Tutorial: MPLS Fast Reroute

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Caveats and Assumptions

- **The views presented here are those of the author and they do not necessarily represent the views of Juniper Networks**
- **Basic understanding of RSVP and MPLS**
  - **Labels (Push, Pop, Swap)**
  - **Path, Resv, error messages**
  - **TE extensions for the IGPs**
  - **RSVP sessions**
- **You will ask a question when you don't understand!**

Why Use Fast Reroute?

- **Traffic protection**
  - **For packets already passing through the LSP**
- **Continuous forwarding of labeled traffic**
- **Application driven concerns**
  - **Real-time traffic**
- **Non-protected transport network?**

Requirements

- **RSVP based solution only**
  - **Needs an "outside" view of the network**
  - **Traffic engineering capabilities**
- **Support for the RSVP-TE extensions and the Fast Reroute objects**

Agenda

- Terminology
- “I want to be protected!”
- One-to-One backup
- Facility Backup
- RSVP packet dumps

Agenda

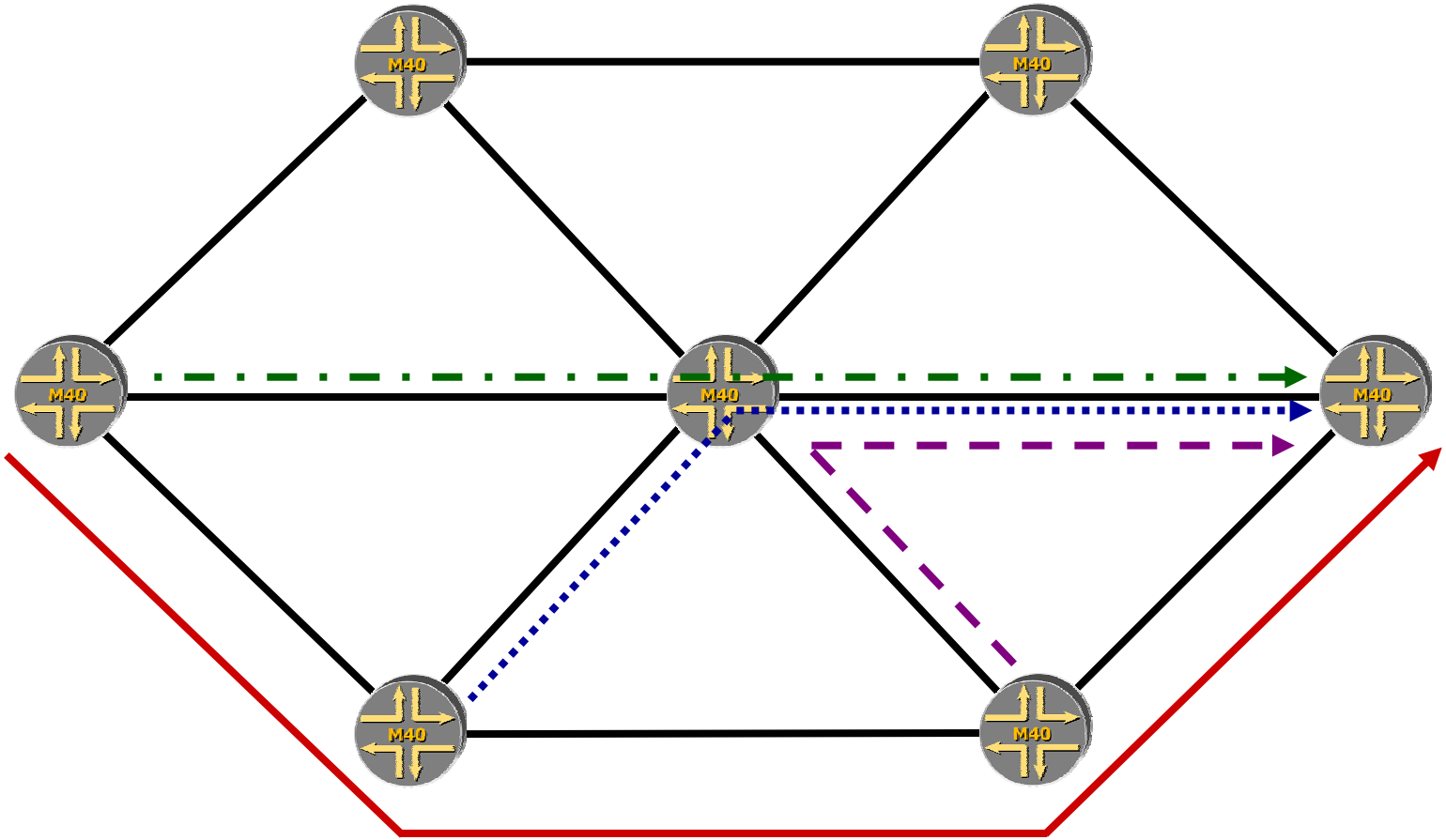
- ➔ **Terminology**
- ◆ "I want to be protected!"
- ◆ One-to-One backup
- ◆ Facility Backup
- ◆ RSVP packet dumps

One-to-One Backup

- Each LSP gets it's own set of protected resources
- Allows for forwarding around the next downstream node and link
  - Except for egress node
- Paths established in the network to avoid the node
  - Always headed towards the egress router
  - Each LSP creates and uses its own Fast Reroute paths
- During a failure, the label is swapped and sent into the alternate path
  - No label stacking

One-to-One Node Protection

- Each node along the LSP's path creates an alternate LSP around the downstream node and headed towards the egress router

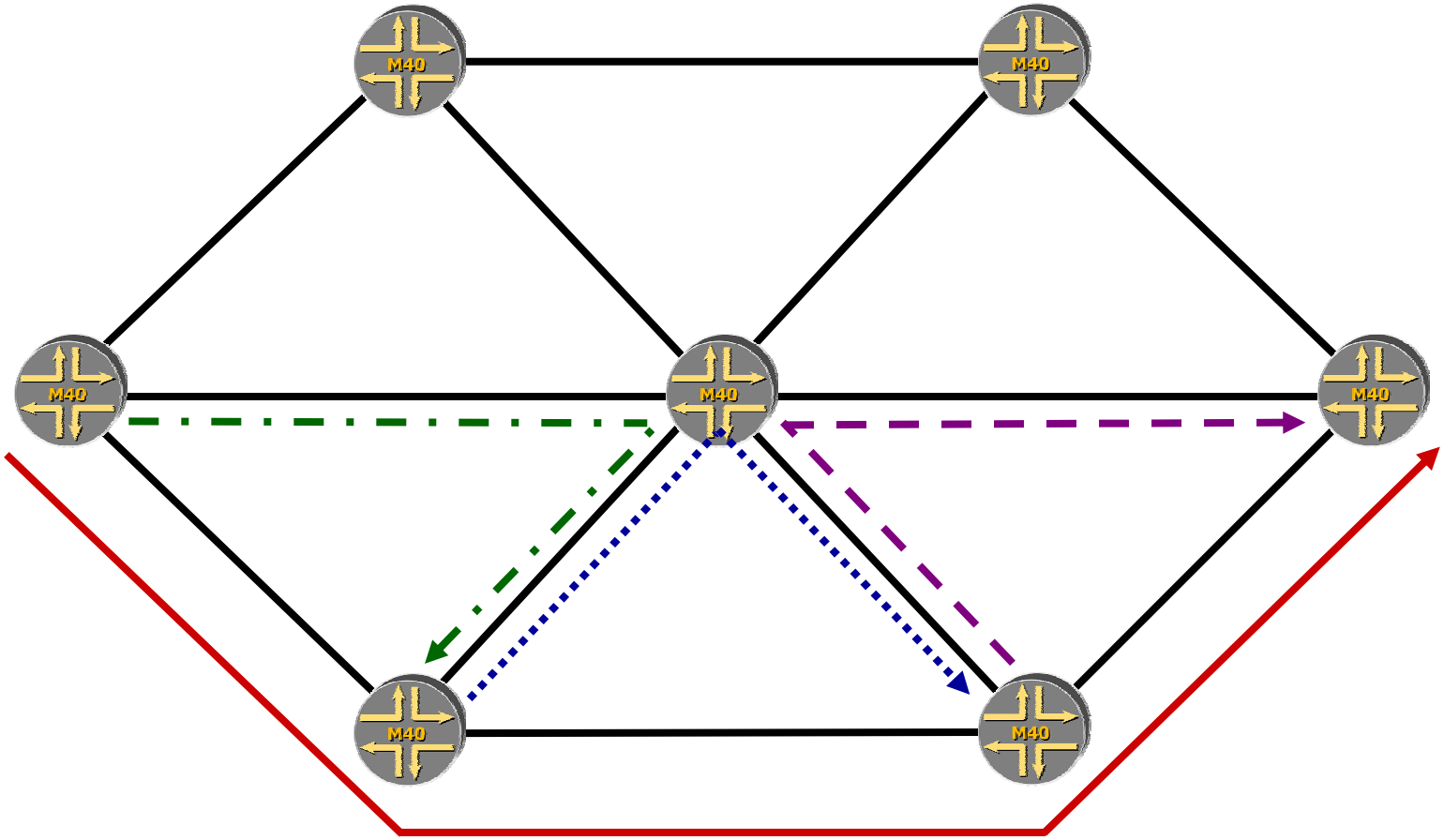


Facility Backup (Many-to-One)

- **Supports Node Protection**
- **Supports Link Protection**
  - **Allows for forwarding around the next downstream link**
  - **Connects to the next downstream node**
  - **Paths established in the network to avoid the link**
  - **Each set of neighbors creates and uses its own Fast Reroute path**
- **During a failure, the label is swapped and a second label is pushed before being sent along the alternate path**

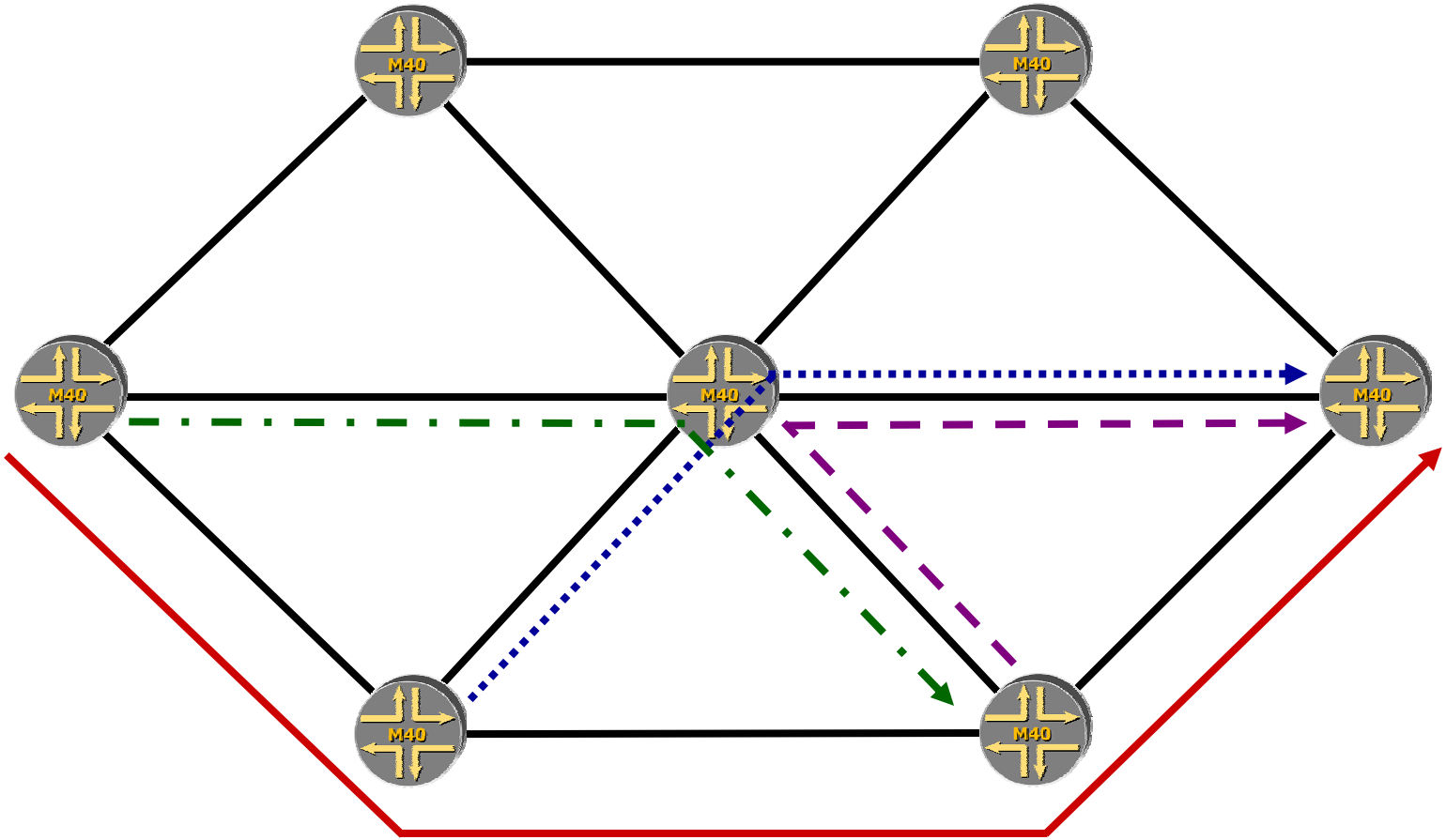
Facility Backup – Link Protection

- Each node creates an alternate LSP around the downstream link



Facility Backup – Node Protection

- **Each node creates an alternate LSP around the downstream node and the interconnecting link**
  - **Penultimate node uses link protection**



Point of Local Repair (PLR)

- Node which notices the failure of:
  - Downstream link
  - Downstream node
- Begins forwarding traffic along the alternate path
- Notifies the ingress router that the main LSP has a problem
  - Sends PathErr upstream

More Terms (1 of 2)

- **Protected LSP**
  - **Has Fast Reroute enabled and alternate paths established in the network**
  - **Both one-to-one and many-to-one provide protection for LSPs**
- **Detour LSP**
  - **Used in a one-to-one protection scheme**
  - **LSP created to avoid the downstream node**
- **Next-Hop Bypass LSP**
  - **Used in a facility backup link protection scheme**
  - **LSP created between the two adjacent neighbors**

More Terms (2 of 2)

- **Next-Next-Hop Bypass LSP**
  - **Used in a facility backup node protection scheme**
  - **LSP created to avoid the downstream node**
- **Merge Point**
  - **Point where the alternate path rejoins the main LSP**
- **Detour Merge Point**
  - **Point where multiple detours join together along the protected path**

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- Terminology
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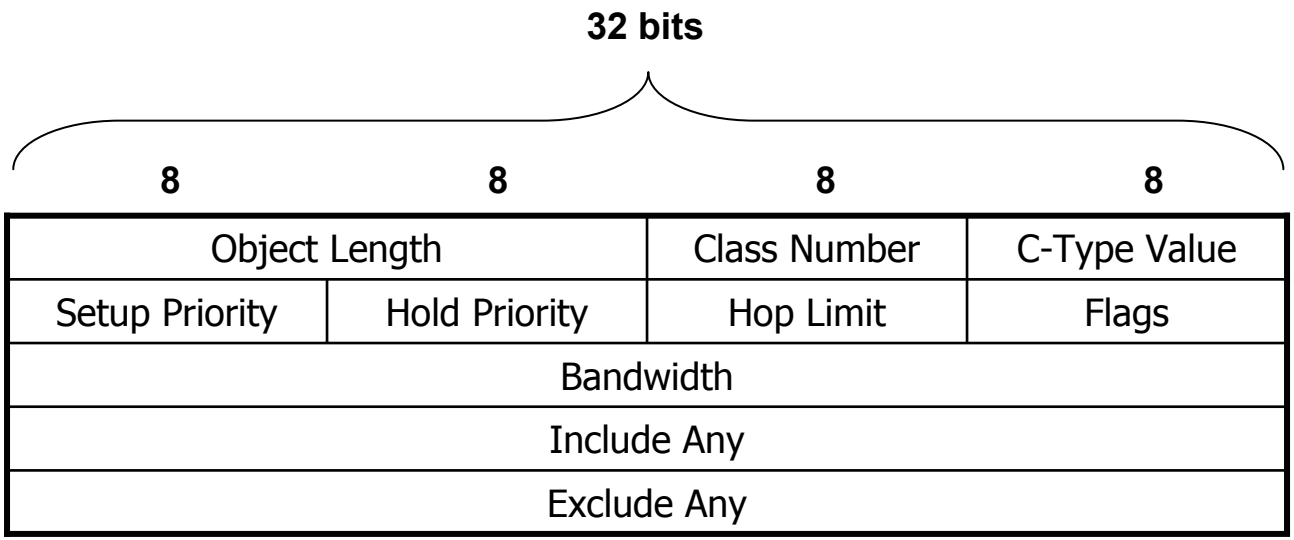
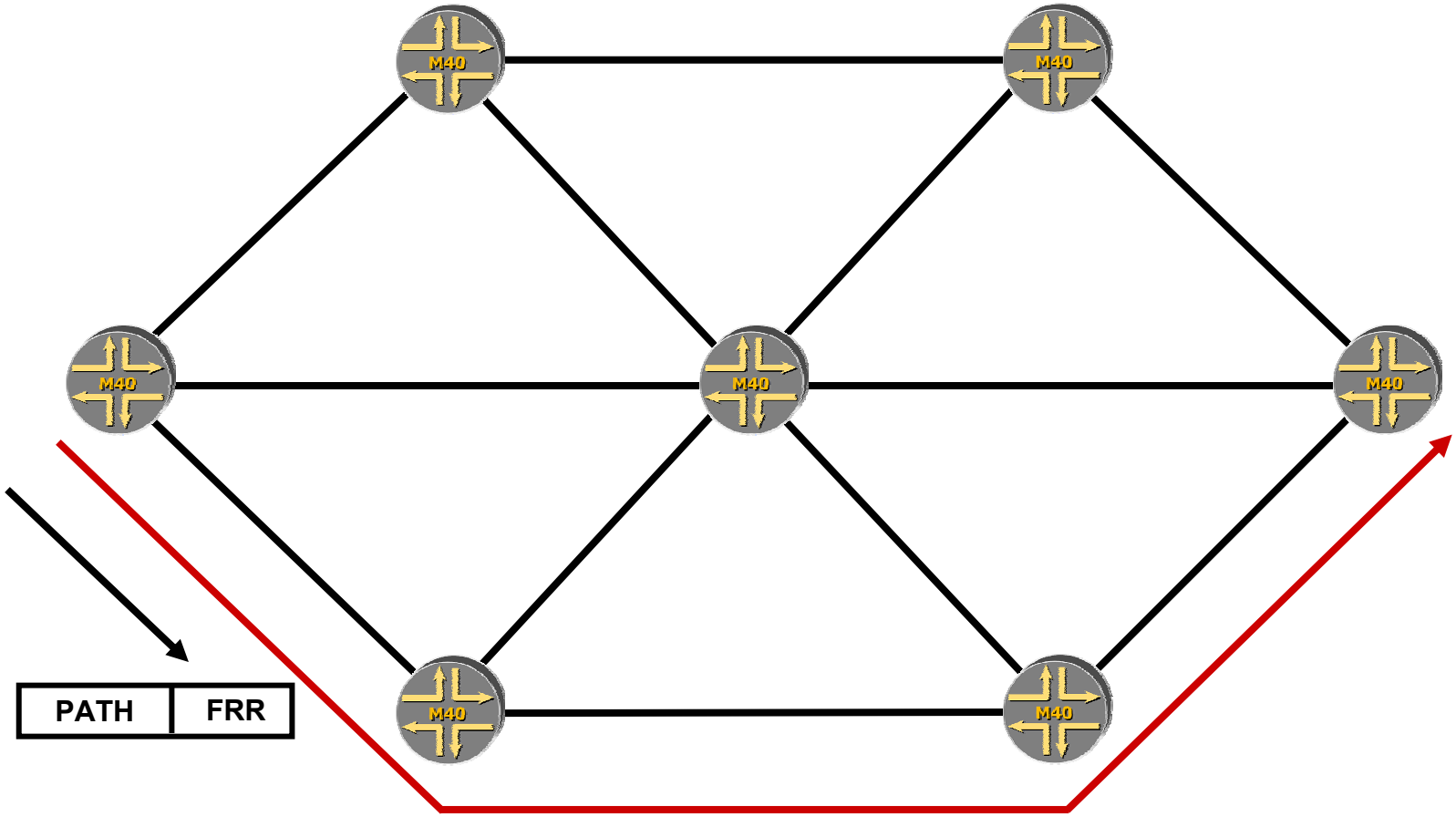
Fast Reroute Object

- **Included in Path messages for the protected LSP**
  - **Signals the ingress router's desire to protect the LSP**
  - **Contains information which each node uses to establish it's protected paths**
  - **Flag values determine the type of protection requested**
    - **0x01 for one-to-one backup**
    - **0x02 for facility backup**



LSP Path Message and FRR Object

- The ingress router inserts the Fast Reroute Object within the Path message for the protected LSP



Session Attribute Flags (1 of 2)

- Informs each router in the path about the characteristics of the LSP
- 0x01 – Local protection desired
  - Allows the LSP routers to establish detour paths in the network which violate the ERO of the LSP.
  - Generic setting which allows the nodes to use either protection scheme
- 0x02 – Label recording desired
  - Requests that the LSP routers include the label they assigned in the RRO

Session Attribute Flags (2 of 2)

- 0x04 – SE style desired
  - Bandwidth should not be double counted for the LSP and it's detours
  - The ingress node for the protected LSP will reroute using "make before break"
- 0x08 – Bandwidth protection desired
  - The detour LSPs should reserve bandwidth in the network along their paths
  - Inherit the BW reserved for the protected LSP or use the BW specified in the Fast Reroute Object
- 0x10 – Node protection desired
  - Explicitly requests that the LSP routers use node protection when establishing their detour paths

Constrained Shortest Path First

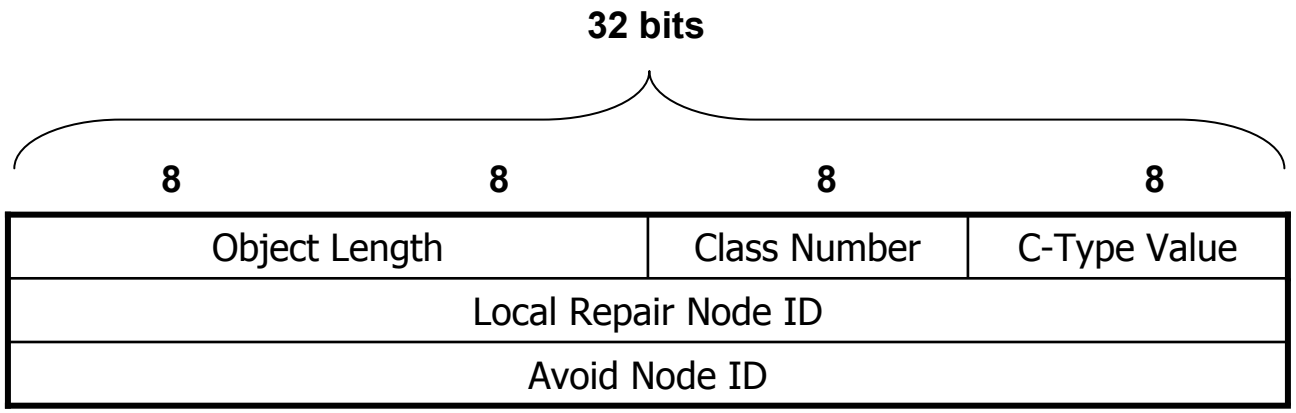
- Each PLR ingress node consults the TED
  - Attempts to locate a path for the particular protection scheme requested
- If the FRR Object requests constraints, the protection path matches those requests
- A complete ERO for the protection path is created
- Protection path is signaled by RSVP

Agenda

- Terminology
- "I want to be protected!"
- → **One-to-One backup**
- Facility Backup
- RSVP packet dumps

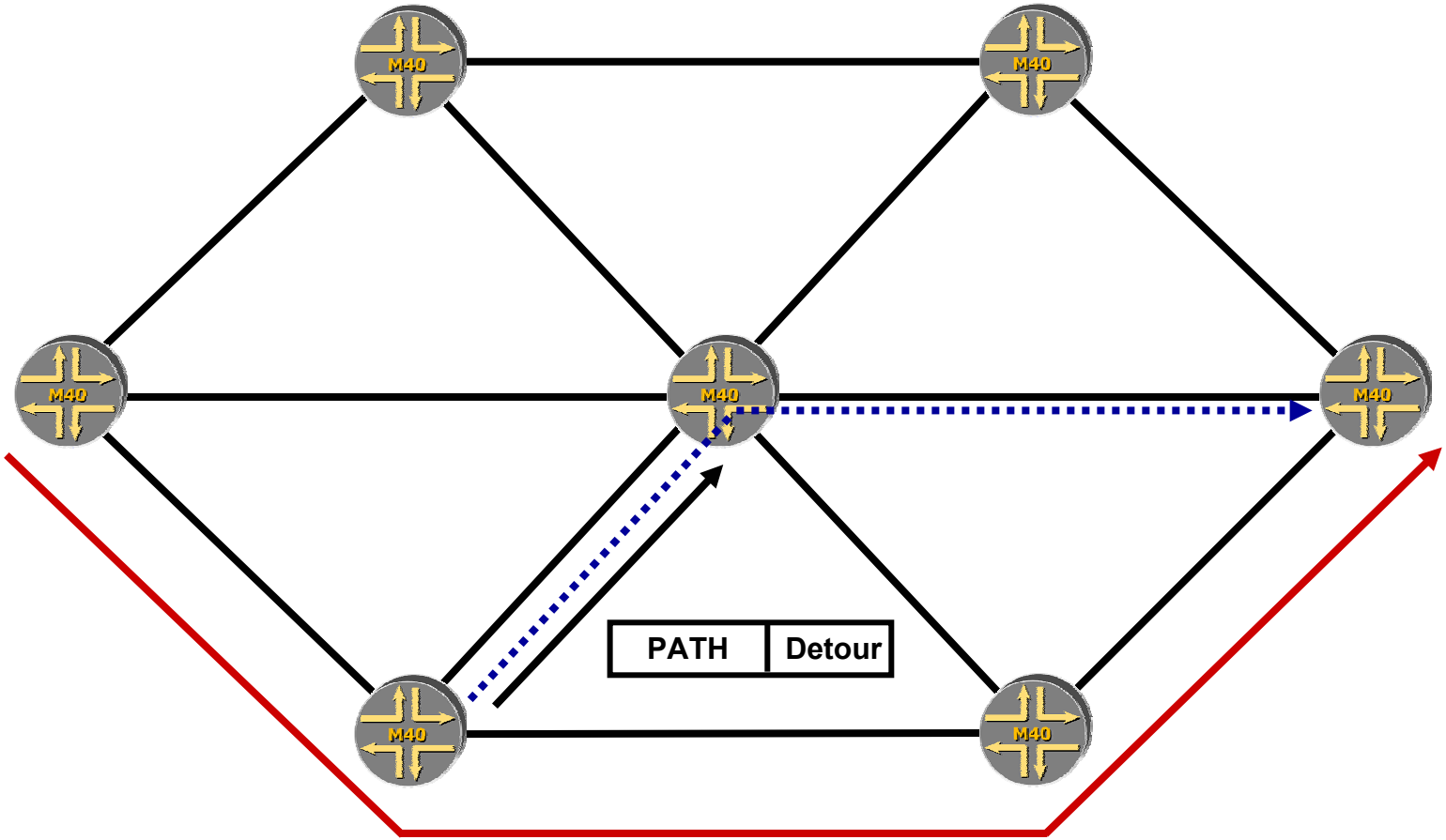
Detour Object

- **Included in Path messages for the detour LSP**
  - **Allows routers along the detour path to associate multiple detours with the same RSVP session**
  - **Includes information about the detour ingress**
  - **Includes the node which the detour is avoiding**



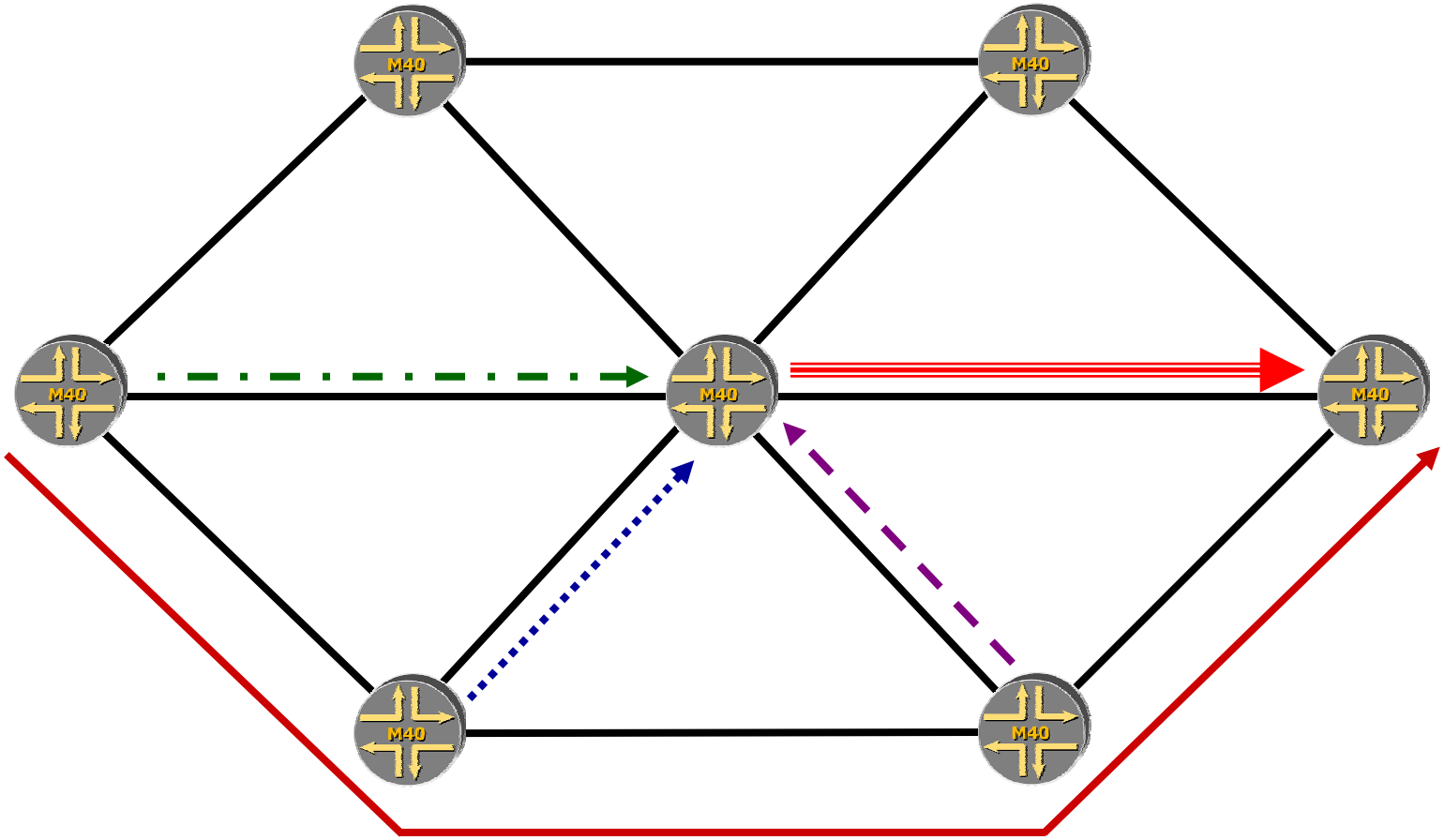
Detour Path Message and Object

- After the routers along the Path assign resources to the LSP, each generates a Path message for the detour path and includes the Detour Object



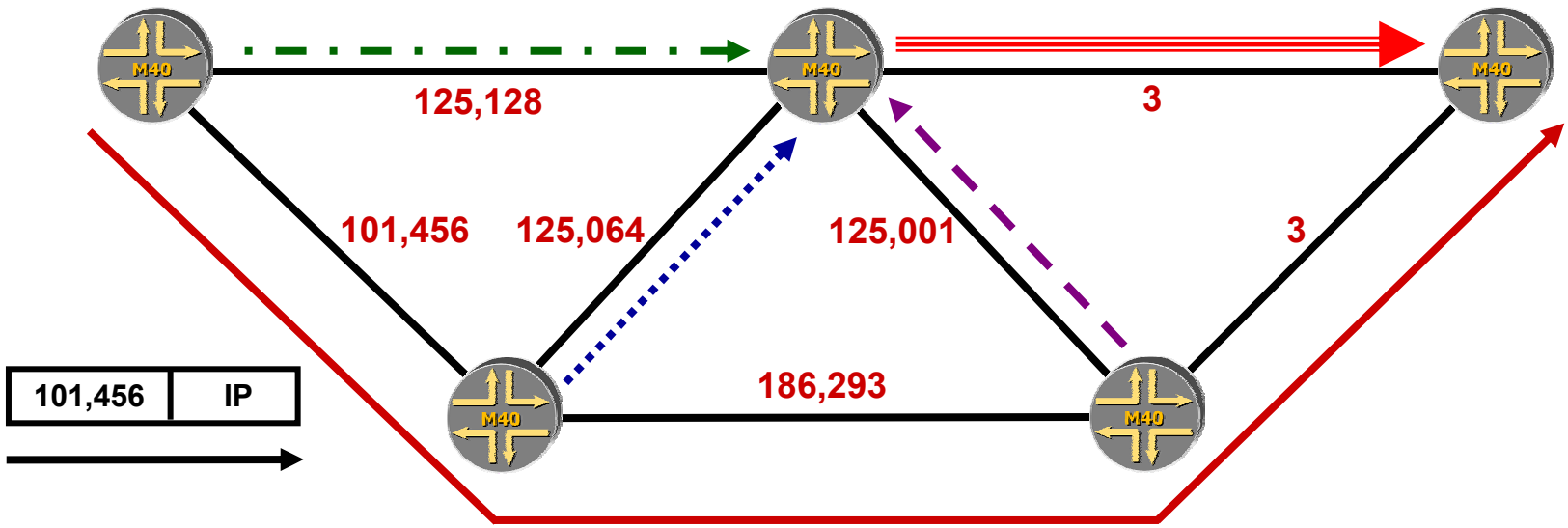
Merging Detours

- **Detour merge points combine detours together**
  - **Router in the middle of the network combines all detours into a single detour path**

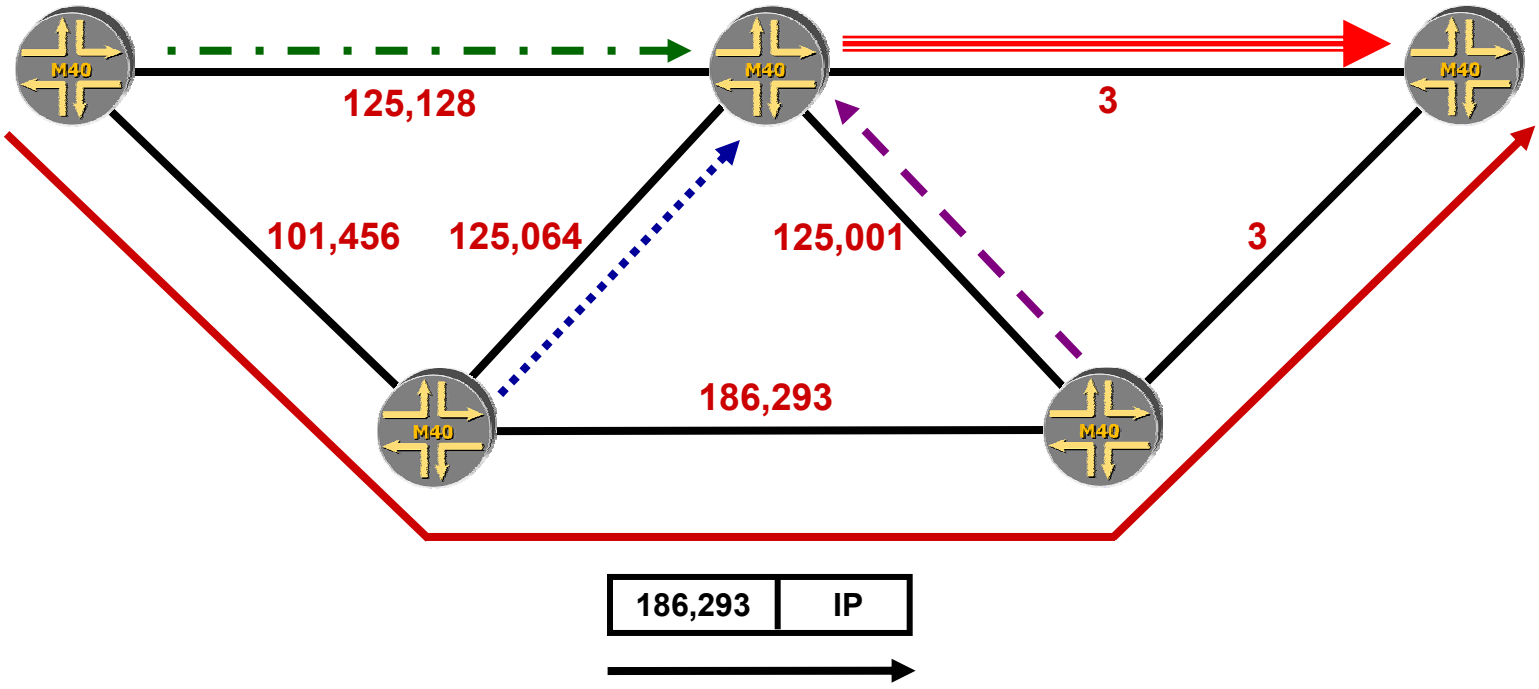


LSP Label Operations (1 of 3)

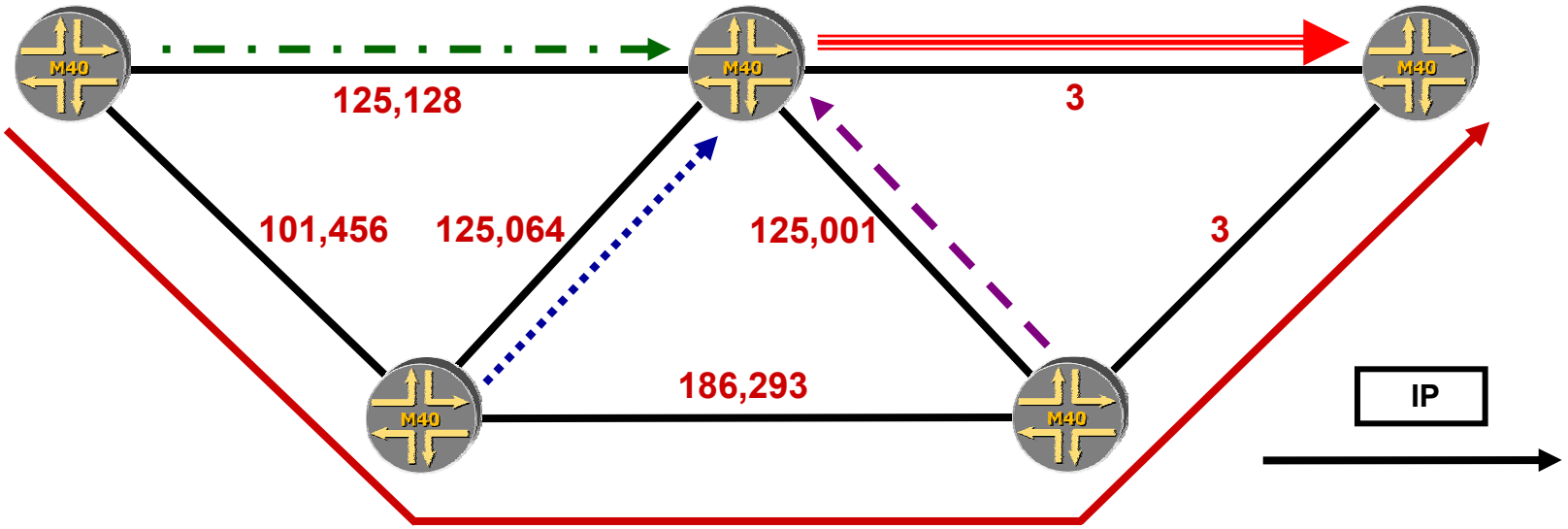
- In a normal operating environment, the routers perform label swaps as expected



LSP Label Operations (2 of 3)

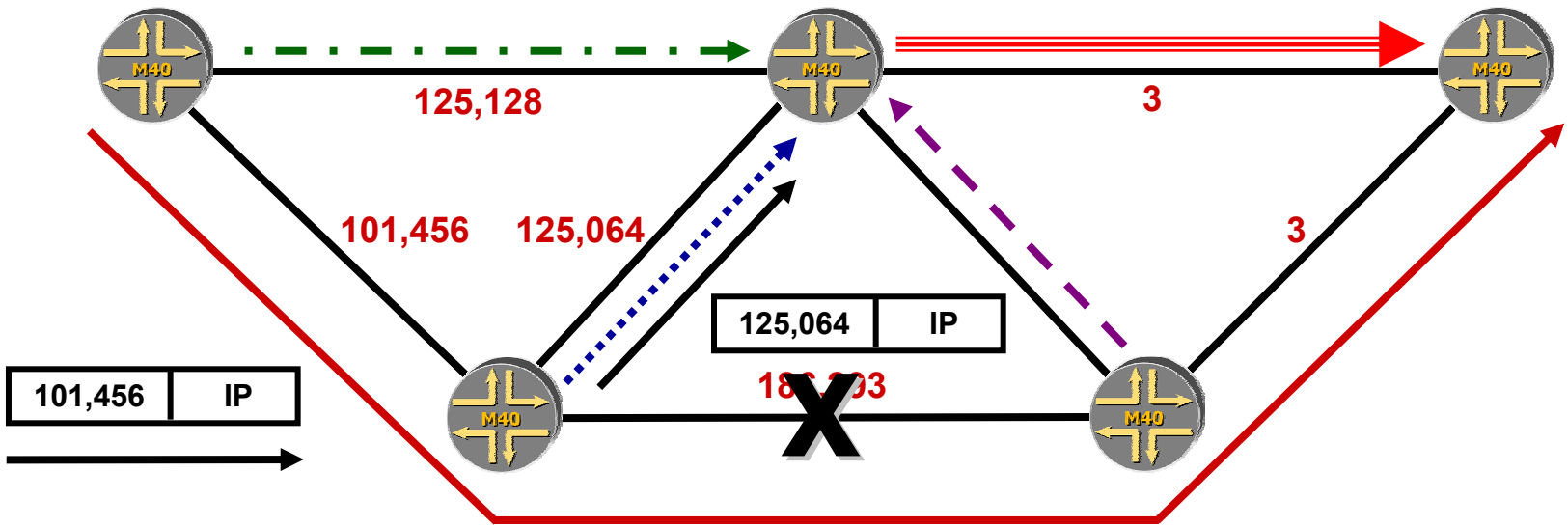


LSP Label Operations (3 of 3)



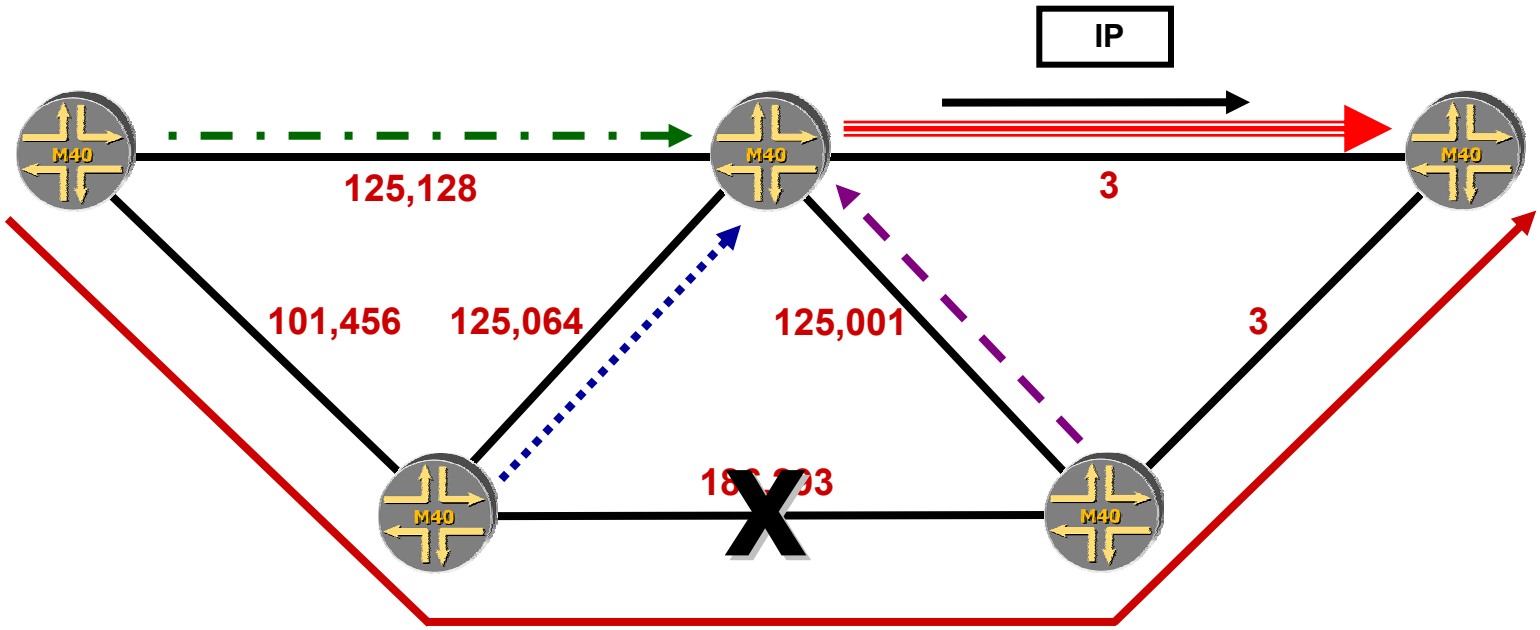
Detour Label Operations (1 of 2)

- **Point of local repair performs a label swap**
  - **Incoming label exchanged for label advertised by the downstream router along the detour**



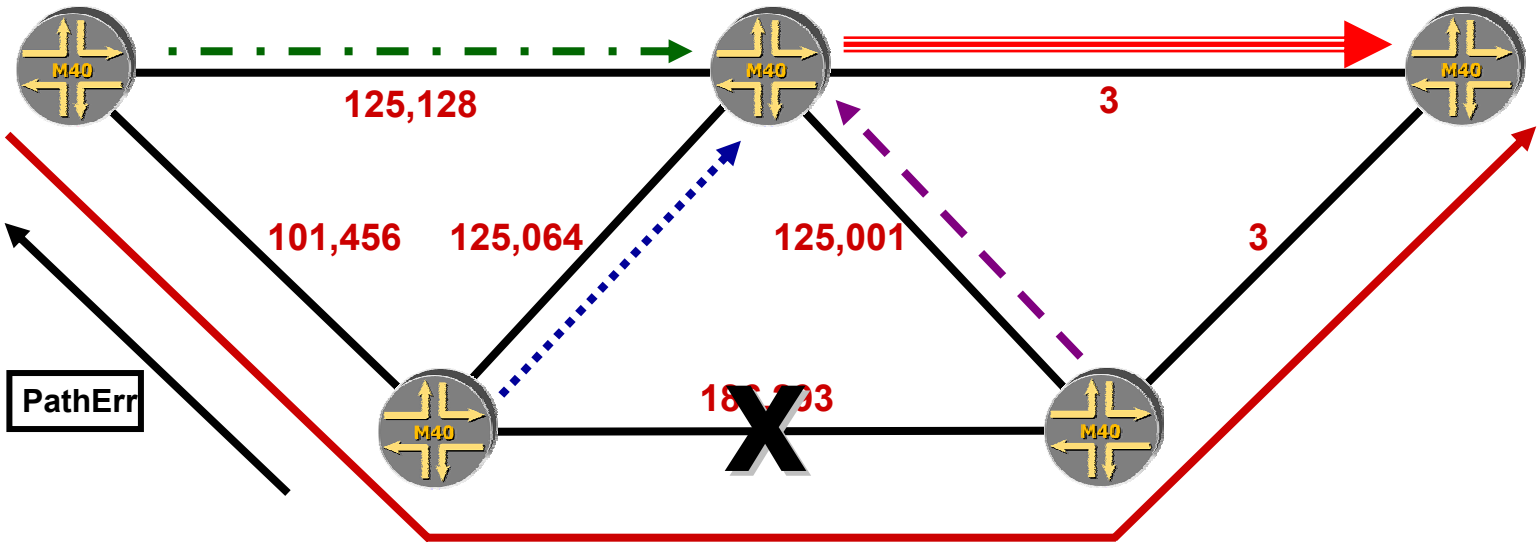
Detour Label Operations (2 of 2)

- **Merge point swaps label and forwards the packet along the detour path**
  - **In our example, the merge point is the penultimate hop so the label is popped**



Notification of Local Repair (PathErr)

- **PLR sends a PathErr message to the ingress router of the protected LSP**
  - **Allows ingress to move to an alternate path for "permanent" recovery**



Record Route Object Flags (1 of 2)

- Allows each router in the path to determine the availability or use of a protection path
- 0x01 – Local protection available
  - Means that the downstream link from the router is protected by a protection mechanism
  - Can be either node or link protection
- 0x02 – Local protection in use
  - Means that the PLR is actively using the protection path for the LSP

Record Route Object Flags (2 of 2)

- 0x04 – Bandwidth protection
  - Means that the router was able to successfully establish a backup path which meets the BW specified by the ingress router for the LSP
- 0x08 – Node protection
  - Means that the downstream node from the router is protected by node protection
  - This is NOT set when only link protection is available

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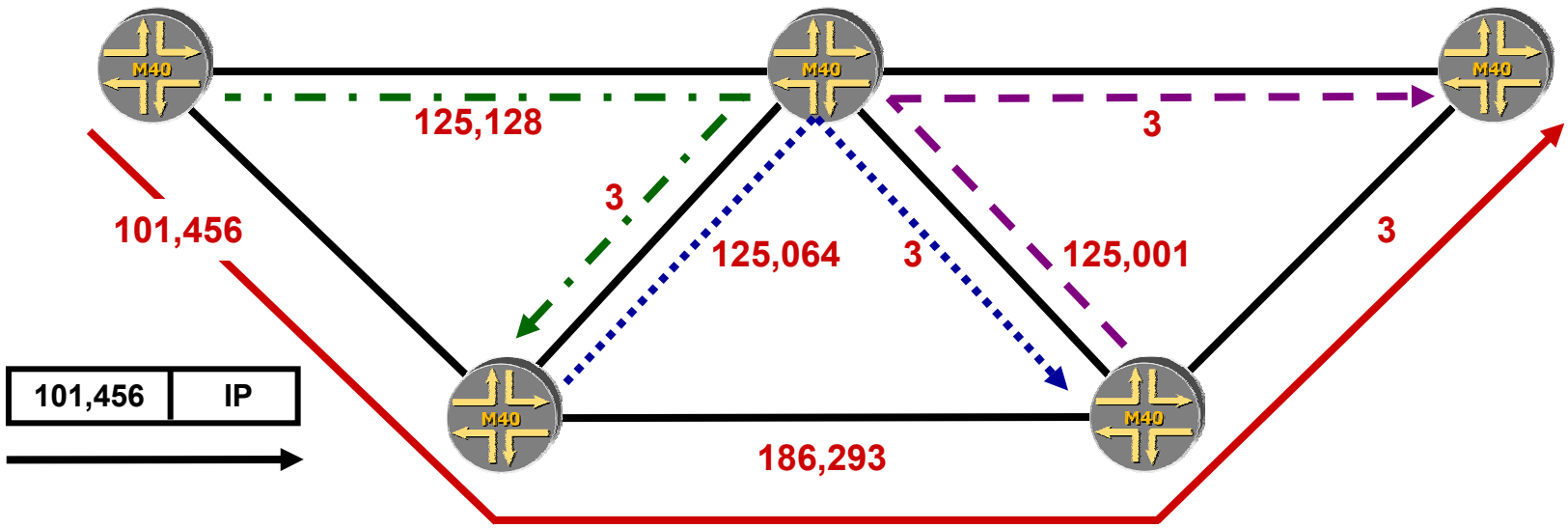
- "I want to be protected!"
- One-to-One backup
- → **Facility Backup**
- RSVP packet dumps

Backup Paths Created

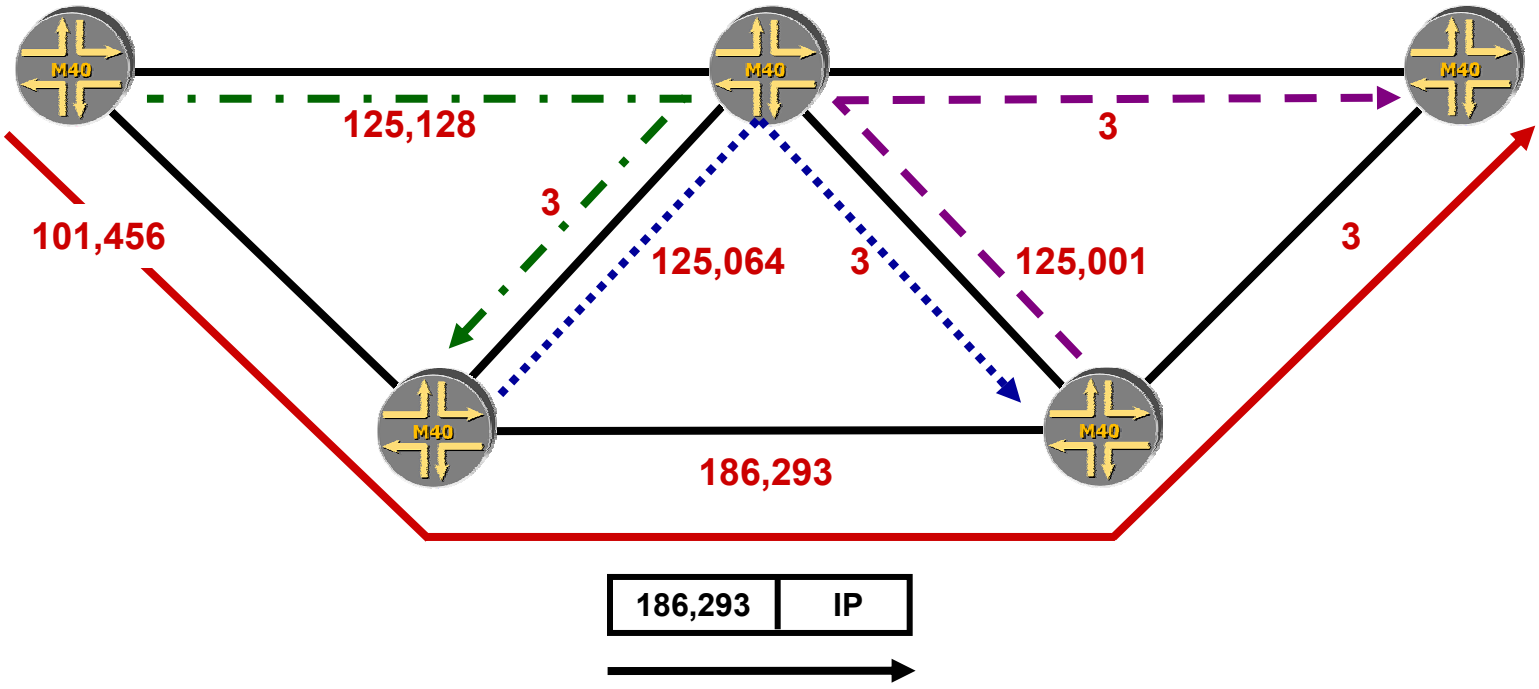
- Once the protected LSP is established, the routers along the path create the backup paths required
  - Could be a Next-Hop Bypass LSP
  - Could be a Next-Next-Hop Bypass LSP
- Any existing Bypass LSPs are used
  - Key to the Many-to-One concept

LSP Label Operations (1 of 3)

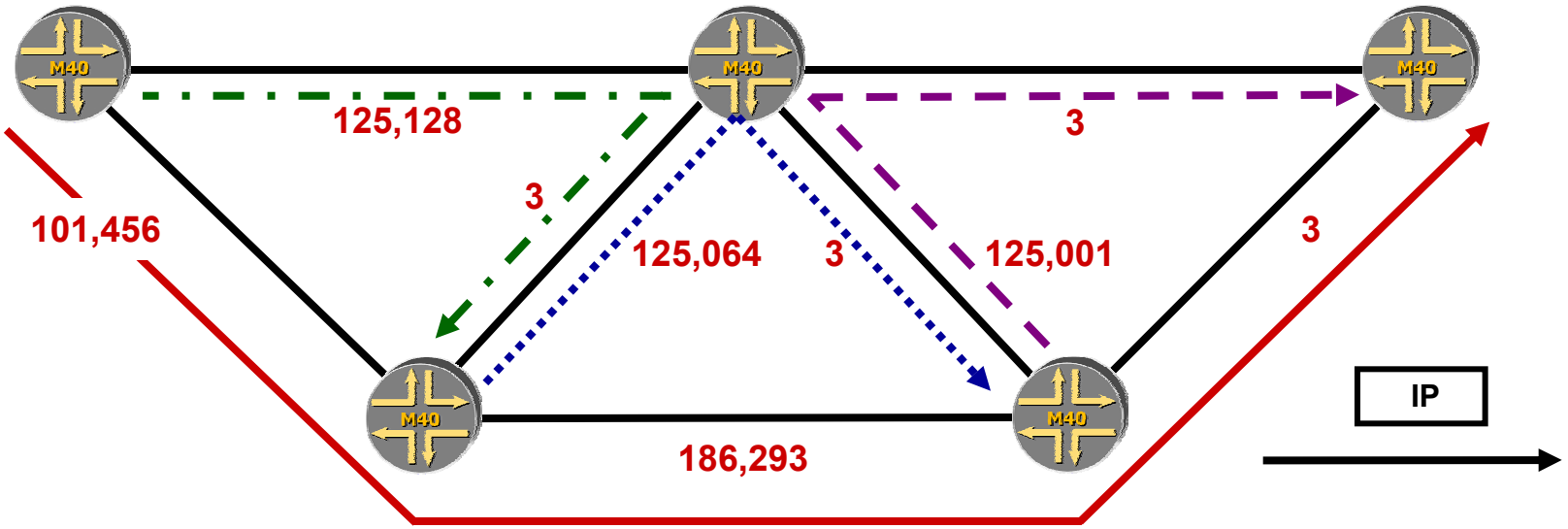
- In a normal operating environment, the routers perform label swaps as expected



LSP Label Operations (2 of 3)

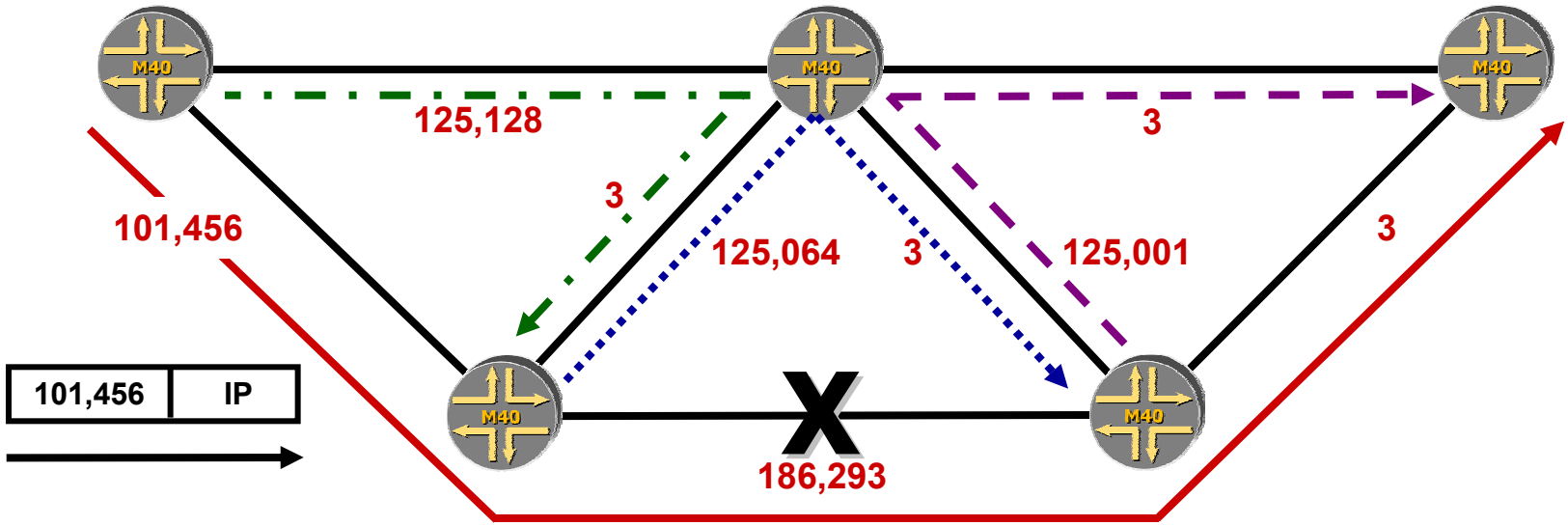


LSP Label Operations (3 of 3)



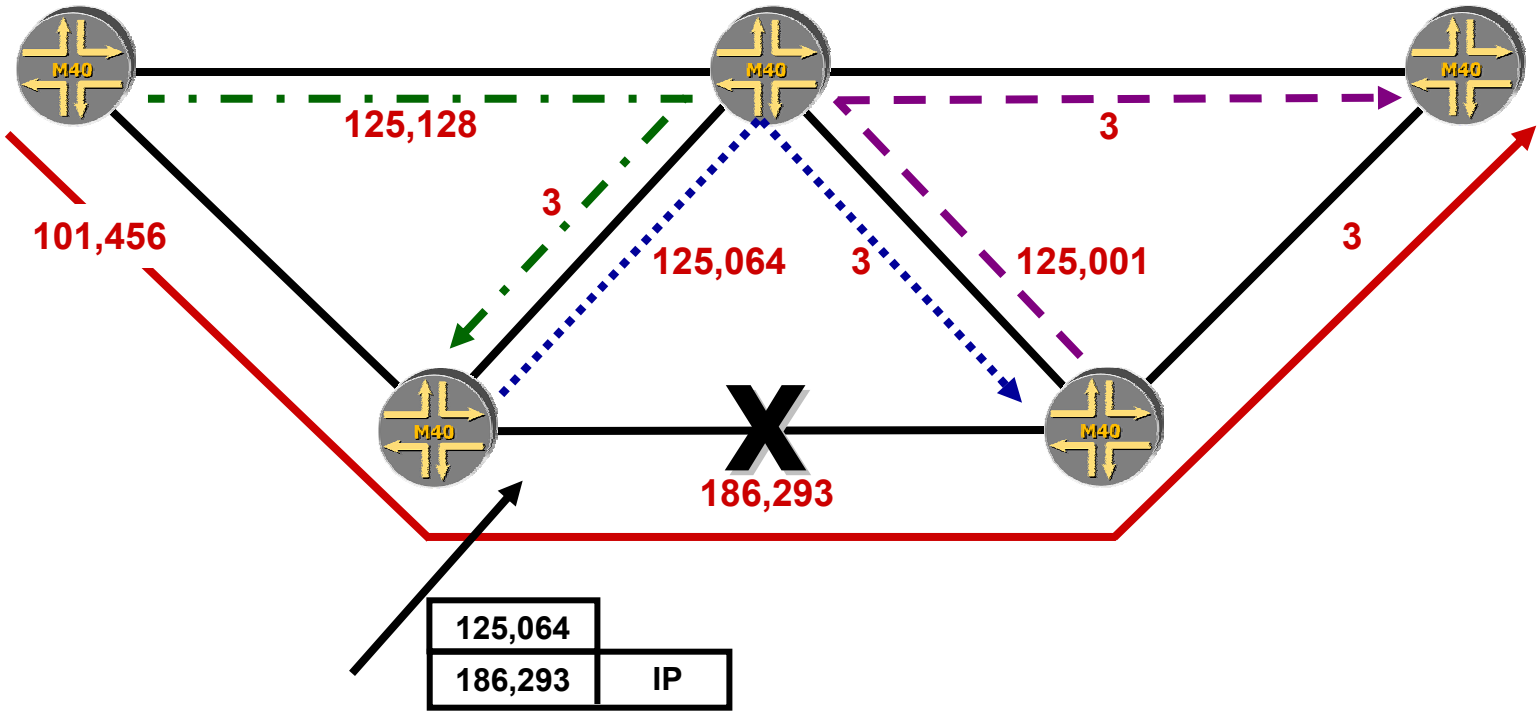
Link Facility Backup Operations (1 of 4)

- **Point of local repair performs a swap and a push**
  - **Incoming label exchanged for label advertised by the downstream router along the protected LSP**
  - **Adds the label representing the first hop along the Bypass LSP**



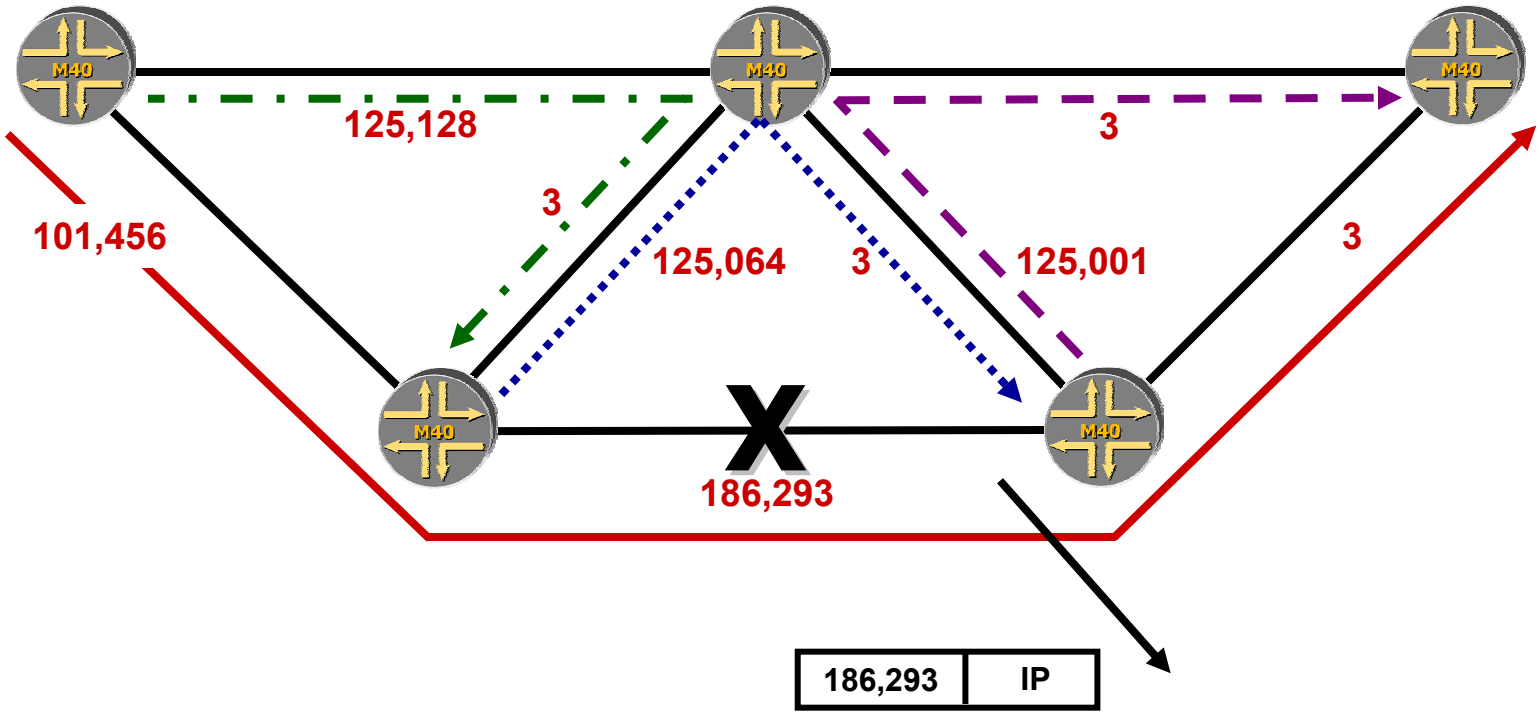
Link Facility Backup Operations (2 of 4)

- **Point of local repair performs a swap and a push**
  - **Incoming label exchanged for label advertised by the downstream router along the protected LSP**
  - **Adds the label representing the first hop along the Bypass LSP**



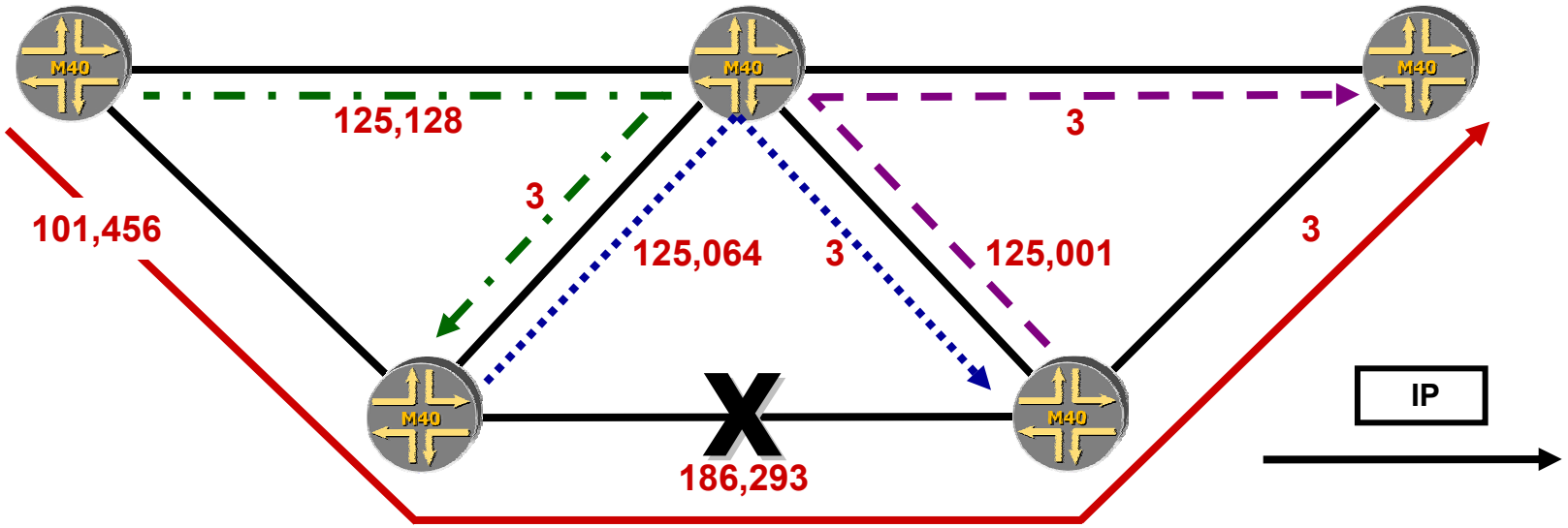
Link Facility Backup Operations (3 of 4)

- **Bypass LSP transit router performs a label pop**
  - **Removes the incoming bypass label and forwards the remaining data to the merge point**



Link Facility Backup Operations (4 of 4)

- **Merge point pops the incoming label along the bypass LSP**
  - **Merge point is the penultimate router in our case**
  - **Label swaps are also possible**



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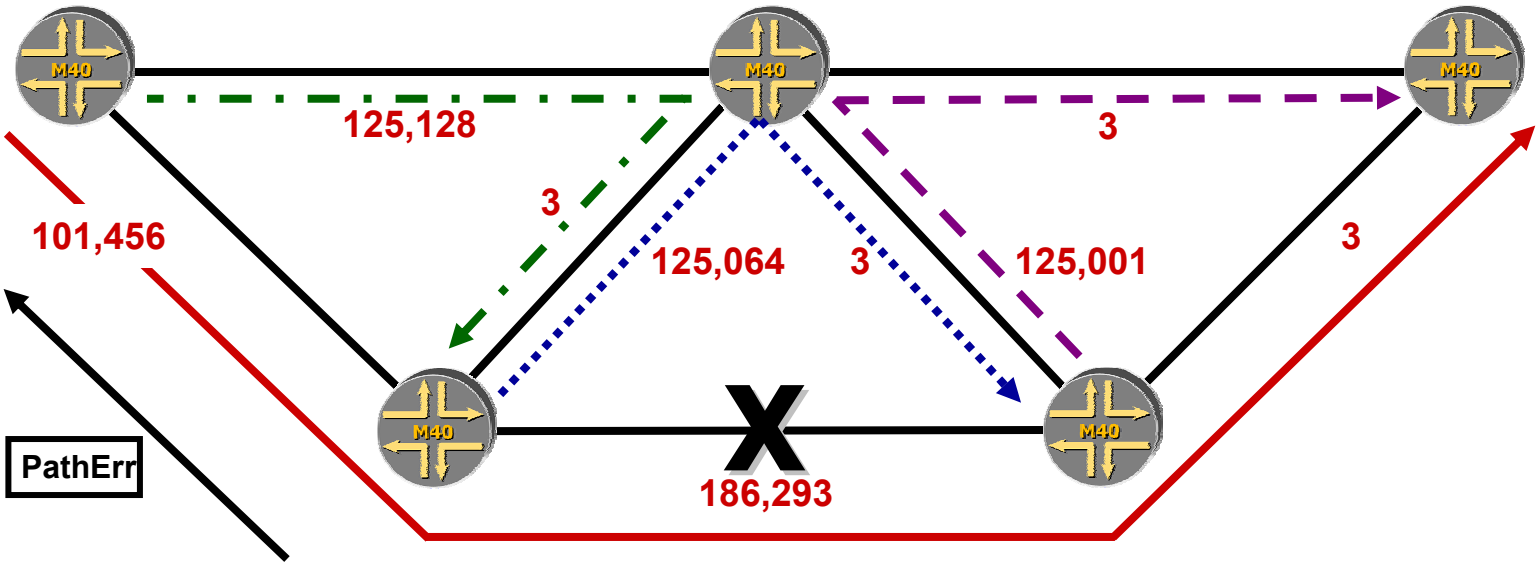

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  - Means that the PLR is actively using the protection path for the LSP

Record Route Object Flags (2 of 2)

- 0x04 – Bandwidth protection
  - Means that the router was able to successfully establish a backup path which meets the BW specified by the ingress router for the LSP
- 0x08 – Node protection
  - Means that the downstream node from the router is protected by node protection
  - This is NOT set when only link protection is available

Facility Backup – RSVP Operations

- In the event of a local repair RSVP messages are passed between neighbors across the bypass LSP
- Path, PathTear, and ResvConf messages use the bypass
- Resv, ResvTear, and PathErr messages are address to the Previous Next-Hop address for protected LSP
  - Uses best-effort routing
  - Extracts address from the RSVP-Hop object

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- "I want to be protected!"
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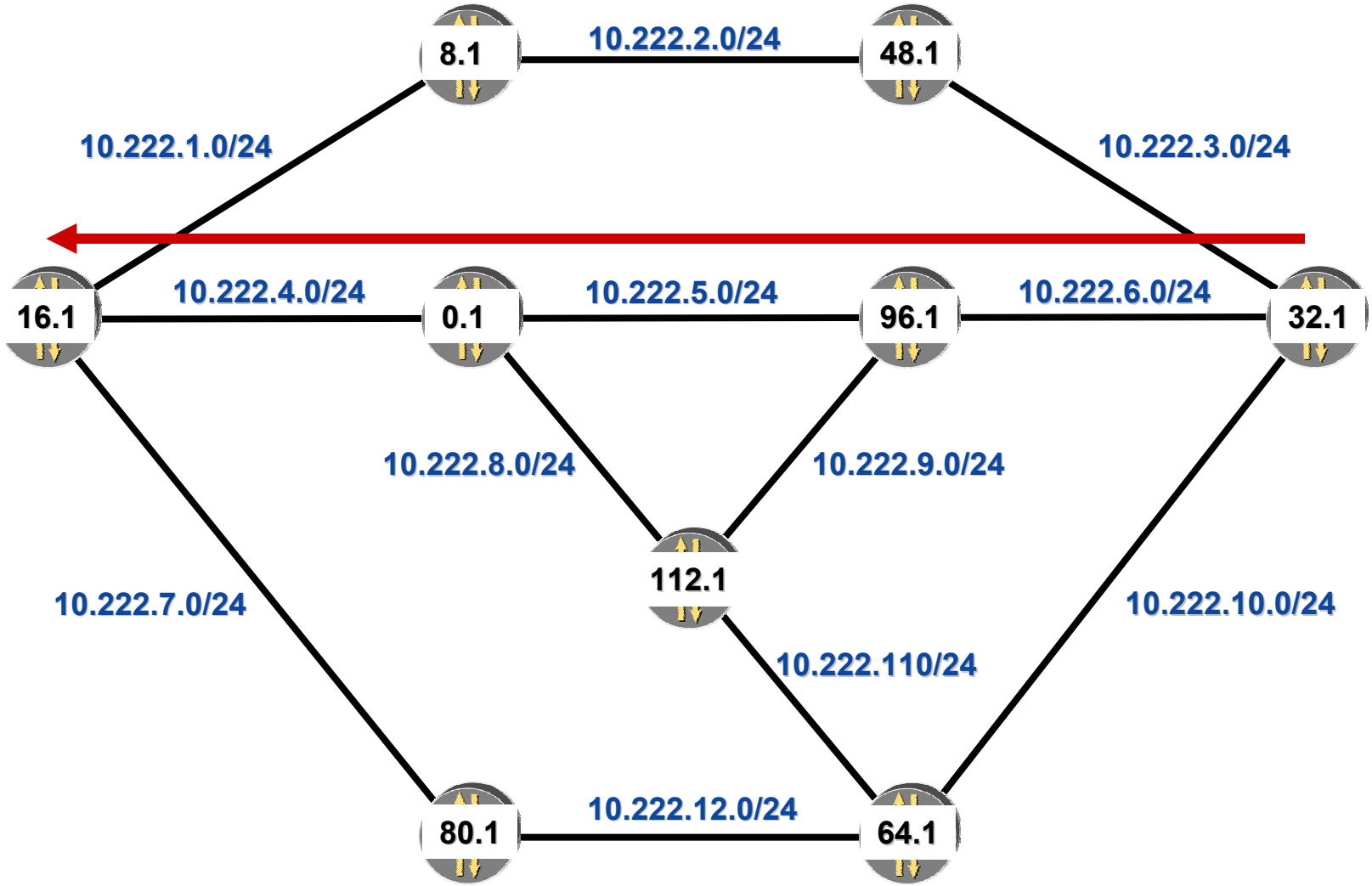
- Facility Backup
- ➔ **RSVP packet dumps**

Sample Network



One-to-One Protection - Path

- **Initial Path message from the ingress is received on the 96.1 router**
  - **Contains Fast Reroute Object**

```
RSVP recv Path 192.168.32.1->192.168.16.1 Len=236 so-0/1/2.0
  Session7 Len 16 192.168.16.1(port/tunnel ID 25124) Proto 0
  Hop      Len 12 10.222.6.2/0x0857cd8c
  Time     Len  8 30000 ms
  SessionAttribute Len 16 Prio (7,0) flag 0x0 "FRR-Test"
  Sender7  Len 12 192.168.32.1(port/lsp ID  1)
  Tspec    Len 36 rate 0bps size 0bps peak Infbps m 20 M 1500
  ADspec   Len 48
  SrcRoute Len 28  10.222.6.1 S 10.222.5.2 S 10.222.4.1 S
  LabelRequest Len  8 EtherType 0x800
  Properties Len 12 Primary path
  RecRoute Len 12  10.222.6.2
  FastReroute Len 20 Prio(7,0) Hop 6 BW 0bps Include 0x00000000 Exclude 0x00000000
```

One-to-One Protection - Resv

- **Resv message for the protected LSP is transmitted back to the ingress router**

```
RSVP send Resv 10.222.6.1->10.222.6.2 Len=136 so-0/1/2.0
  Session7 Len 16 192.168.16.1(port/tunnel ID 25124) Proto 0
  Hop      Len 12 10.222.6.1/0x0857cd8c
  Time     Len  8 30000 ms
  Style    Len  8 FF
  Flow     Len 36 rate 0bps size 0bps peak Infbps m 20 M 1500
  Filter7  Len 12 192.168.32.1(port/lsp ID  1)
  Label    Len  8  100144
  RecRoute Len 28  10.222.6.1 10.222.5.2 10.222.4.1
```

One-to-One Protection - Detour

- **PLR generates a Path message containing a Detour object**

```
RSVP send Path 192.168.32.1->192.168.16.1 Len=244 so-0/1/2.0
  Session7 Len 16 192.168.16.1(port/tunnel ID 25124) Proto 0
  Hop      Len 12 10.222.6.1/0x0857cd8c
  Time     Len  8 30000 ms
  SessionAttribute Len 16 Prio (7,0) flag 0x0 "FRR-Test"
  Sender7  Len 12 192.168.32.1(port/lsp ID  1)
  Tspec    Len 36 rate 0bps size 0bps peak Infbps m 20 M 1500
  ADspec   Len 48
  SrcRoute Len 36  10.222.6.2 S 10.222.10.2 S 10.222.12.1 S 10.222.7.2 S
  LabelRequest Len  8 EtherType 0x800
  Properties Len 12 Primary path
  RecRoute Len 20  10.222.6.1 10.222.6.2
  Detour   Len 12  Branch from 10.222.6.1 to avoid 192.168.0.1
```

One-to-One Protection - Detour

- **PLR receives a Resv message which confirms the Detour LSP is established**

```
RSVP recv Resv 10.222.6.2->10.222.6.1 Len=144 so-0/1/2.0
  Session7 Len 16 192.168.16.1(port/tunnel ID 25124) Proto 0
  Hop      Len 12 10.222.6.2/0x0857cd8c
  Time     Len  8 30000 ms
  Style    Len  8 FF
  Flow     Len 36 rate 0bps size 0bps peak Infbps m 20 M 1500
  Filter7  Len 12 192.168.32.1(port/lsp ID  1)
  Label    Len  8  100048
  RecRoute Len 36  10.222.6.2 10.222.10.2 10.222.12.1 10.222.7.2
```

One-to-One Protection – Notify Ingress

- **PLR sets flags in RRO stating that protection is available**

```
RSVP send Resv 10.222.6.1->10.222.6.2 Len=136 so-0/1/2.0
  Session7 Len 16 192.168.16.1(port/tunnel ID 25124) Proto 0
  Hop      Len 12 10.222.6.1/0x0857cd8c
  Time     Len  8 30000 ms
  Style    Len  8 FF
  Flow     Len 36 rate 0bps size 0bps peak Infbps m 20 M 1500
  Filter7  Len 12 192.168.32.1(port/lsp ID  1)
  Label    Len  8  100144
  RecRoute Len 28  10.222.6.1(flag=9) 10.222.5.2(flag=1) 10.222.4.1
```

Facility Link Protection - Path

- **Initial Path message from the ingress is received on the 96.1 router**
  - **Session Attribute flags set to 0x7 for link (0x01), label recording (0x02), and SE reservation (0x04)**

```
RSVP recv Path 192.168.32.1->192.168.16.1 Len=216 so-0/1/2.0
  Session7 Len 16 192.168.16.1(port/tunnel ID 25118) Proto 0
  Hop      Len 12 10.222.6.2/0x0857cd8c
  Time     Len  8 30000 ms
  SessionAttribute Len 16 Prio (7,0) flag 0x7 "FRR-Test"
  Sender7  Len 12 192.168.32.1(port/lsp ID  1)
  Tspec    Len 36 rate 0bps size 0bps peak Infbps m 20 M 1500
  ADspec   Len 48
  SrcRoute Len 28  10.222.6.1 S 10.222.5.2 S 10.222.4.1 S
  LabelRequest Len  8 EtherType 0x800
  Properties Len 12 Primary path
  RecRoute Len 12  10.222.6.2
```

Facility Link Protection - Resv

- **Resv message for the protected LSP is transmitted back to the ingress router**
  - **RRO contains labels assigned to the LSP**

```
RSVP send Resv 10.222.6.1->10.222.6.2 Len=160 so-0/1/2.0
  Session7 Len 16 192.168.16.1(port/tunnel ID 25118) Proto 0
  Hop      Len 12 10.222.6.1/0x0857cd8c
  Time     Len  8 30000 ms
  Style    Len  8 SE
  Flow     Len 36 rate 0bps size 0bps peak Infbps m 20 M 1500
  Filter7  Len 12 192.168.32.1(port/lsp ID  1)
  Label    Len  8  100112
  RecRoute Len 52  10.222.6.1(Label=100112) 10.222.5.2(Label=100096)
                     10.222.4.1(Label=3)
```

Facility Link Protection - Bypass

- **PLR generates a Path message to establish the Next-Hop Bypass LSP**

```
RSVP send Path 192.168.96.1->192.168.0.1 Len=208 so-0/1/1.0
  Session7 Len 16 192.168.0.1(port/tunnel ID 9546) Proto 0
  Hop      Len 12 10.222.9.1/0x0857ccc0
  Time     Len  8 30000 ms
  SessionAttribute Len 28 Prio (7,0) flag 0x4 "Bypass->10.222.5.2"
  Sender7  Len 12 192.168.96.1(port/lsp ID  1)
  Tspec    Len 36 rate 0bps size 0bps peak Infbps m 20 M 1500
  ADspec   Len 48
  SrcRoute Len 20  10.222.9.2 S 10.222.8.1 S
  LabelRequest Len  8 EtherType 0x800
  RecRoute Len 12  10.222.9.1
```

Facility Link Protection - Bypass

- **PLR receives a Resv message which confirms the Next-Hop Bypass LSP is established**

```
RSVP recv Resv 10.222.9.2->10.222.9.1 Len=128 so-0/1/1.0
  Session7 Len 16 192.168.0.1(port/tunnel ID 9546) Proto 0
  Hop      Len 12 10.222.9.2/0x0857ccc0
  Time     Len  8 30000 ms
  Style    Len  8 SE
  Flow     Len 36 rate 0bps size 0bps peak Infbps m 20 M 1500
  Filter7  Len 12 192.168.96.1(port/lsp ID  1)
  Label    Len  8  100256
  RecRoute Len 20  10.222.9.2 10.222.8.1
```

Facility Link Protection – Notify Ingress

- **PLR sets flags in RRO stating that protection is available**

```
RSVP send Resv 10.222.6.1->10.222.6.2 Len=160 so-0/1/2.0
  Session7 Len 16 192.168.16.1(port/tunnel ID 25118) Proto 0
  Hop      Len 12 10.222.6.1/0x0857cd8c
  Time     Len  8 30000 ms
  Style    Len  8 SE
  Flow     Len 36 rate 0bps size 0bps peak Infbps m 20 M 1500
  Filter7  Len 12 192.168.32.1(port/lsp ID  1)
  Label    Len  8  100112
  RecRoute Len 52  10.222.6.1(flag=1 Label=100112) 10.222.5.2(flag=1 Label=100096)
                     10.222.4.1(Label=3)
```

Facility Node Protection - Path

- **Initial Path message from the ingress is received on the 96.1 router**
  - **Session Attribute flags set to 0x17 for link (0x01), label recording (0x02), SE reservation (0x04), and node protection (0x10)**

```
RSVP recv Path 192.168.32.1->192.168.16.1 Len=216 so-0/1/2.0
  Session7 Len 16 192.168.16.1(port/tunnel ID 25121) Proto 0
  Hop      Len 12 10.222.6.2/0x0857cd8c
  Time     Len  8 30000 ms
  SessionAttribute Len 16 Prio (7,0) flag 0x17 "FRR-Test"
  Sender7  Len 12 192.168.32.1(port/lsp ID  1)
  Tspec    Len 36 rate 0bps size 0bps peak Infbps m 20 M 1500
  ADspec   Len 48
  SrcRoute Len 28  10.222.6.1 S 10.222.5.2 S 10.222.4.1 S
  LabelRequest Len  8 EtherType 0x800
  Properties Len 12 Primary path
  RecRoute Len 12  10.222.6.2
```

Facility Node Protection - Resv

- **Resv message for the protected LSP is transmitted back to the ingress router**
  - **RRO contains labels assigned to the LSP**

```
RSVP send Resv 10.222.6.1->10.222.6.2 Len=160 so-0/1/2.0
  Session7 Len 16 192.168.16.1(port/tunnel ID 25121) Proto 0
  Hop      Len 12 10.222.6.1/0x0857cd8c
  Time     Len  8 30000 ms
  Style    Len  8 SE
  Flow     Len 36 rate 0bps size 0bps peak Infbps m 20 M 1500
  Filter7  Len 12 192.168.32.1(port/lsp ID  1)
  Label    Len  8  100128
  RecRoute Len 52  10.222.6.1(Label=100128) 10.222.5.2(Label=100112)
                     10.222.4.1(Label=3)
```

Facility Node Protection - Bypass

- **PLR generates a Path message to establish the Next-Next-Hop Bypass LSP**

```
RSVP send Path 192.168.96.1->192.168.16.1 Len=236 so-0/1/1.0
  Session7 Len 16 192.168.16.1(port/tunnel ID 9547) Proto 0
  Hop      Len 12 10.222.9.1/0x0857ccc0
  Time     Len  8 30000 ms
  SessionAttribute Len 40 Prio (7,0) flag 0x4 "Bypass->10.222.5.2->10.222.4.1"
  Sender7  Len 12 192.168.96.1(port/lsp ID  1)
  Tspec    Len 36 rate 0bps size 0bps peak Infbps m 20 M 1500
  ADspec   Len 48
  SrcRoute Len 36  10.222.9.2 S 10.222.11.2 S 10.222.12.1 S 10.222.7.2 S
  LabelRequest Len  8 EtherType 0x800
 RecRoute Len 12  10.222.9.1
```

Facility Node Protection - Bypass

- **PLR receives a Resv message which confirms the Next-Next-Hop Bypass LSP is established**

```
RSVP recv Resv 10.222.9.2->10.222.9.1 Len=144 so-0/1/1.0
  Session7 Len 16 192.168.16.1(port/tunnel ID 9547) Proto 0
  Hop      Len 12 10.222.9.2/0x0857ccc0
  Time     Len  8 30000 ms
  Style    Len  8 SE
  Flow     Len 36 rate 0bps size 0bps peak Infbps m 20 M 1500
  Filter7  Len 12 192.168.96.1(port/lsp ID  1)
  Label    Len  8  100272
  RecRoute Len 36  10.222.9.2 10.222.11.2 10.222.12.1 10.222.7.2
```

Facility Node Protection – Notify Ingress

- **PLR sets flags in RRO stating that protection is available**

```
RSVP send Resv 10.222.6.1->10.222.6.2 Len=160 so-0/1/2.0
  Session7 Len 16 192.168.16.1(port/tunnel ID 25121) Proto 0
  Hop      Len 12 10.222.6.1/0x0857cd8c
  Time     Len  8 30000 ms
  Style    Len  8 SE
  Flow     Len 36 rate 0bps size 0bps peak Infbps m 20 M 1500
  Filter7  Len 12 192.168.32.1(port/lsp ID  1)
  Label    Len  8  100128
  RecRoute Len 52  10.222.6.1(flag=9 Label=100128)
                   10.222.5.2(flag=1 Label=100112) 10.222.4.1(Label=3)
```

Failure Mode Processing

- **Protected LSP is using facility link protection**
  - **Link failure between egress and penultimate hop generates PathErr messages upstream**
  - **We see this from the viewpoint of the 96.1 router**

```
RSVP recv PathErr 10.222.5.2->10.222.5.1 Len=84 so-0/1/0.0
  Session7 Len 16 192.168.16.1(port/tunnel ID 25126) Proto 0
  Error    Len 12 code 25 value 3 flag 0 by 10.222.5.2
  Sender7  Len 12 192.168.32.1(port/lsp ID  1)
  Tspec    Len 36 rate 0bps size 0bps peak Infbps m 20 M 1500

RSVP send PathErr 10.222.6.1->10.222.6.2 Len=84 so-0/1/2.0
  Session7 Len 16 192.168.16.1(port/tunnel ID 25126) Proto 0
  Error    Len 12 code 25 value 3 flag 0 by 10.222.5.2
  Sender7  Len 12 192.168.32.1(port/lsp ID  1)
  Tspec    Len 36 rate 0bps size 0bps peak Infbps m 20 M 1500
```

Failure Mode Processing

- **Next-Hop Bypass LSP is currently in use**
  - **Flags in received RRO on the 96.1 router tell us that protection is in use**

```
RSVP recv Resv 10.222.5.2->10.222.5.1 Len=144 so-0/1/0.0
  Session7 Len 16 192.168.16.1(port/tunnel ID 25126) Proto 0
  Hop      Len 12 10.222.5.2/0x0857cbf4
  Time     Len  8 30000 ms
  Style    Len  8 SE
  Flow     Len 36 rate 0bps size 0bps peak Infbps m 20 M 1500
  Filter7  Len 12 192.168.32.1(port/lsp ID  1)
  Label    Len  8  100144
  RecRoute Len 36  10.222.5.2(flag=3 Label=100144) 10.222.7.2(Label=3)
```

Questions and Comments

- **Feedback on this presentation is highly encouraged**
  - **jms@juniper.net**
- **Questions?**

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Thank you!

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