Cisco Systems

MPLS Deployment Forum London – 14/03/02

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MPLS Traffic Engineering Fast Reroute

Agenda

- Introduction
- Terminology of protection/restoration
    - Protection versus Restoration,
    - Protection: 1+1, M:N, 1:1,
    - Restoration,
    - Time to restore and Time to switch back,
    - Local versus Global repair,
    - Usage of protected Path,
    - Revertive versus Non revertive mode

Agenda

- MPLS Traffic Engineering
    - Global restoration: TE LSP rerouting
    - Global protection: Path protection
    - Local protection:
        - Link protection
        - Node protection
    - Backup path computation and provisioning
- IETF Update
- Conclusion

Agenda

- Introduction
- Terminology of protection/restoration
- MPLS Traffic Engineering Fast Reroute
- IETF Update
- Conclusion

Protection/Restoration in IP/MPLS networks

As IP/MPLS networks carry a very large amount of critical IP traffic (MPLS VPN, VoIP, …)

Protection/Restoration is a key component of the overall architecture just as Routing, QOS, …

Protection/restoration in IP/MPLS networks

- Many various protection/restoration schemes (co)exist today:

  Optical protection

  Sonet/SDH

  IP

  MPLS Traffic Engineering Fast Reroute

- The objective being to avoid double protection

Protection/Restoration in IP/MPLS networks

- IP routing protocol typically offers a convergence on the order of seconds (default=40s with OSPF, 30s with ISIS)
- IP restoration is Robust and protects against link AND node protection
- IP convergence may be dramatically improve and could easily offers a few seconds convergence (1, 2, 3 secs ?) using various enhancements:

  fast fault detection,

  fast SPF and LSA propagation triggering,

  priority flooding,

  Incremental Dijsktra,

  Load Balancing

Protection/Restoration in IP/MPLS networks

- 1-3 secs may be sufficient for some traffic as others (ex: voice trunking) will require more aggressive target, typically 50 ms.
- Solutions ?
  - Optical protection,
  - Sonet/SDH (GR 253)
  - MPLS protection/restoration

Protection/Restoration in IP/MPLS networks

MPLS Traffic Engineering Protection/Restoration

- Compared to lower layers mechanism, MPLS offers:
  - A protection against link AND node failures
  - A much better bandwidth usage
  - Finer granularity. Different level of protection may be applied to various classes of traffic.
    - Ex: an LSP carrying VoIP traffic will require a 50ms protection scheme as Internet traffic may rely on IP convergence
  - A much cost effective protection mechanism

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Protection/Restoration in GMPLS networks

Terminology

- Protection: a back-up path is pre-established to be used as soon as the failure has been detected
- Restoration: set of mechanisms by which a new path is being dynamically calculated as soon as the failure has been detected and propagated
- Protection is faster, requires more spare resources but provides stronger guarantees.
- Protection may be combined with Restoration

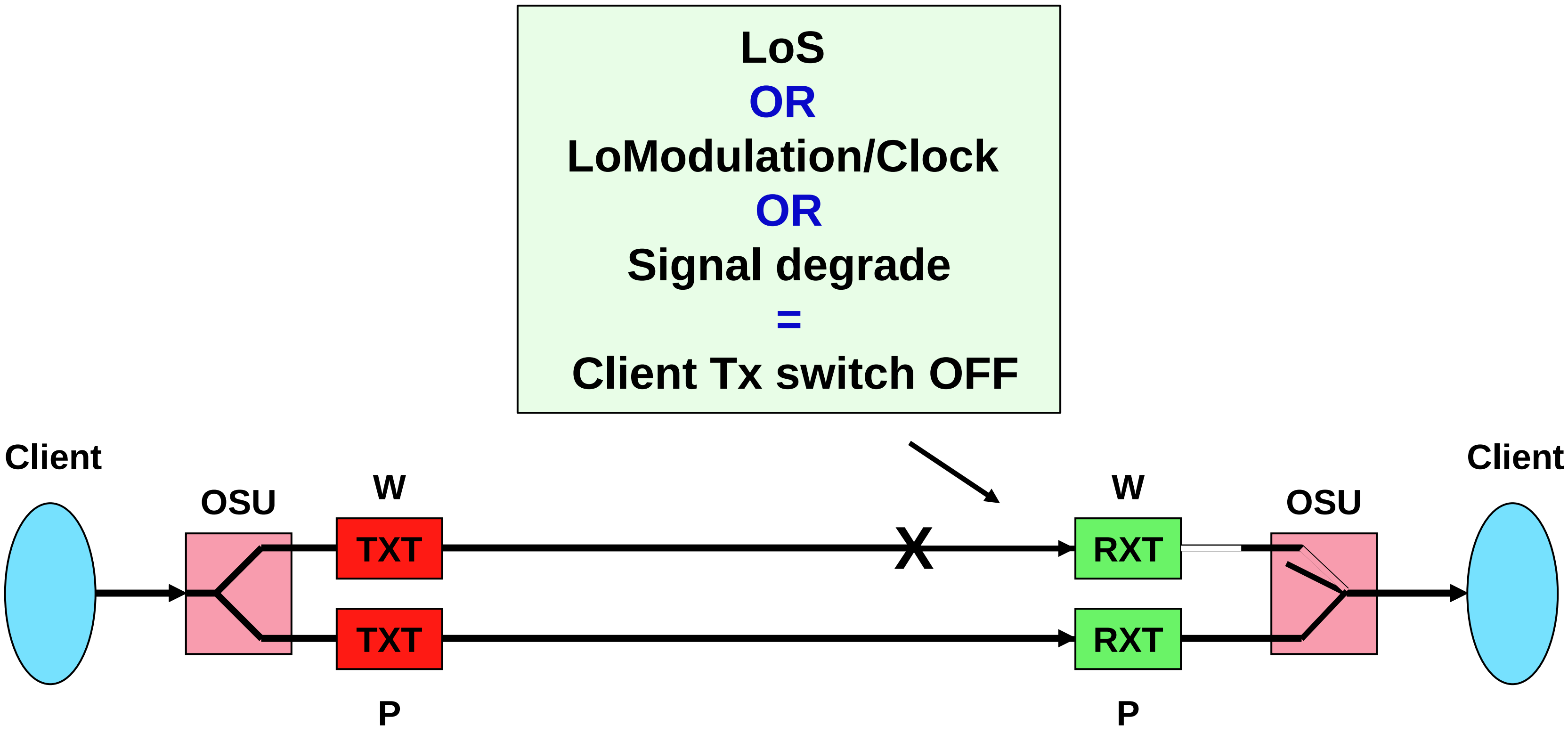
Protection/Restoration in IP/MPLS networks

Protection

- 1+1 the traffic is being duplicated on the protected path (constantly bridged).
- The Path switch LSR performs the switching or replication of the traffic between the working and recovery path.
- The Path Merge LSR receives both the working and recovery path traffics and performs the selection.
- Switching is performed at the tail-end which does not require sophisticated signalling (also called single ended protocol)

Protection/Restoration in IP/MPLS networks

Example: 1+1 protection in Point to point DWDM system (similar protection scheme exists in Optical mesh network)



LoS
OR
LoModulation/Clock
OR
Signal degrade
=
Client Tx switch OFF

1+1 protection does not exist in IP/MPLS

Protection/Restoration in IP/MPLS networks

Protection (cont)

- **M:N: M protected paths for N working paths are signalled <u>but may be used for low priority traffic</u> which makes a more efficient use of the spare resource.**
- **When a failure occurs, the protected path is requested and low priority traffic is preempted.**
- **Ex: 1:1, 1 protected path being established for every working path**

Restoration

- Once the failure has been detected, propagated and signalled, a new path/route is dynamically calculated
- A well known example is IP
  - The failure is detected (through the layer 2 protocol or IGP hellos)
  - The failure is propagated (through the LSP flooding)
  - A new route is dynamically calculated (SPF) and the routing table is updated

Protection/Restoration in IP/MPLS networks

Examples

- **<u>Protection</u>**

  1+1 Optical protection (single ended protocol) ←

  Sonet/SDH BLSR and UPSR ← 10-50 msecs

  MPLS Fast Reroute (link and node protection) ←

  MPLS TE Path protection, ← Θ(100 (s) of msecs)

- **<u>Restoration</u>**

  IP routing protocol ← 2 – 40 seconds

  MPLS TE LSP reroute ← Θ(s)

Protection/Restoration in IP/MPLS networks

TTR: Time to Restore (convergence time)

- TTR = time between the fault and traffic recovery

  Fault detection may differ from the lower layers

  Hold-off timer. Waiting time to let lower layers protection mechanisms (if any) to operate. May be 0

  Fault localization

  Fault notification. May be a non negligible factor, the propagation delay may be relatively high even compared to the path calculation in Restoration techniques.

  Fault restoration. Time once the fault has been detected, localized and notified for the LSR in charge of rerouting the traffic to actually reroute the traffic (also called switch over)

TTS (Time to switch back)

- **TTS = once the fault has been cleared, time to switch back to the previous working path.**

  Fault clearing time. Time to detect the fault has been cleared. Highly depends on lowers layers.

  Wait to Restore timer. Allows not to switch back immediately to improve stability in case of flapping. A back-off mechanism may also be used there.

  Traffic restoration time

Protection/Restoration in IP/MPLS networks

Scope of recovery: local repair versus global repair

- **Local (link/node) repair: the recovery is being performed by the node immediately upstream to the failure**

  Protection (most of the time): the protected (back-up) path is pre-established and diversely routed from the working path

  Restoration: the back-up path is dynamically established around the failure network component (link or node)

- **Example**

  MPLS local repair FRR (link/node protection)

Protection/Restoration in IP/MPLS networks

- Global repair: the recovery is being performed by the head-end (where the LSP is initiated)

  Both restoration and protection may be used.

  The head-end needs a notification also called FIS (Fault indication signal).

- Then, the head-end may use restoration to reroute the traffic or protection to reroute the traffic onto a pre established protected path

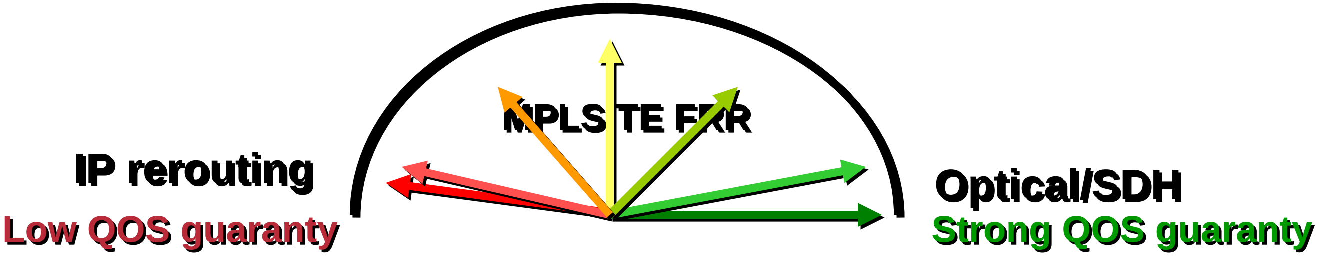
Protection/Restoration in IP/MPLS networks

- Slower than local repair (propagation delay of the FIS may be a non negligible component)
- Examples of global repair mechanisms
  - IP is a global repair mechanism using restoration. TTR is typically Θ(s)
  - MPLS TE Path protection is a global repair mechanism that may use
    - Protection: the protected TE LSP is pre signalled
    - Restoration: the protected TE LSP is dynamically established

Protection/Restoration in IP/MPLS networks

- **Path mapping**: refers to the method of mapping traffic from the faulty working path onto the protected path (1:1, M:N)

- **QOS of the protected path**: does the protected path offer an equivalent QOS as the working path during failure ?



- **Recovery granularity**: from a portion of one working path to a bundle of working path.

Protection/Restoration in IP/MPLS networks

- Usage of the protected path

  Dedicated 1+1: the back-up LSP (protected) cannot be used for low priority traffic

  Dedicated 1:1 and shared M:N. The back-up path may be used for low priority traffic.

Protection/Restoration in IP/MPLS networks

Switch back operation

- Revertive versus non revertive

  In revertive mode, once the failure is cleared the working path is being automatically re established (always preferred to the protected path)

  In non revertive mode, when the faulty path is restored, it may become the recovery path.

Protection/Restoration in IP/MPLS networks

Performance

- The recovery class may or not be equivalent
- IP offer a lower class, MPLS TE may offer an equivalent or lower class

Protection/Restoration in IP/MPLS networks

A few comparison criterias

- Recovery time
- Setup vulnerability
- Back-up capacity
- Additive latency
- Protection QOS
- Re-ordering
- State overhead
- Loss
- Coverage (link/node, concurrent faults, % of coverage, number of recovery paths, number of protected paths, …)

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Terminology

Terminology

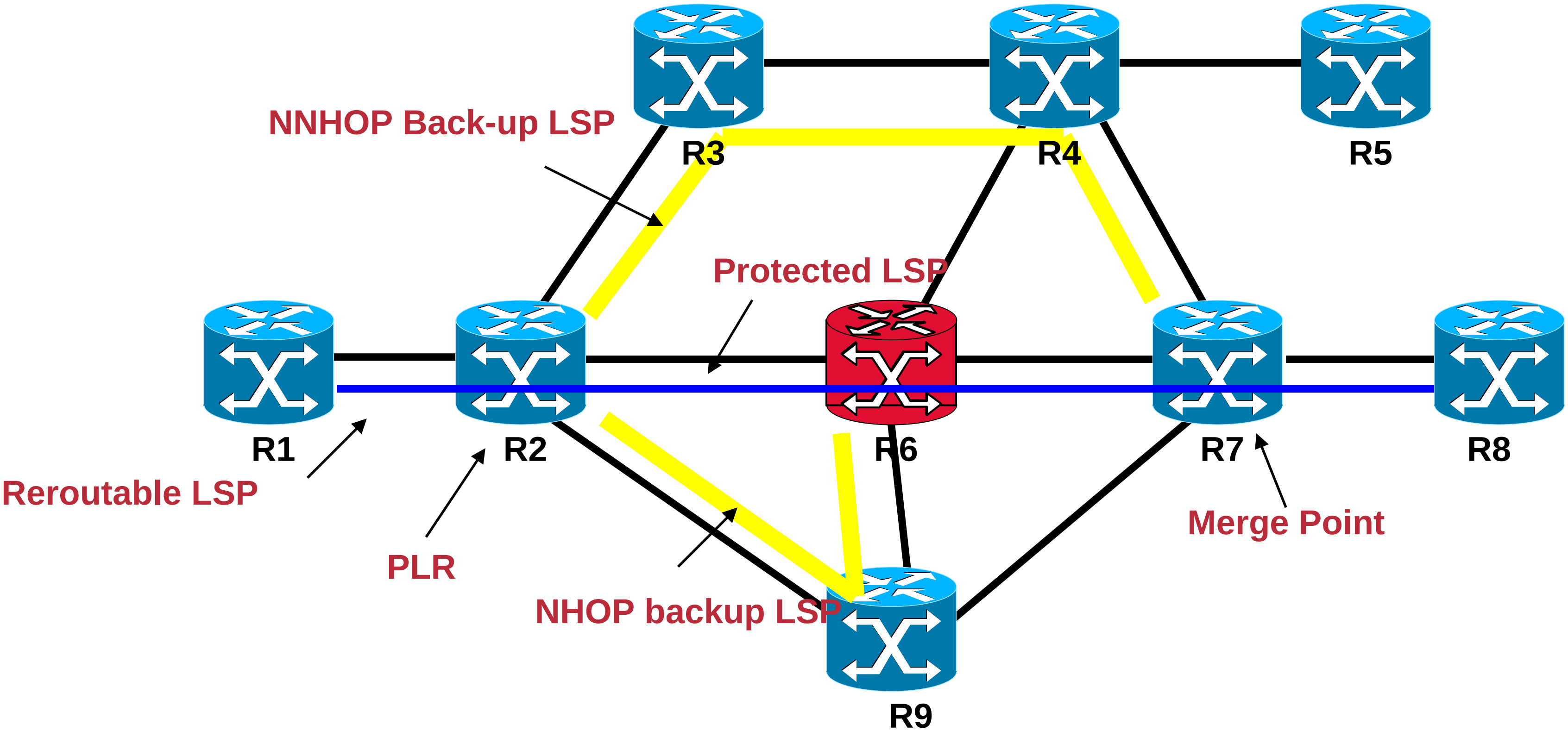
- Reroutable LSP: TE LSP for which a local protection is desired
- Protected LSP: an LSP is being protected at a HOP H if and only if it does have a backup tunnel associated at hop H.
- Primary LSP: a protected LSP prior to any failure
- PLR: Point of local repair (head-end of the backup tunnel)
- Backup tunnel/LSP: TE LSP used to backup the protected LSP

Terminology

Terminology (cont)

- **Merge point: Tail-end of the backup tunnel**
- **NHOP backup tunnel: a Backup Tunnel which bypasses a single link of the Primary Path.**
- **NNHOP backup tunnel: a Backup Tunnel which bypasses a single node of the Primary Path.**

Terminology



MPLS TE LSP rerouting (Global restoration)

MPLS TE rerouting

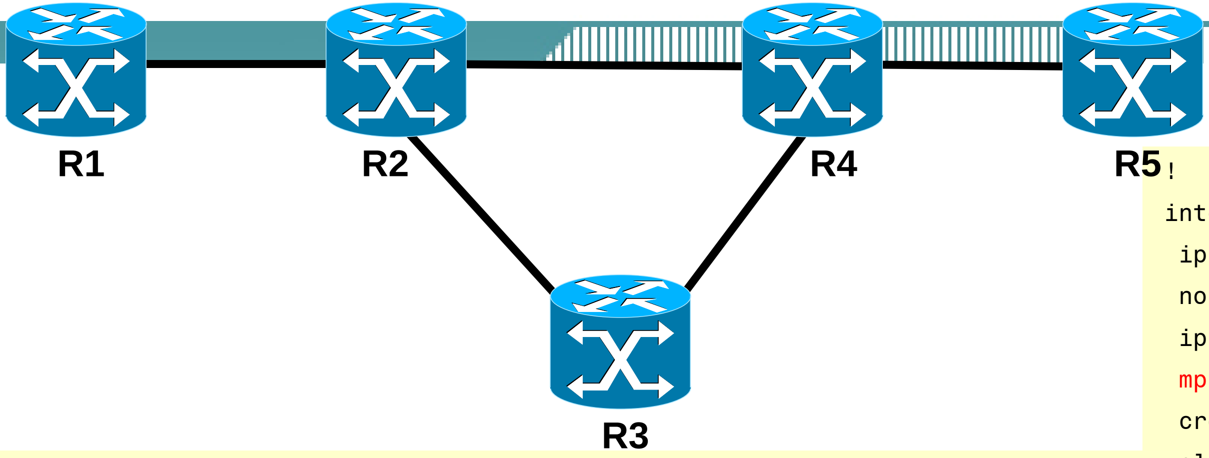
TE LSP rerouting (Global restoration)

- Controlled by the head-end of a trunk via the resilience attribute of the trunk
- Fallback to either (pre)configured or dynamically computed path. Pre-configured path may be either pre-established, or established “on demand”

```
interface Tunnel0
 ip unnumbered Loopback0
 no ip directed-broadcast
 tunnel destination 10.0.1.102
 tunnel mode mpls traffic-eng
 tunnel mpls traffic-eng autoroute announce
 tunnel mpls traffic-eng priority 3 3
 tunnel mpls traffic-eng bandwidth 10000
 tunnel mpls traffic-eng path-option 1 explicit name prim_path
 tunnel mpls traffic-eng path-option 2 dynamic
```

```
ip explicit-path name prim_path
enable
 next-address 10.0.1.123
 next-address 10.0.1.100
```

MPLS TE rerouting

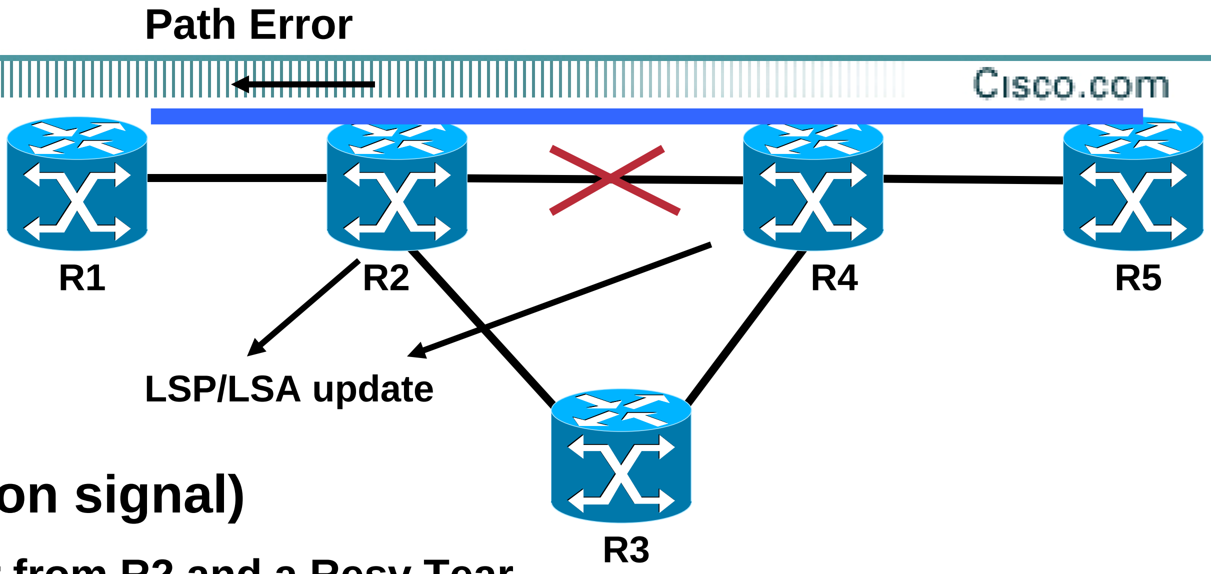


All the routers have standard MPLS TE configuration

```
!
mpls traffic-eng tunnels
clns routing
!
interface Tunnel0
 ip unnumbered Loopback0
 no ip directed-broadcast
 tunnel destination 10.0.1.102
 tunnel mode mpls traffic-eng
 tunnel mpls traffic-eng autoroute announce
 tunnel mpls traffic-eng priority 3 3
 tunnel mpls traffic-eng bandwidth 10000
 tunnel mpls traffic-eng path-option 1 dynamic
 tunnel mpls traffic-eng record-route
 !
```

```
!
interface POS0/0
 ip address 10.1.33.5 255.255.255.252
 no ip directed-broadcast
 ip router isis
 mpls traffic-eng tunnels
 crc 32
 clock source internal
 pos framing sdh
 pos scramble-atm
 pos flag s1s0 2
 ip rsvp bandwidth 155000 155000
!
!
router isis
 passive-interface Loopback0
 mpls traffic-eng router-id Loopback0
 mpls traffic-eng level-2
 net 49.0001.0000.0000.0011.00
 is-type level-2-only
 metric-style transition
 log-adjacency-changes
!
```

MPLS TE rerouting



- **The FIS (failure indication signal)**

  *** R1 receives a Path Error from R2 and a Resv Tear**

  *** R1 will receive a new LSA/LSP indicating the R2-R4 is down and will conclude the LSP has failed (if R1 is in the same area as the failed network element)**

  Which one on those two events will happen first ? It depends of the failure type and IGP tuning

- **An optimisation of the Path Error allows to remove the failed link from the TE database to prevent to retry the same failed link (if the ISIS LSP or the OSPF LSA has not been received yet).**

  mpls traffic-eng topology holddown sigerr <seconds>

MPLS TE rerouting

- **Use RSVP pacing to limit the loss of RSVP message in case of rerouting of several TE LSP:**

```
ip rsvp msg-pacing [period msec [burst msgs [max_size qsize]]]
```

- **ISIS scanner (controls the propagation of TE information form ISIS to the TE database) may be used to speed-up convergence:**

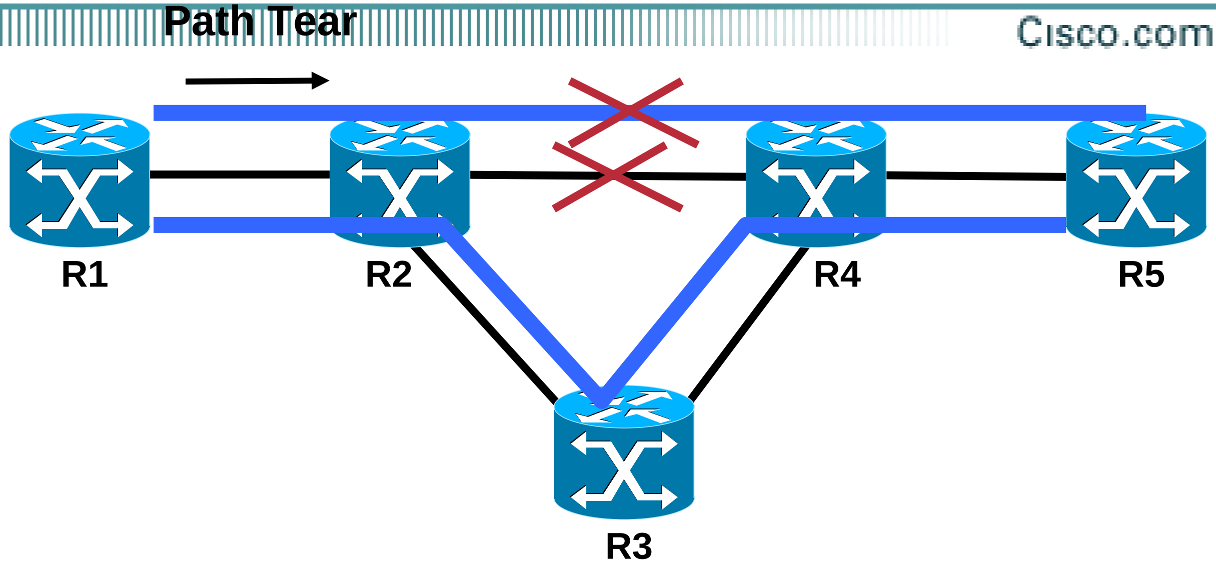
```
mpls traffic-eng scanner [interval <1-60>] [max-flash <0-200> ]
```

Interval: 5 seconds

Max-flash: 15 updates

MPLS TE rerouting

- R1 is now informed that the LSP has suffered a failure



- R1 clear the Path state with an RSVP Path Tear message
- R1 recalculates a new Path for the Tunnel and will signal the new tunnel. If no Path available, R1 will continuously retry to find a new path (local process)
- PATH Protection time = O(s).

Does it reach the target ?

MPLS TE rerouting

MPLS Traffic Engineering TE LSP reroute

- TTR= time between the fault and restoration

Fault detection may differ from the lower layers. May be done by the IGP (hello's), layer 2 triggers

Hold-off timer. 0

Fault notification. Fault Indication Signal may be

* the IGP (LSA/LSP update)

* RSVP Path Error/Resv Tear/RSVP notify message

FIS should be reliably transmitted with high priority.

RSVP notify message may also be used.

MPLS TE rerouting

MPLS TE reroute (cont)

Fault restoration.

Restoration: the head must recalculate a Path (CSPF), signal the LSP and reroute the traffic

TTR = O(seconds)

MPLS TE Path Protection (global protection)

MPLS TE Path Protection

MPLS TE Path Protection

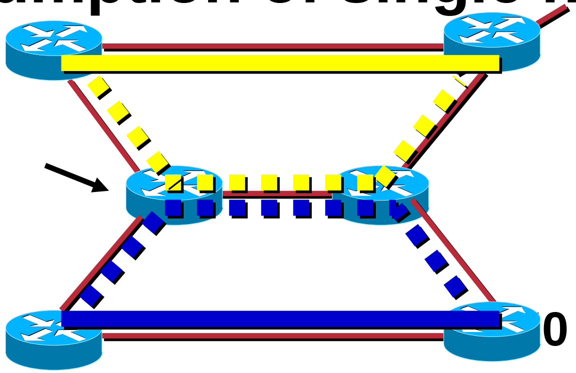
- MPLS TE Path Protection is a global repair mechanism using protection switching
- The idea is to be able to set up a primary LSP AND a back-up LSP (pre-signalled) so once the failure has been detected and signalled (by the IGP or RSVP signalling) to the head-end the traffic can be switched onto the back-up LSP
- No path computation and signalling of the new LSP once the failure has been detected and propagated to the head-end (compared to LSP reroute)

MPLS TE Path Protection

- By configuration the TE back-up LSP attributes may or not be different as the primary TE LSP:
  - The bw of the back-up LSP may some % of the primary bw
  - RCA of the back-up LSP may or not be taken into account
- Diversely routed paths are calculated by the CSPF on the head-end (they may be link, node or SRLG diverse)

MPLS TE Path Protection

- **Limitation of MPLS TE Path protection**
  - **The FIS propagation may be unacceptable especially for very sensitive traffic,**
  - **The number of states in the network is doubled !!**
  - **CSPF is likely to be highly inefficient in term of bandwidth usage.**
    - **→primary diversely routed paths may share backup bandwidth (under the assumption of single network element failure)**



Shared capacity

MPLS TE Path Protection

- **Path protection may be an attractive solution if and only if:**
  - **Just a few LSPs require protection**
  - **A few hundreds of msecs convergence time is acceptable**

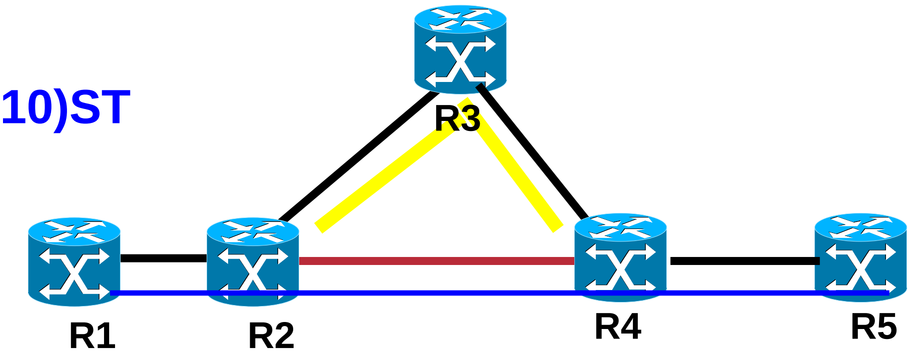
Principles of
MPLS TE Fast Reroute
(local protection)

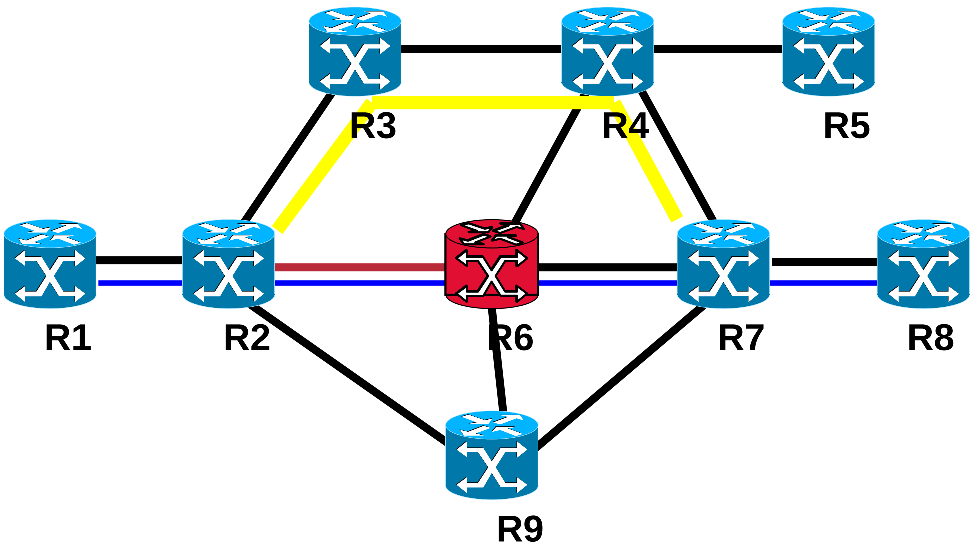
MPLS TE FRR – Local protection

MPLS Fast Reroute local repair

- **Link protection**: the backup tunnel tail-head (MP) is one hop away from the PLR

12.0(10)ST





- **Node protection + Enhancements**: the backup tunnel tail-end (MP) is two hops away from the PLR.

12.0(22)S

MPLS TE FRR – Local protection

- MPLS Fast Reroute link and node protection is:
  - LOCAL (compared to IGP or Path protection which are global protection/restoration mechanisms) which allows to achieve the 50msecs convergence time
  - Uses Protection (to provide fast rerouting)
  - Non Revertive but the previous path may be reused if more optimal (via reoptimization)
  - Reoptimization with Make before break to find a more optimal path

MPLS TE FRR – Local protection

- A key principle of Local repair is to guaranty a very fast traffic recovery with or without QOS guaranty (bandwidth guaranty) during a transient phase while other mechanisms (reoptimization) are used over a longer time scale.

MPLS TE FRR Local repair

- Controlled by the PLR
  - local repair is configured on a per link basis
  - the resilience attribute of a trunk allows to control whether local repair should be applied to the trunk (tu mpls tra fast-reroute).

→“Local Protection Desired” bit of the SESSION_ATTRIBUTE object flag is set.

  - Just the reroutable LSPs will be backed-up (fine granularity)

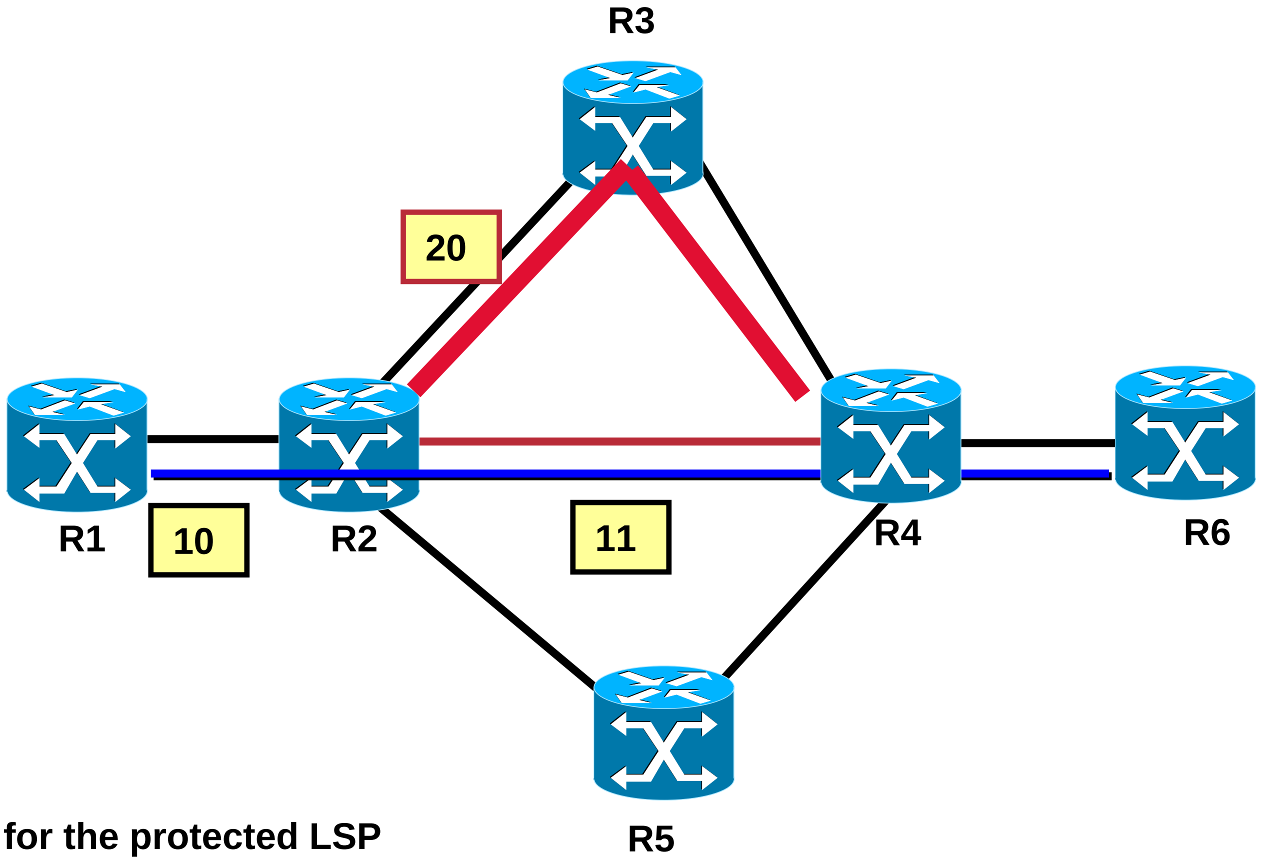
- Uses nested LSPs (stack of labels)

  1:N protection is KEY for scalability. N protected LSP will be backed-up onto the SAME backup LSP

MPLS TE Fast Reroute Link Protection (local protection)

MPLS TE FRR – Link Protection

- **Backup labels (NHOP Backup Tunnel)**

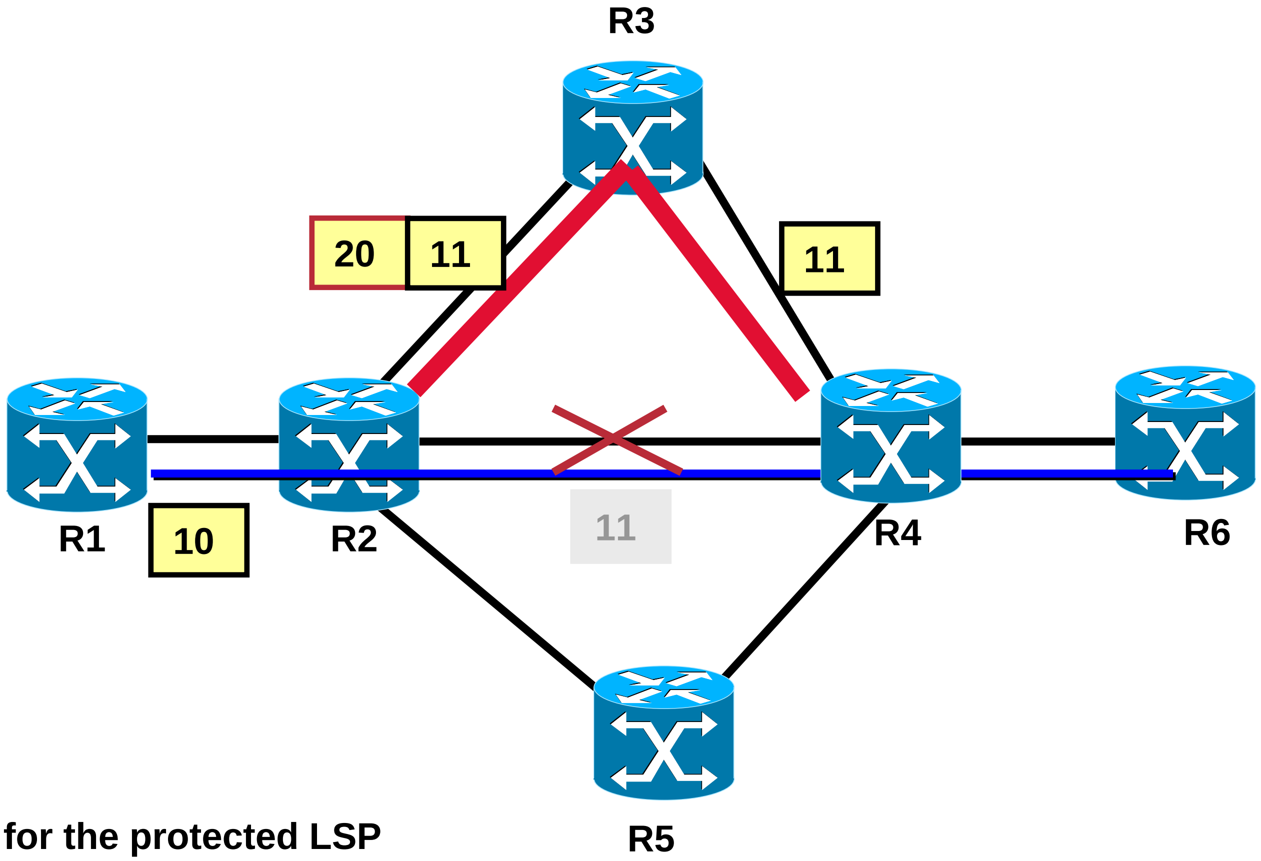


x **Label for the protected LSP**

x **Label for the bypass LSP**

MPLS TE FRR – Link Protection

- **Backup labels (NHOP Backup Tunnel)**

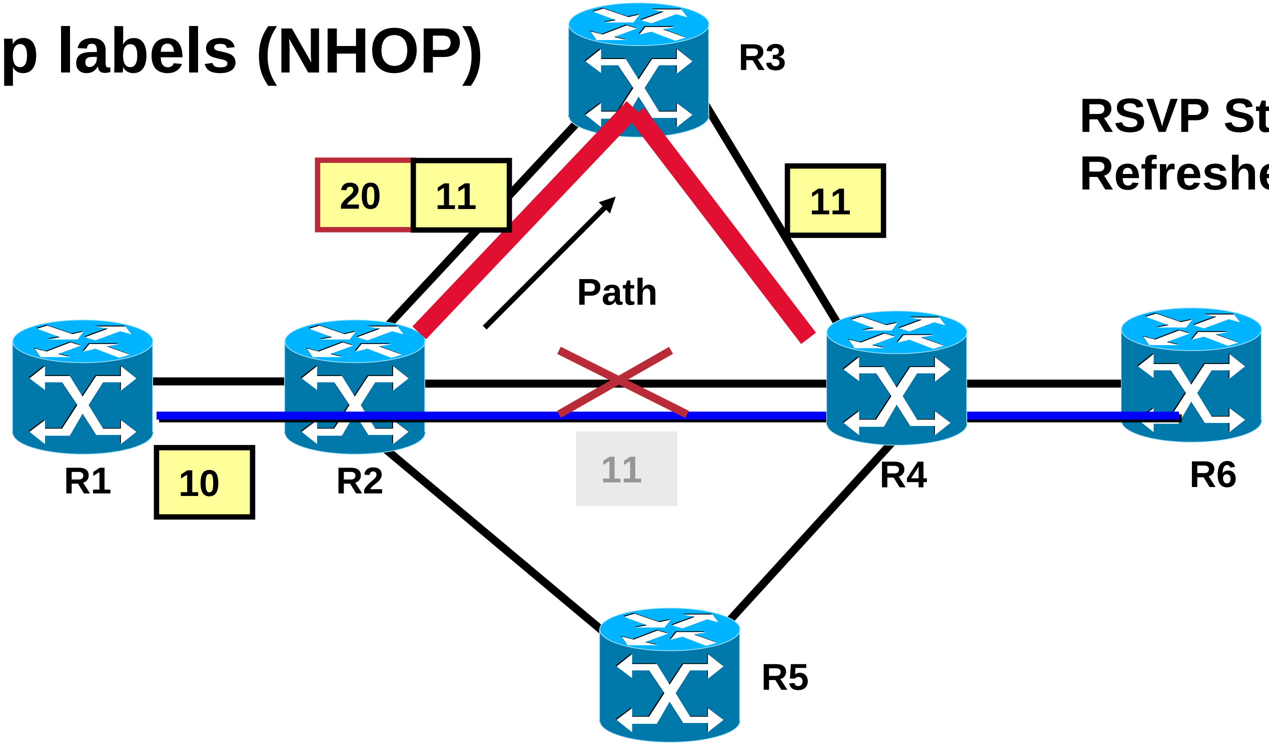


Label for the protected LSP

Label for the bypass LSP

MPLS TE FRR – Link Protection

- Backup labels (NHOP)



RSVP States Refreshes

2 remarks:

* The path message for the old Path are still forwarded onto the Back-Up LSP

* Modifications have been made to the RSVP code so that

- R2 could receive a Resv message from a different interface than the one used to send the Path message

- R4 could receive a Path message from a different interface (R3-R4 in this case)

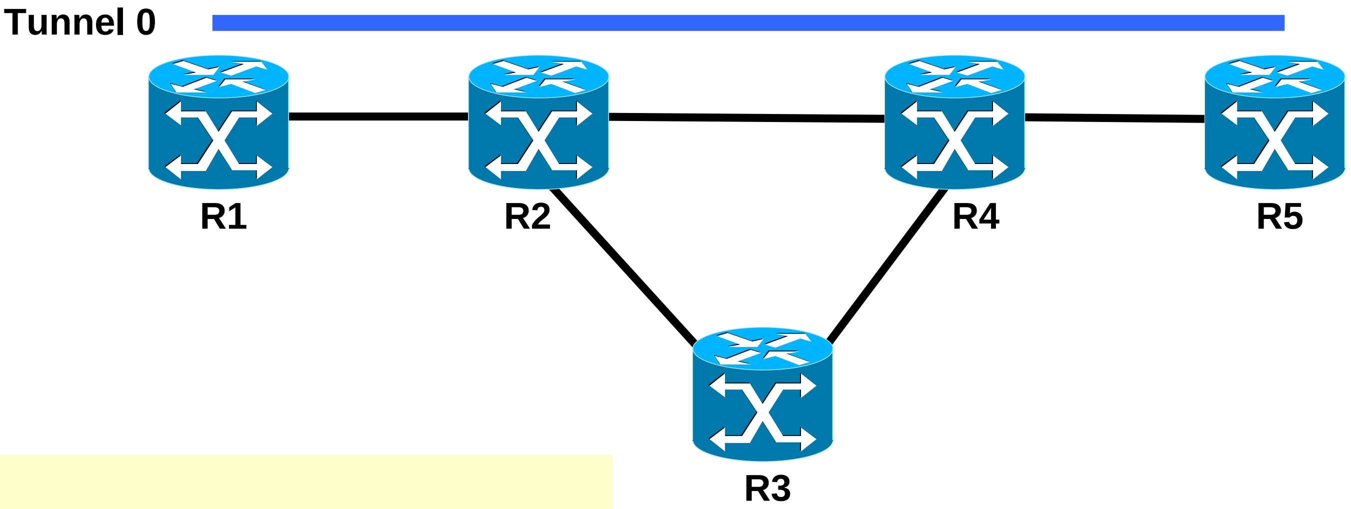
MPLS TE FRR – Link Protection

- The PLR SHOULD send a PathErr message with error code of "Notify" (Error code =25) and an error value field of ss00 cccc cccc cccc where ss=00 and the sub-code = 3 ("Tunnel locally repaired").

→ This will trigger the head-end reoptimization

- Then the TE LSP will be rerouted over an alternate Path (may be identical) using Make Before Break.

MPLS TE FRR - Link Protection - Configuration



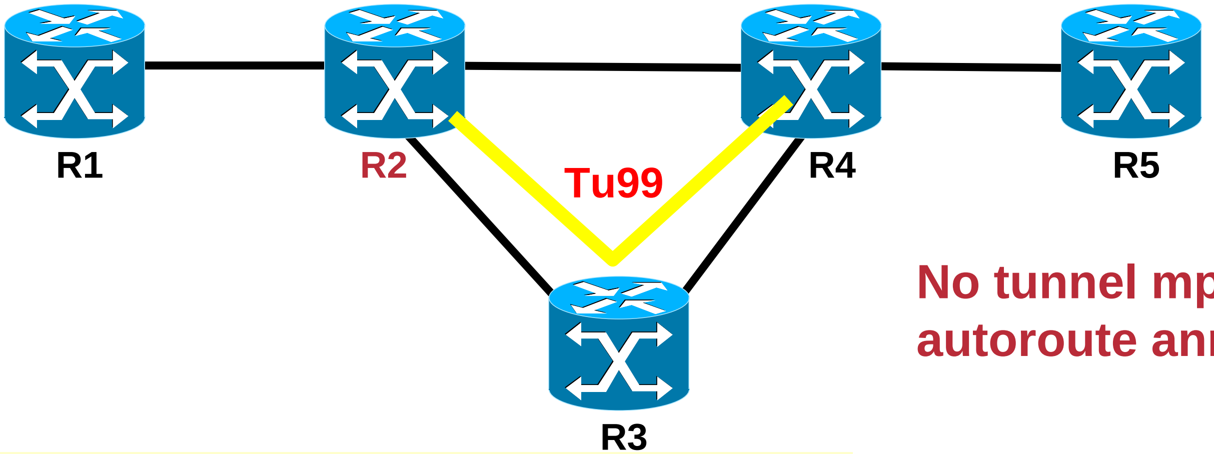
- ***On R1***

```
!
interface Tunnel0
 ip unnumbered Loopback0
 no ip directed-broadcast
 tunnel destination 10.0.1.102
 tunnel mode mpls traffic-eng
 tunnel mpls traffic-eng autoroute announce
 tunnel mpls traffic-eng priority 3 3
 tunnel mpls traffic-eng bandwidth 10000
 tunnel mpls traffic-eng path-option 1 dynamic
 tunnel mpls traffic-eng record-route
 tunnel mpls traffic-eng fast-reroute
```

Tunnel 0 is configured as fast reroutable

"Local Desired Protection" flag set in the SESSION_ATTRIBUTE object

MPLS TE FRR - Link Protection - Configuration



No tunnel mpls traffic-eng autoroute announce !

A Back-Up Tunnel Tu99 explicitly routed is configured on R2

```
interface Tunnel99
 ip unnumbered Loopback0
 no ip directed-broadcast
 tunnel destination 10.0.1.100
 tunnel mode mpls traffic-eng
 tunnel mpls traffic-eng priority 1 1
 tunnel mpls traffic-eng bandwidth 10000
 tunnel mpls traffic-eng path-option 1 explicit name secours
 tunnel mpls traffic-eng record-route
```

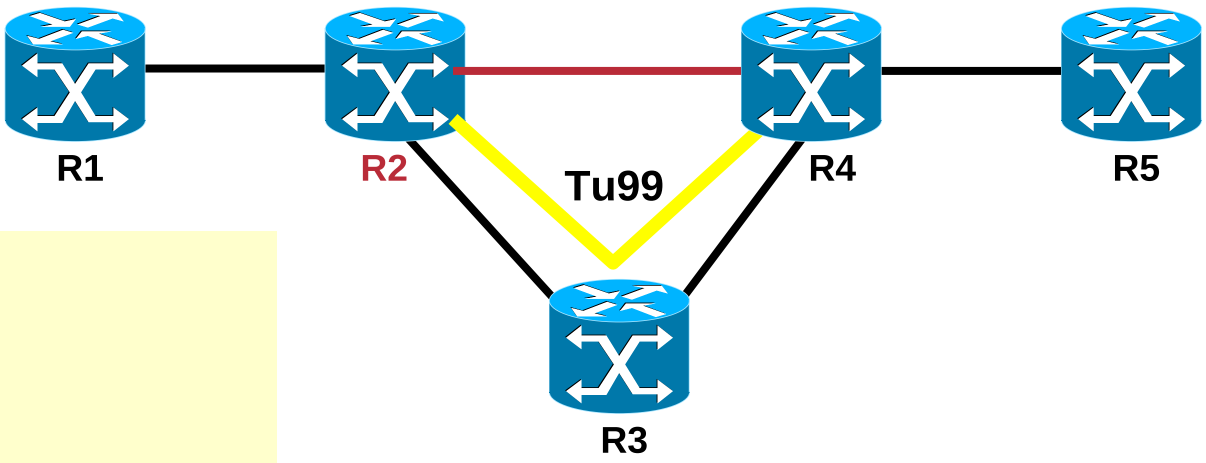
Use also:

Router (cfg-ip-expl-path)# exclude-address a.b.c.d

Where a.b.c.d is a link address or a router ID to exclude a node

```
ip explicit-path name secours enable
 next-address 10.0.1.123
 next-address 10.0.1.100
```

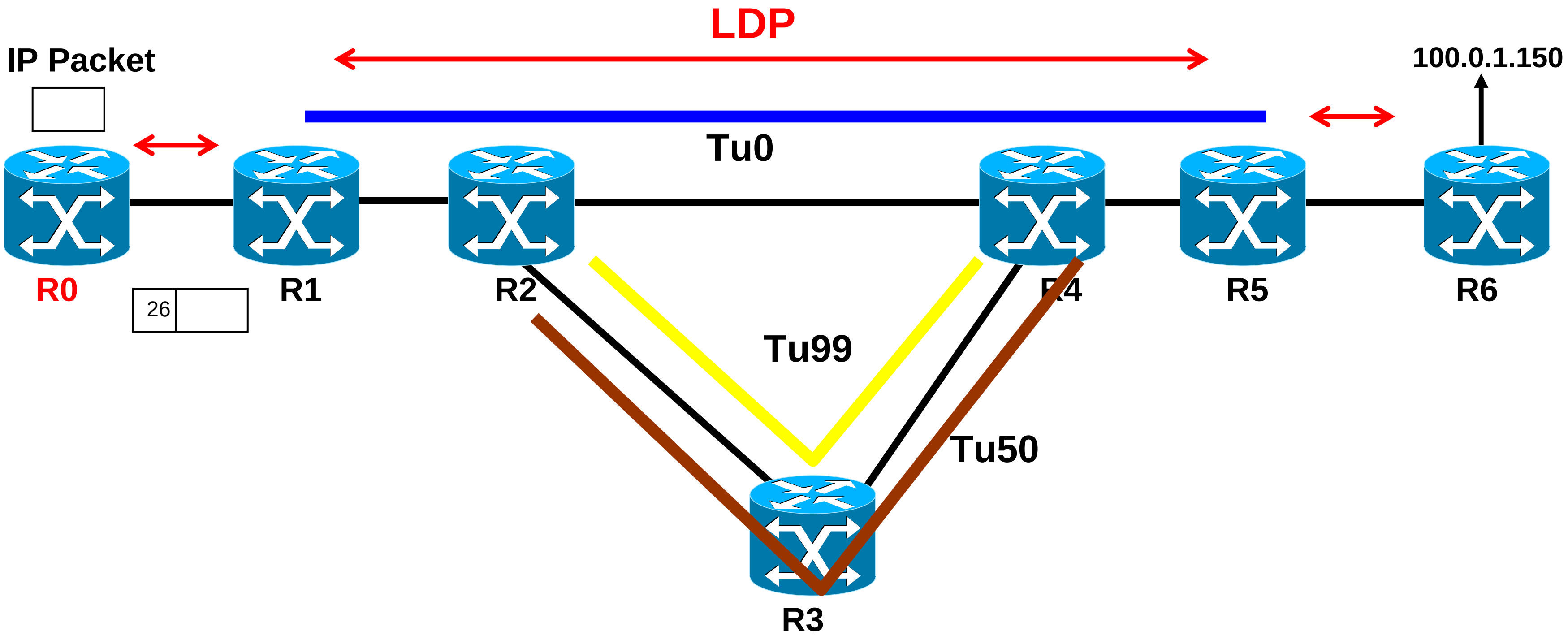
MPLS TE FRR - Link Protection - Configuration



On R2

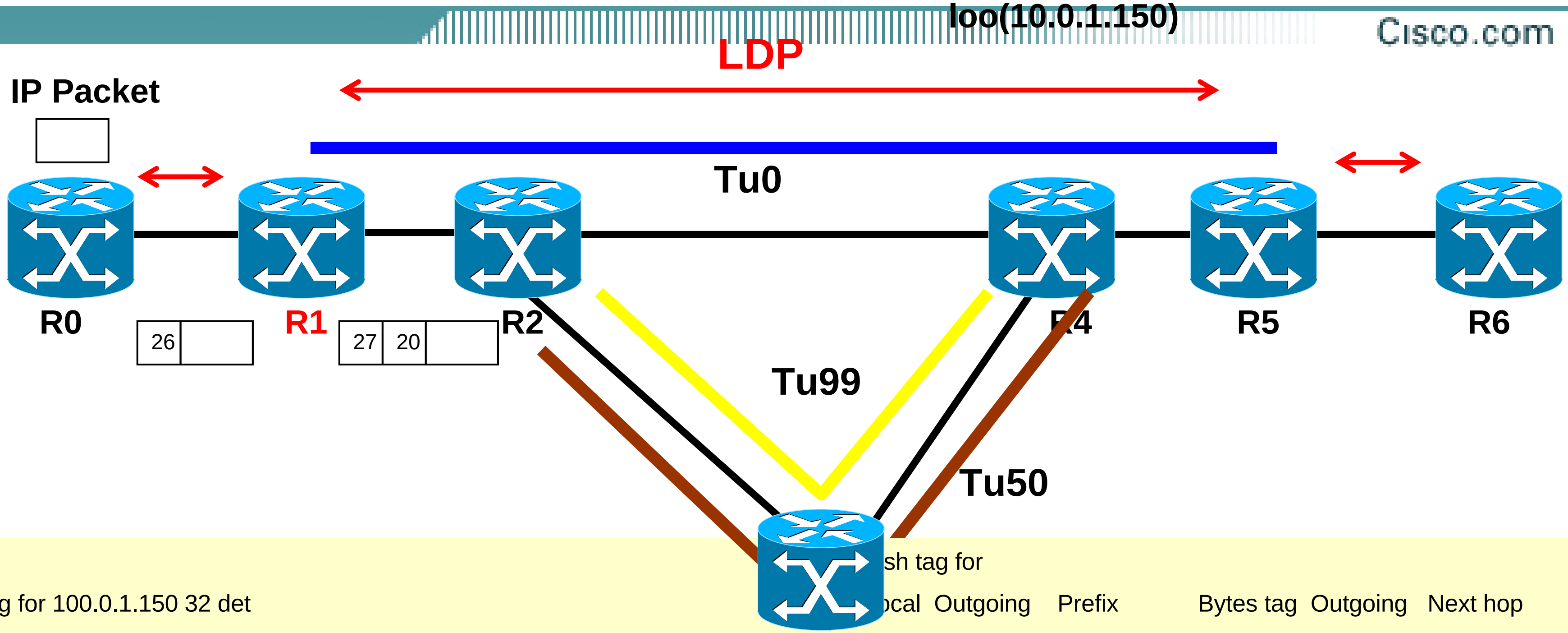
```
interface POS4/0
 description Link to R4
 ip address 10.1.13.2 255.255.255.252
 no ip directed-broadcast
 ip router isis
 encapsulation ppp
 mpls traffic-eng tunnels
 mpls traffic-eng backup-path Tunnel99
 tag-switching ip
 no peer neighbor-route
 crc 32
 clock source internal
 pos ais-shut
 pos report lrdi
 ip rsvp bandwidth 155000 155000
```

MPLS TE FRR - Link Protection



MPLS TE FRR - Link Protection

Traffic is running from R0's loo to R6's loo(10.0.1.150)



On R1

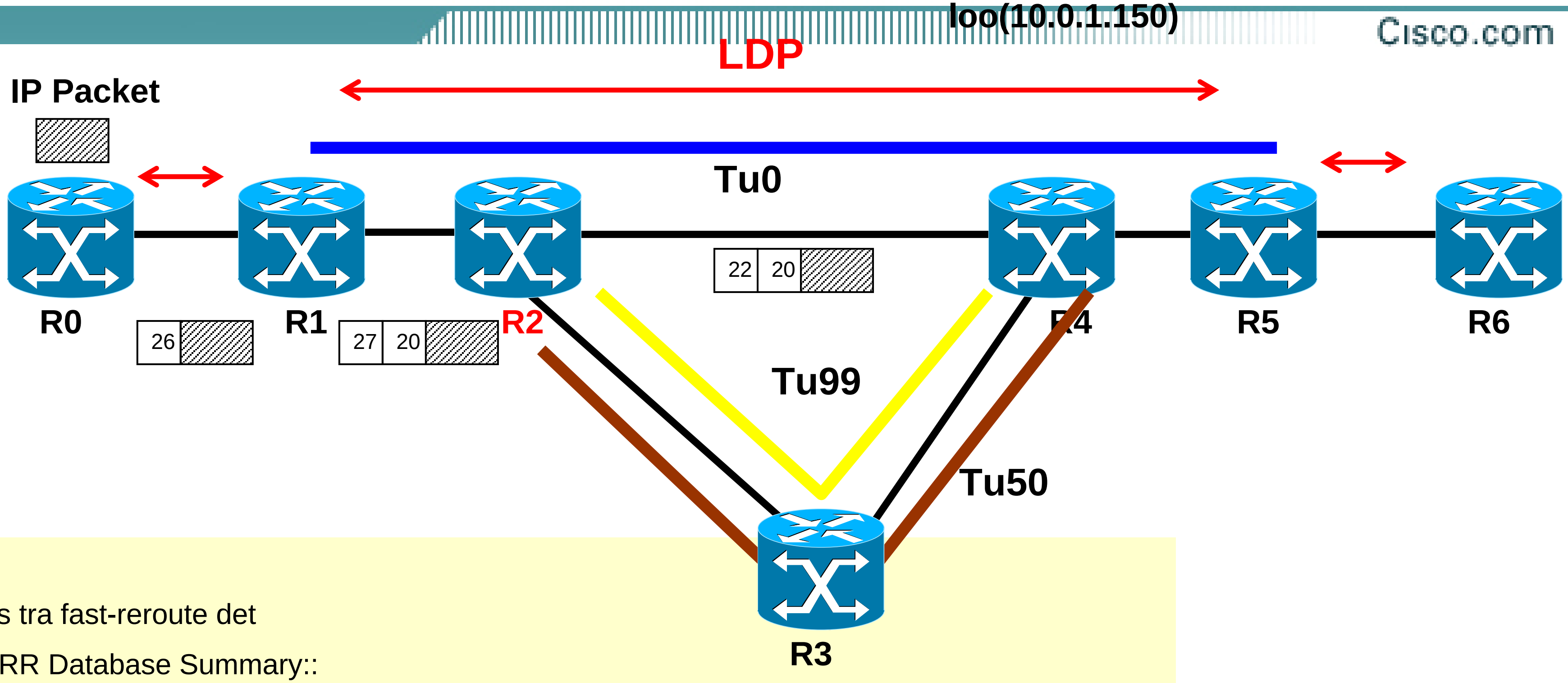
```
Show tag for 100.0.1.150 32 det
Local  Outgoing    Prefix           Bytes tag  Outgoing   Next Hop
tag    tag or VC   or Tunnel Id      switched   interface
26     20          10.0.1.150/32     0          Tu0        point2point
       MAC/Encaps=4/12, MTU=4466, Tag Stack{27 20}, via PO0/0
       0F008847 0001B00000014000
       Fast Reroute Protection via {UnknownIF, outgoing label 27}
    Per-packet load-sharing, slots: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
```

```
sh tag for
ocal  Outgoing   Prefix             Bytes tag  Outgoing   Next hop
tag   tag or VC  or Tunnel Id        switched   interface
...
26    20         [T] 10.0.1.150/32   0          Tu0        point2point
...

[T]    Forwarding through a TSP tunnel.
       View additional tagging info with the 'detail' option
```

MPLS TE FRR - Link Protection

Traffic is running from R0’s loo to R6’s loo(10.0.1.150)



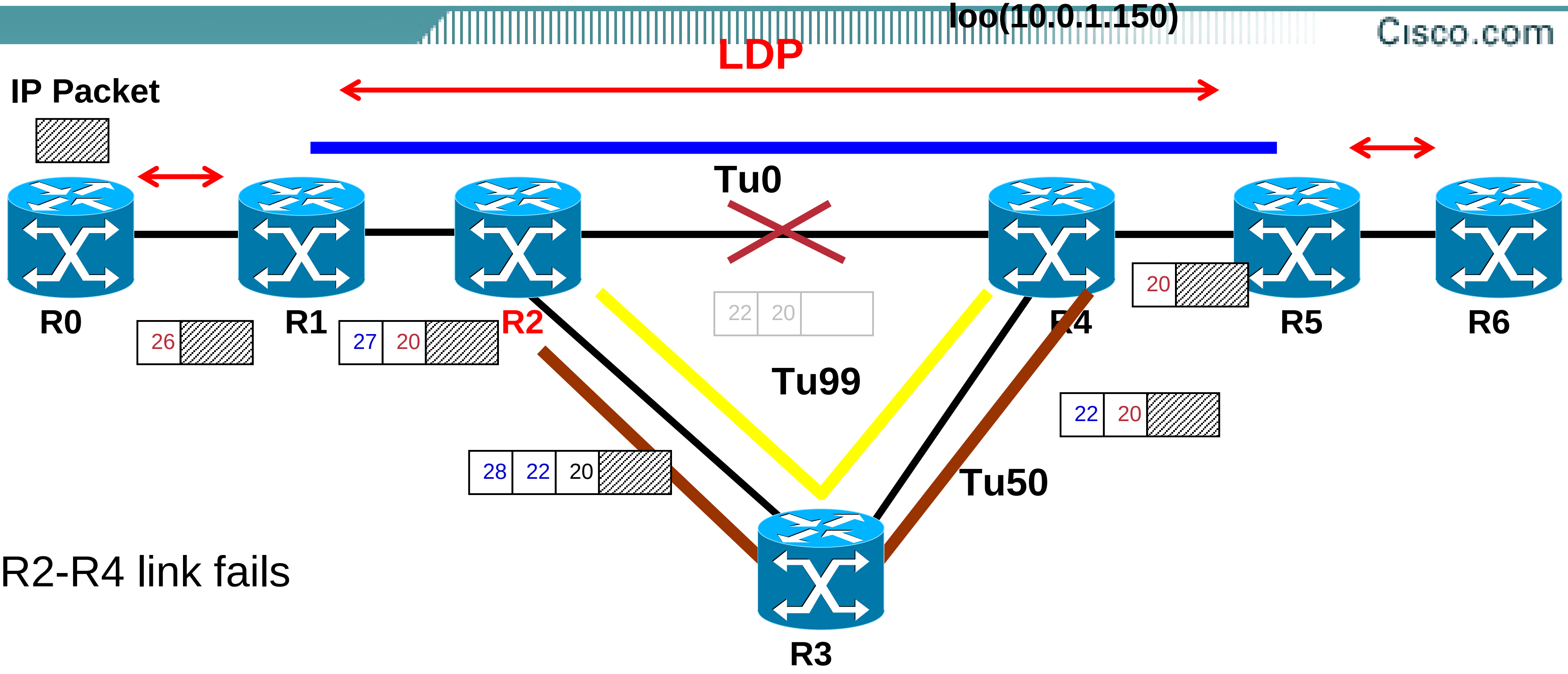
On R2

```
sh mpls tra fast-reroute det
LFIB FRR Database Summary::
   Total Clusters:      1
   Total Groups:         1
   Total Items:         1
Link 10:: PO4/0 (Up, 1 group)
   Group 16:: PO4/0->Tu99 (Up, 1 member)
      Transit Item 810D60 (complete) [FRR OutLabel: 22]
         Key {incoming label 27}
```

```
sh tag for
Local  Outgoing   Prefix            Bytes tag   Outgoing     NextHop
tag      tag or VC   or Tunnel Id      switched      interface
...
27     22         10.0.1.127 0 [1]  16896      PO4/0       point2point
...
```

MPLS TE FRR - Link Protection

Traffic is running from R0's loo to R6's loo(10.0.1.150)



t0: R2-R4 link fails

t1:

Data plane: R2 will immediately swap 27 <-> 22 (as before) and Push 28 (This is of course done for all the protected LSPs crossing the R2-R4 link)

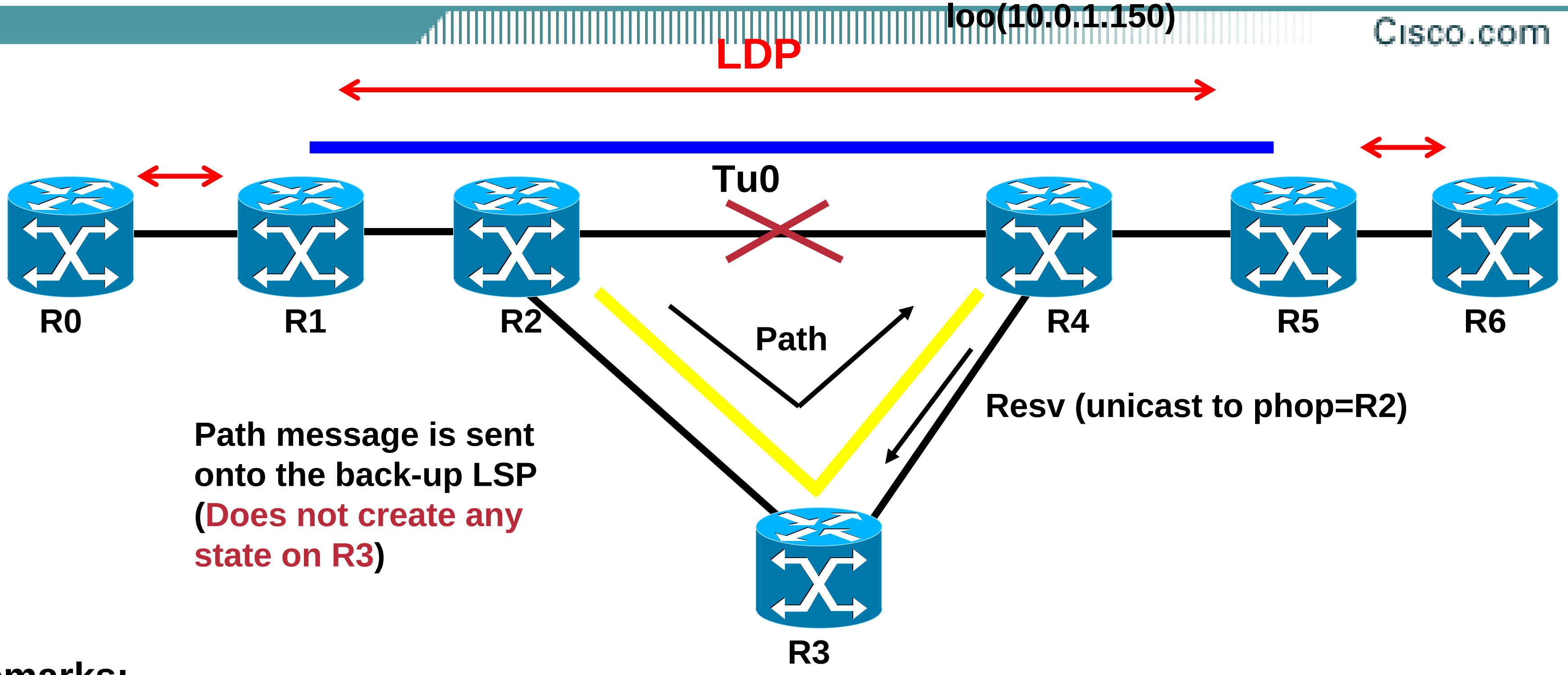
Control Plane registers for a link-down event. Once the RSVP process receives this event, it will send out an RSVP PERR msg (O(s))

t2: R3 will do PHP

t3: R4 receives an identical labeled packet as before (Global Label Allocation needed)

MPLS TE FRR - Link Protection

Traffic is running from R0's loo to R6's loo(10.0.1.150)



Resv (unicast to phop=R2)

Path message is sent onto the back-up LSP (Does not create any state on R3)

2 remarks:

* The path message for the old Path are still forwarded onto the Back-Up LSP

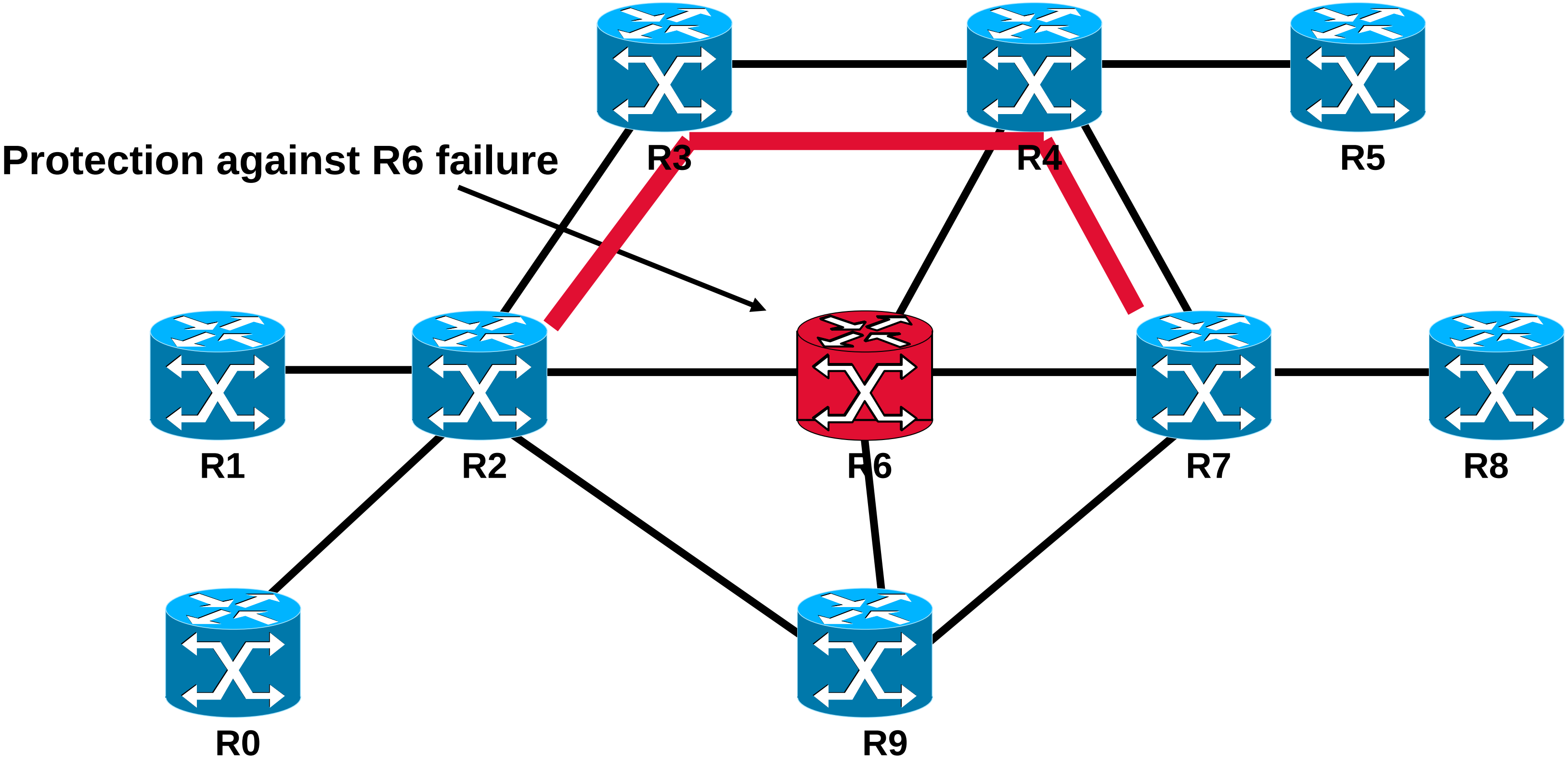
* Modifications have been made to the RSVP code so that

- R2 could receive a Resv message from a different interface than the one used to send the Path message
- R4 could receive a Path message from a different interface (R3-R4 in this case)

MPLS TE Fast Reroute Node Protection (local protection)

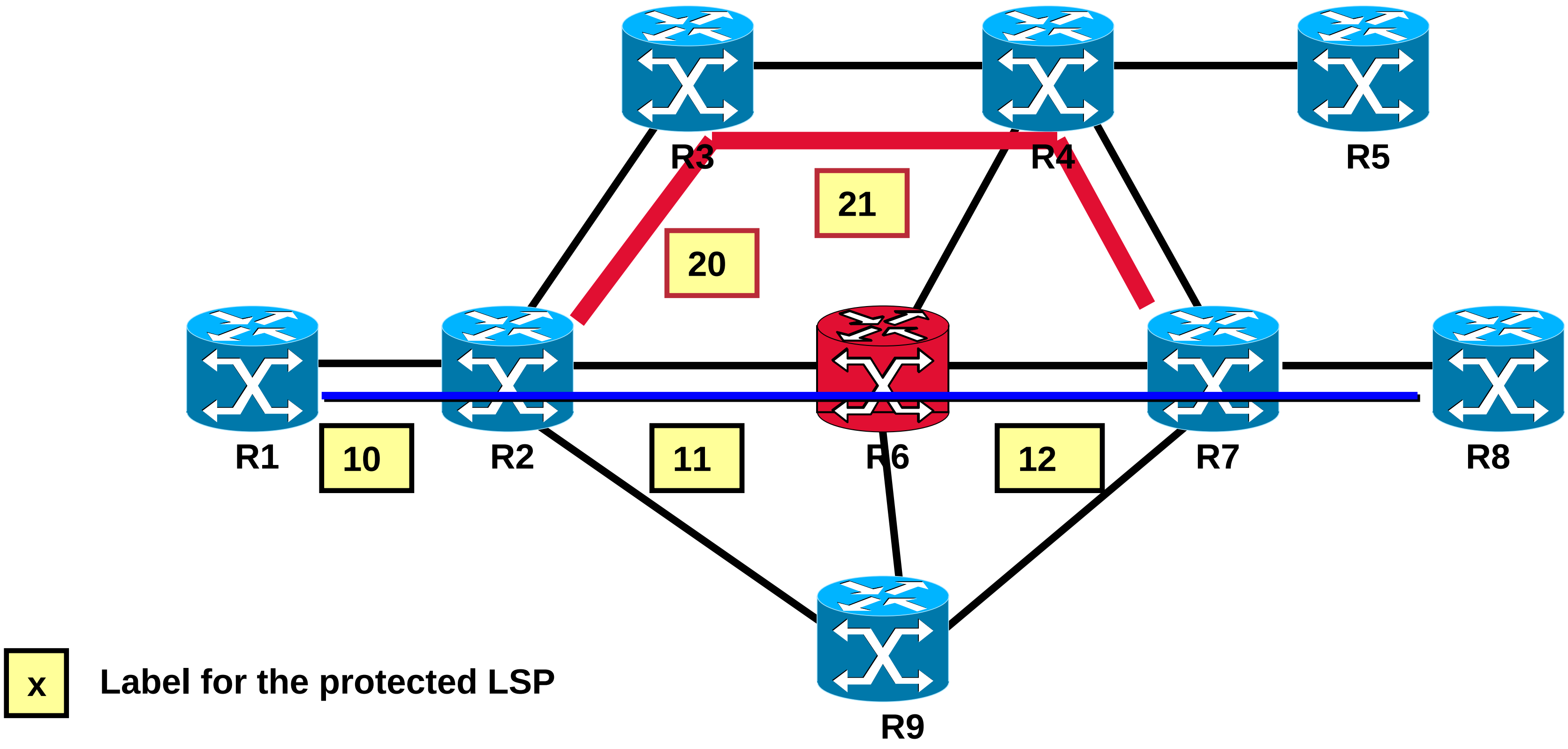
MPLS TE FRR – Node Protection

- Node protection allows to configure a back-up tunnel to the next-next-hop ! This allows to protect against link AND node failure



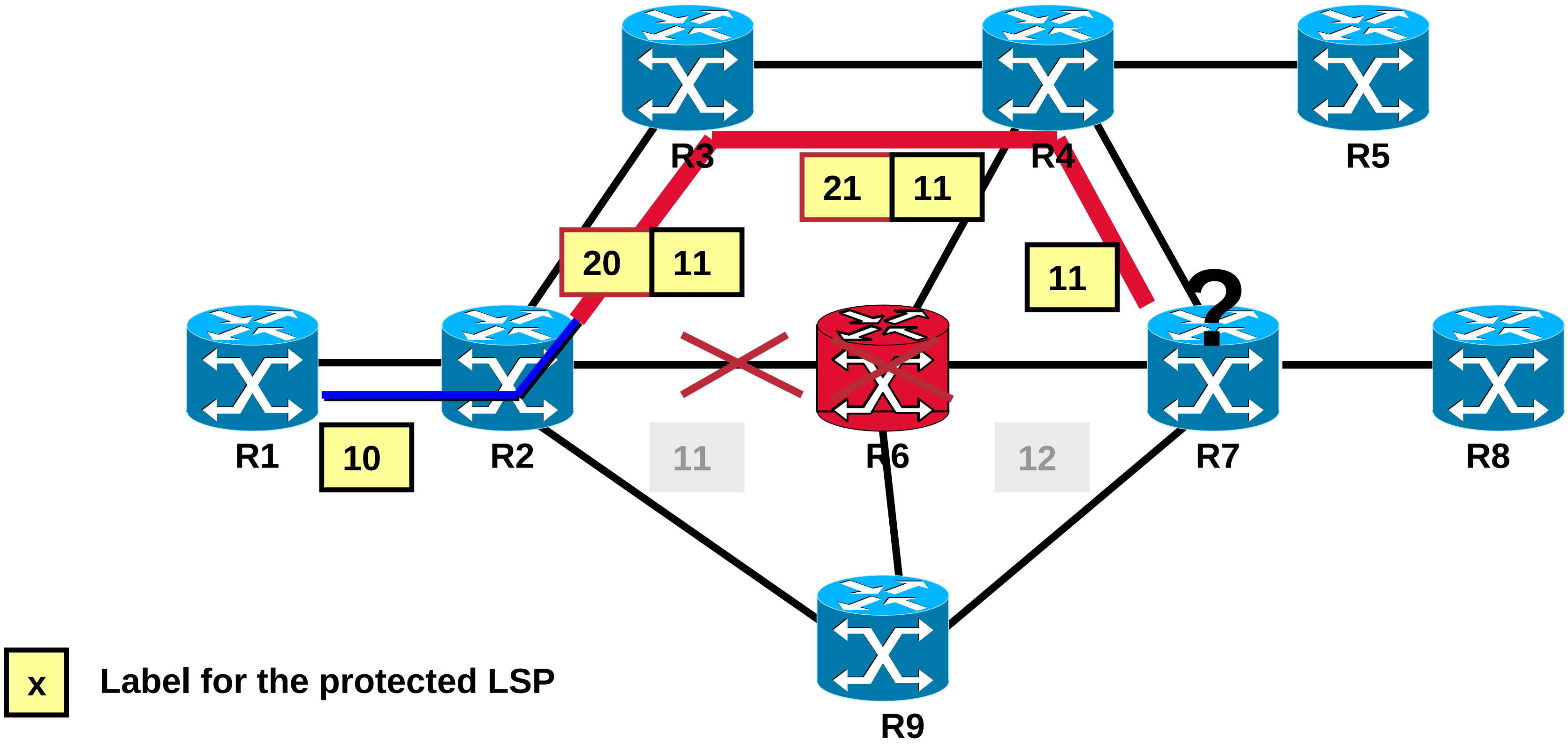
MPLS TE FRR – Node Protection

- **Backup labels**



MPLS TE FRR – Node Protection

- Backup labels



- The PLR learns the label to use from the RRO object carried in the Resv message when the reroutable LSP is first established – With global label space allocation on the MP

MPLS TE FRR – Node Protection

For each fast reroutable LSP ("Local protection Desired" bit set in the SESSION_ATTRIBUTE in the Path message), the tail-head LSR must include an RRO object in its Resv message (with label sub-object)

MPLS TE FRR – Node Protection

Subobject 1: IPv4 address

RRO Object

```
    0                   1                   2                   3
   0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      Type     |     Length    | IPv4 address (4 bytes)        |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | IPv4 address (continued)      | Prefix Length |      Flags    |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Flags

0x01 Local protection available

Indicates that the link downstream of this node is protected via a local repair mechanism. This flag can only be set if the Local protection flag was set in the SESSION_ATTRIBUTE object of the corresponding Path message.

0x02 Local protection in use

Indicates that a local repair mechanism is in use to maintain this tunnel (usually in the face of an outage of the link it was previously routed over , or an outage of the neighboring node).

MPLS TE FRR – Node Protection

Subobject 1: IPv4 address

Flags (cont)

Bandwidth protection: 0x04

The PLR will set this when the protected LSP has a backup path which provides the desired bandwidth, which is that in the FAST_REROUTE object or the bandwidth of the protected LSP, if no FAST_REROUTE object was included. The PLR may set this whenever the desired bandwidth is guaranteed; the PLR MUST set this flag when the desired bandwidth is guaranteed and the "bandwidth protection desired" flag was set in the SESSION_ATTRIBUTE object.

Node protection: 0x08

When set, this indicates that the PLR has a backup path providing protection against link and node failure on the corresponding path section. In case the PLR could only setup a link-protection backup path, the "Local protection available" bit will be set but the "Node protection" bit will be cleared.

MPLS TE FRR – Node Protection

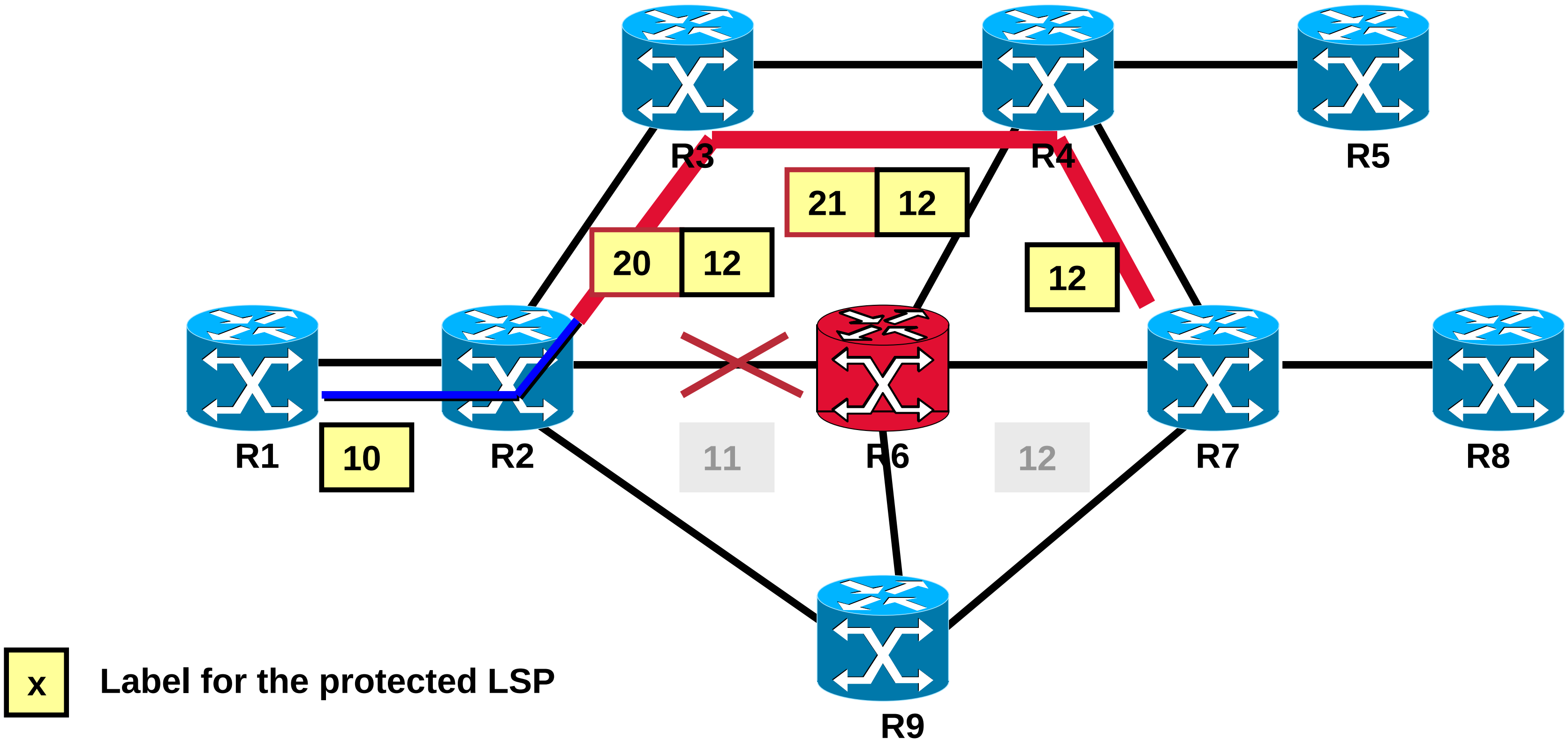
- The PLR learns the label to use from the RRO object carried in the Resv message when the reroutable LSP is first established

The "label recorded desired" bit must be set in the SESSION-ATTRIBUTE pf the Path message

```
                 Subobject 0x03, Label
                  0                   1                   2                   3
                  0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
                  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                  |     Type      |     Length    |    Flags      |   C-Type      |
Type              +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
0x03  Label       |                Contents of Label Object                       |
Length            +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
The Length contains the total length of the subobject in bytes, including the Type and Length
   fields.
Flags
0x01 = Global label
This flag indicates that the label will be understood if received on any interface.
C-Type
The C-Type of the included Label Object.  Copied from the Label Object.
Contents of Label Object
The contents of the Label Object.  Copied from the Label Object
```

MPLS TE FRR – Node Protection

- **Backup labels**



- **The PLR swaps 10 <-> 12, pushes 20 and forward the traffic onto the backup tunnel**

MPLS TE FRR – Node Protection

- **Path states maintenances**
  - **As in the case of NHOP backup tunnel, the Path messages are sent onto the backup tunnel to refresh the downstream states**

MPLS TE FRR – Node Protection

- **When the failure occurs, the PLR also updates:**
  - **The ERO object,**
  - **The PHOP object,**
  - **The RRO object**
- **As with Link protection, the PLR should the Point of Local Repair SHOULD send a PathErr message with error code of "Notify" (Error code =25) and an error value field of ss00 cccc cccc cccc where ss=00 and the sub-code = 3 ("Tunnel locally repaired").** **→ This will trigger the head-end reoptimization**

MPLS TE FRR – Local repair

- When the failed link or node comes UP again the new resources may be re used once reoptimization has been triggered on the head-ends.

- As a reminder, reoptimization is triggered:

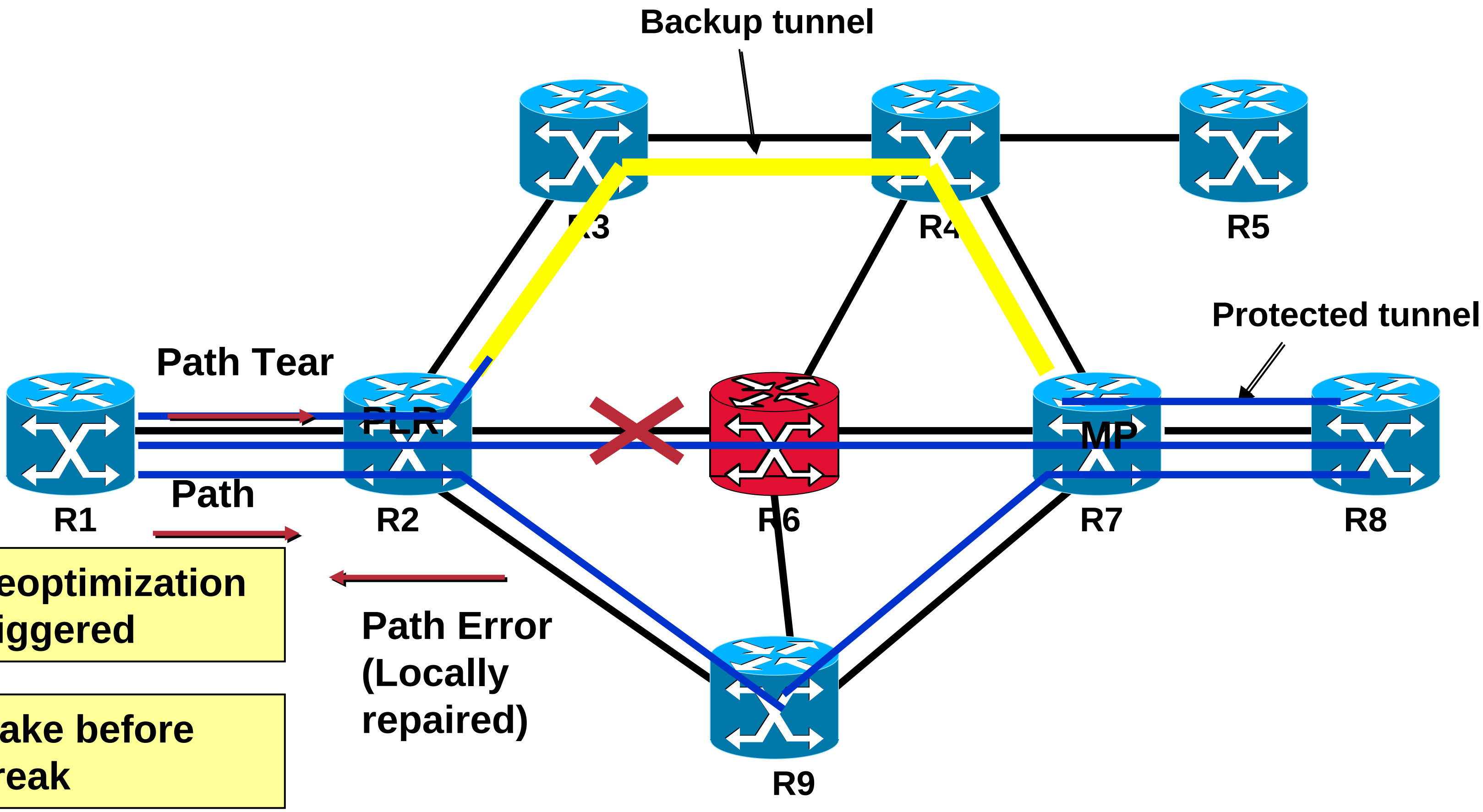
  - Periodically: “mpls traffic-eng reoptimize timers frequency <0-604800>

  - When a link comes “UP” if “mpls traffic-eng reoptimize events link-up”

  - When explicitly triggered (exec mode): “mpls traffic-eng reoptimize <tunnel x>”

- Make before break prevents any traffic disruption

MPLS TE FRR – Node Protection



Reoptimization triggered

Path Error (Locally repaired)

Make before break

MPLS TE FRR – Node Protection

- **The number of back-up tunnels for an interface is no longer limited to one !**

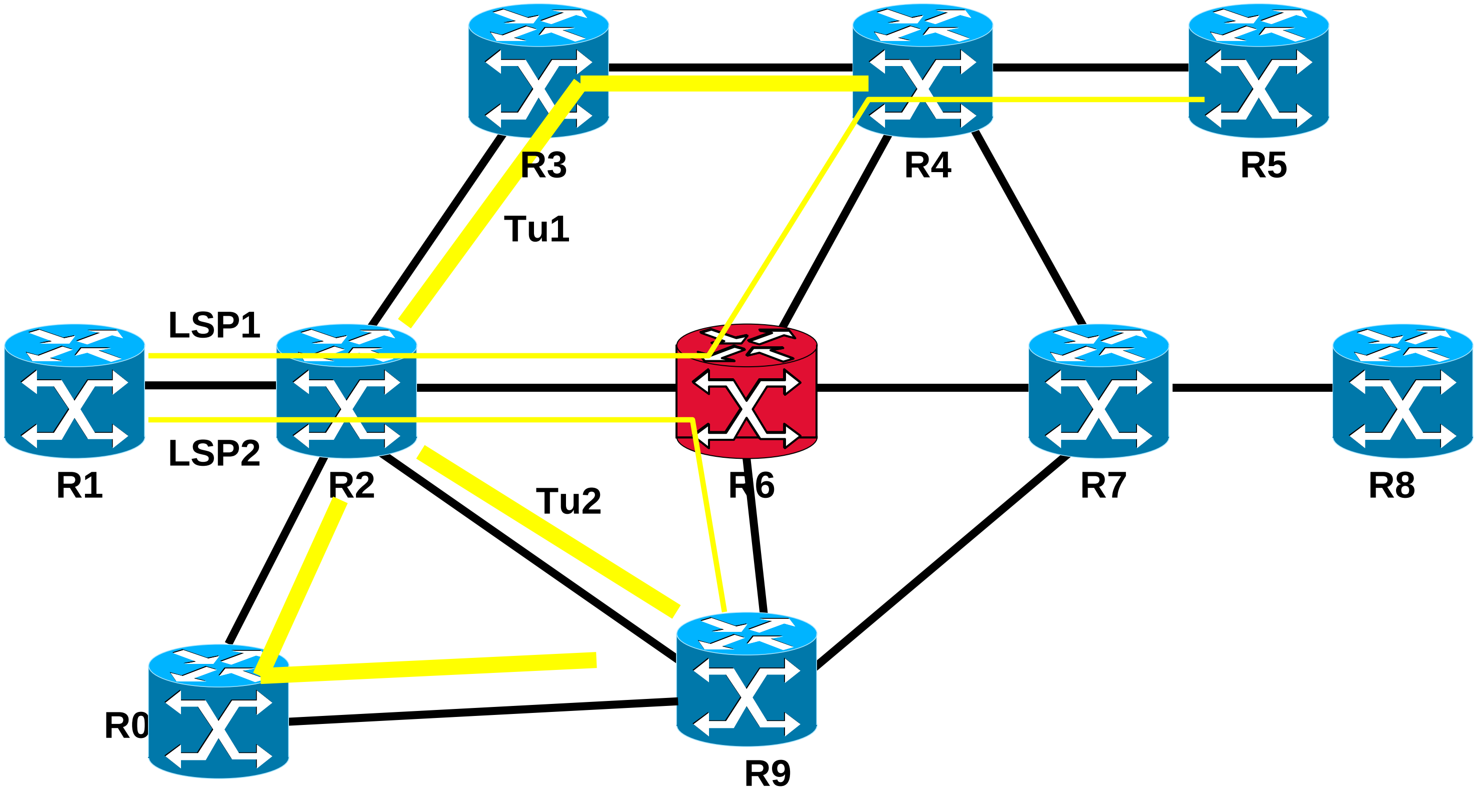
On R2

```
interface POS4/0
 description Link to R4
 ip address 10.1.13.2 255.255.255.252
 no ip directed-broadcast
 ip router isis
 encapsulation ppp
 mpls traffic-eng tunnels
 mpls traffic-eng backup-path Tunnel10
 mpls traffic-eng backup path Tunnel15
 tag-switching ip
 no peer neighbor-route
 crc 32
 clock source internal
 pos ais-shut
 pos report lrdi
 ip rsvp bandwidth 155000 155000
```

- ***Which is mandatory for Node protection …***

MPLS TE FRR – Node Protection

- Back-up tunnel selection for a given LSP



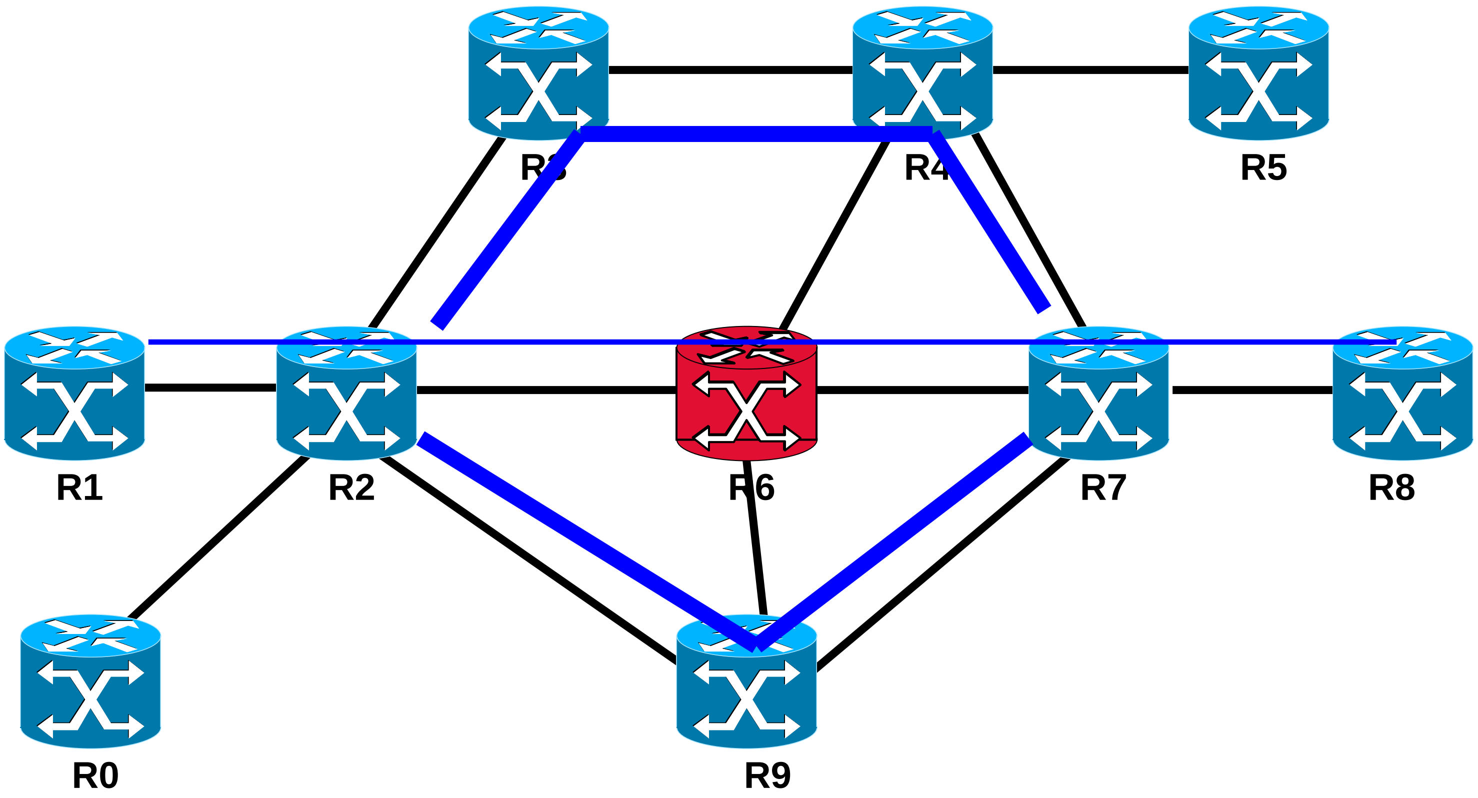
- Tu1 is chosen for LSP1
- Tu2 is chosen for LSP2

MPLS TE FRR – Node Protection

- One may combine tunnels terminating on the next hop and next-next-hop
- This allows to increase redundancy,
- In case of un availability of a back-up tunnel the other one is used (order of preference is determined by the tunnel ID number)
- Load balancing between to back-up tunnels terminating on the same nnhop.

MPLS TE FRR – Node Protection

- Load balancing: Multiple back-up tunnels to the same destination may be created.

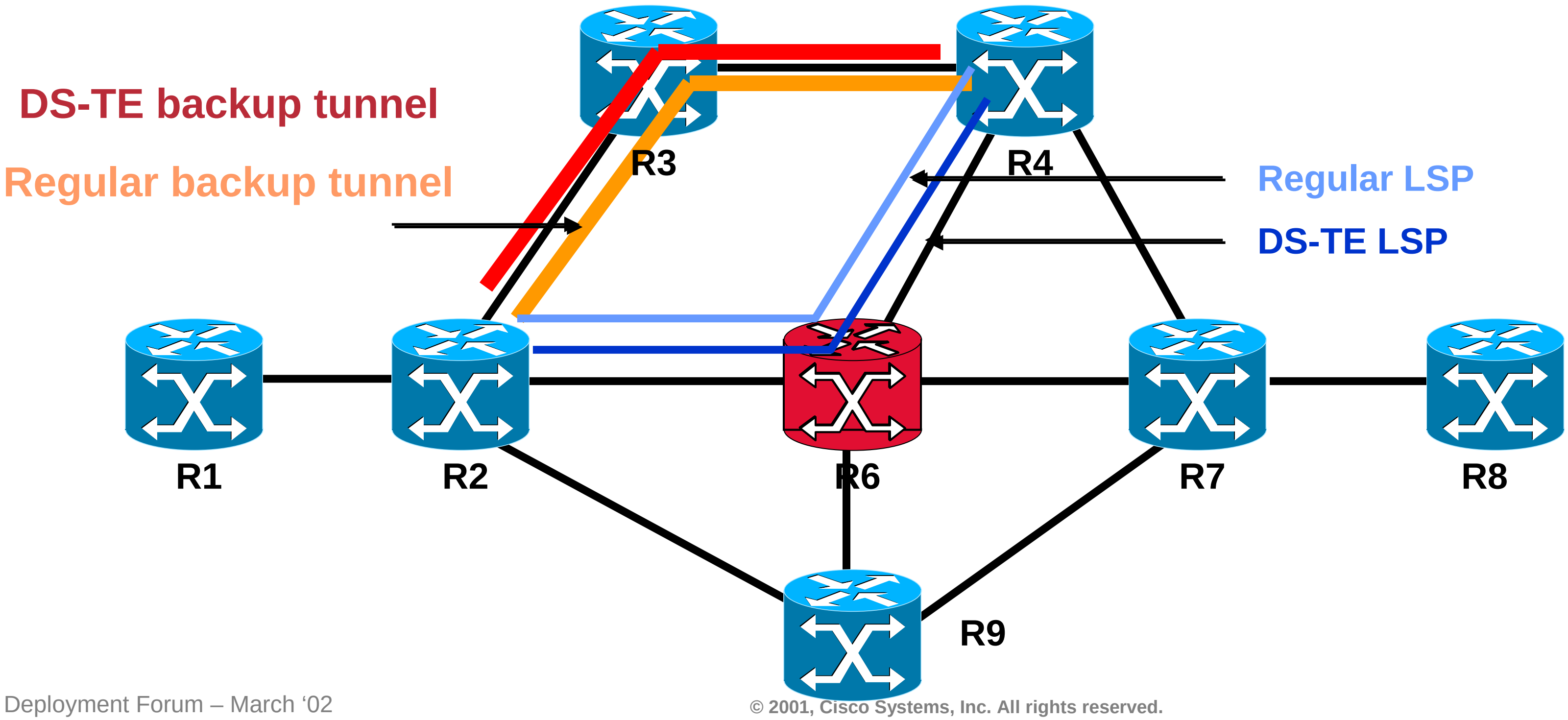


Backup tunnel path computation and provisioning

- Packing algorithm: refers to the method used to select the backup tunnel for each protected LSP.
- For each protected LSP at a given PLR:
  - Select the set of backup tunnel whose merge point crosses the primary path,
  - Find a backup tunnel whose remaining bandwidth is >= of the protected LSP (if bandwidth protection is required)
  - Multiple backup tunnel selection policies are available

Per Class backup tunnel

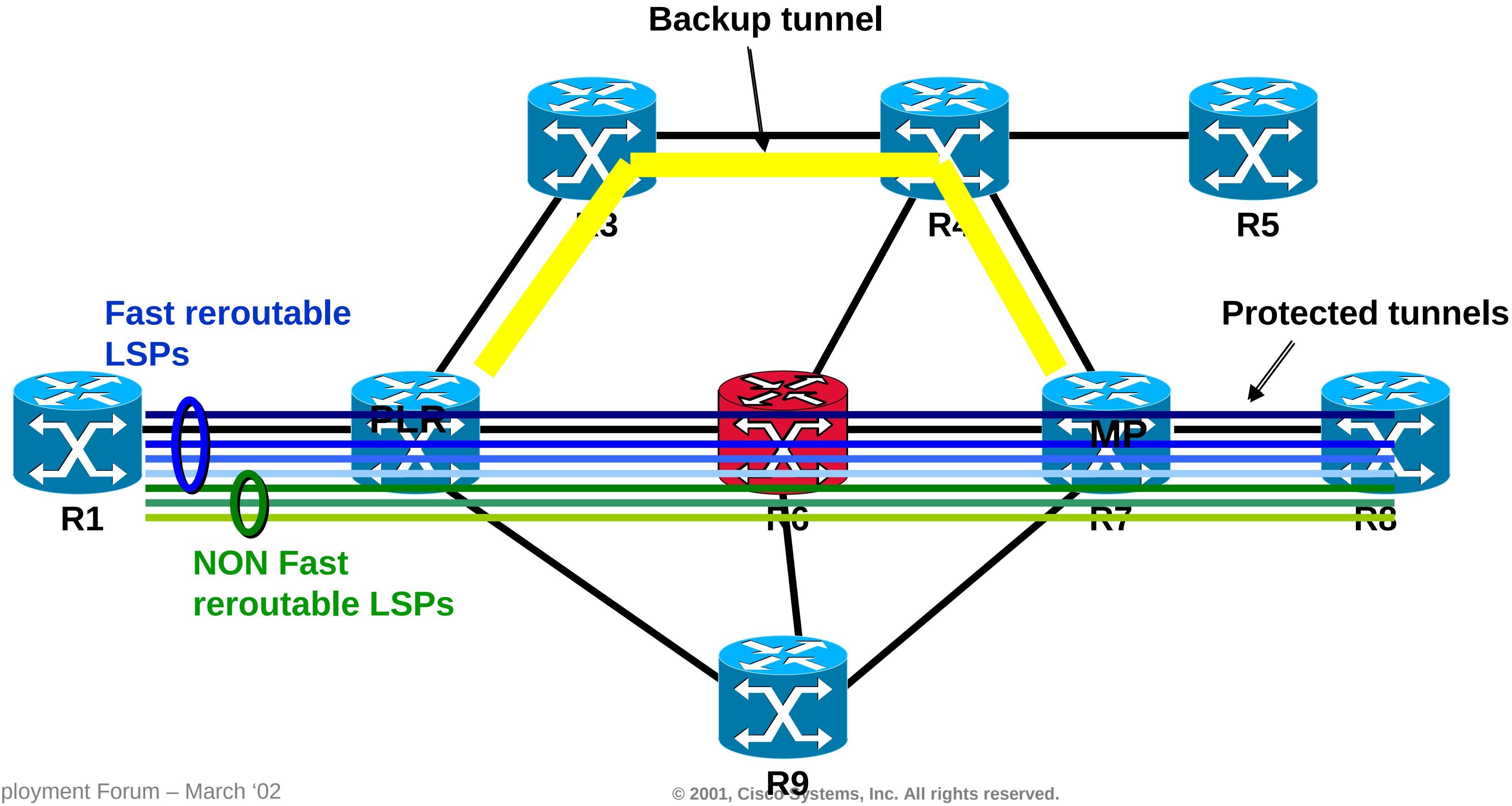
- When using both regular and DS-TE tunnels, it may desirable to configure regular and DS-TE backup tunnels.
- Other combinations are also possible
- Packing algorithm enhancements



MPLS TE FRR Local repair

- **Uses nested LSPs (stack of labels)**

  1:N protection is KEY for scalability. N protected LSP will be backed-up onto the SAME backup LSP



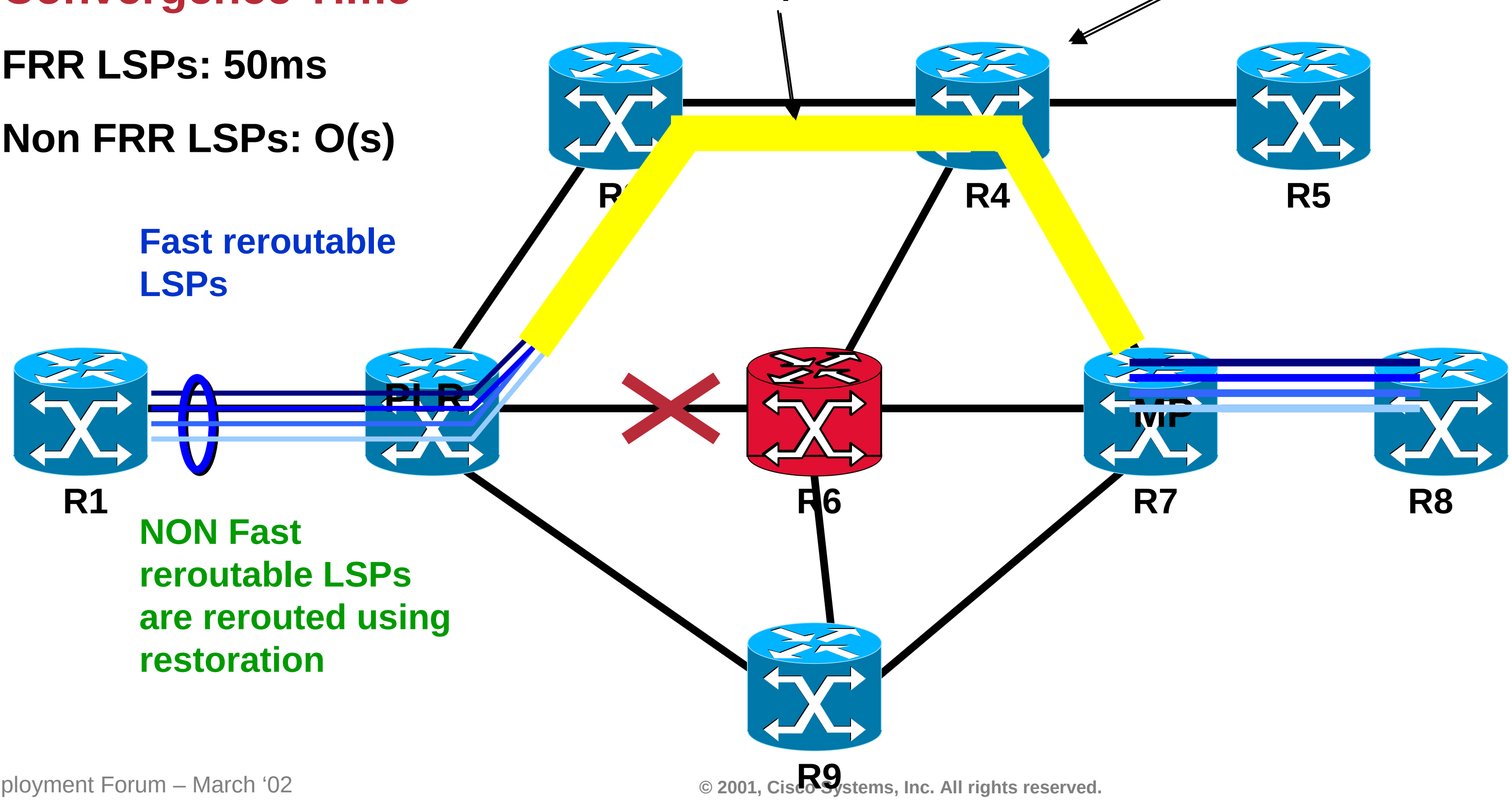
MPLS TE FRR Local repair

- Uses nested LSPs (stack of labels)

Convergence Time

FRR LSPs: 50ms

Non FRR LSPs: O(s)



Backup tunnel

No states for the rerouted LSP

Fast reroutable LSPs

NON Fast reroutable LSPs are rerouted using restoration

Link/Node Failure detection

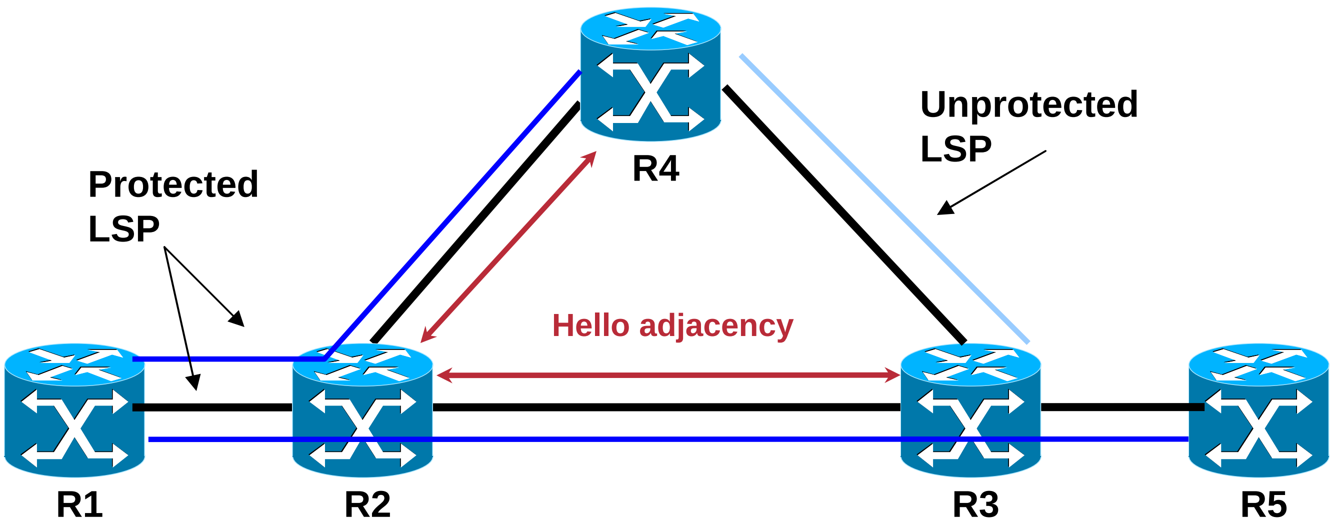
- Link failure detection
  - On POS, link failure detection is handled by Sonet/SDH alarms
    - On Receive side: LOS/LOF/LAIS
    - On Transmit side: LRDI
    - Very fast.
- Node failure detection is a more difficult problem
  - Node hardware failure => Link failure
  - Software failure … Need for a fast keepalive scheme (IGP, RSVP hellos)

RSVP Hellos

- RSVP Hellos extension is defined in RFC3209
- The RSVP hello extension enables an LSR to detect node failure detection
- Allows to detect:
  - Link failure when layer 2 does not provide failure detection mechanism,
  - Node failure when the layer 2 does not fail.

RSVP Hellos

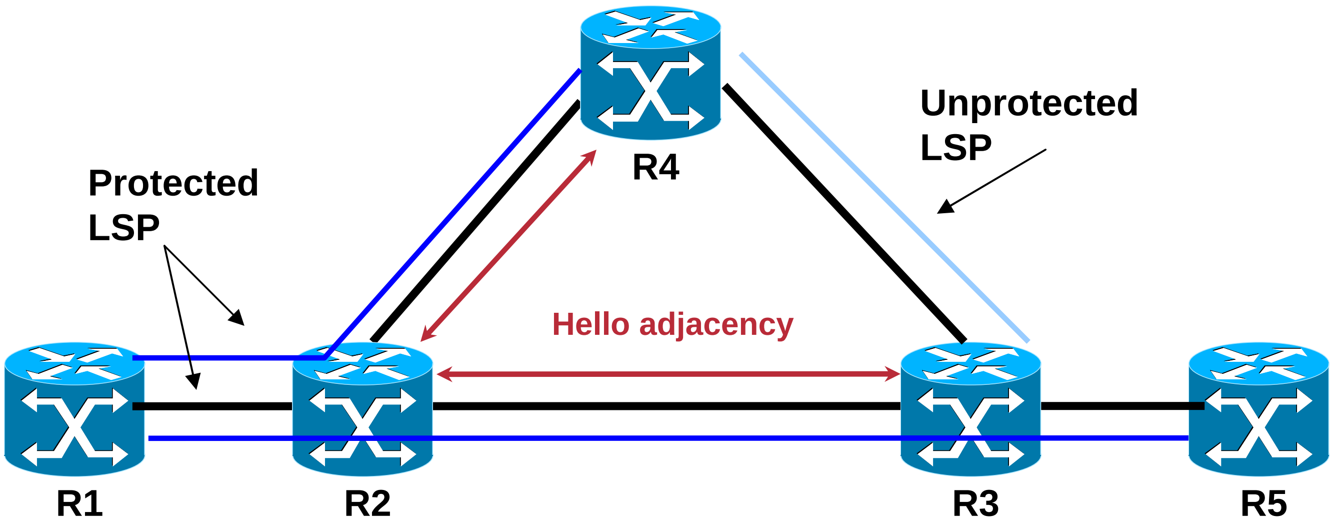
- RSVP hello adjacency are brought up dynamically (if at least one protected LSP in READY state (with one backup tunnel operational))
- One RSVP hello adjacency per link per neighbor (not per protected LSP !!)



- An hello adjacency is removed when the last protected LSP in READY state is torn down

RSVP Hellos

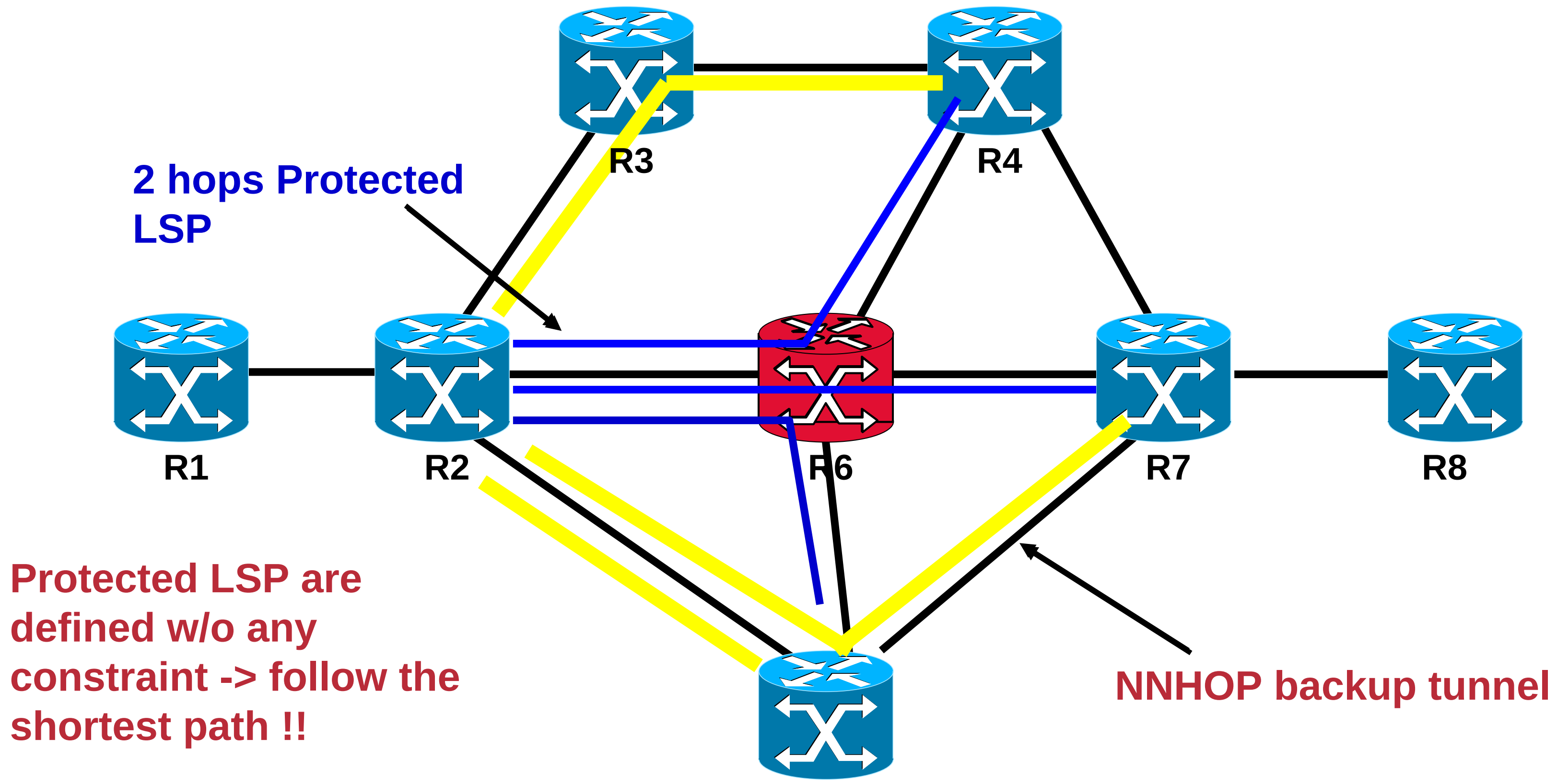
- RSVP hello has been designed for Node failure detection. Fast link failure detection already exist on Sonet/SDH links.



- But can also be used as a fast link failure detection on GE links (point to point or behind a switch) → FRR over GE links

Using FRR without MPLS TE

- **MPLS TE FRR is backing-up TE LSP. If MPLS TE is not used in the network, one may use Fast Reroute for fast convergence using unconstraint 2 hops protected tunnel.**
- **Ex:**



2 hops Protected LSP

Protected LSP are defined w/o any constraint -> follow the shortest path !!

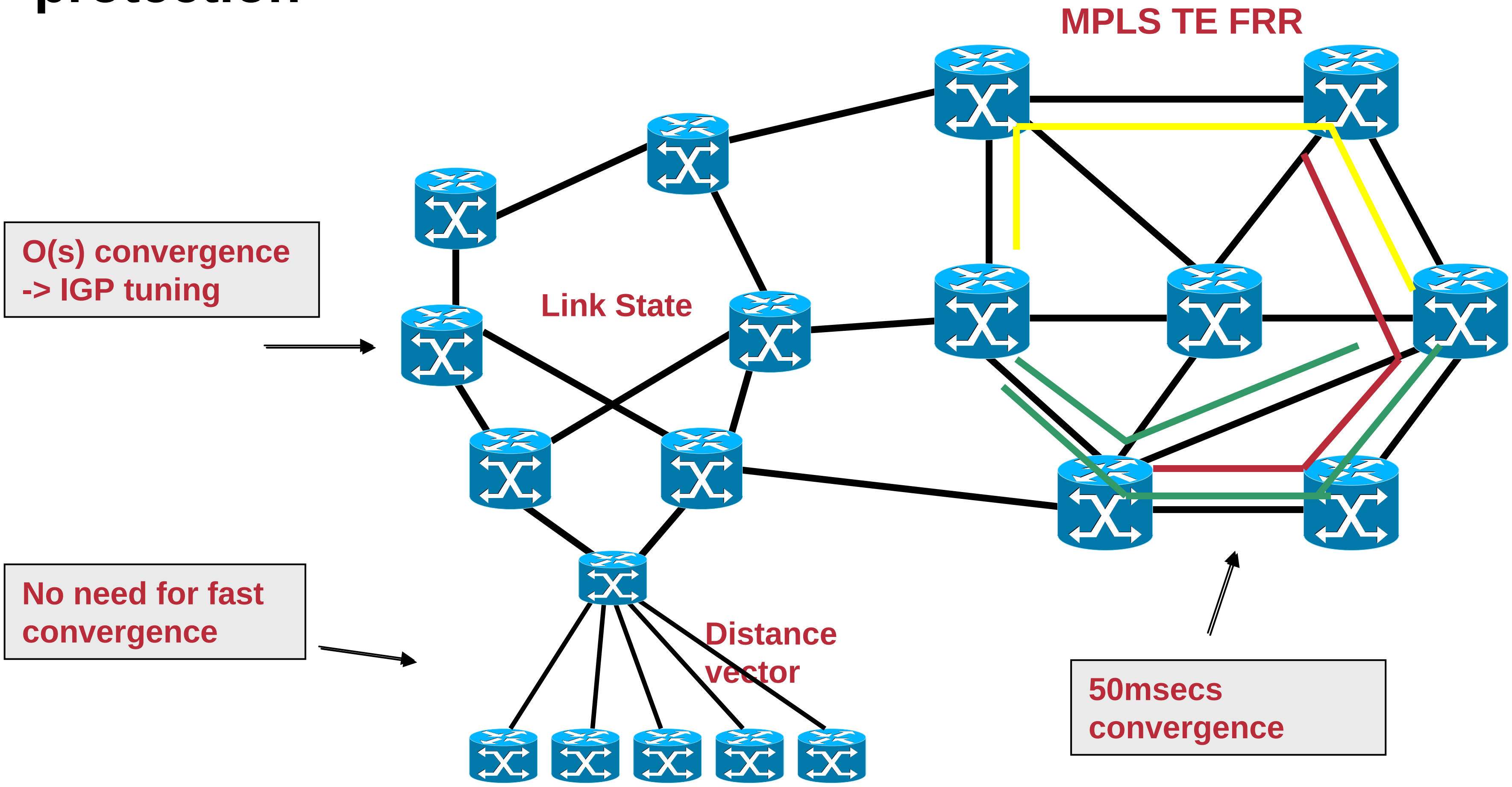
NNHOP backup tunnel

MPLS TE protection/restoration schemes

- **MPLS TE FRR may be used in specific parts of the network where very fast convergence is required,**
- **Compared to other protection schemes (optical, Sonet/SDH) no backup bandwidth is wasted.**

MPLS TE protection/restoration schemes

- Combining IP routing restoration and MPLS TE FRR fast protection



O(s) convergence
-> IGP tuning

No need for fast convergence

50msecs convergence

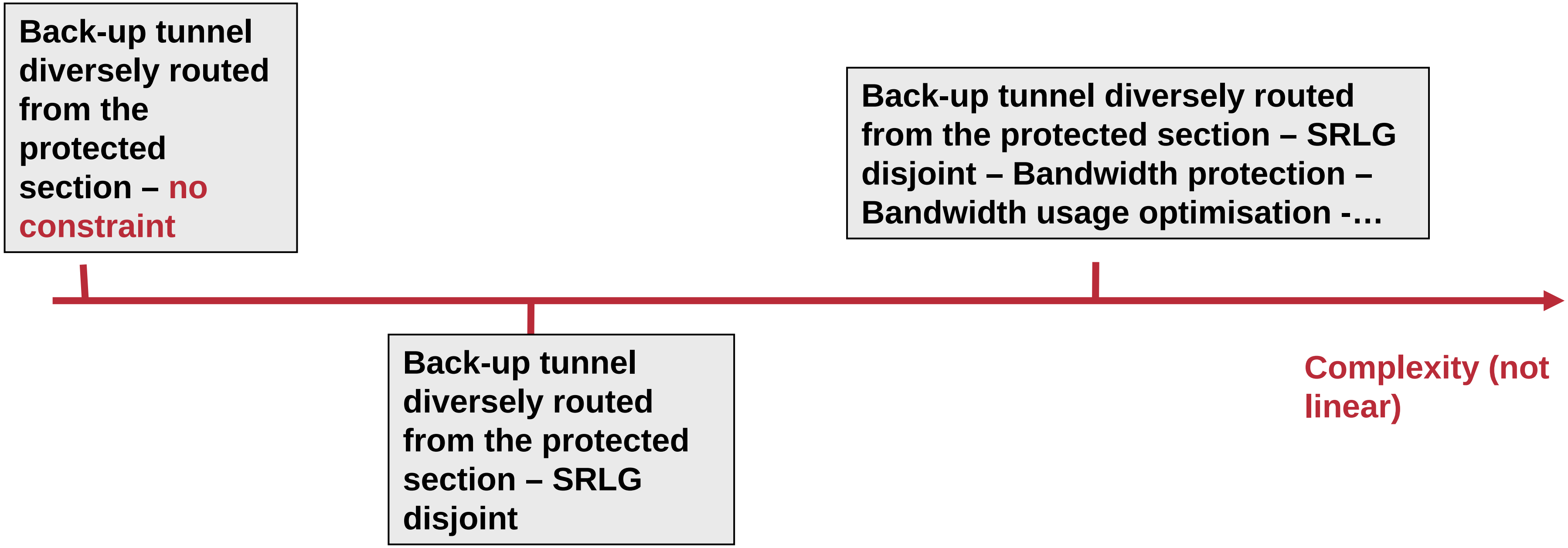
MPLS TE protection/restoration schemes

- IP convergence versus MPLS TE FRR
  - IP convergence is O(s) and may be even speed-up around 1 second
  - For faster convergence (<50msec), MPLS TE Fast Reroute should be used.

Backup tunnel path computation and provisioning

MPLS TE protection/restoration schemes

- **Backup tunnel path computation and provisioning is definitely an important topic,**
- **Complexity is driven by the parameters to take into account and the degree of optimality**



Back-up tunnel diversely routed from the protected section – no constraint

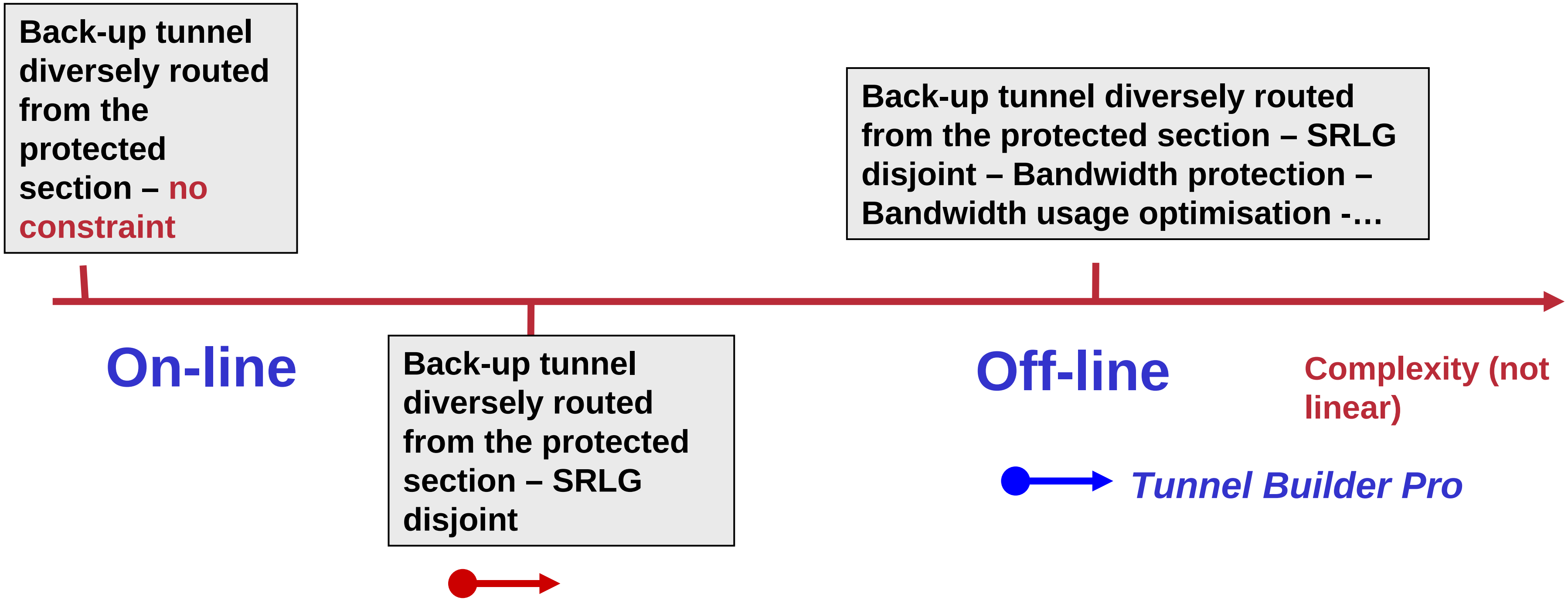
Back-up tunnel diversely routed from the protected section – SRLG disjoint

Back-up tunnel diversely routed from the protected section – SRLG disjoint – Bandwidth protection – Bandwidth usage optimisation -…

Complexity (not linear)

MPLS TE protection/restoration schemes

- The level of complexity will also determine whether the backup tunnel complexity is done Off-line or On-line (distributed)



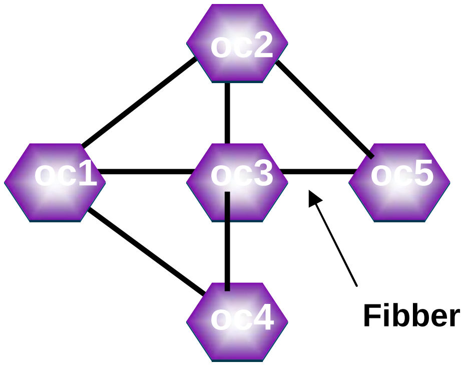
Back-up tunnel diversely routed from the protected section – no constraint

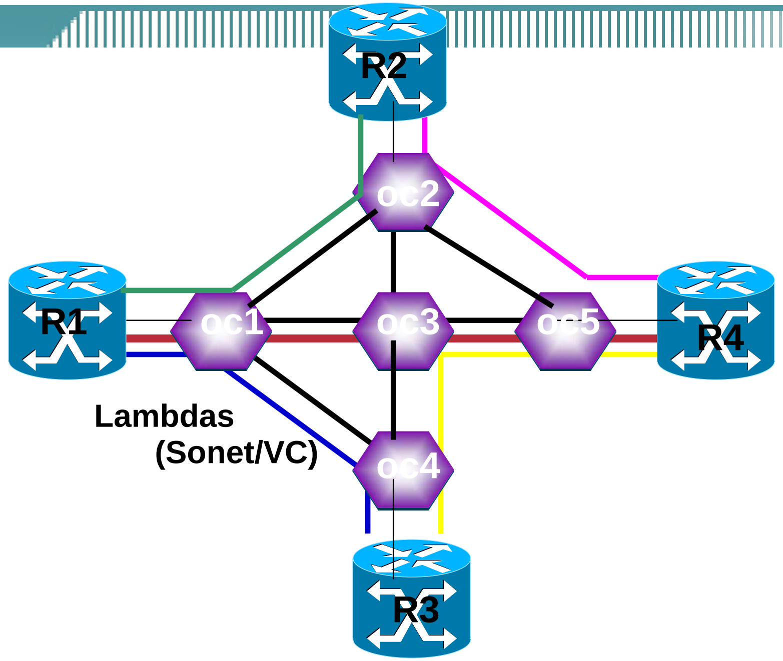
Back-up tunnel diversely routed from the protected section – SRLG disjoint

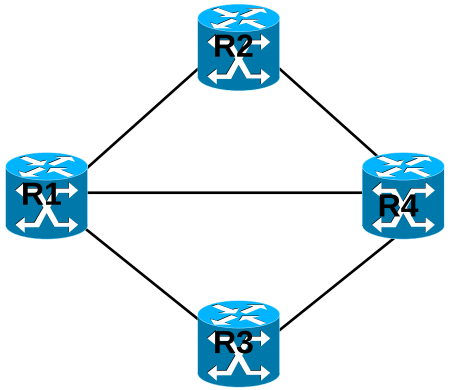
Back-up tunnel diversely routed from the protected section – SRLG disjoint – Bandwidth protection – Bandwidth usage optimisation -…

Diversely routed paths

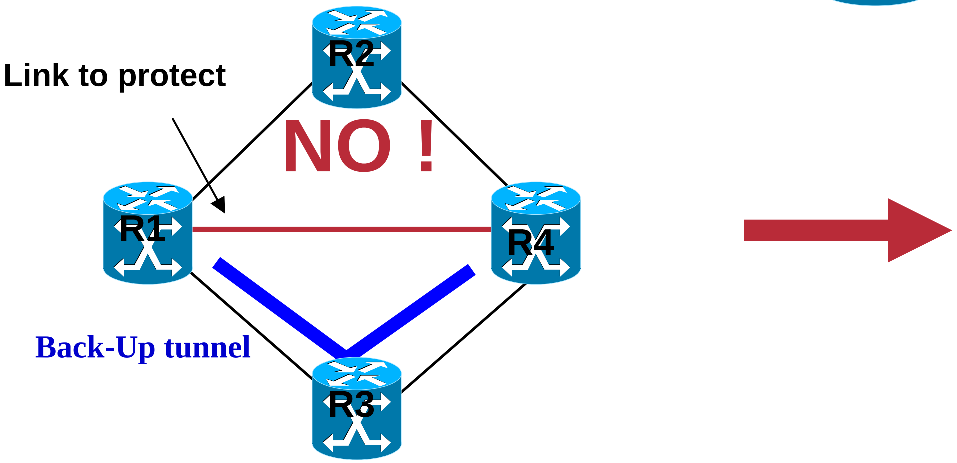
Optical plane

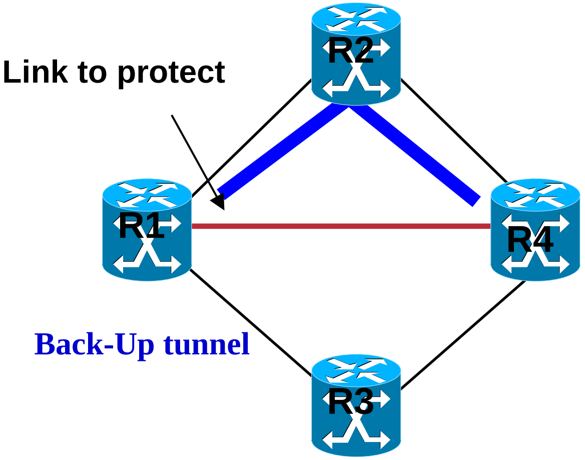






IP/MPLS view



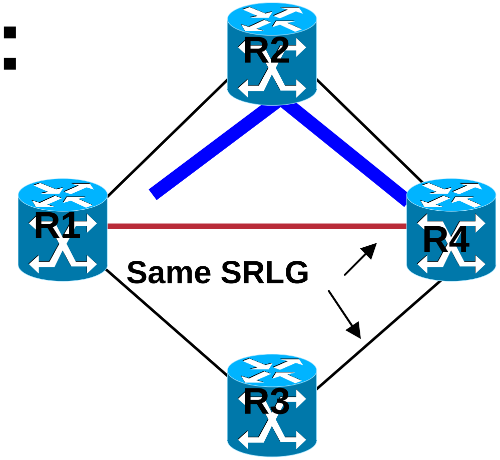


FRR design

FRR design

Diversely routed paths

- SRLG are configured on each link so that:
  - The back-up path is computed as SRLG disjoint from the protected LSP (Path protection) ,
  - The backup path is computed as SRLG disjoint from the protected section (Local repair)
- SRLG are flooded by the IGP:
  - New TLV for ISIS
  - Sub TLV of link TLV 18 (type 16)
- More than one SRLG may be configured on a link



Diversely routed paths

- An example with ISIS

Sub-TLV Type	Length	Name
3	4	Administrative group (color)
4	4	Outgoing Interface Identifier
5	4	Incoming Interface Identifier
6	4	IPv4 interface address
8	4	IPv4 neighbor address
9	4	Maximum link bandwidth
10	4	Reservable link bandwidth
11	32	Unreserved bandwidth
12	32	Maximum LSP Bandwidth
18	3	TE Default metric
19	1	Link Mux Capability
20	2	Link Protection Type
250-254	-	Reserved for cisco specific extensions
255	-	Reserved for future expansion

+ 2 new TLVs.

TLV Type	Length	Name
136 (TBD)	variable	Link Descriptor
138 (TBD)	variable	Shared Risk Link Group

Backup tunnel path computation and provisioning

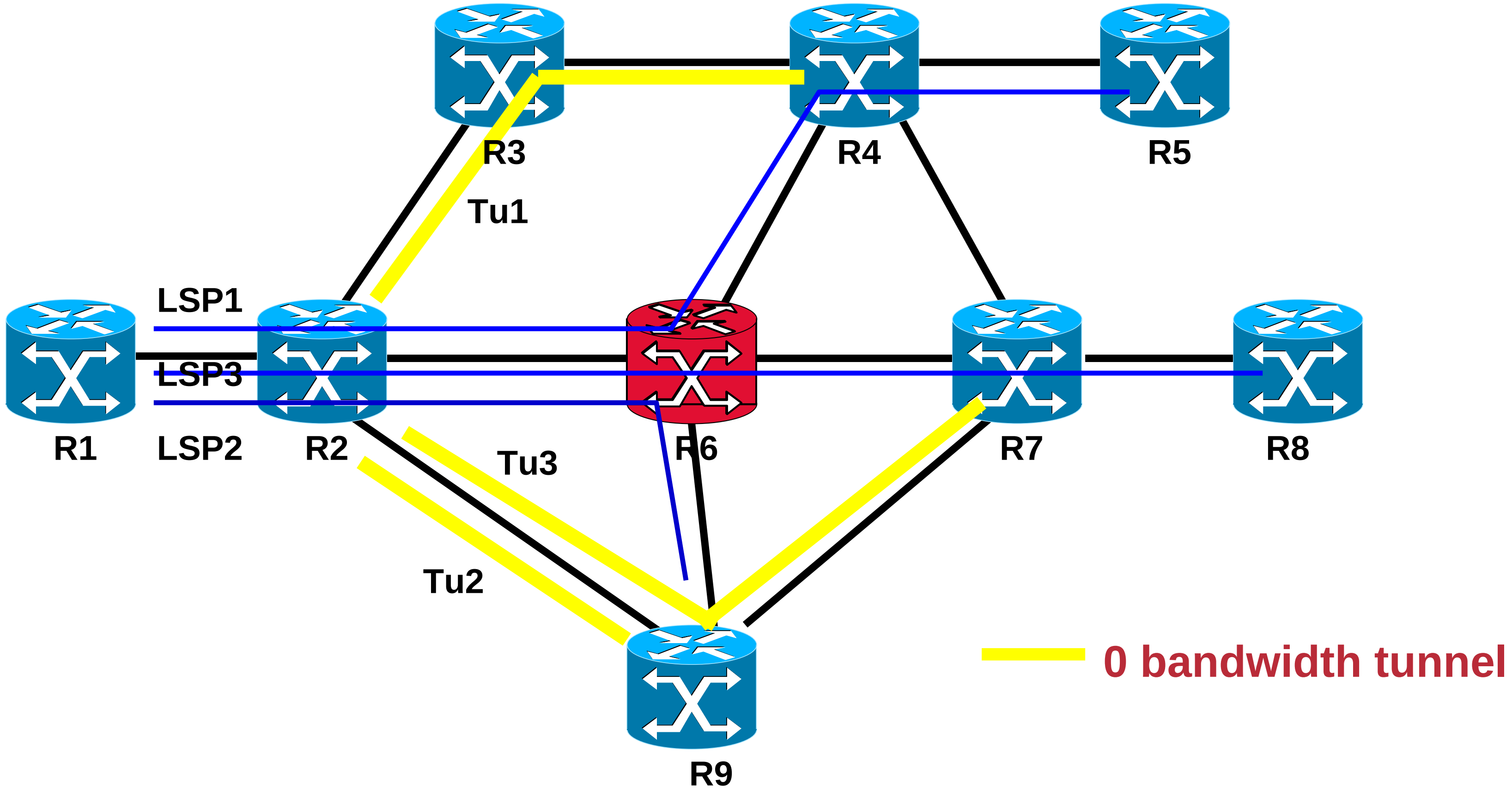
- Two possible approaches
    - Local repair without bandwidth protection
        - Once the link/node failure occurs, the protected LSP is rerouted within 50msecs but the rerouted LSP does not get any bandwidth guaranty. Note Diffserv should be used to protect sensitive traffic over the backup (potentially congested) path
    - Local repair with bandwidth protection
        - The protected LSP are rerouted onto a backup tunnel that provides bandwidth guaranty.
- This relates to the amount of bandwidth that the protected LSP will receive (before being reoptimized by the head-end (if possible)).

Backup tunnel path computation and provisioning

- Whether a protected LSP receives bandwidth protection or not depends on the backup tunnel constraints.
- Local repair without bandwidth protection
  - Does not require backup tunnel computation complexity.
  - Backup tunnel with 0 bandwidth
  - For each PLR, a NNHOP backup tunnel is configured to every NNHOP.

Backup tunnel path computation and provisioning

Local repair without bandwidth protection



- **Backup tunnel path computation and provisioning is straightforward**

Backup tunnel path computation and provisioning

Local repair with bandwidth protection

- Problem definition: find a set of backup tunnels between each PLR and its NNHop such that the protected LSPs could receive the appropriate amount of bandwidth when rerouted over the (those) backup LSPs.
- Note that between the PLR and the MP more than one backup tunnel may be used (Load balancing)

Backup tunnel path computation and provisioning

Local repair with bandwidth protection

- The problem of QOS guaranty can be reduced to a problem of bandwidth provisioning (provided the propagation delay is bounded)
- May also cover Propagation delay increase guaranty
- Requires much more complexity (complex backup tunnel path computation).

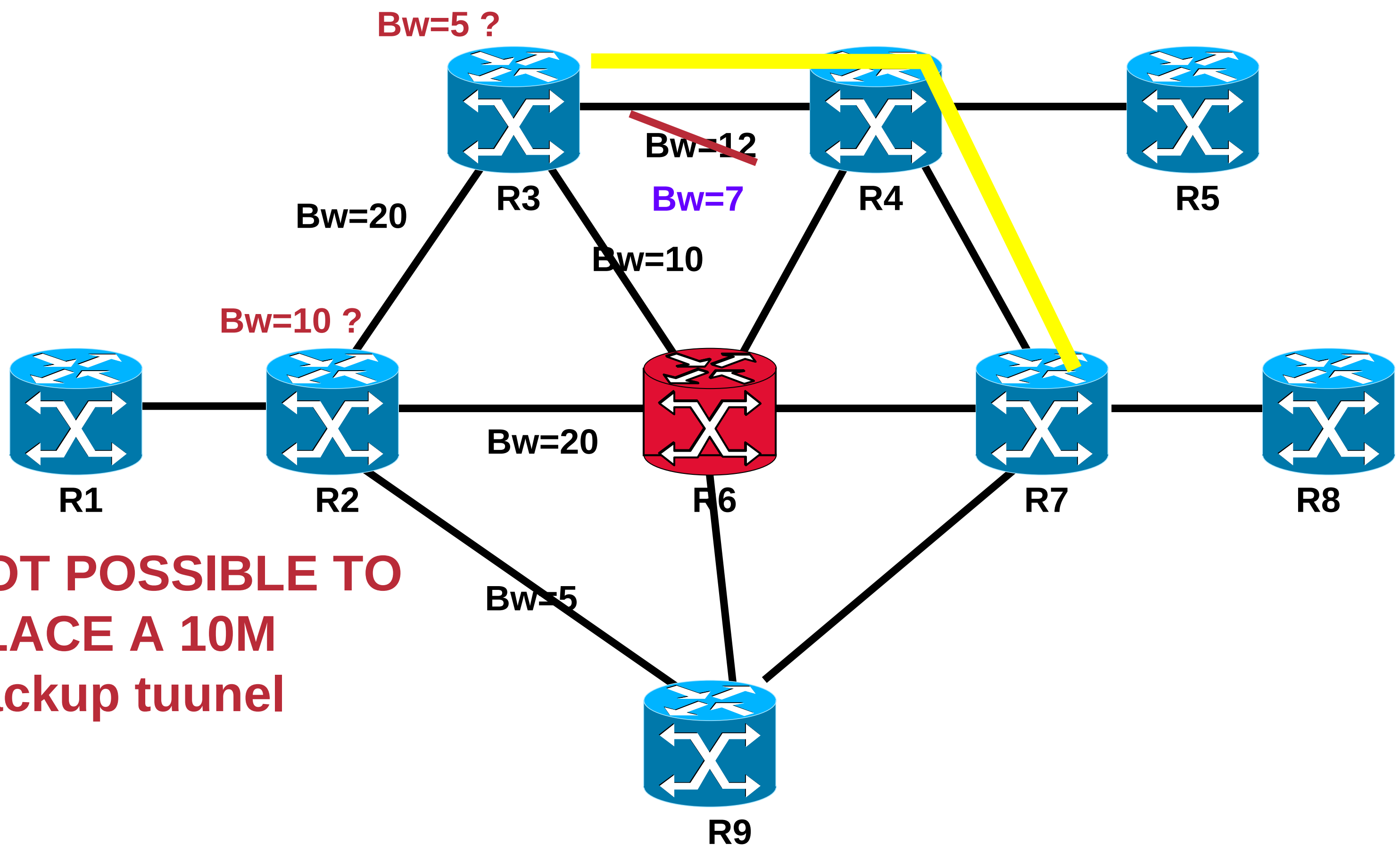
Backup tunnel path computation and provisioning

Local repair with bandwidth protection

- **CSPF is likely to be highly inefficient.**
- **Other more sophisticated backup tunnel path computation methods may be required.**

Backup tunnel path computation and provisioning

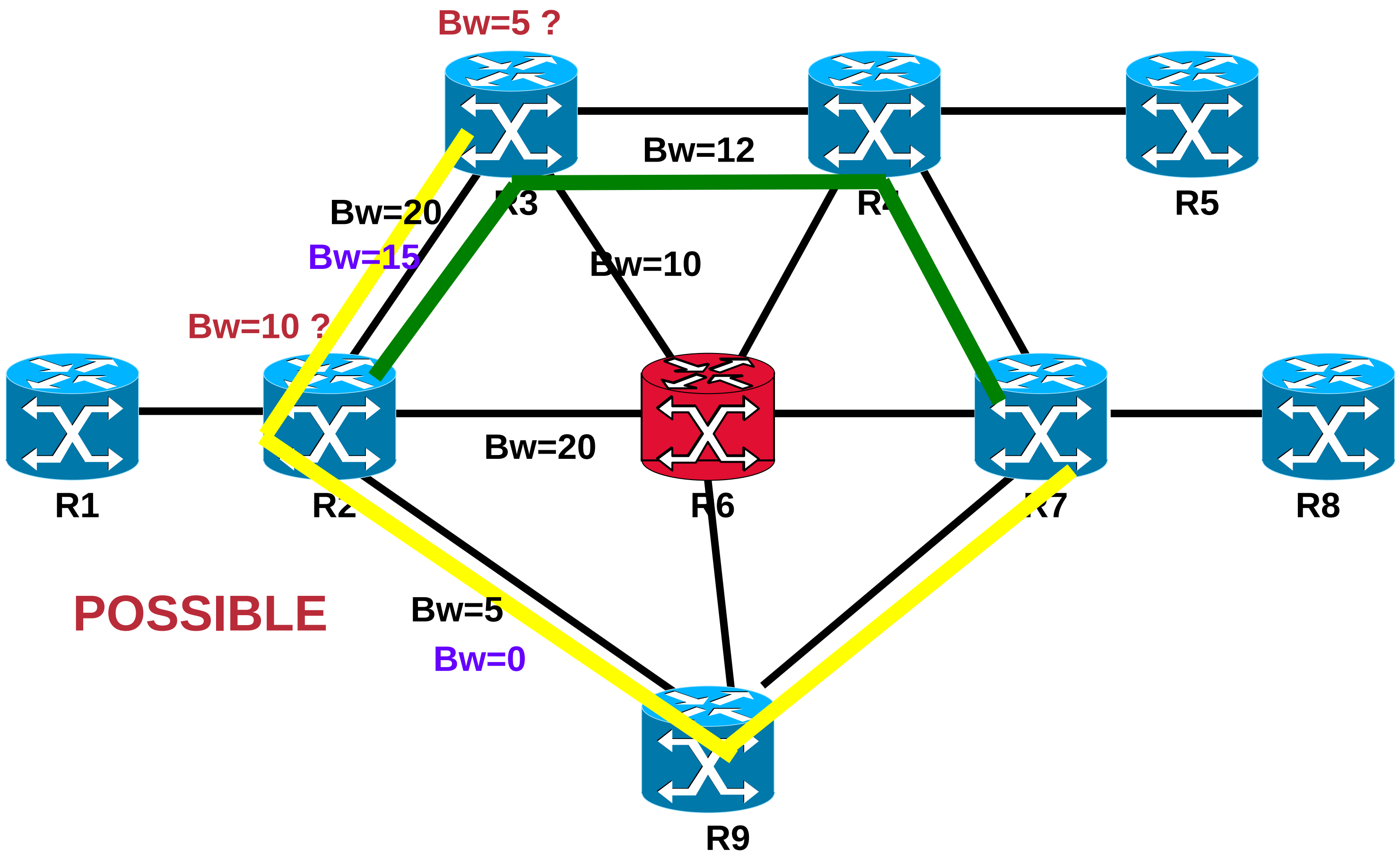
Local repair with bandwidth protection



NOT POSSIBLE TO PLACE A 10M backup tuunel

Backup tunnel path computation and provisioning

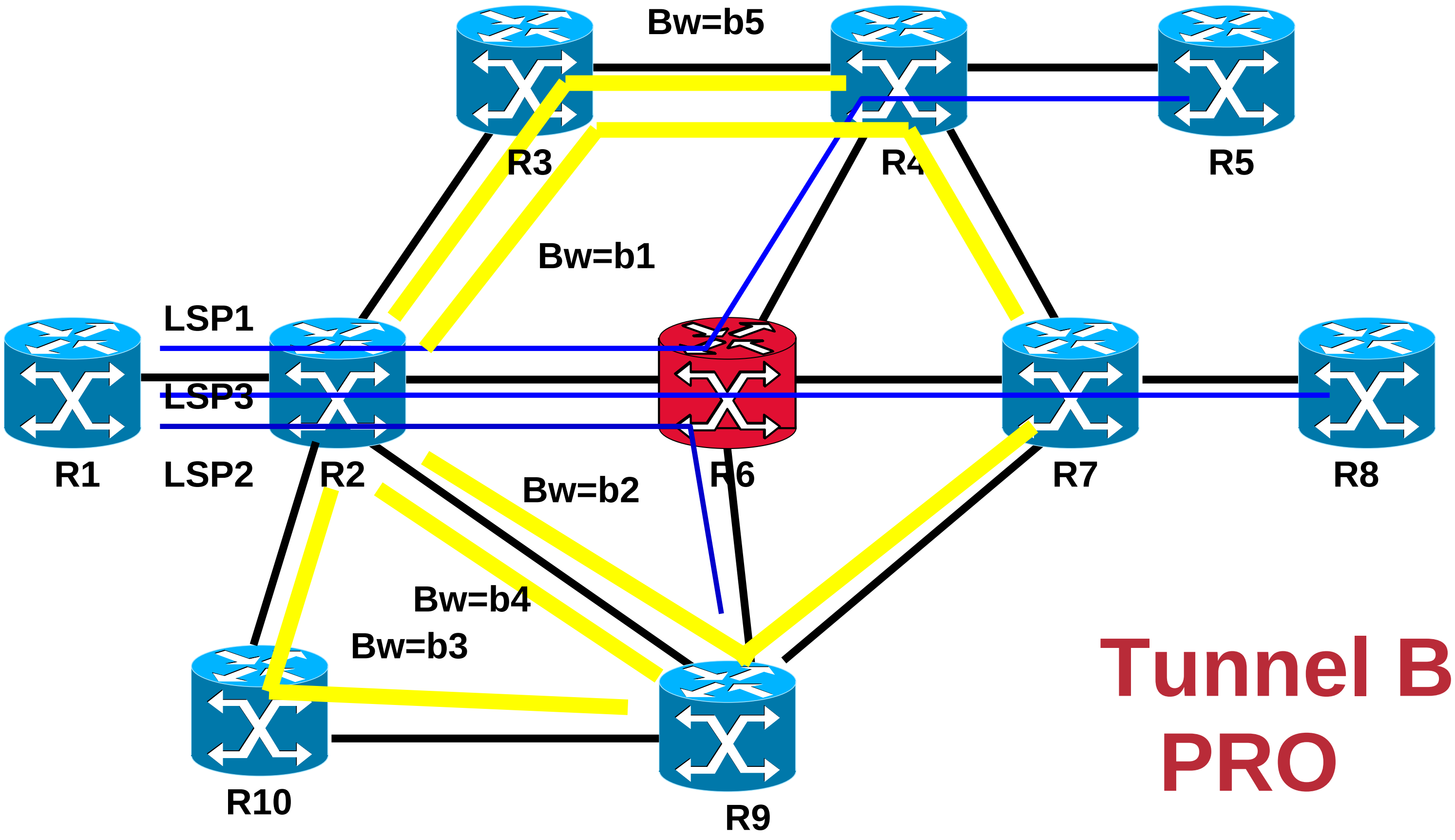
Local repair with bandwidth protection



POSSIBLE

Backup tunnel path computation and provisioning

Local repair with bandwidth protection



Tunnel Builder PRO

MPLS TE protection/restoration schemes

- Number of back-up LSPs required (impact on the number of states)
  - LSP reroute: 0
  - Path protection: O(# LSPs)
  - FRR Link protection: O(# links)
  - FRR Node protection: O(up to (# Node)^2)

Agenda

- Introduction
- Terminology of protection/restoration
- MPLS Traffic Engineering Fast Reroute
- IETF Update
- Conclusion

IETF Update

IETF

- WG IETF draft (adopted as a WG document at IETF 52, SLC):

draft-ietf-rsvp-lsp-fastreroute-00.txt

P Pan, DH. Gan: JUNIPER networks,

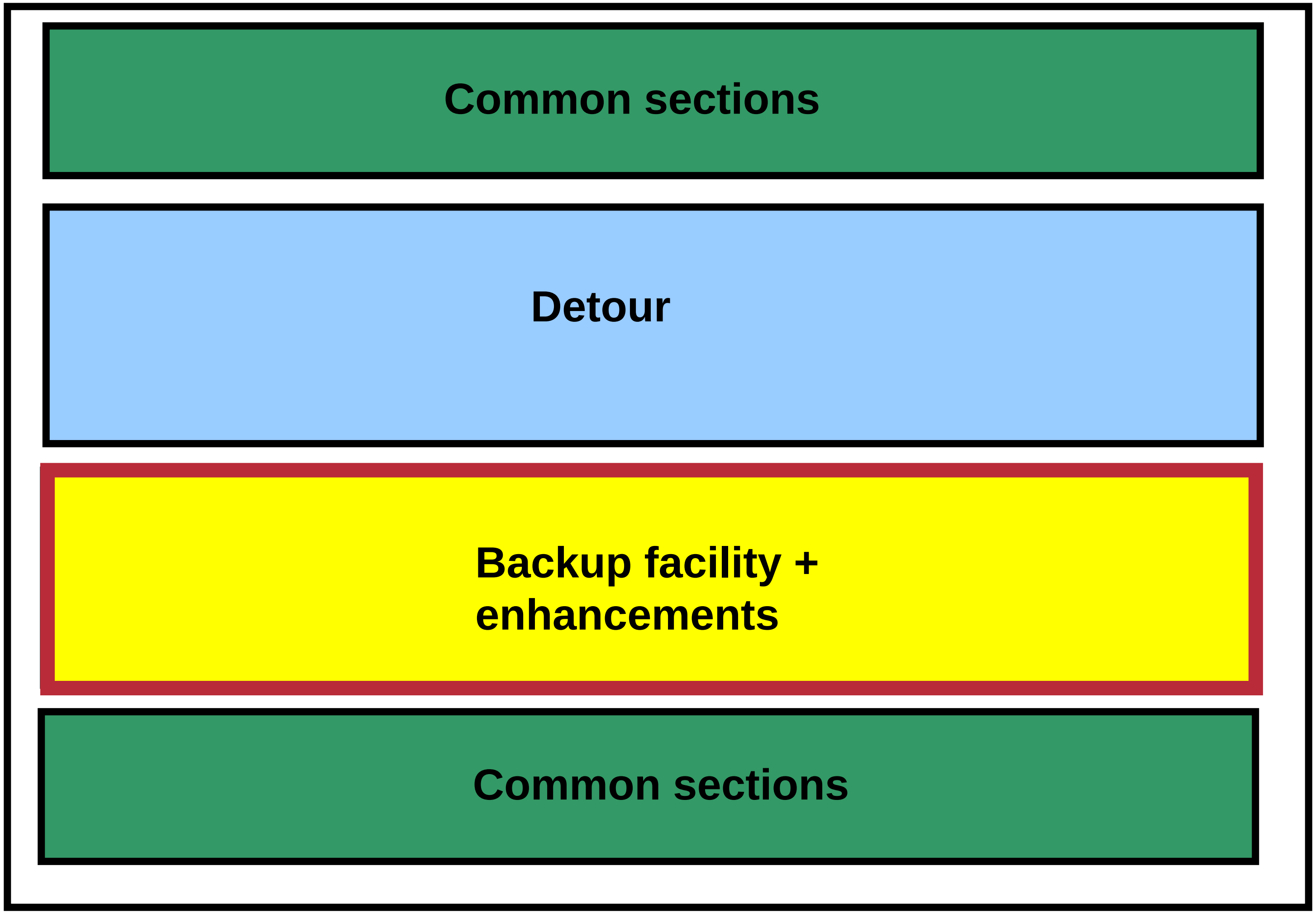
G. Swallow, JP Vasseur: CISCO SYSTEMS

D. Cooper: Global Crossing

A. Atlas, M. Jork: AVICI Systems

IETF Update

IETF



Common sections

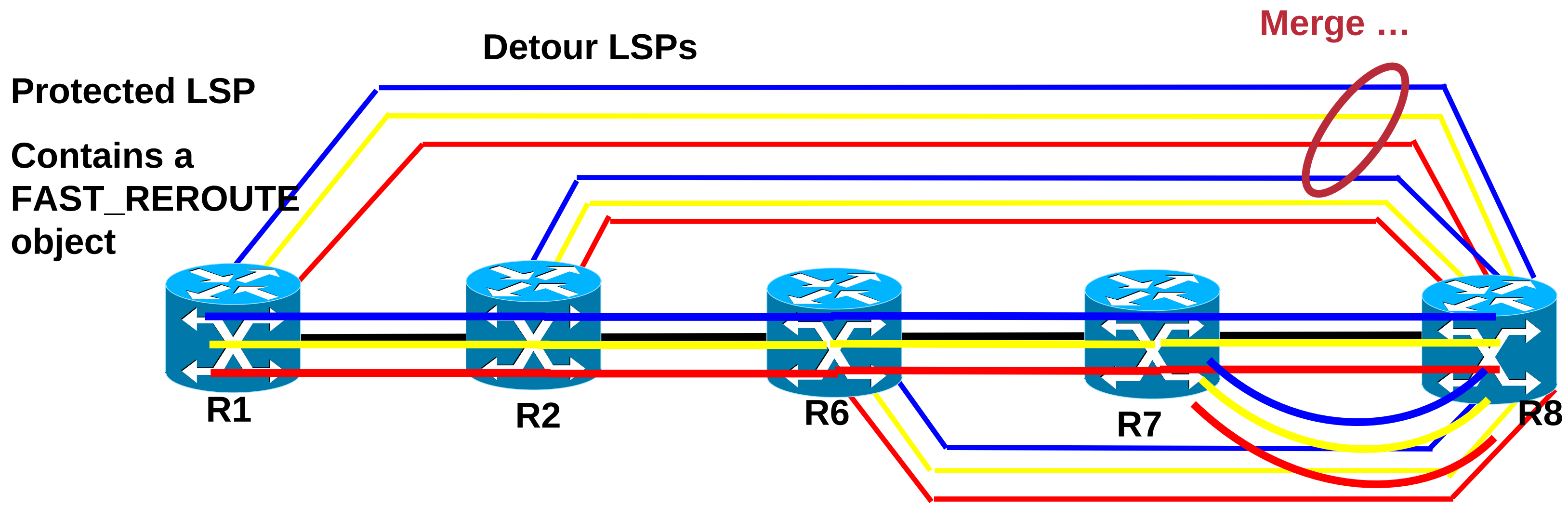
Detour

Backup facility + enhancements

Common sections

MPLS TE protection/restoration schemes

- The Detour LSP solution overview



- The protected LSPs are signalled with a FAST_REROUTE object specifying the attributes of the detour:
  - priority, max hops, bandwidth.
- Detour LSP are set up at each PLR
- Detour path computed using CSPF (periodic …)

MPLS TE protection/restoration schemes

- The number of detour LSPs= nb of protected LSPs * (N – 1) w/o merging

  Where N : average number of hops per LSP

- With 5000 protected LSPs and an average diameter of 6 hops, this represents 25000 TE LSPs (w/o merging)
- So the main issue of this solution is the scalability.
- With bypass, a single backup tunnel is used to backup a set of protected LSPs.

Agenda

- Introduction
- Terminology of protection/restoration
- MPLS Traffic Engineering Fast Reroute
- IETF Update
- Conclusion

MPLS TE protection/restoration schemes

- In summary,
  - **LSP reroute** (Global Restoration) is the default TE rerouting mode (slow)
  - **Path protection** (Global protection) if just a few protected LSPs, no sub seconds TTR required,
  - **FRR link protection** (Global protection) provides 50 msecs (may replace SDH/Sonet protection), could be configured on a few specific links. Limit the number of extra states required (using M:N protection) – label stacking.
  - **Node protection** (Global protection) the most efficient protection scheme providing 50ms in case of link and node protection. Limit the number of extra states required (using M:N protection) – label stacking

Thank You !

Agenda

- Failure profiles

  → Link failures,

  → Hardware node failures,

  → Software failures

  - Control plane Node failures (GRP frozen, …),

  - Forwarding plane node failures

  → “Planned” Hw/Sw failures

  - Software upgrades,

  - Hardware upgrades (LC, GRP, Chassis, …)

Agenda

→ Determining the network failure profiles to key prior to determining the set of protection/restoration schemes to deploy

Agenda

- Improving network reliability

→By network architecture (load balancing, elimination of central point of failure, …),

→ Improving network element redundancy

o Hardware redundancy (GRP, Chassis, …),

o Software redundancy (High Availability)

→ Protection network elements (links/nodes/SRLG) with Fast rerouting (IGP, FRR).

Phasing

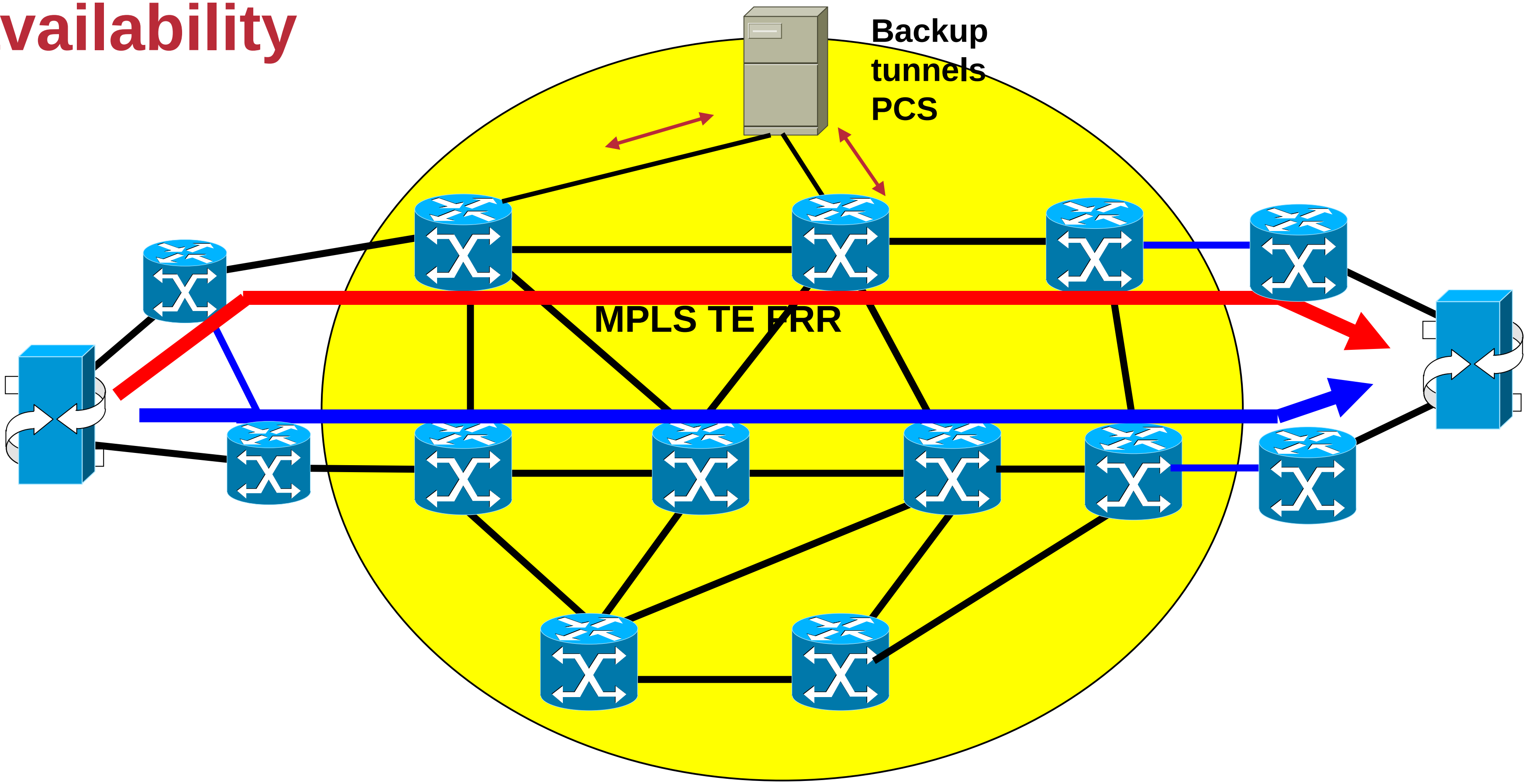
Protection/restoration schemes

Protected link

unprotected link

Improving network availability

Centralized



Backup tunnels PCS

MPLS TE FRR

Link/Node/SRLG Fast protection (50msecs) with BW guaranties

Agenda

Failure profiles

- ➢Link failure

  ✓ Link protection: Optical (1+1, 1:N, …), SDH SONET, … MPLS TE FRR

- ➢ Hardware node failures,

  ✓ IGP, MPLS TE Fast Reroute

- ➢ Software failures

  - Control plane Node failures (GRP frozen, …),

    ✓ IGP + MPLS TE Fast Reroute

  - Forwarding plane node failures

    ✓ per box mechanism

- ➢ Planned Hw/Sw failure

  - Software upgrades,

    ✓ Overload bit, MPLS TE Fast Reroute (RSVP hellos)

  - Hardware upgrades (LC, GRP, Chassis, …)

    ✓ Overload bit, MPLS TE Fast Reroute (RSVP hellos)

Agenda

- **Protection/Restoration scheme performances. Multidimensional problem …**

  - convergence speed (50msecs – 2-3 secs – minutes). Controls packet loss.

  - QOS on the rerouted Path

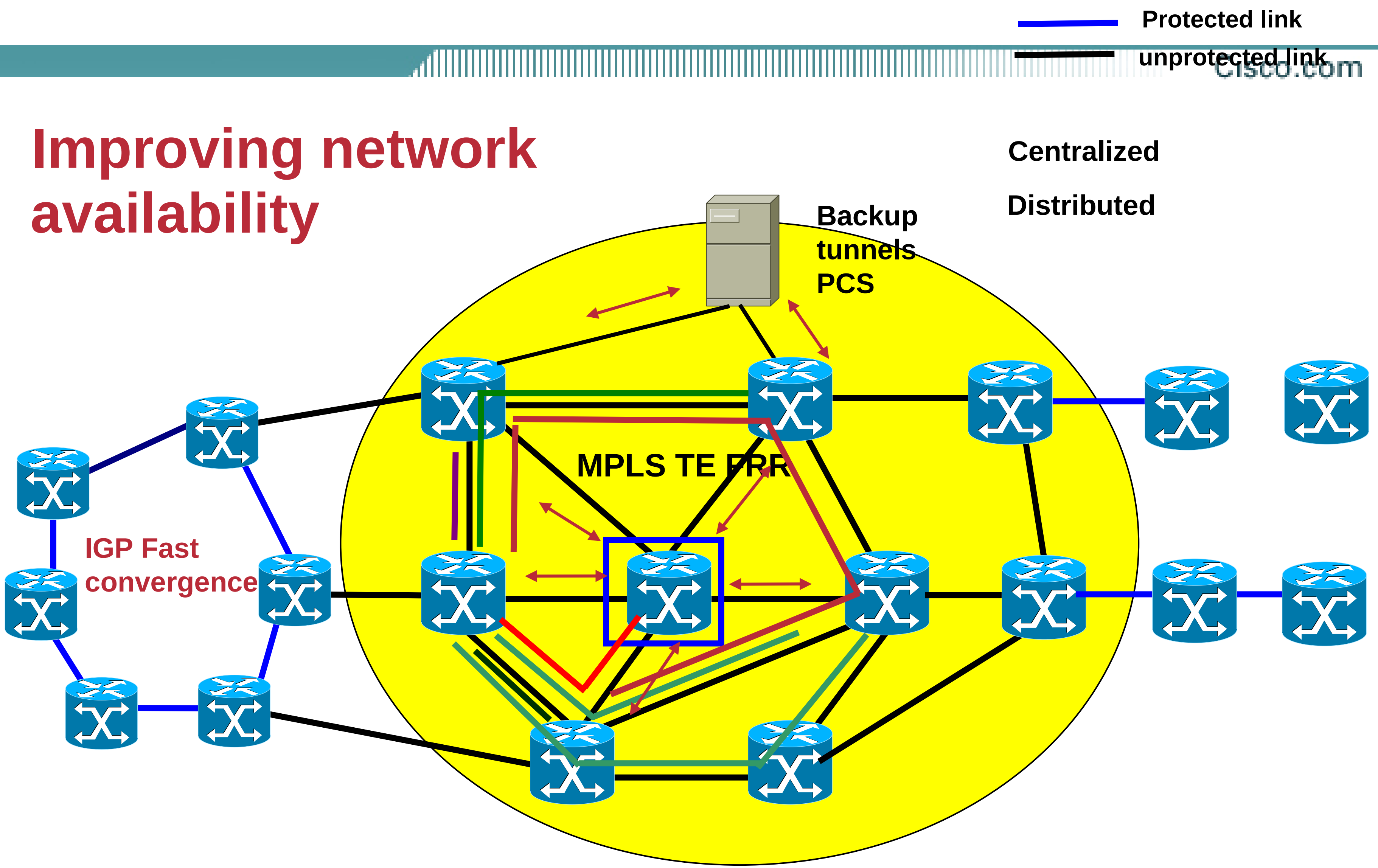
  → Queueing algorithm (Forwarding plane)

  → Bandwidth guaranty (Control plane)

  → Bounded propagation delay (control plane)

Protection/restoration schemes

Improving network availability



Link/Node/SRLG Fast protection (50msecs) with BW guaranties

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