
ARIA Networks



Intelligence for Converging Networks

Latest Developments in Techniques for Computing Inter-Layer and Multi-Region Paths for Multi-Layer Traffic Engineering.

Adrian Farrel

CTO

adrian.farrel@aria-networks.com





Agenda

- Regions, Layers, and Domains
- Why do Multi-Layer Networking?
- Management and Signaling Models
- Application of PCE to Multi-Layer Path Computation
- Global Visibility
- Per-Domain Path Computation
- Backward Recursive Path Computation
- Cooperating PCEs with VNT Management
- Computational Challenges and Solutions

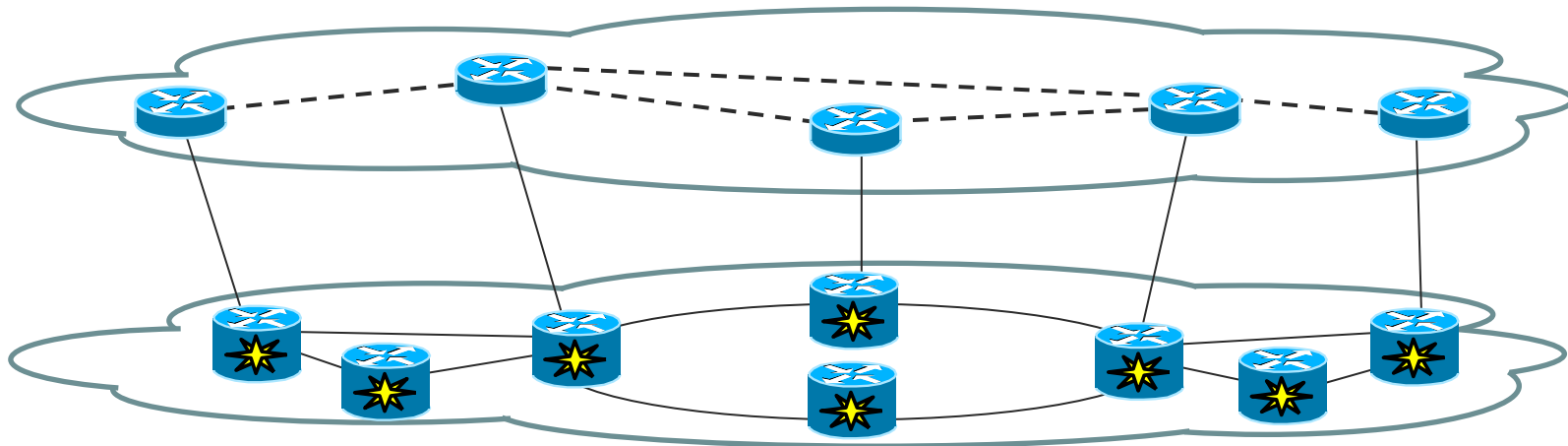


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Terms and Concepts

- Services delivered by layered networking
 - Layers have client/server relationship



- Network layers may be same or different technologies
 - If the technologies are different switching types we call them **regions**
 - For example, IP/MPLS over Optical
 - If the technologies are the same switching type we call them **layers**
 - For example, OC-12 over OC-48
- Path computation is performed on a **domain** of visibility
 - Network layers are often administered as domains



Why Multi-Layered Networking?

- This is nothing new
 - Connectivity in client networks has always been provided by connections in transport networks
- What is new?
 - Mixed technology networks
 - One administrative network with multiple technology devices
 - Multi-technology nodes
 - Can switch multiple technologies
 - Can adapt between different technology interfaces
 - Multi-layer end-to-end paths
 - A single end-to-end LSP is computed to transit multiple layers
 - Multi-layer traffic engineering
 - Traffic engineering considers optimality in more than one layer

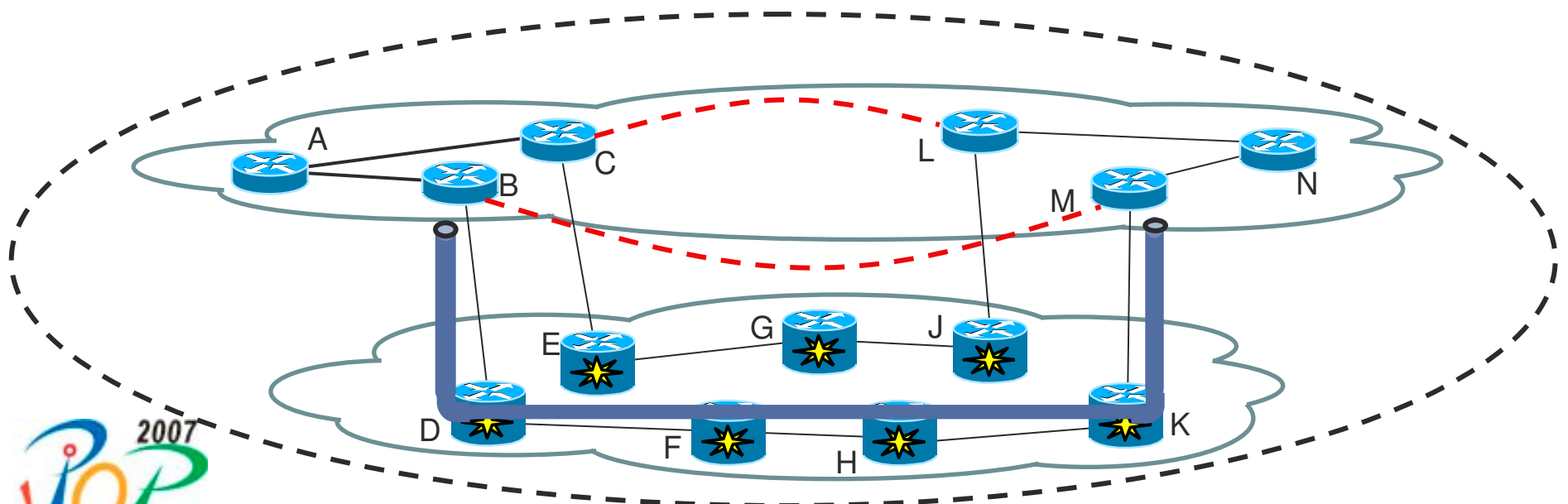


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Operational Models

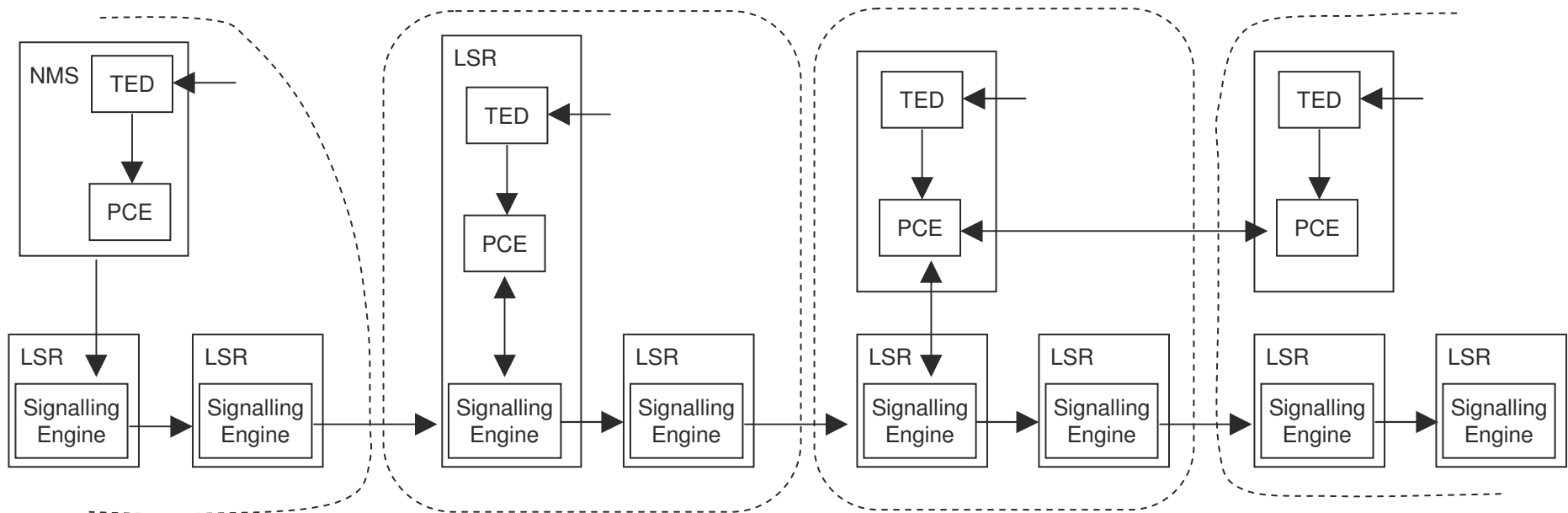
- Management Model
- Triggered Signaling Model
 - Full visibility
 - Assumed lower-layer connectivity
- Virtual Network Topology Management
 - Coordinated policy control
 - Connectivity may be pre-established or triggered





Path Computation Element (PCE)

“An entity (component, application, or network node) that is capable of computing a network path or route based on a network graph and applying computational constraints” - RFC 4655

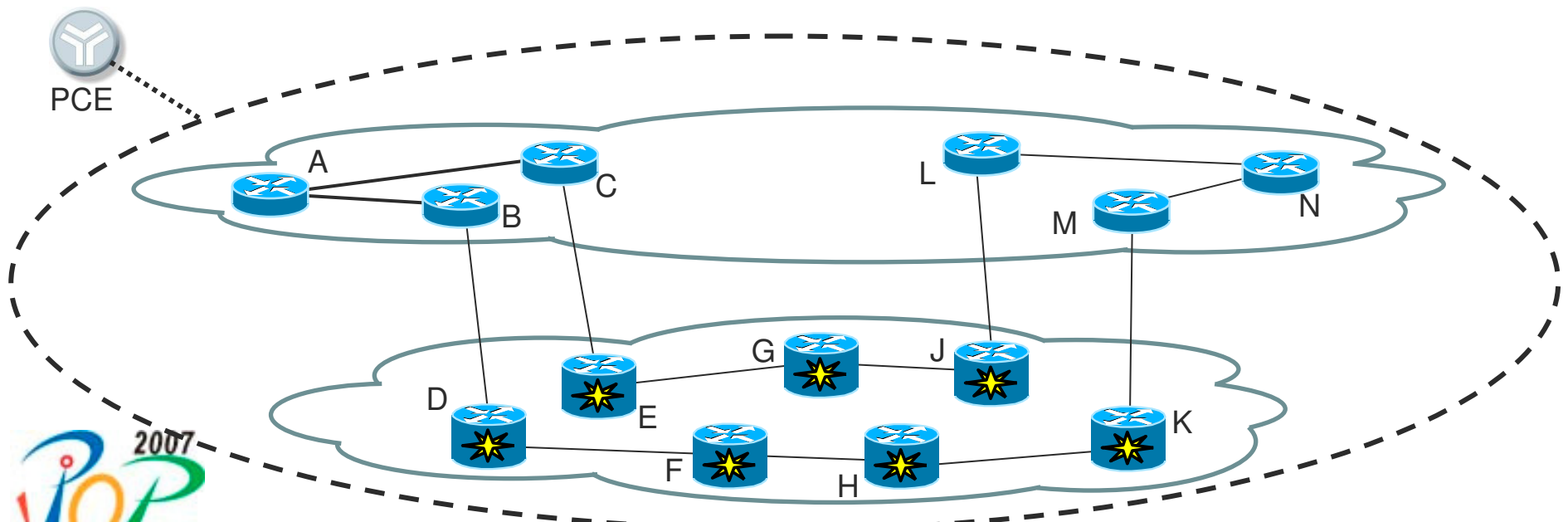


- What's new?
 - Nothing! Just look at NMS and LSRs today
 - A formalisation of the functional architecture
 - The ability to perform path computation as a (remote) service



PCE With Global Visibility

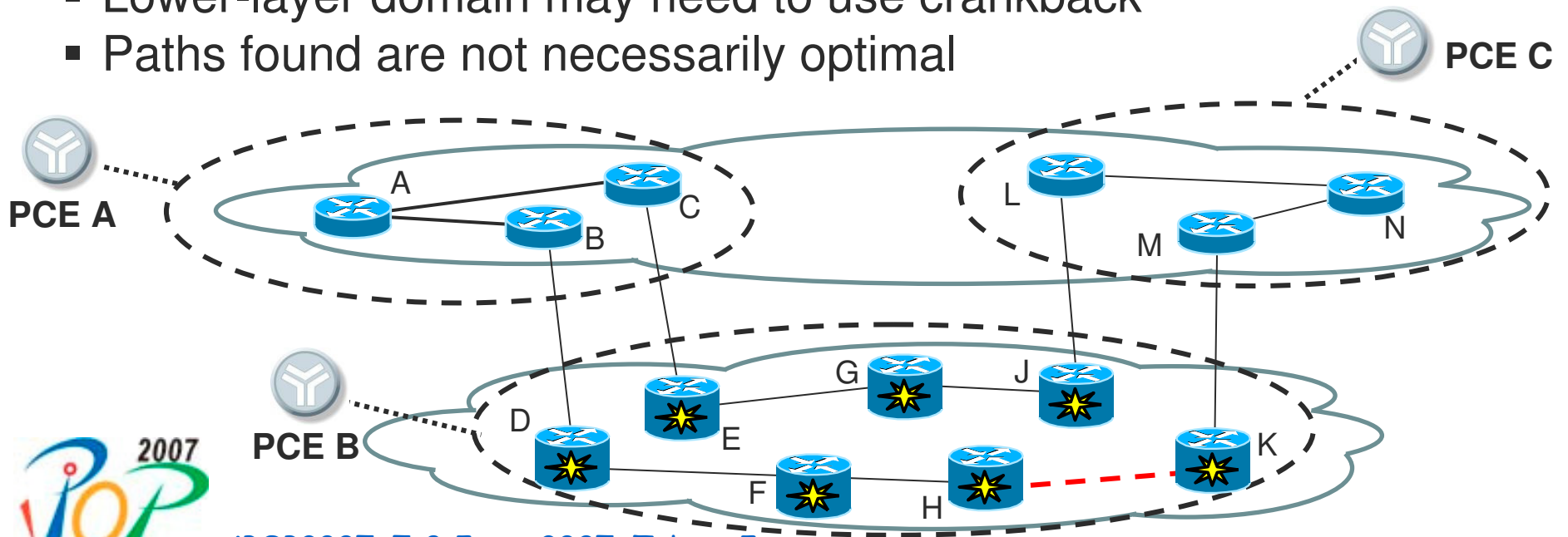
- One PCE has full visibility of all layers
- Traffic Engineering Database (TED) may be:
 - Integrated (all links and nodes together)
 - Separated by layers
- Computed end-to-end path crosses layers
 - Tunnels set up on-demand (triggered), and re-used if available
 - Need to know adaptation capabilities at layer boundaries (Are these implicit?)
- May be scaling and administrative concerns





Multi-Layer Per-Domain Computation

- Application of draft-ietf-ccamp-inter-domain-pd-path-comp-05.txt
- Global visibility is not required
- Node A consults PCE A to find best path across first domain to reach lower-layer network
- Node D consults PCE B to find best path across lower-layer to remote higher-layer domain
- Triggered signaling is used
- Lower-layer domain may need to use crankback
- Paths found are not necessarily optimal





Backward Recursive Path Computation

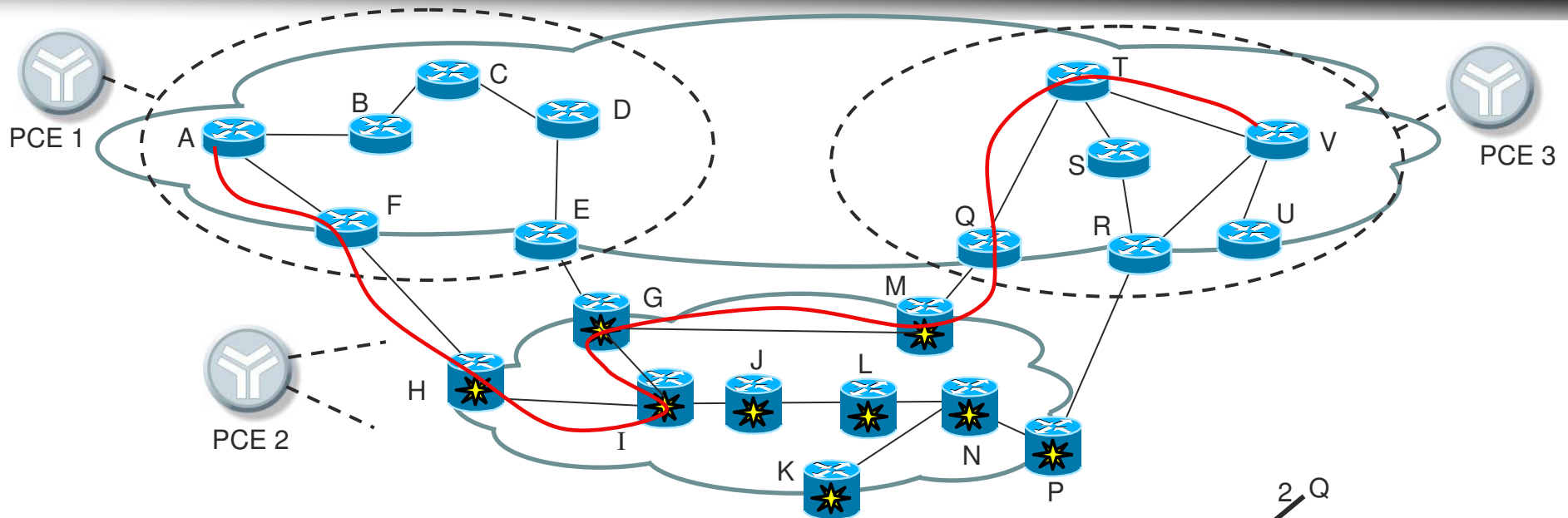
- Application of draft-ietf-pce-brpc-02.txt
- Global visibility not required
- Optimal path found through cooperation between PCEs
 - Assumes each PCE can compute any path across a domain
 - Assumes each PCE knows a PCE for the neighbouring domains
- Start at the destination domain
 - Compute optimal path from each entry point
 - Pass the set of paths to the neighbouring PCEs
- At each PCE in turn
 - Compute the optimal paths from each entry point to each exit point
 - Build a tree of potential paths rooted at the destination
 - Prune out branches where there is no/inadequate reachability
- Faster resolution if the sequence of domains is “known”
 - Fully adaptable to multiple server networks and layers



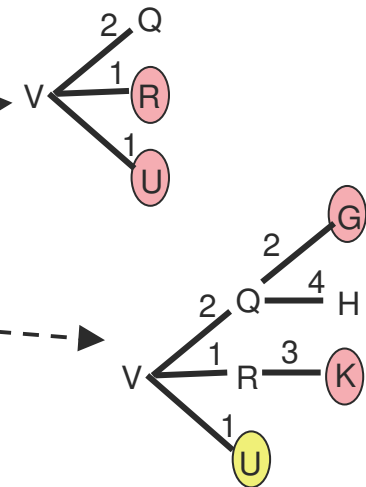
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Multi-Layer BRPC Example



- PCE 3 considers shortest paths from entry-points to node V
- ⊗ PCE 3 supplies PCE 2 with the tree
- ⊗ PCE 2 considers shortest paths from entry-points to exit points
- ⊗ PCE 2 supplies PCE 1 with the tree
- ⊗ PCE 1 considers shortest paths from node A to exit-points
- ⊗ PCE 1 selects AFHIGMQTV cost 8



But are the policies the same in each layer?



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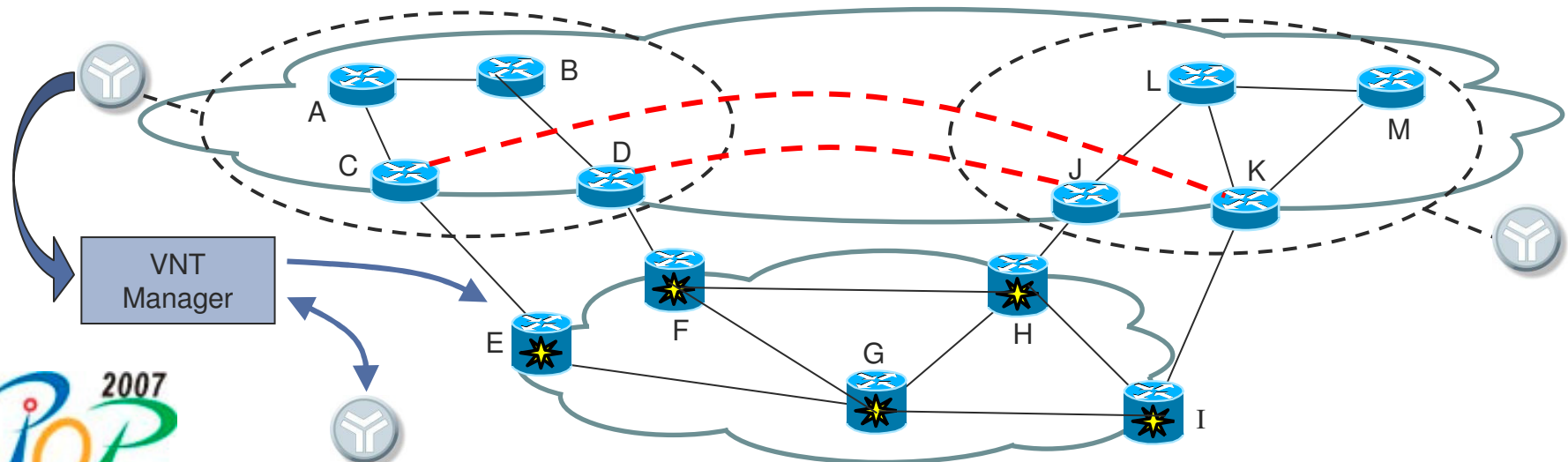
Why Do We Need VNT Management

- The application of constraints is different in each layer
 - Requires high-level PCEs to understand lower layers
- Administrative policy is very different for lower layers
 - Especially true of transport networks
 - Multiplexing issues must be considered carefully
 - Operator **MUST** keep control over lower layer resources
- VNT Manager provides a point of control between cooperating PCEs
 - Triggered signaling is still retained
 - For realizing potential links approved by VNT Manager



Cooperating PCEs with VNT Management

- A combination of BRPC and VNT
- Best of all worlds
 - Optimal end-to-end paths
 - Full TE and optimal use of lower-layer network
 - Full administrative and policy control of lower layer network and service delivery
 - Limited distribution of TE information
 - TE links made available in upper layer
 - May be real or virtual
- Relies on a VNT Manager Component
 - Receives notifications and requests from higher layer PCE
 - Consults lower layer PCE (and possibly other higher layer PCEs)
 - Issues provisioning requests and advertises TE links





Path Computation Challenges

- Multi-layer path computation is non-trivial
- Multiplexing models can be wasteful
 - Need predictive demand models
 - Need grooming facilities
- Layered architectures hide resource sharing
 - Upper layer TE links may appear to be disjoint, but actually use same lower layer links
- Client/server relationship might not be 1:1
 - Server network has multiple clients
 - The clients don't know each other
 - Client network may have multiple server networks
 - Server networks may also have client/server relationships
- Different networks and technologies have different constraints and objectives



Holistic Path Computation

- Solve the whole network
 - Different service levels, switching types, service types
 - Varying constraints and interactions
- Optimize across all network layers
- Adapt to changes in network, service, and constraints
- May use heuristic processes
 - We don't need **the** right solution
 - We need a solution that is good enough
 - We **do** need speed and flexibility
- A new era of computation servers
 - Abandon rigid linear programming techniques
 - Flexible trading of constraints and objectives in a dynamic network



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Summary

- Networks are multi-layered
- Convergence requires integrated management
- Multi-layer TE facilitates network optimization
- Building blocks
 - Signaling techniques
 - PCE and Computation techniques
 - VNT and VNT Management
- Challenges remain
- “Smart” multi-feature tools are needed
 - To bridge the gap between planning, management and control plane
 - To handle complex constraints and different network layers
 - To perform multiple functions
 - Network failure analysis
 - Capacity planning
 - Rapid turn-around of network experiments
 - Network re-optimisation
 - Integrated planning and activation (NMS, PCE, and LSR)



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References

- RFC 4655: A Path Computation Element (PCE)-Based Architecture
- RFC 4726: A Framework for Inter-Domain Multiprotocol Label Switching Traffic Engineering
- RFC 4206: Label Switched Paths (LSP) Hierarchy with Generalized Multi-Protocol Label Switching (GMPLS) Traffic Engineering (TE)
- draft-ietf-ccamp-inter-domain-pd-path-comp: A Per-domain path computation method for establishing Inter-domain Traffic Engineering (TE) Label Switched Paths (LSPs) (work in progress)
- draft-ietf-pce-brpc: A Backward Recursive PCE-based Computation (BRPC) procedure to compute shortest inter-domain Traffic Engineering Label Switched Paths (work in progress)
- draft-ietf-ccamp-gmpls-mln-reqs: Requirements for GMPLS-based multi-region and multi-layer networks (MRN/MLN)
- draft-ietf-pce-inter-layer-frwk: Framework for PCE-Based Inter-Layer MPLS and GMPLS Traffic Engineering



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Questions?

adrian.farrel@aria-networks.com



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