Send to abort the LABEL REQUEST message

- LABEL MAPPING

  Are the TLV object containing <Label, prefix> information

- LABEL WITHDRAWAL

  Used to revoke a previously advertised label binding

Notification message

- NOTIFICATION

  Used for Error Notification and Advisory

LDP Session Establishment

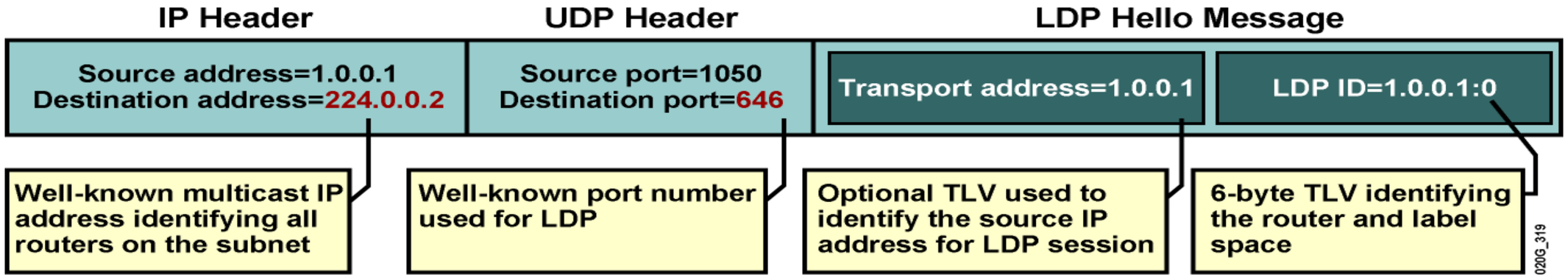
- LDP establishes a session by performing the following:

  Hello messages are periodically sent on all interfaces that are enabled for MPLS.

  If there is another router connected to that interface, that it also has MPLS enabled, it will respond by trying to establish a session with the source of the hello messages.

- UDP is used for hello messages. It is targeted at “all routers on this subnet” multicast address (224.0.0.2).
- TCP is used to establish the session.
- Both TCP and UDP use well-known LDP port number 646 (711 for TDP).

LDP Hello Message



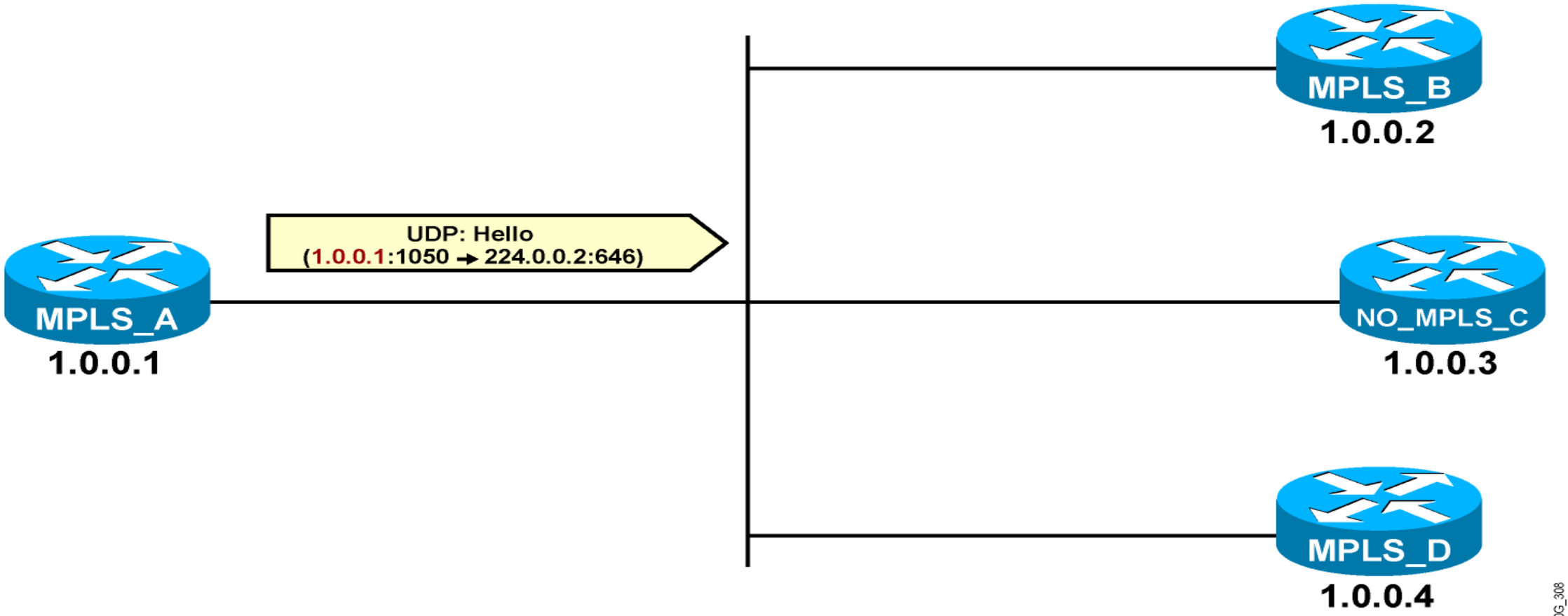
–Hello messages are targeted at all routers reachable through an interface.

–LDP uses well-known (UDP and TCP) port number 646.

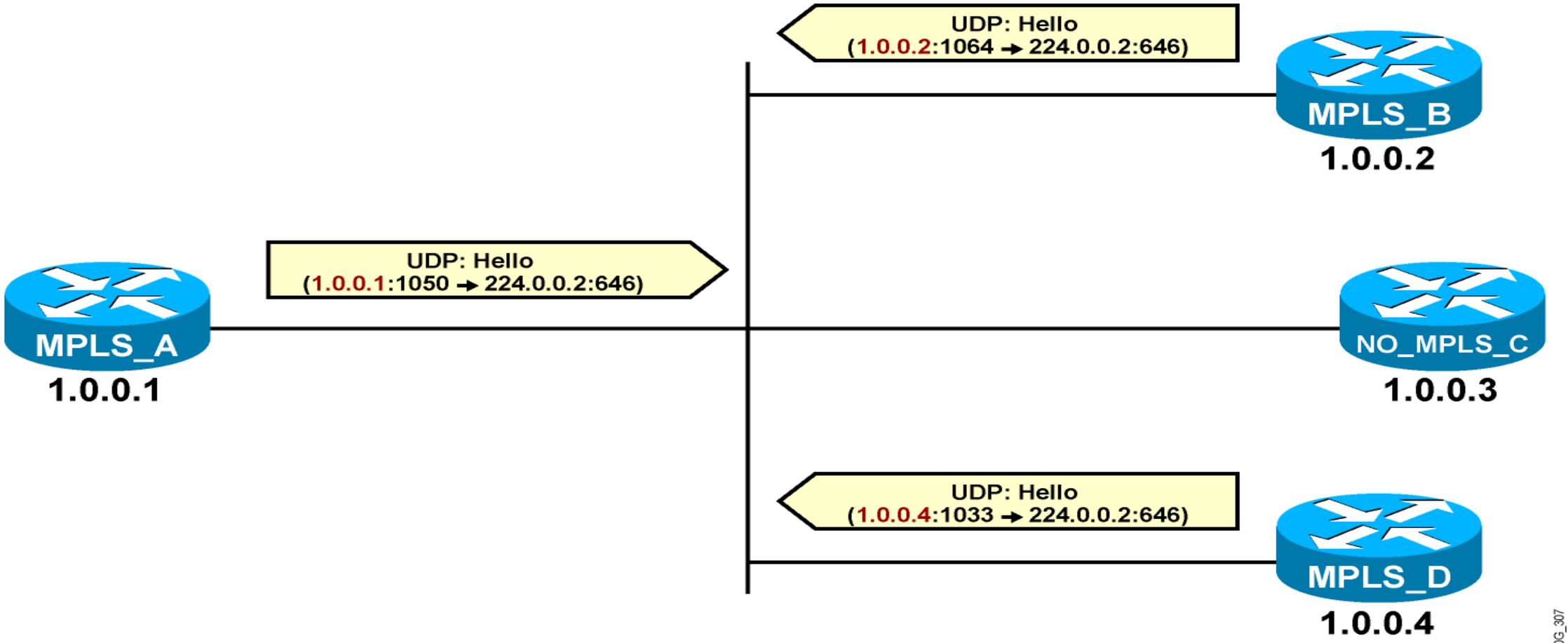
–The source address used for an LDP session can be set by adding the transport address TLV to the hello message.

–A 6-byte LDP identifier (TLV) identifies the router (first four bytes) and label space (last two bytes).

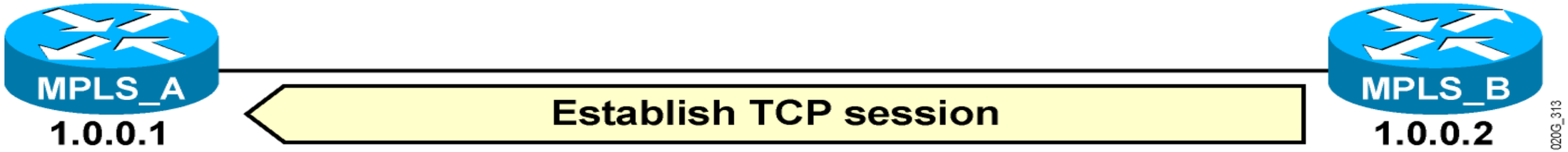
LDP Neighbor Discovery



LDP Neighbor Discovery



LDP Session: Transport Connection

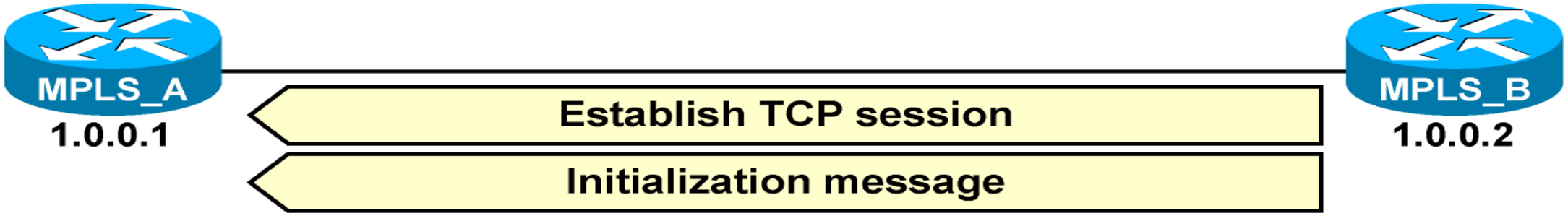


–Once LDP peers receive hellos, they establish a TCP connection

–Peer with higher LDP router-id is active LSR and the peer with lower LDP router-id is the passive LSR

–Active LSR tries to open a TCP connection to the well-known LDP port number 646 of the passive LSR, while the passive LSR waits for the active LSR to initiate the connection

LDP Session: Session Initialization



–Active LDP peer (1.0.0.2) sends Initialization message to passive LDP peer

–Initialization message contains important parameters:

Session keepalive time (default=180 sec)

Label distribution method: Downstream unsolicited

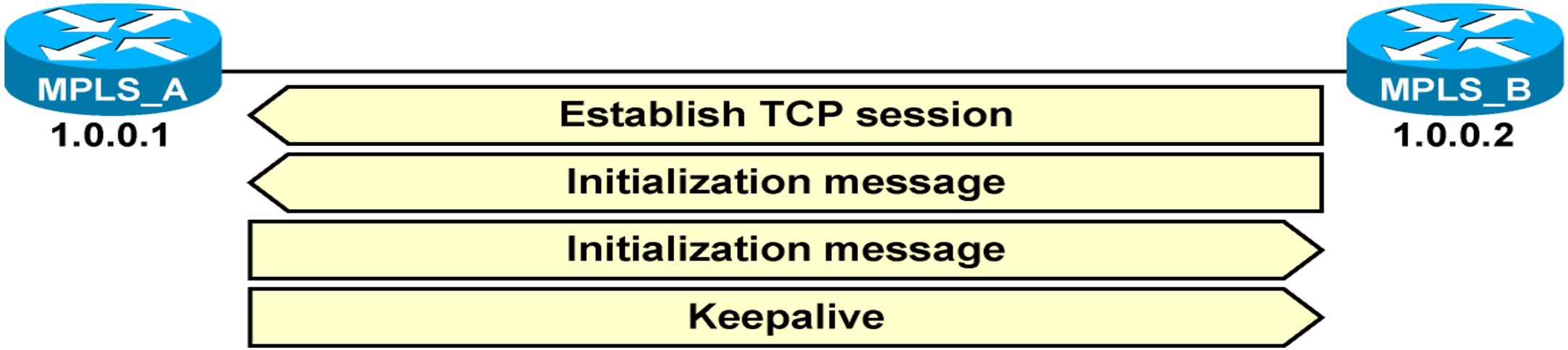
Max PDU length

Receiver's LDP Identifier

Whether Loop Detection is enabled

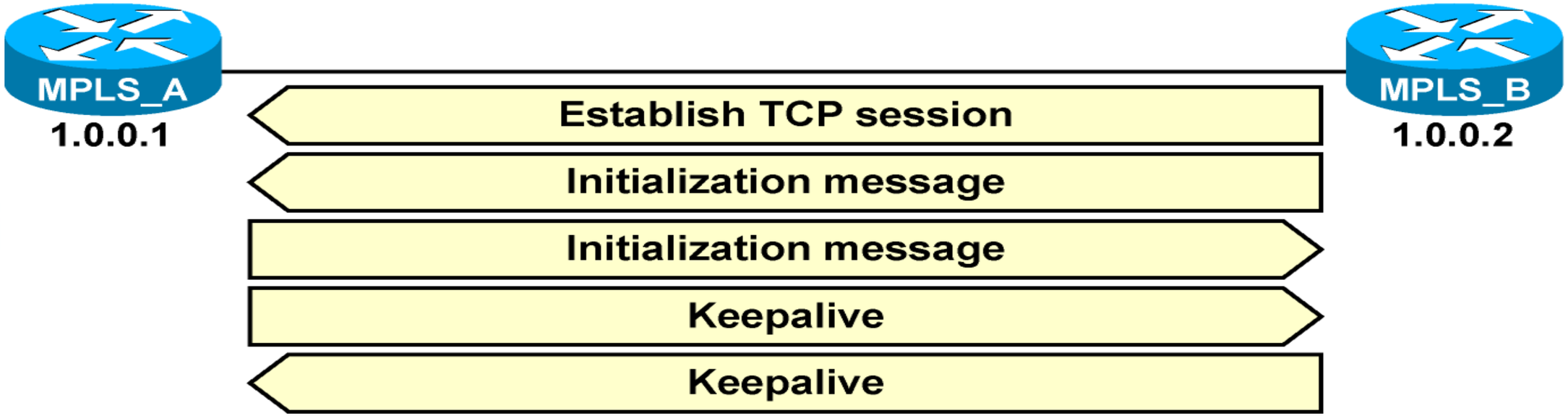
Some optional parameters

LDP Session:
Session Initialization (cont.)



- Passive LDP peer sends Initialization message and/or keepalive message to active LDP peer if Initialization message parameters are acceptable
- Passive LDP peer could also send Error Notification & close the LDP connection if something was unacceptable

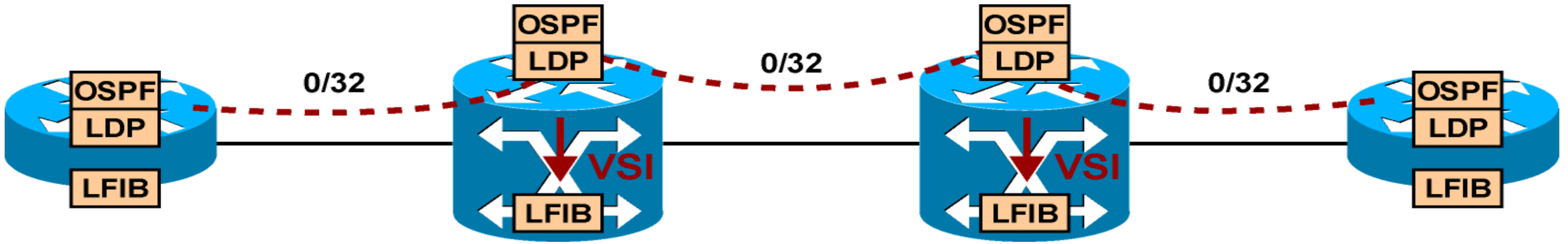
LDP Session:
Session Initialization (cont.)



–Active LDP peer sends keepalive to passive LDP peer & the LDP session is up

–The session is ready to exchange label mappings after receiving the first keepalive.

LDP Sessions Between ATM LSRs



–An IP adjacency between ATM LSRs is established through the control virtual circuit (0/32).

–The control virtual circuit is used for LDP as well as for IP routing protocols.

–VSI protocol is used to populate the ATM switching matrix (LFIB) in the data plane of some ATM switches (Cisco implementation).

Targeted LDP Sessions

–LDP neighbor discovery of nonadjacent neighbors differs from normal discovery only in the addressing of hello packets:

Hello packets use unicast IP addresses instead of multicast addresses.

–When a neighbor is discovered, the mechanism to establish a session is the same.

Summary

- TCP is used to establish LDP sessions between neighbors.
- LDP uses PDUs to carry messages
- LDP hello messages contain an identifier field that uniquely identifies the neighbor and the label space.
- Per-platform label space requires only one LDP session.
- Routers that have the higher IP address must initiate the TCP session.
- LDP session negotiation is a three-step process.
- LDP sessions between ATM LSRs use the control VPI/VCI, which by default is 0/32.
- Nonadjacent neighbor discovery is accomplished by using unicast IP addresses instead of multicast.

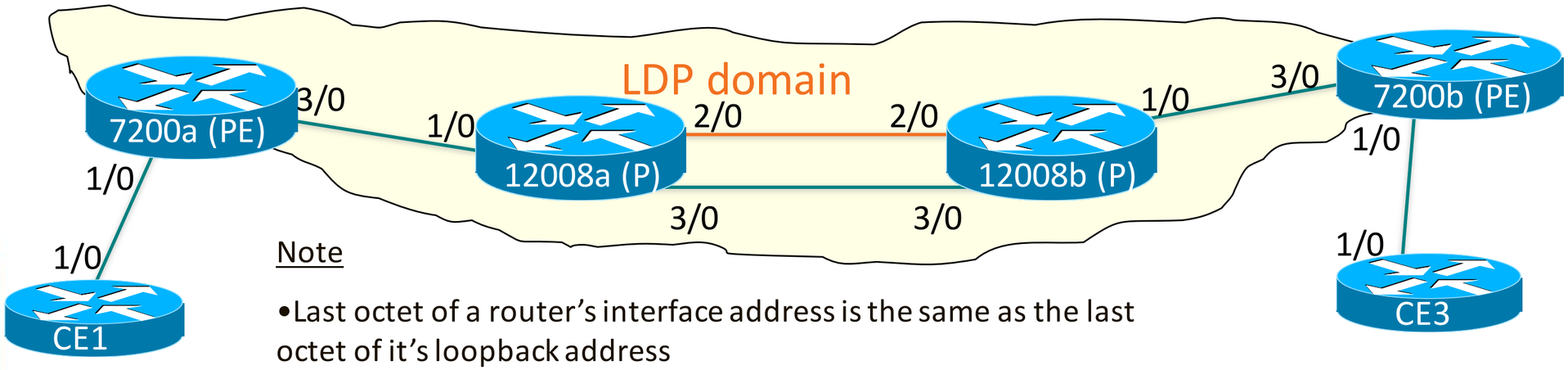
Agenda LDP Configuration and Monitoring

- Configuration
- Verifying Your Configuration
- Monitoring LDP

Configuring MPLS

- Mandatory
  - Enable CEF switching if this is not the platform default
  - Configure TDP or LDP on every label-enabled interface
  - TDP not supported on IOS XR
- Optional
  - Configure MTU size for labeled packets
  - Configure IP TTL propagation
  - Configure conditional label advertising

Network Topology



Note

- Last octet of a router's interface address is the same as the last octet of it's loopback address
- All pt-pt links are /24

	7200a	CE1	12008a	12008b	7200b	CE3
7200a	4.4.4.4 (lo0)	10.0.20.0	10.0.3.0			
CE1	10.0.20.0	100.100.100.100(lo0)				
12008a	10.0.3.0		5.5.5.5 (lo0) 10.0.5.0 (3/0) 10.0.4.0 (2/0)	10.0.4.0 (2/0) 10.0.5.0 (3/0)		
12008b				11.11.11.11(lo0)	10.0.17.0	
7200b				10.0.17.0	12.12.12.12 (lo0)	10.0.22.0
CE3					10.0.22.0	30.30.30.30(lo0)

Configuring LDP (IOS)

Global

```
ip cef <distributed>

mpls label protocol <ldp | tdp | both>

tag-switching tdp router-id Loopback0

mpls ldp explicit-null (optional)

no mpls ip propagate-ttl (optional)
```

Interface

`mpls ip` or `tag-switching ip` (enables this interface for MPLS forwarding)

```
mpls label protocol ldp
```

(optional, if you want to run LDP on this interface only, while other interfaces don't run LDP or run another label protocol such as TDP)

Configuring LDP (IOS XR)

```
mpls ldp
 router-id 1.1.1.1
 explicit-null (optional)
 log
  neighbor
 !
 interface GigabitEthernet0/4/1/3
 !
!
mpls ip-ttl-propagate disable (optional)
mpls oam
!
```

Configuring Conditional Label Distribution (IOS)

tag-switching advertise-tags for *net-acl* [to *tdp-acl*]

- By default, labels for all destinations are announced to all LDP/TDP neighbors.
- This command enables you to selectively advertise some labels to some LDP/TDP neighbors.
- Conditional label advertisement only works over frame-mode interfaces.
- Parameters:
  - Net-ACL – the IP ACL that selects the destinations for which the labels will be generated.
  - TDP-ACL – the IP ACL that selects the TDP neighbors that will receive the labels.

Configuring Conditional Label Distribution (IOS XR)

```
label advertise [ disable | for prefix-acl [ to peer-acl ] |
    interface type interface-path-id ]
```

- By default, labels for all destinations are announced to all LDP neighbors.
- This command enables you to selectively advertise some labels to some LDP neighbors.
- Conditional label advertisement only works over frame-mode interfaces.
- Parameters:
  - PREFIX-ACL – the IP ACL that selects the prefixes for which the labels will be generated.
  - PEER-ACL – the IP ACL that selects the LDP neighbors that will receive the labels.

Conditional Label Distribution Example

- The customer is already running IP infrastructure.
- MPLS is only needed to support MPLS/VPN services.
  - Labels should only be generated for loopback interfaces (BGP next-hops) of all routers.
  - All loopback interfaces are in one contiguous address block (192.168.254.0/24).

Conditional Label Distribution Router Configuration (IOS)

- Enable conditional label advertisment

```
no tag-switching advertise-tags
!
! Configure conditional advertisments
!
tag-switching advertise-tags for 90 to 91
!
access-list 90 permit ip 192.168.254.0 0.0.0.255
access-list 91 permit ip any
```


Conditional Label Distribution Router Configuration (IOS XR)

- Enable conditional label advertisment

```
ipv4 access-list pfx_acl_1
 10 permit ipv4 host 31.0.0.0 any
!
ipv4 access-list peer_acl_1
 10 permit ipv4 host 9.9.9.9 any
!
mpls ldp
 label
  advertise
   disable
   for pfx_acl_1 to peer_acl_1
  !
 !
!
```


Agenda LDP Configuration and Monitoring

- Configuration
- Verifying Your Configuration
- Monitoring LDP

Verifying your configuration (IOS)

```
hostname mpls-7200a
!
ip cef
mpls label protocol ldp
tag-switching tdp router-id Loopback0
!
interface Ethernet3/0
 tag-switching ip
```


Verifying your configuration (IOS XR)

```
mpls ldp
 router-id 1.1.1.1
 log
  neighbor
 !
 interface GigabitEthernet0/4/1/3
 !
!
mpls oam
!
```

Agenda LDP Configuration and Monitoring

- Configuration
- Verifying Your Configuration
- Monitoring LDP

Monitoring LDP

- show mpls interface <x> detail
- show mpls ldp discovery
- show mpls ldp neighbor
- show mpls ip/ldp binding <prefix> <prefix-length>
- show mpls forwarding-table <prefix> <prefix-length>
- sh ip cef <prefix>
- show mpls ldp parameters

Show mpls interface

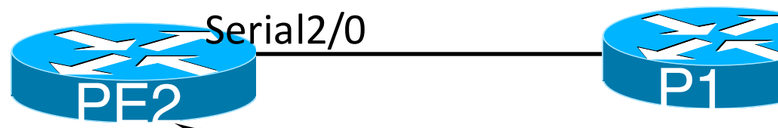
```
mpls-7200a#sh mpls interface
Interface              IP         Tunnel   Operational
Ethernet3/0            Yes (ldp)  No       Yes


mpls-7200a#sh mpls interface ethernet3/0 detail
Interface Ethernet3/0:
        IP labeling enabled (ldp)
        ........<snip>.......
          Fast Switching Vectors:
          IP to MPLS Fast Switching Vector
          MPLS Turbo Vector
          MTU = 1500
```


Show mpls interface (contd..)

- "sh mpls interface [detail]"
  - –Lists whether MPLS is enabled and the application that enabled MPLS on the interface

```
PE2#sh mpls interface
Interface              IP             Tunnel    Operational
Serial2/0              Yes (ldp)      No        Yes
PE2#
```

```
PE2#sh mpls interface ser2/0 detail
Interface Serial2/0:
        IP labeling enabled (ldp)
        LSP Tunnel labeling not enabled
        BGP tagging not enabled
        Tagging operational
        Fast Switching Vectors:
          IP to MPLS Fast Switching Vector
          MPLS Turbo Vector
        MTU = 1508
PE2#
```



MPLS Enabled

LDP Enabled

MPLS MTU

```
interface Serial2/0
 description To P1 ser2/0
 ip address 10.13.2.6/30
 mpls label protocol ldp
 tag-switching ip
 tag-switching mtu 1508
```

Show mpls interface (contd..)

- This slide is to show that BGPipv4+label (or MP-eBGP) is another application that can enable MPLS; *what's different here -*

```
RSP-PE-SOUTH-6#sh mpls int
Interface              IP             Tunnel   Operational
Fddi1/0/0              Yes (ldp)      No       Yes
ATM1/1/0.108           No             No       Yes
RSP-PE-SOUTH-6#
```

MPLS is Operational.

LDP not enabled

```
RSP-PE-SOUTH-6#sh mpls int ATM1/1/0.108 detail
Interface ATM1/1/0.108:
        IP labeling not enabled
        LSP Tunnel labeling not enabled
        BGP tagging enabled
        Tagging operational
        Optimum Switching Vectors:
          IP to MPLS Feature Vector
          MPLS Feature Vector
        Fast Switching Vectors:
          IP to MPLS Fast Feature Switching Vector
          MPLS Feature Vector
        MTU = 4470
RSP-PE-SOUTH-6#
```

LDP not enabled

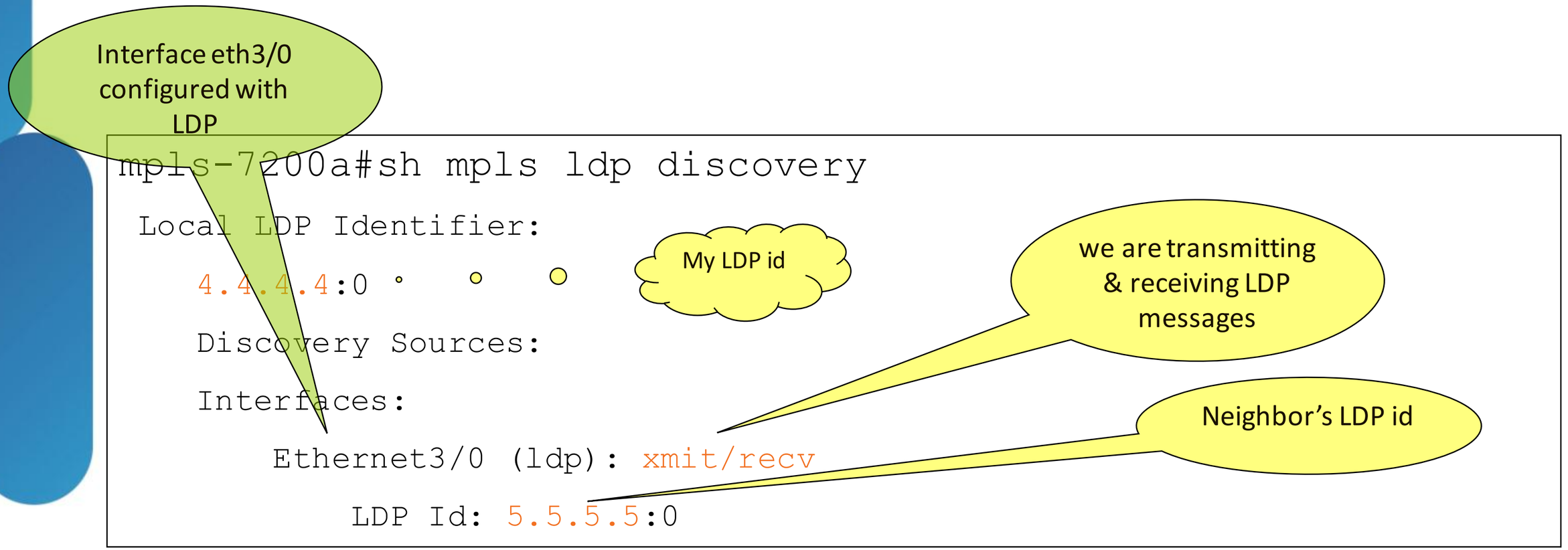
BGP+Label Enabled

MPLS MTU

LDP discovery/adjacency: commands and debugs

- `show mpls ldp discovery`
- `debug mpls ldp transport`
- `debug mpls ldp session io`

LDP discovery



"debug mpls ldp transport events"

- Should give information regarding whether the HELLOS are advertised/received

LDP neighbor

```
mpls-7200a#sh mpls ldp neighbor
    Peer LDP Ident: 5.5.5.5:0; Local LDP Ident 4.4.4.4:0
       TCP connection: 5.5.5.5.11000 - 4.4.4.4.646
       State: Oper; Msgs sent/rcvd: 268/264; Downstream Up time: 03:41:45
       LDP discovery sources:
          Ethernet3/0, Src IP addr: 10.0.3.5
       Addresses bound to peer LDP Ident:
          10.0.3.5        10.0.4.5        10.0.5.5        5.5.5.5
```

LDP neighbor (contd..)

- LDP session is a TCP session (port = 646)
- Multiple links between two routers still mean single LDP session.

```
PE1#sh mpls ldp neighbor
    Peer LDP Ident: 10.13.1.101:0; Local LDP Ident 10.13.1.61:0
        TCP connection: 10.13.1.101.11031 - 10.13.1.61.646
        State: Oper; Msgs sent/rcvd: 58/60; Downstream
        Up time: 00:39:27
        LDP discovery sources:
          Ethernet0/0, Src IP addr: 10.13.1.5
          Ethernet1/0, Src IP addr: 10.13.1.9
        Addresses bound to peer LDP Ident:
          10.13.1.9       10.13.1.5       10.13.2.5      10.13.1.101
PE1#
```

LDP ID

*Unsolicited Label Distribution**

Interfaces on which peer is discovered

Peer's Connected int

```
PE1#sh tcp brief| i 646
43ABB020  10.13.1.101.11031        10.13.1.61.646         ESTAB
PE1#
```

LDP binding commands

- “sh mpls ip binding detail”
  - –Lists all prefixes with labels & LDP neighbors
- “sh mpls ip binding <*prefix*> <mask> det”
  - –Lists ACLs (if any), *prefix* bindings, and LDP neighbors. Notice “Advertised to:” field.
- “sh mpls ip binding advertisement-acls”
  - –Lists LDP filter, if there is any, on the first line. Prefixes followed by “Advert acl(s):” are advertised via LDP, others are not.

LIB information

```
mpls-7200a#sh mpls ip binding 12.12.12.12 32
  12.12.12.12/32
        in label:     21
        out label:    19         lsr: 5.5.5.5:0         in use



mpls-7200a#sh mpls ldp binding 12.12.12.12 32
  tib entry: 12.12.12.12/32, rev 48
        local binding:  tag: 21
        remote binding: tsr: 5.5.5.5:0, tag: 19
```


LFIB information

```
show mpls forwarding-table <prefix>
  <prefix-length>
sh ip cef <prefix> internal
```


Looking at LFIB

Looking at LFIB on 12008a

```
mpls-12008a#sh mpls forwarding 12.12.12.12 32 detail
Local  Outgoing    Prefix           Bytes tag  Outgoing    Next Hop
tag    tag or VC   or Tunnel Id     switched   interface
19     19          12.12.12.12/32   498        Et2/0       10.0.4.11
       MAC/Encaps=14/18, MTU=1500, Tag Stack{19}
       AABBCC000502AABBCC0004028847 00013000
       No output feature configured
 Per-destination load-sharing, slots: 0 2 4 6 8 10 12 14
       19          12.12.12.12/32   498        Et3/0       10.0.5.11
       MAC/Encaps=14/18, MTU=1500, Tag Stack{19}
       AABBCC000503AABBCC0004038847 00013000
       No output feature configured
 Per-destination load-sharing, slots: 1 3 5 7 9 11 13 15
```

Ethertype=
8847
Label Value in MPLS shim=
13 Hex=19 dec

Destination MAC=
AABBCC000502
Source MAC=
AABBCC000402

CEF command

```
mpls-12008a#sh ip cef 12.12.12.12 internal
12.12.12.12/32, version 24, epoch 0, per-destination sharing
0 packets, 0 bytes
  tag information set, local tag: 19
  via 10.0.4.11, Ethernet2/0, 0 dependencies
    traffic share 1
    next hop 10.0.4.11, Ethernet2/0
    valid adjacency
    tag rewrite with Et2/0, 10.0.4.11, tags imposed: {19}
  via 10.0.5.11, Ethernet3/0, 0 dependencies
    traffic share 1
    next hop 10.0.5.11, Ethernet3/0
    valid adjacency
    tag rewrite with Et3/0, 10.0.5.11, tags imposed: {19}
0 packets, 0 bytes switched through the prefix
.....(contd..)
```

tmstats: external 0 packets, 0 bytes

internal 0 packets, 0 bytes

Load distribution: 0 1 0 1 0 1 0 1 0 1 0 1 0 1 (refcount 1)

Hash	OK	Interface	Address	Packets	Tags imposed
1	Y	Ethernet2/0	10.0.4.11	0	{19}
2	Y	Ethernet3/0	10.0.5.11	0	{19}
3	Y	Ethernet2/0	10.0.4.11	0	{19}
4	Y	Ethernet3/0	10.0.5.11	0	{19}
5	Y	Ethernet2/0	10.0.4.11	0	{19}
6	Y	Ethernet3/0	10.0.5.11	0	{19}
7	Y	Ethernet2/0	10.0.4.11	0	{19}
8	Y	Ethernet3/0	10.0.5.11	0	{19}
9	Y	Ethernet2/0	10.0.4.11	0	{19}
10	Y	Ethernet3/0	10.0.5.11	0	{19}
11	Y	Ethernet2/0	10.0.4.11	0	{19}
12	Y	Ethernet3/0	10.0.5.11	0	{19}
13	Y	Ethernet2/0	10.0.4.11	0	{19}
14	Y	Ethernet3/0	10.0.5.11	0	{19}
15	Y	Ethernet2/0	10.0.4.11	0	{19}
16	Y	Ethernet3/0	10.0.5.11	0	{19}

Monitoring LDP: LDP parameters

```
mpls-7200a#sh mpls ldp parameters
Protocol version: 1
Downstream label generic region: min label: 16; max label: 100000
Session hold time: 180 sec; keep alive interval: 60 sec
Discovery hello: holdtime: 15 sec; interval: 5 sec
Discovery targeted hello: holdtime: 180 sec; interval: 5 sec
Downstream on Demand max hop count: 255
TDP for targeted sessions
LDP initial/maximum backoff: 15/120 sec
LDP loop detection: off
```

Forwarding traffic down the LSP

```
mpls-7200a#sh mpls forwarding-table 12.12.12.12
Local  Outgoing    Prefix            Bytes tag  Outgoing    Next Hop
tag    tag or VC   or Tunnel Id      switched   interface
21     19          12.12.12.12/32    0          Et3/0       10.0.3.5
Note: Bytes tag switched this will increment if packets are being tag switched
using this entry
```

```
mpls-12008a#sh mpls forwarding-table label 19
Local  Outgoing    Prefix            Bytes tag  Outgoing    Next Hop
tag    tag or VC   or Tunnel Id      switched   interface
19     19          12.12.12.12/32    498        Et2/0       10.0.4.11
       19          12.12.12.12/32    1176       Et3/0       10.0.5.11
```

```
mpls-12008b#sh mpls forwarding-table labels 19
Local  Outgoing    Prefix            Bytes tag  Outgoing    Next Hop
tag    tag or VC   or Tunnel Id      switched   interface
19     Pop tag     12.12.12.12/32    4176       Et1/0       10.0.17.12
```

BUILT FOR
THE HUMAN
NETWORK