# A PCE-based MPLS Traffic Engineering LSP path computation approach

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MPLS TE LSP Path computation approaches

Distributed Approach

Hybrid Approach

Pure Off-line Approach
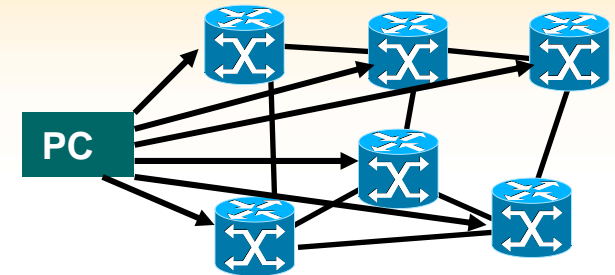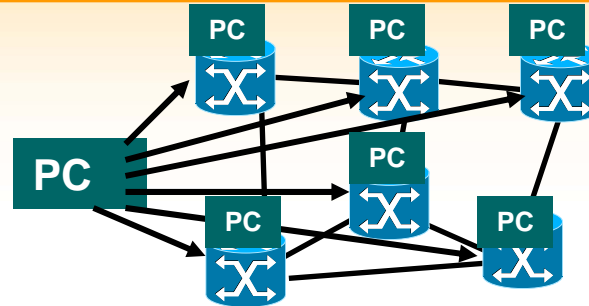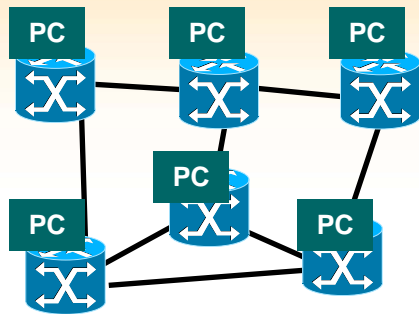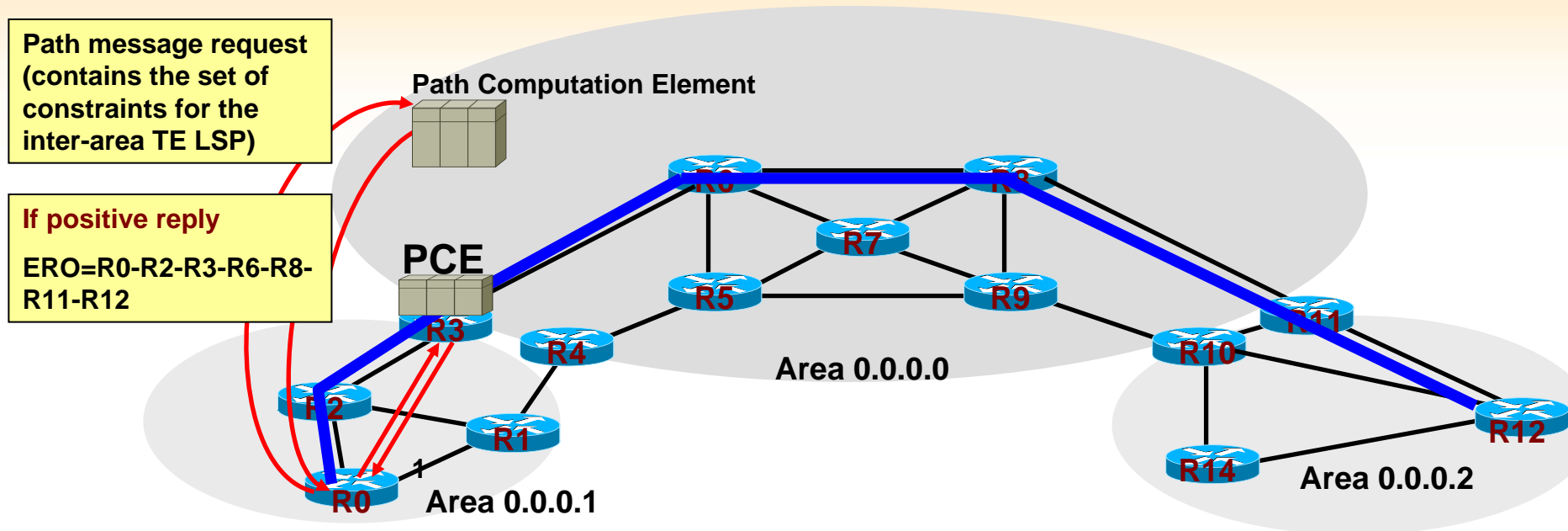
The two well-known path computation approaches:

➢ Distributed CSPF-based approach

- By far, the most commonly adopted approach whereby each head-end LSR is responsible for computing path of its TE LSPs independently of the other LSRs in the network.

- Highly flexible: dynamic adaptation the traffic patterns with auto-bw, fast reaction to network changes (e.g. failures), scale to very large number of TE LSPs (current networks with tens of thousands of LSPs)

➢ Pure off-line approach

- The paths of the TE LSPs in the network are simultaneously computed by an off-line server and then downloaded on each router.

- Allows for a more optimal (globally optimal) path computation leading to additional bandwidth usage.

Path Computation Element: Definition

Path message request (contains the set of constraints for the inter-area TE LSP)

If positive reply

ERO=R0-R2-R3-R6-R8-R11-R12

Path Computation Element

PCE

R0 **R1** **R2** **R3** **R4** **R5** **R6** **R7** **R8** **R9** **R10** **R11** **R12** **R14**

Area 0.0.0.0

Area 0.0.0.1

Area 0.0.0.2

1

The PCE approach is defined in <u>draft-ash-pce-architecture</u> where various models are described + the various components of such architecture.

" … A Path Computation Element (PCE) is an entity that is capable of computing a network path or route based on a network graph, and applying computational constraints. The PCE entity can be located within an application, on a network node or component, on an out-of-network server, etc."
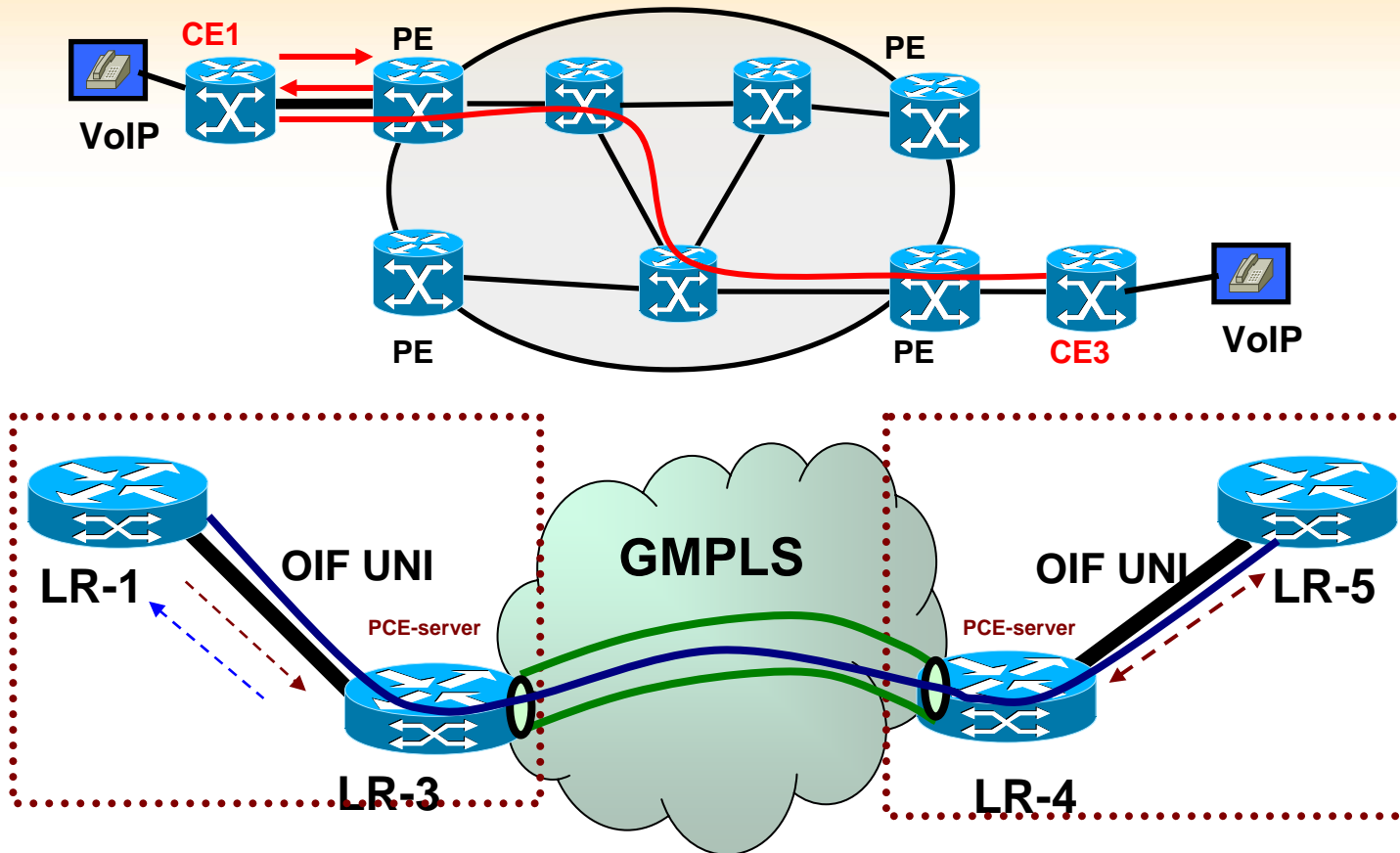
PCE Applicability:
Partial Visibility
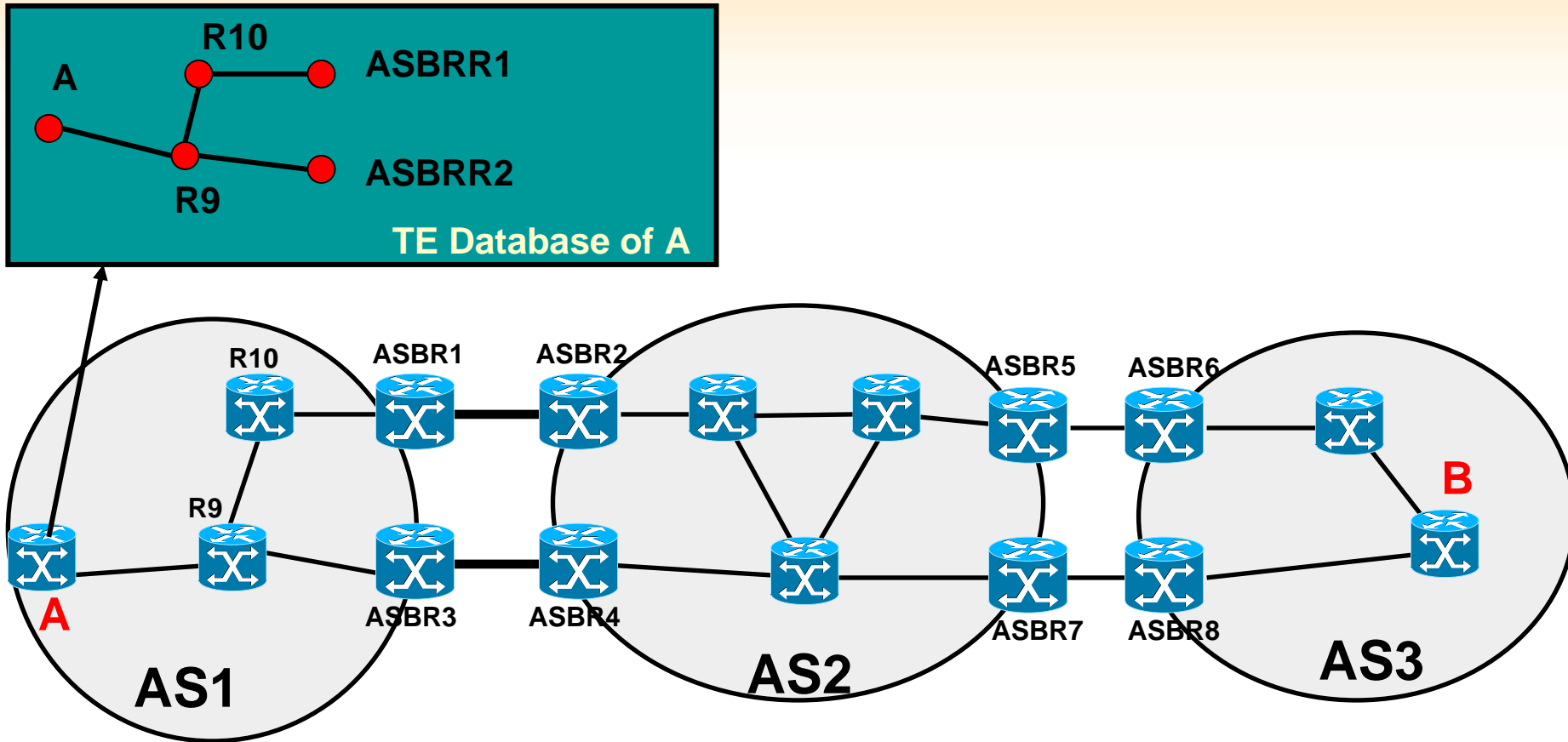
- **Partial visibility**: Inter-area or Inter-AS MPLS Traffic Engineering.

PCE Applicability:
Node outside of the routing domain

CE1 — PE — PE
VoIP

PE — PE — CE3 — VoIP

LR-1 — OIF UNI — GMPLS — OIF UNI — LR-5
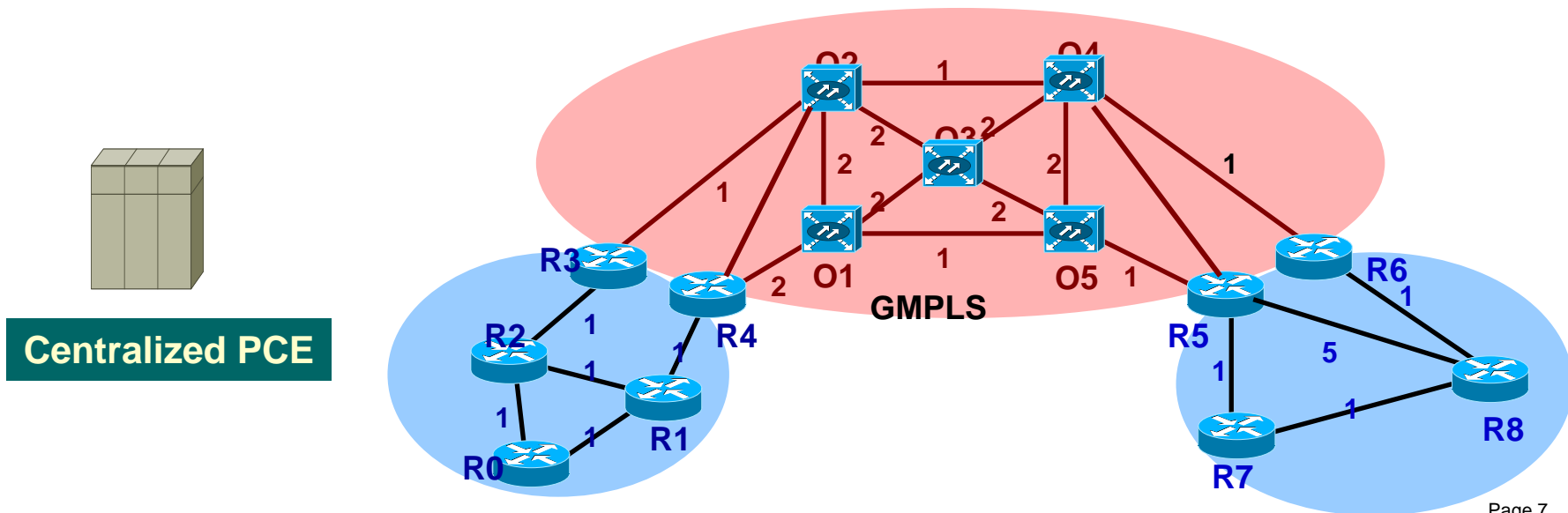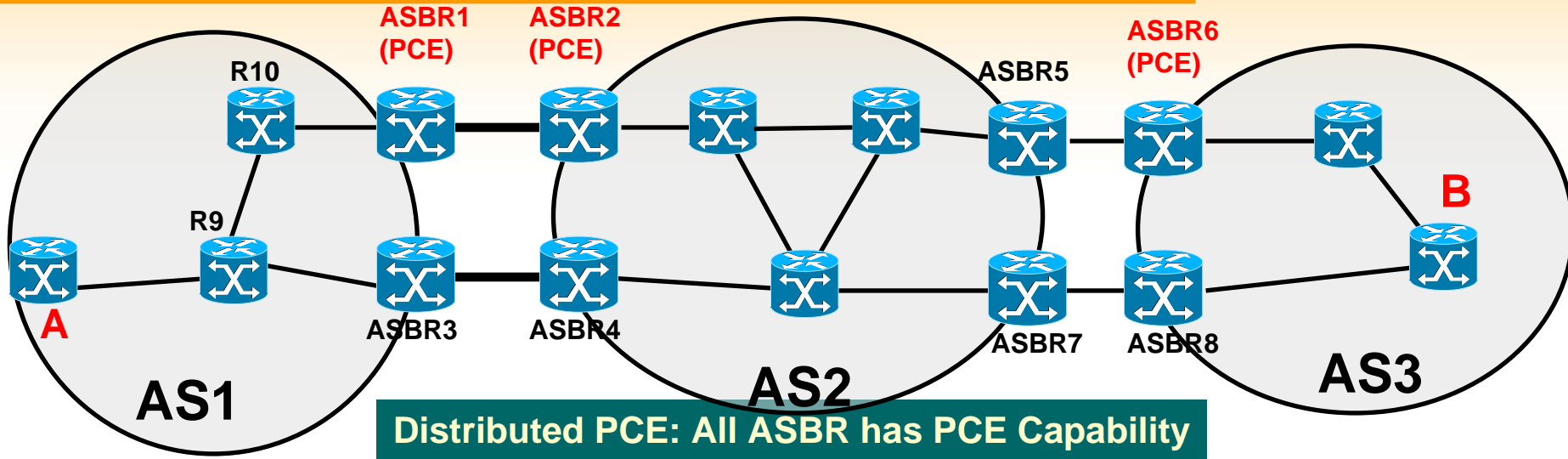
PCE-server — PCE-server

LR-3 — LR-4

- **Node outside of the routing domain**: For example, a CE requiring an end to end TE LSP from CE to CE for guaranteed bandwidth, GMPLS core accessed via UNI, etc.

PCE Applicability:
CPU-intensive path computation

CISCO SYSTEMS

PCE

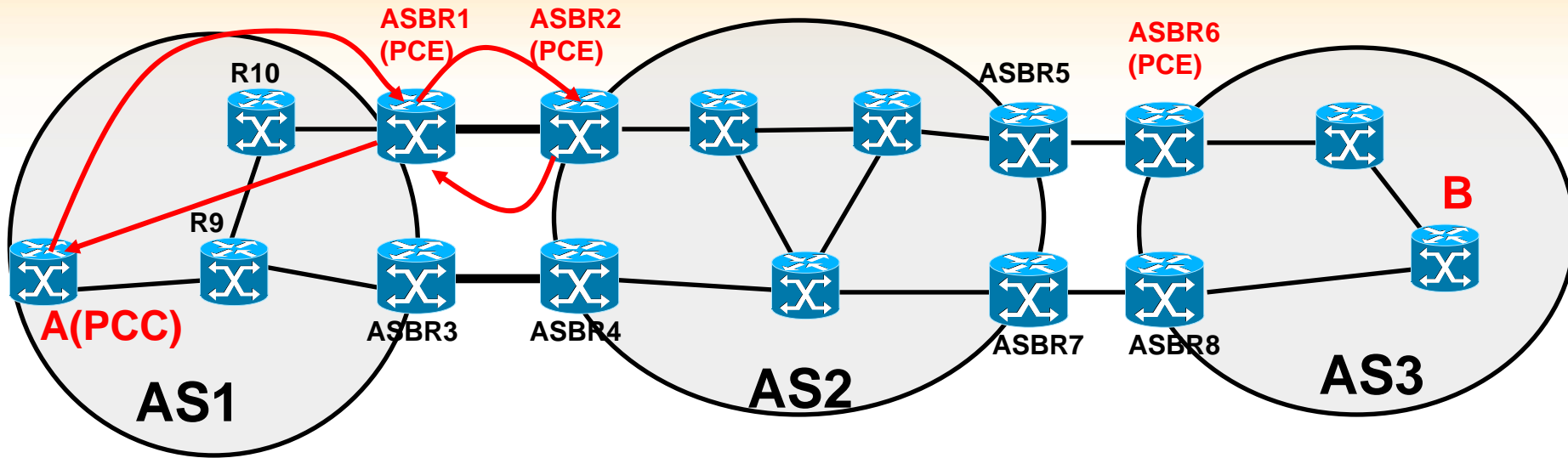**IP + Optical Topology (at PCE)**
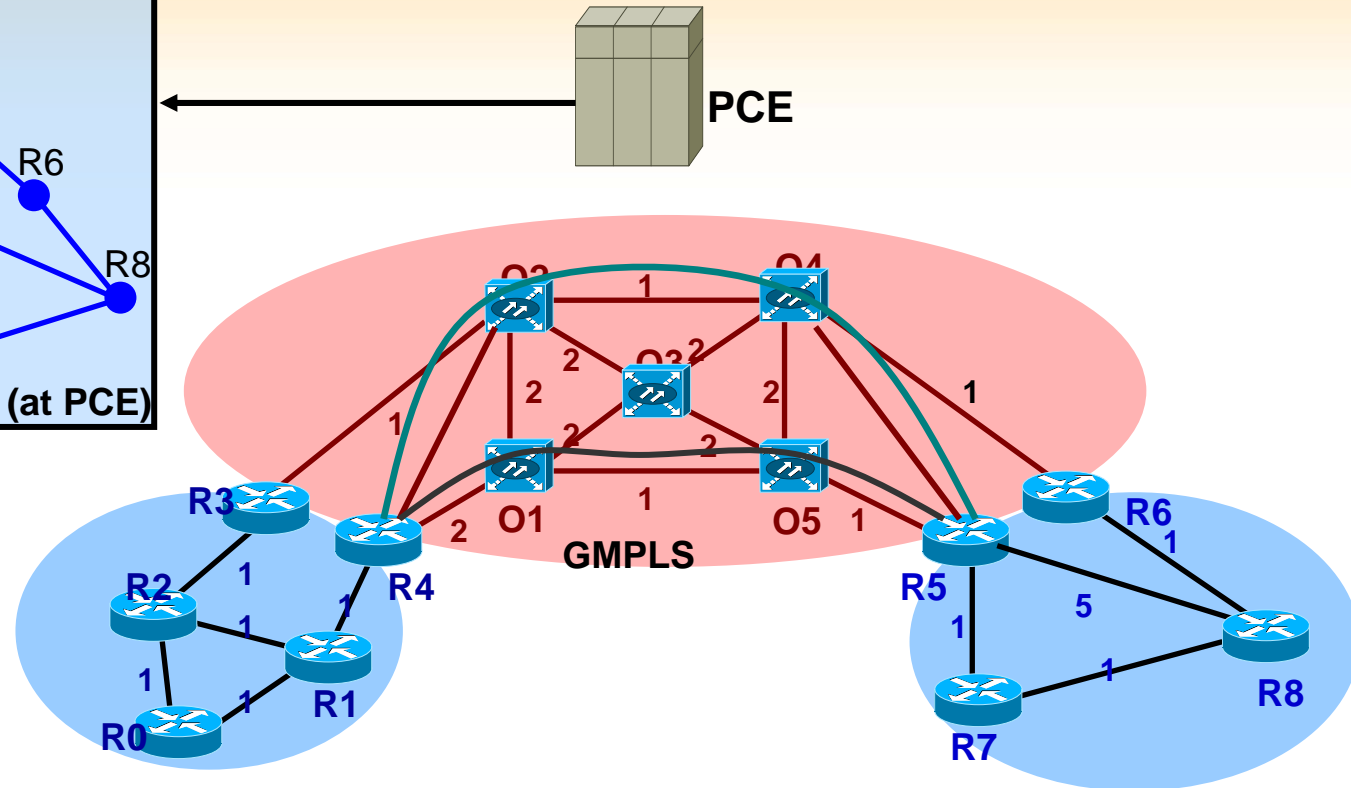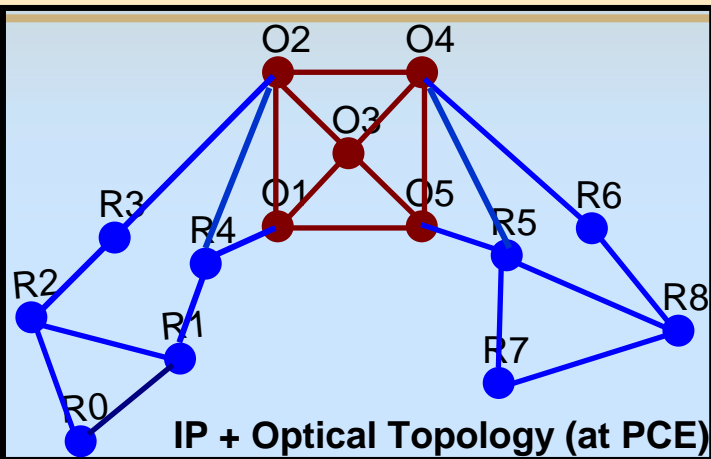
GMPLS

- **CPU-intensive path computation**: Global optimization, multi-constraints path computation (typically useful for GMPLS networks), path diversity computation, Multi-layers traffic engineering optimization, Single and Multi-layers network recovery approach, …)

Centralized Vs. Distributed PCE

ASBR1 (PCE)   ASBR2 (PCE)   ASBR5   ASBR6 (PCE)

R10

R9

A

ASBR3   ASBR4   ASBR7   ASBR8

B

AS1   **AS2**   **AS3**

Distributed PCE: All ASBR has PCE Capability

O2   O4

O3

O1   O5

GMPLS

R3

R2   R4

R5   R6

Centralized PCE

R1

R0   R7   R8

Scope of PCE Standardization:
Difference between PCE and an off-line tool

- **Communication between PCCs and PCEs, and between cooperating PCEs**
- **PCE Discovery and Load Balancing**
- **Signaling of inter-domain paths**
- **Synchronization Aspects**
- **Detecting PCE Liveness**
- **Definition of metrics to evaluate path quality, scalability, responsiveness and robustness of path computation models**
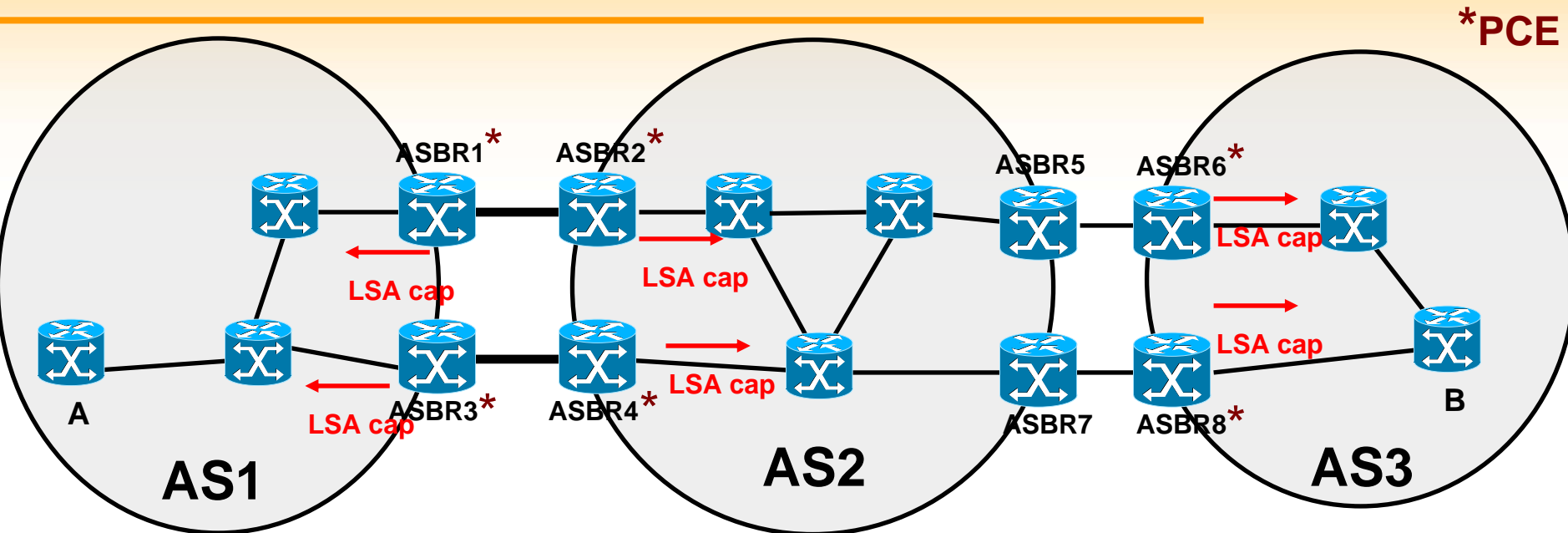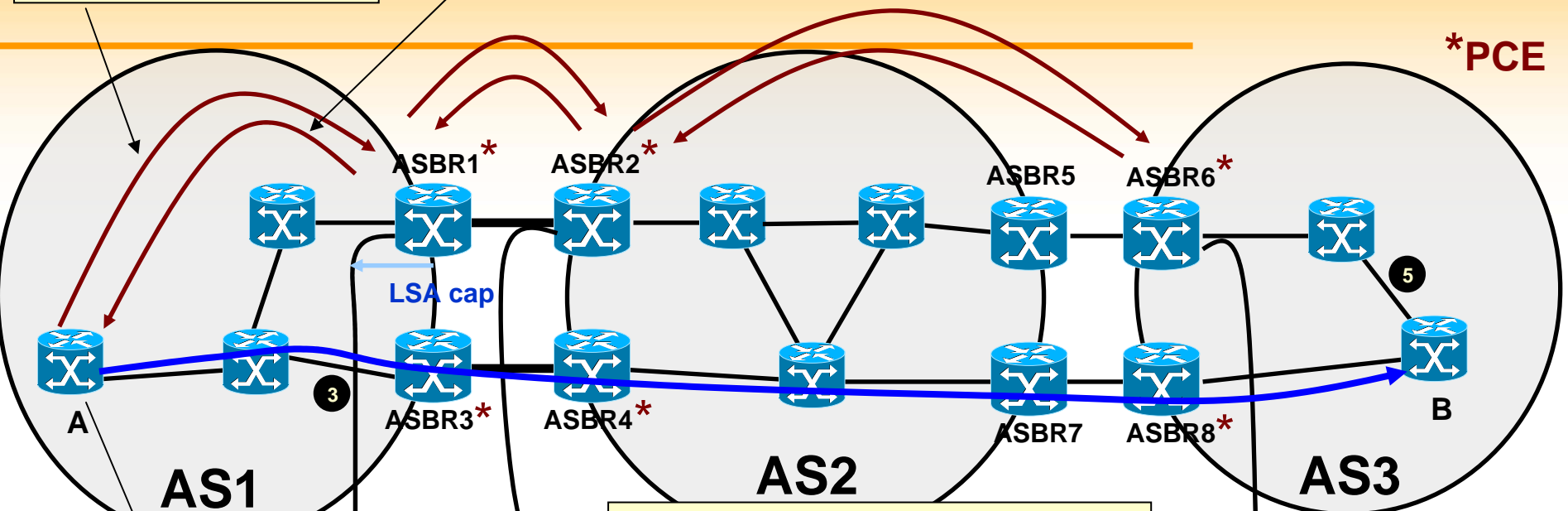
- **There are several ways for the PCC to learn the PCS(s) location (IP addresses) and capabilities:**
  - **By static configuration**
  - **Using IGP extensions for an automatic PCS discovery, see**
    - *(draft-ietf-ospf-caps + draft-vasseur-ospf-te-caps) and,*
    - *(draft-ietf-isis-caps + draft-vasseur-isis-te-caps)*

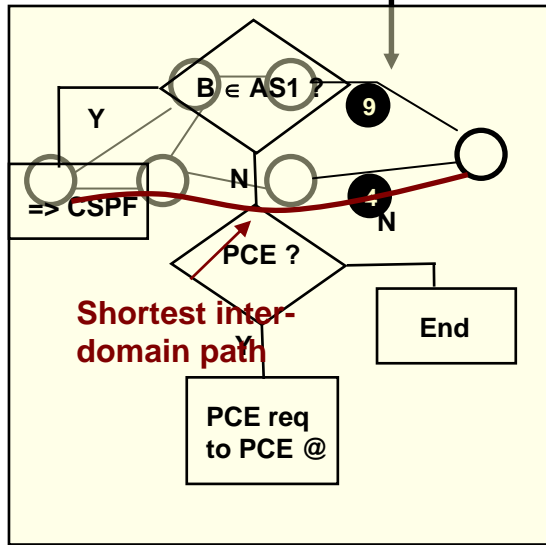# Signaling of inter-domain paths using Distributed PCE
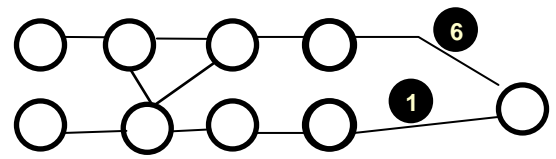
Path Computation Request
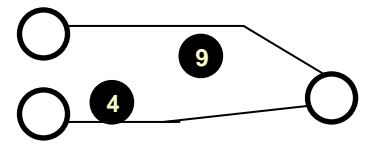
Path Computation reply

*PCE

ASBR1 *   ASBR2 *   ASBR5   ASBR6 *

LSA cap

A

ASBR3 *   ASBR4 *   ASBR7   ASBR8 *   B

5

3

AS1   **AS2**   **AS3**

B ∈ AS1 ?   9

Y

N   4

=> CSPF   N

PCE ?

Shortest inter-domain path   Y

End

PCE req to PCE @

ASBR1 build a virtual SPT (the shortest path is built using a backward recursive computation)

Shortest path satisfying the constraint(s) from every entry ASBR in AS3:
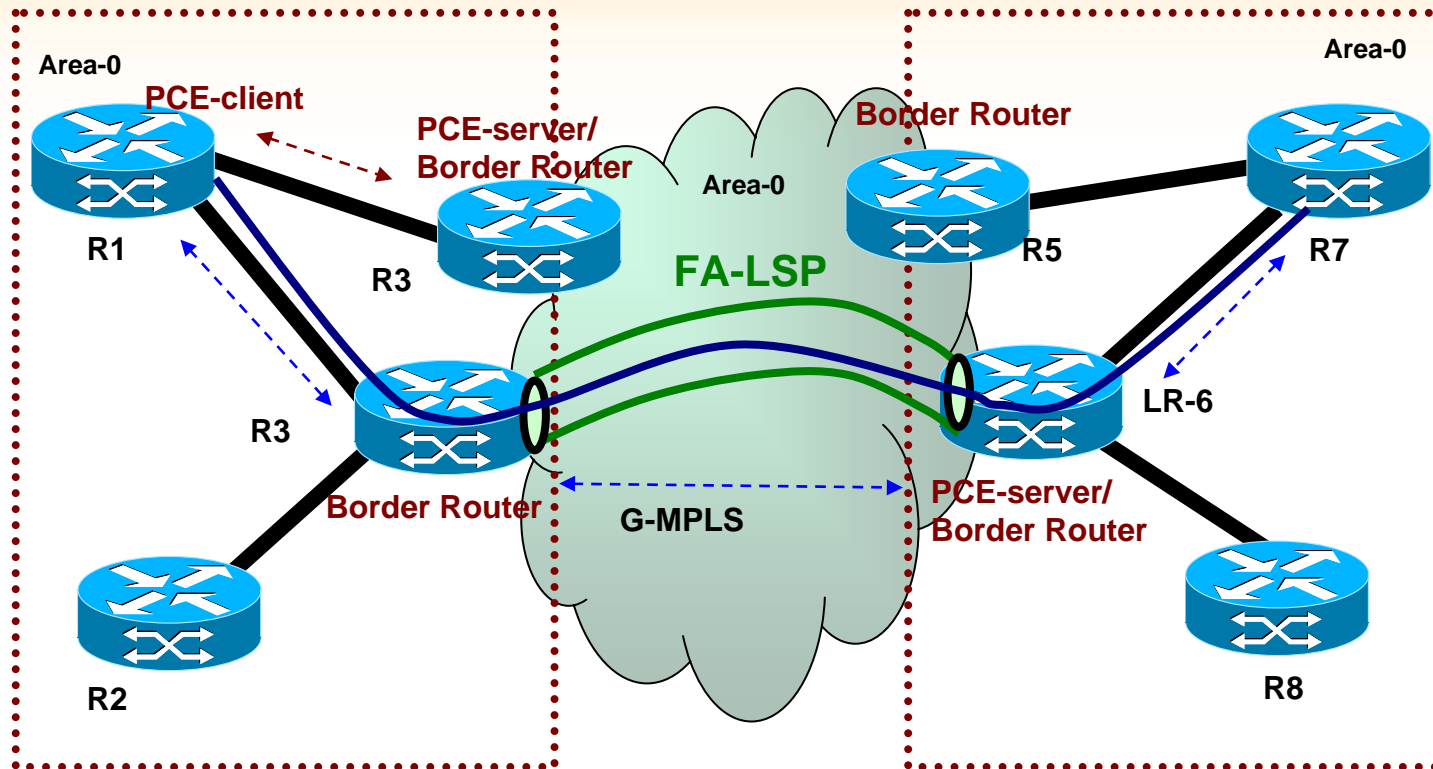Path1: ASBR6-B(L), 6
Path2: ASBR8-B(L), 1

6

1

Virtual SPT computation

6

The resulting Virtual SPT is then provided to ASBR1 (path computation reply)

1

9
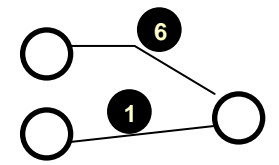
PCE discovery is performed via IGP extensions:

4

Applicability of PCE to GMPLS Networks and Border Model

Area-0

PCE-client

PCE-server/
Border Router

Border Router

Area-0

R1

R3

FA-LSP

Area-0

R5

R7

R3

LR-6

Border Router

G-MPLS

PCE-server/
Border Router

R2

R8

—— GMPLS tunnel	⇠- - - - - -⇢ RSVP Signaling messages
—— MPLS tunnel	⇠- - - - - -⇢ RSVP Path request/reply messages (PCE)

Reference: M. Tatipamula, Z. Ali, "Deployment consideration for GMPLS", iPOP'2005

# Another example: PCE-based Multi-layer Traffic Engineering

A PCE-based architecture is use to perform <u>Multi-Layer Traffic engineering</u> (bandwidth optimization) and/or implement an <u>optimized Multi-Layer network recovery strategy</u> (so as to minimize backup resources while guaranteeing service recovery)

A Wide set of models are possible !

➢ **Each layer can interact with the PCE <u>independently or in a coordinated manner</u>,**

➢ **Provisioning of new Optical LSP can be <u>PCE driven or LSR driven</u> with the use of the PCE for more optimal solutions**

➢ **The PCE approach could be used for <u>both or one of the two layers</u>. Furthermore, distributed CSPF can be used in conjunction with the PCE-based approach**

PCE → **Multi-layers traffic engineering or dynamic multi-layers network recovery**

PCE IETF Standardization
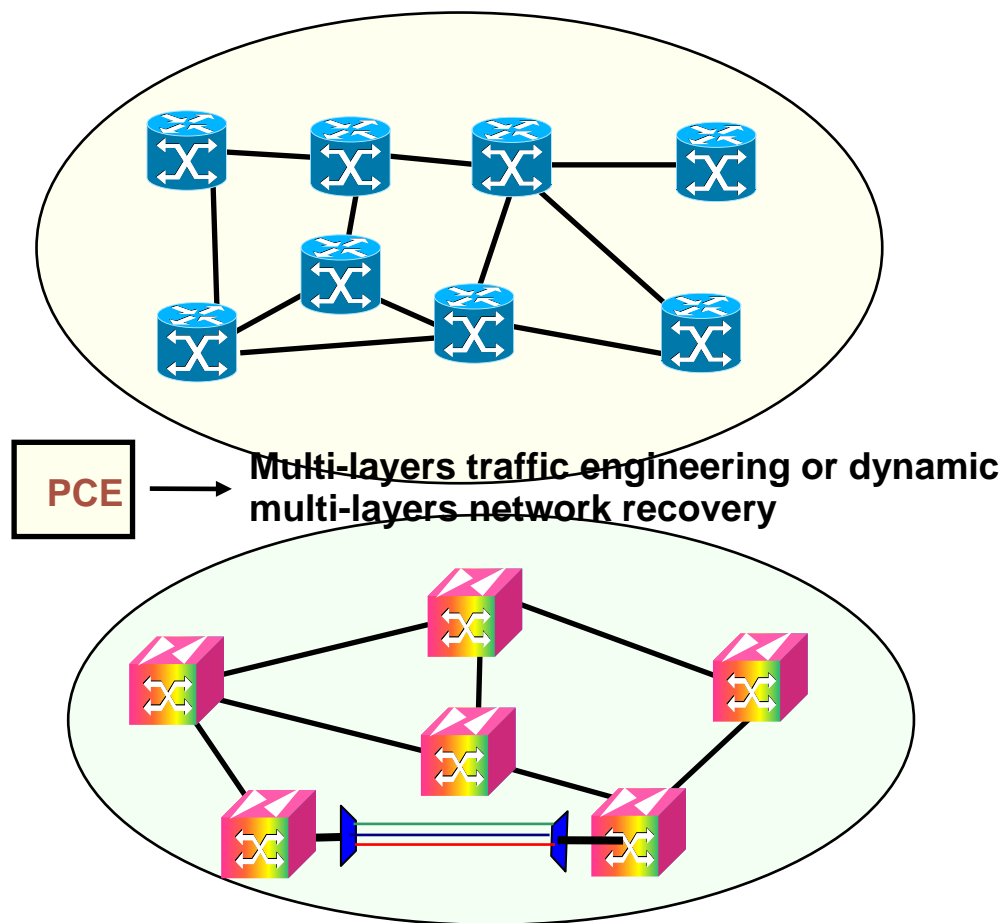
➢ **PCE related work are done at the IETF in the PCE Working group (IETF Routing area)**

- **Chairs: A. Farrel, JP Vasseur**

- **Mailing list: pce@ietf.org**

- **PCE WG charter can be found at:
  http://www.ietf.org/html.charters/pce-charter.html**

- **To register:General Discussion: pce@ietf.org**

- **To Subscribe: pce-request@ietf.org (In Body: subscribe)**

- **PCE Archive: http://www.ietf.org/mail-archive/web/pce/**

Conclusion

- **Many applications have been identified so far where a PCE-based approach (or a combined approach) could be very advantageous (two examples have been seen in this presentation)**

- **Will lead to standardized solutions at the IETF (PCE WG).**

Further reading

- **IETF Specifications: www.ietf.org (MPLS, CCAMP, PCE and TE Working Groups)**

- **Books**

"Network Recovery" - JP Vasseur, Mario Pickavet and Piet Demeester - Morgan Kaufmann - July 2004

Extensive coverage of network recovery aspects at multiple layers, including multi-layers recovery

"Definitive MPLS Network Designs" - Jim Guichard, F. Le Faucheur and JP Vasseur - Cisco Press - March 2005

Includes a case study on multiple distributed PCE-based path computation

"GMPLS: Architecture and Applications" - Adrian Farrel and Igor Bryskinpub. Morgan Kaufmann "later this year"