# The Role of the Path Computation Element Centralized Controller in SDN & NFV

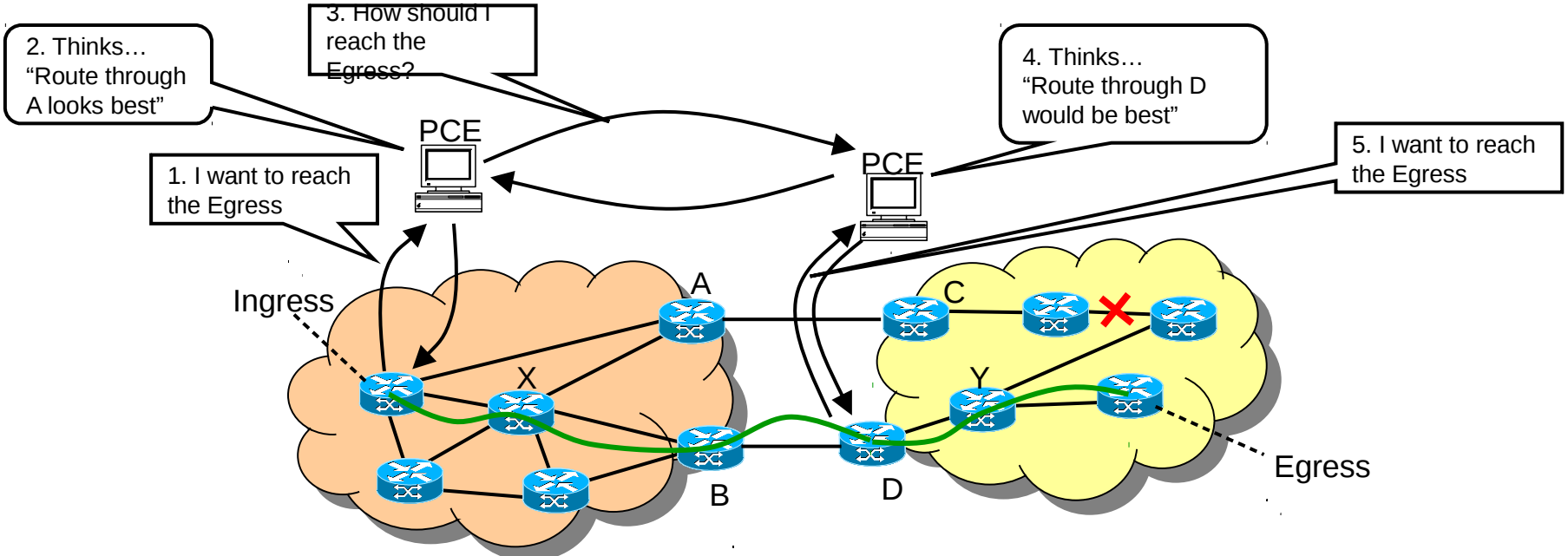
draft-zhao-teas-pce-central-controller-use-cases-00.txt
draft-zhao-pce-pcep-extension-for-pce-controller-03.txt

# What is the Path Computation Element?

- PCE: Path Computation Element - *"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"* from RFC 4655.
- That means that a PCE is a *functional component* in an abstract architecture.
  - It's purpose is to determine paths though a network
  - It operates on a topology map (the Traffic Engineering Database – TED)
    - Nodes and links == connectivity graph
    - Node constraints and link constraints == metrics and capabilities
    - Learned from the routing protocol in the network, or from the inventory database, or direct from the network nodes
  - It can be realised as a component of an existing device (NMS, router, switch) or as a dedicated server (or virtualised service)
- Benefit of identifying PCE as a separate service…
  - Offload CPU-heavy computations
    - Provide advanced and sophisticated algorithms
  - Coordinate computation across multiple paths
  - Operate on an enhance TED
- Primary initial purpose was for Traffic Engineered MPLS LSPs
  - Rapidly picked up for optical transport networks

# Cooperating PCEs

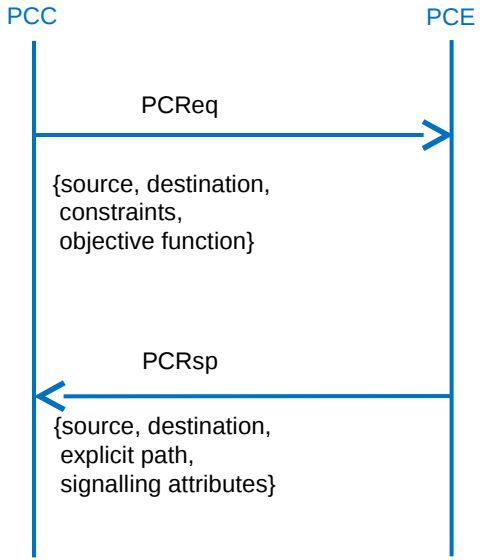
- The first "interesting" problem for PCE was inter-domain TE
  - "*A domain is any collection of network elements within a common sphere of address management or path computation responsibility.*" RFC 4655
  - An IGP area or an Autonomous System
  - An optical island
- Nodes in one network cannot see into other networks
  - PCEs must ask each other for advice



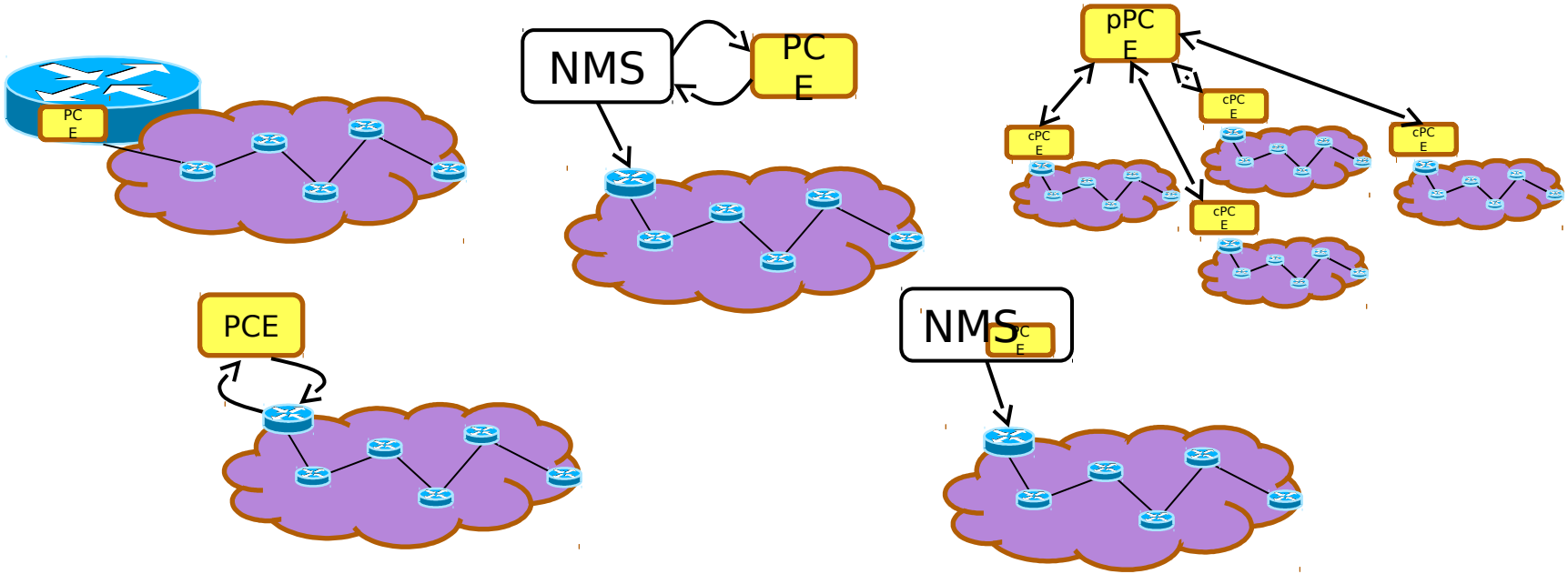
# The PCE Protocol (PCEP)

- The PCE architecture originates in the IETF
  - The main focus of the IETF is to specify protocols
- PCEP is the request/response protocol for accessing the services of a PCE

- Like PCE, PCEP had a very narrow purpose
  - Simple path computation request/response for MPLS-TE LSPs
- Initial proposals and early implementations
  - Used RSVP-TE Path messages
    - It is “kind of obvious”: that is exactly what we will signal
    - Just use the TCP session to give context to the usage
  - It really worked
- But was that really extensible?
  - Even in the MPLS-TE context we needed multiple extensions
  - RSVP has a lot of baggage
- Result:
  - A new container protocol and re-use of RSVP objects



# PCE Deployment Options

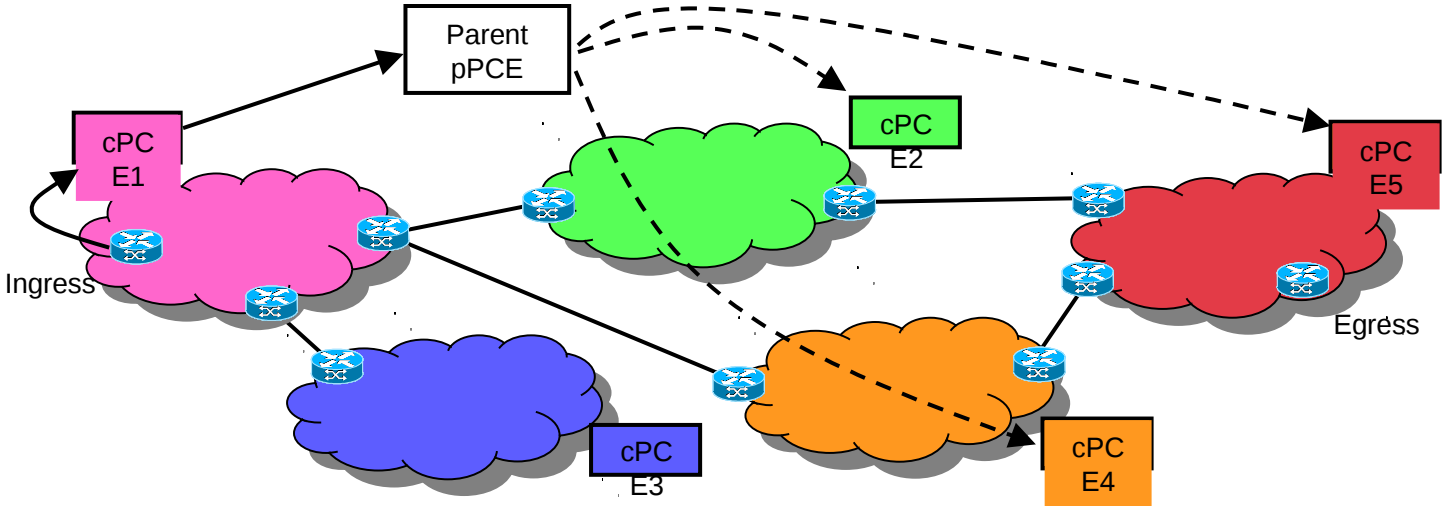


# PCE Evolution

- The PCE evolved very quickly after it was invented
- Advanced PCEP encodings for non-packet environments
- PCEP extensions for coordinated path computations
  - Path protection
  - Network re-optimisation
- Cooperating PCEs for multi-domain applications
- Applicability to sophisticated services such as point-to-multipoint
- Hierarchical PCE for selection of paths across multiple domains
- And evolution continues today

# Hierarchical PCE

- How do I select a path across multiple domains?
- Parent PCE (pPCE) has
  - An overview topology showing connectivity between domains
  - Communications with all Child PCEs (cPCE)
- Parent can selectively and simultaneously invoke children to assemble an end-to-end path



# The Stateful PCE

- The “classic” PCE uses network state stored in the TED
  - This information may be gathered from the network
    - Passive participation in the IGP
    - Export from the network using BGP-LS
  - Or it may be gathered by “other mechanisms” (RFC 4655)
    - Inventory, management systems, configuration export
- There is also transitory per-computation state in the PCE
  - This allows bulk computation or “Please compute a path considering this other LSP”
- A Stateful PCE is aware of other LSPs in the network
  - A PCE could retain knowledge of paths it previously computed
  - Or it may gather information about LSPs as exported from the network
    - BGP-LS
    - PCEP
      - “Yes, I used that path you gave me”
      - “Here are some other LSPs I know about”
- A Stateful PCE is able to do more intelligent path computation

# The Active PCE

- An Active PCE is able to advise the network
  - About more optimal paths
  - When congestion is a problem
- As far as the protocol is concerned, it is only a small step
  - The PCC can say "Please worry about these LSPs for me."
  - The PCE can say "Here is a path you didn't ask for."
    - Delegation of LSPs from the PCC to the PCE
    - New LSPs
- This enriches PCEP
  - From a request/response protocol
  - Adding notifications and advice
  - To become a configuration / provisioning protocol
- Architecturally it is "interesting"
  - PCEP used to be the language spoken by the computation engine (PCE)
  - Now it is the language spoken by the network management system (NMS) that has a computation component
  - That doesn't make it wrong. It does make it different.
- It also opens up PCEP as an SDN protocol as we will see later

# Remotely Initiated LSP Setup

- Coupled with Stateful and Active PCE
  - Service (LSP) placement needs to change in response to application demands.
  - Useful to support dynamic creation and tear down of LSPs.
- The ability for a PCE to trigger the creation of LSPs on demand makes it possible for agile software-d riven network operations (SDN)
  - Integrated into a controller-based network architecture, where intelligence in the controller can determin e when and where to set up and tear down paths.
- An application can request a path with certain constraints between two nodes by contacting the PCE
- The PCE can compute a path satisfying the constraints, and instruct the head end LSR to instantiate a nd signal it
  - When the path is no longer required by the application, the PCE can request the teardown of the service.
- Another use case is one of dynamically adjusting aggregate bandwidth between two points in the netw ork using multiple LSPs.
  - This functionality is very similar to auto-bandwidth, but allows for providing the desired capacity through multiple LSPs.

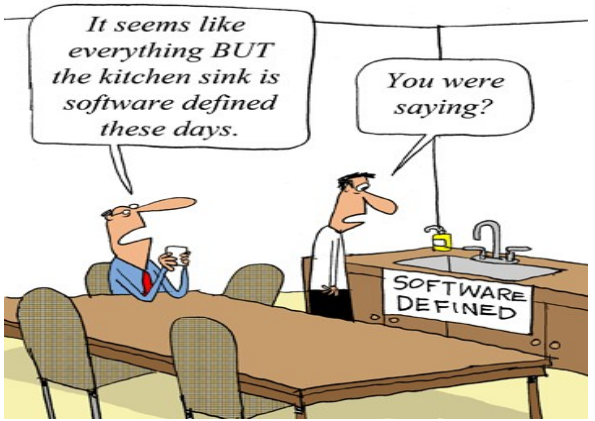
# New Networks and PCE

- New IETF effort : SPRING Working Group
  - Source Packet Routed Networking
  - Path through the network is predetermined for each packet
  - Path is encoded in the packet header as a series of hops
  - Some form of path computation is required
    - Could be as simple as SPF
    - May achieve load balancing
    - Might assign flows to different quality paths (delay, jitter, reliability, etc.)
- Service Function Chaining
  - Another new IETF effort : SFC Working Group
  - A Service Function Chain is an ordered list of service functions and servers
    - That means some form of path computation is necessary
- Deterministic wireless networks
  - For example TSCH
  - Path planning is an important aspect of operating these networks
- PCE is being investigated as a tool for these new networks
  - This really means that PCEP extensions are being proposed

# What do we mean by “SDN”?

- Software
  - It’s all software!
  - We are looking for automation
  - Tools and applications
- **D**riven or **D**efined
  - Does it matter?
- Networks
  - Management of forwarding decisions
  - Control of end-to-end paths
  - Whole-sale operation of network

- **The goals of commercial SDN networks**
  - Make our networks better
  - Provide cool services at lower prices
  - Reduce OPEX and simplify network operations
  - Enable better monitoring and diagnostics
  - Make better use of deployed resources
- Converged services are the future
- Converged infrastructure is the future



# What gaps exist for the PCE?

- Three PCE Architectures
  - RFC 4655 defines the PCE Architecture
  - RFC 5623 extended PCE for multi-layer networking with Virtual Network Topology Manager (VNTM)
  - RFC 6805 defines Hierarchical PCE (H-PCE)
- These three architectural views of PCE are applicable within the ABNO framework
- Some key questions unanswered especially with respect to the interactions between architectur al components

- What Is Topology Information and How Is It Gathered?
- How Do I Find My PCE, And How Do I Select Between PCEs?
- How Do Redundant PCEs Synchronize TEDs?
- Where Is the Destination?
- Who Runs Or Owns a Parent PCE?
- Does H-PCE Solve The Internet?
- What are Sticky Resources?
- What Is A Stateful PCE For?
- How Is the LSP-DB Built?
- How Do Redundant Stateful PCEs Synchronize State?
- What Is An Active PCE? What is a Passive PCE?
- What is LSP Delegation?
- Is An Active PCE with LSP Delegation Just a Fancy NMS?
- Comparison of Stateless and Stateful PCE
- How Does a PCE Work With A Virtual Network Topology?
- How Does PCE Communicate With VNTM?
- How Does Service Scheduling and Calendering Work?
- Where Does Policy Fit In?
- What Is A Path Computation Elephant?

# PCECC for Enabling Network Controllers

◆ OPEN-Flow Based SDN technologies **Not easy to be deployable within the current existing IP/MPLS network, especaily in the service provider network.**

◆Current IP/MPLS technologies have their own issues which can not be solved by themselves:

- ◆ The complexity of deployment and maintaining;
- ◆ It is not easy to add new services to the existing network architecture;

◆ IGP extension based SR solution provides a practical SDN network supporting the application orientated services**, but it can only provide p2p related services**.

◆Stateful PCE solution can provide the application orientated services, but it still uses the distributed IP/MPLS architecture, **so the complexity issue still exists.**

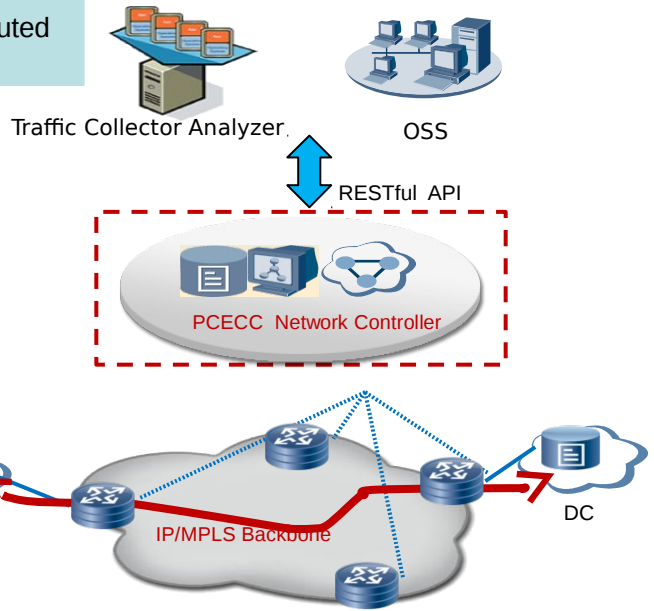
## 【 PCECC Network Use-cases 】

Ethernet &Access Network

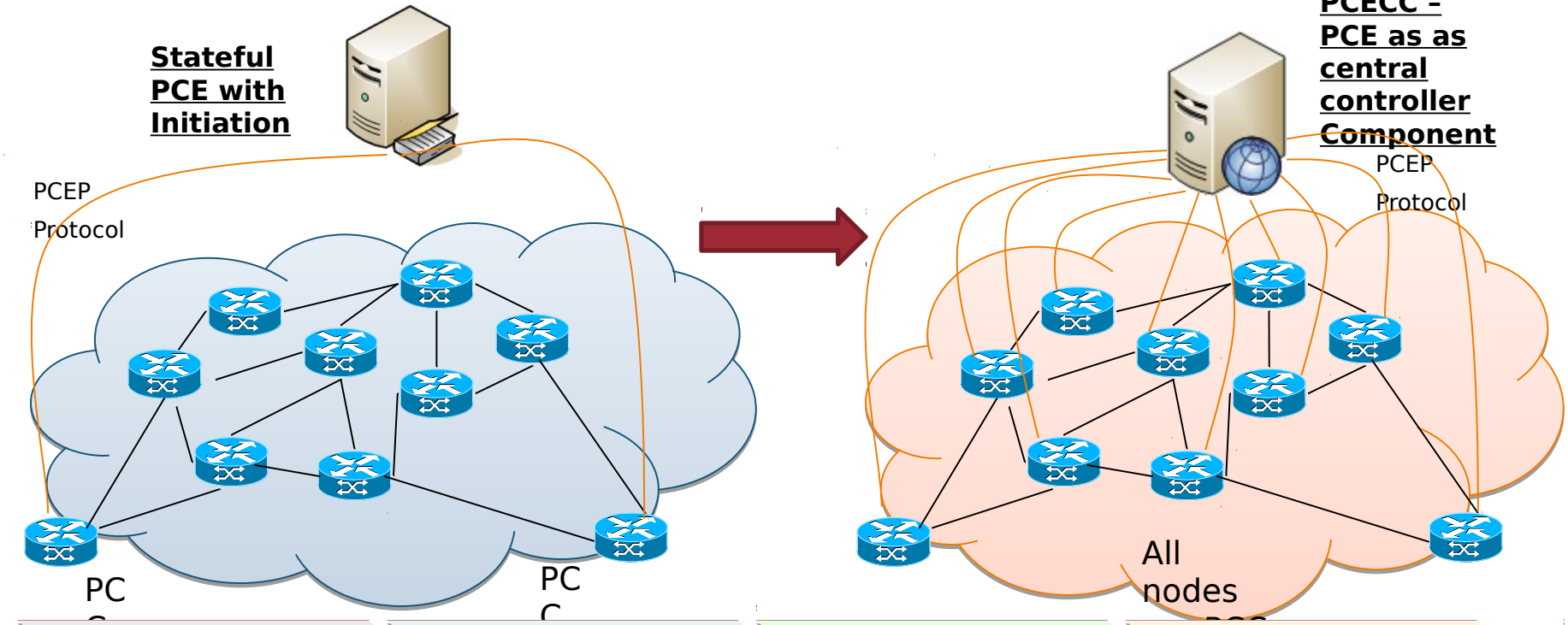
- ❖ Data Center;
- ❖ Content Delivery Networks;
- ❖ Core networks ;
- ❖ SDN Transition;
- ❖Transport Network

## 【 PCECC Network Key Techs 】

- ❖ Source Routing Based Forwarding;
- ❖ Multitopology for NV;
- ❖ Path Computation; LSP monitoring;
- ❖ IP+Optical PCE ； H-PCE;
- ❖ Network Resiliency;
- ❖ Application-Aware Smart TE



# Stateful PCE to PCECC!




Free from signaling protocols

PCECC communicates to all nodes

PCECC responsible for label allocation

Central controller!

# PCECC Use Cases

1. Use Cases of PCECC for Label Resource Reservations

2. Using PCECC for SR without the IGP Extension
   - Use Cases of PCECC for SR Best Effort(BE) Path
   - Use Cases of PCECC for SR Traffic Engineering (TE) Path

3. Use Cases of PCECC for TE LSP

4. Use Cases of PCECC for Multicast LSPs
   - Using PCECC for P2MP/MP2MP LSPs' Setup
   - Use Cases of PCECC for the Resiliency of P2MP/MP2MP LSPs
     - PCECC for the End-to-End Protection of the P2MP/MP2MP LSPs
     - PCECC for the Local Protection of the P2MP/MP2MP LSPs

5. Use Cases of PCECC for LSP in the Network Migration

6. Use Cases of PCECC for L3VPN and PWE3

# PCECC Basic Use Cases

## TE LSP

- Forwarding similar to RSVP-TE without RSVP-TE signaling
- Use of local label along the LSP path
- PCECC allocates local label and downloads to LSR

## P2MP LSP

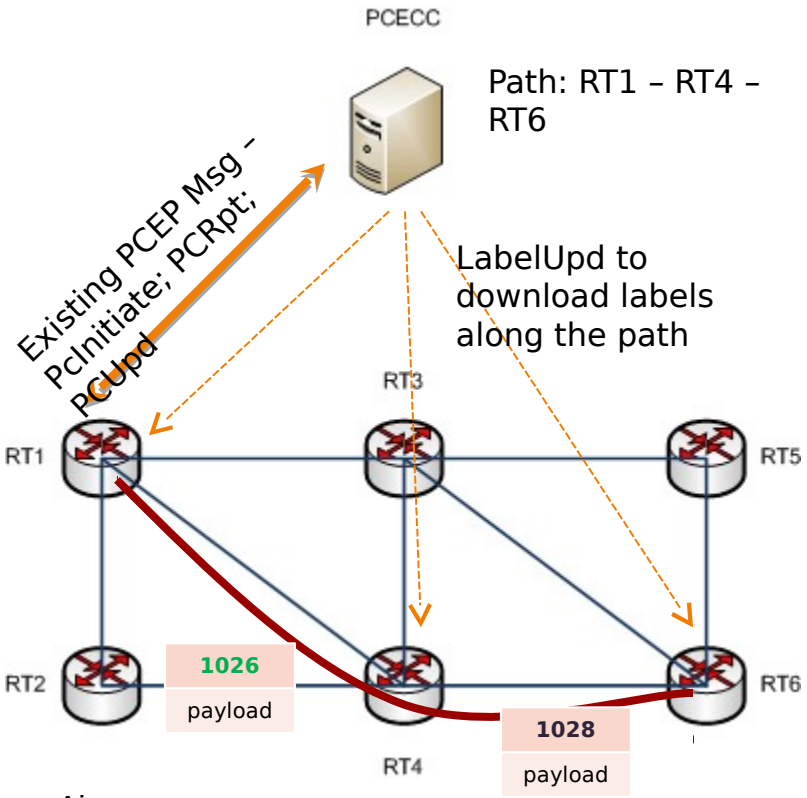
- Forwarding similar to mLDP/P2Mp RSVP-TE LSP without mLDP and P2Mp RSVP-TE signaling
- Use of local label along the P2Mp LSP path
- PCECC allocates Local label and distribute them

## PCECC SR-TE

- Forwarding similar to IGP-SR-TE
- Use of SR node and Adj label allocated and distributed by PCECC
- Rest processing similar to stateful PCE with SR

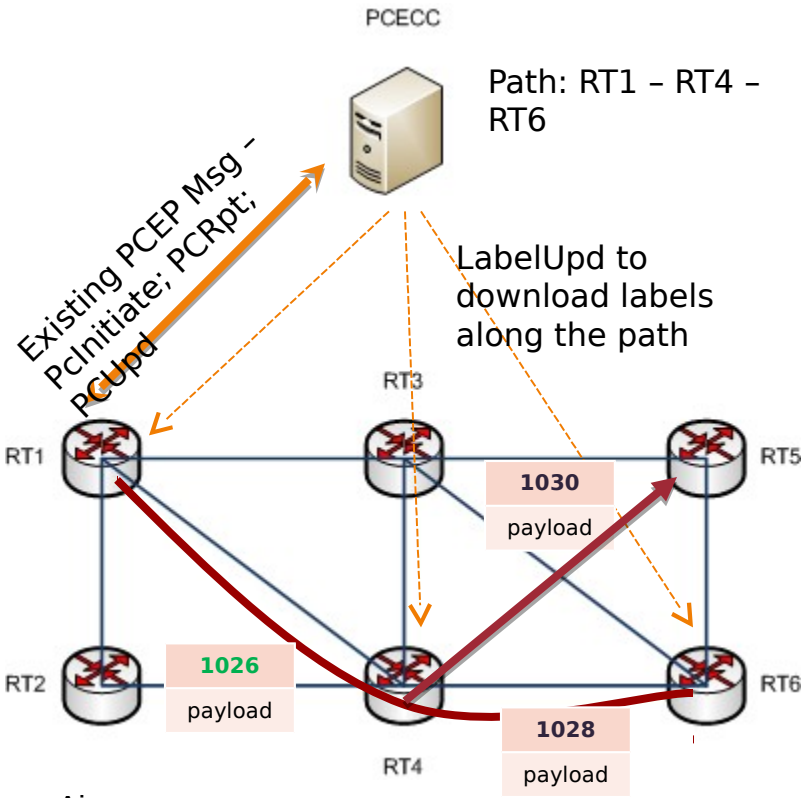
# PCECC – Basic TE LSP

1. Request PCECC to initiate LSP
2. PCECC computes the path and allocates label along the path for each node
3. PCE sends PCInitiate message to the ingress and Ingress sends PCRpt message back
4. PCECC sends PCLabelUpd to each node along the path with label information to download
5. PCECC sends PCUpd to the ingress and PCC sends PCRpt back with status-up.

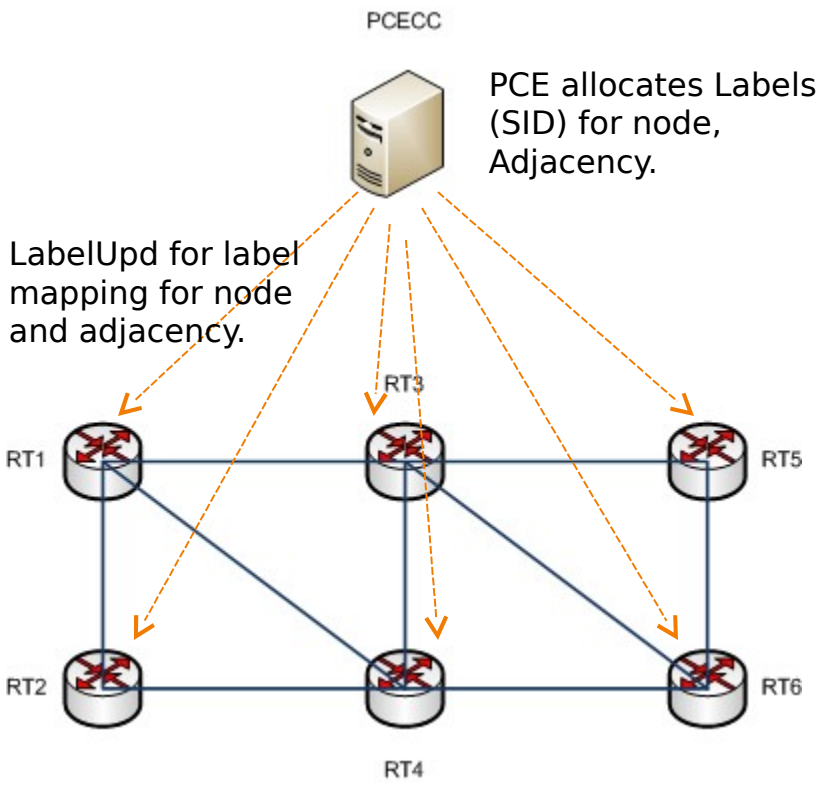


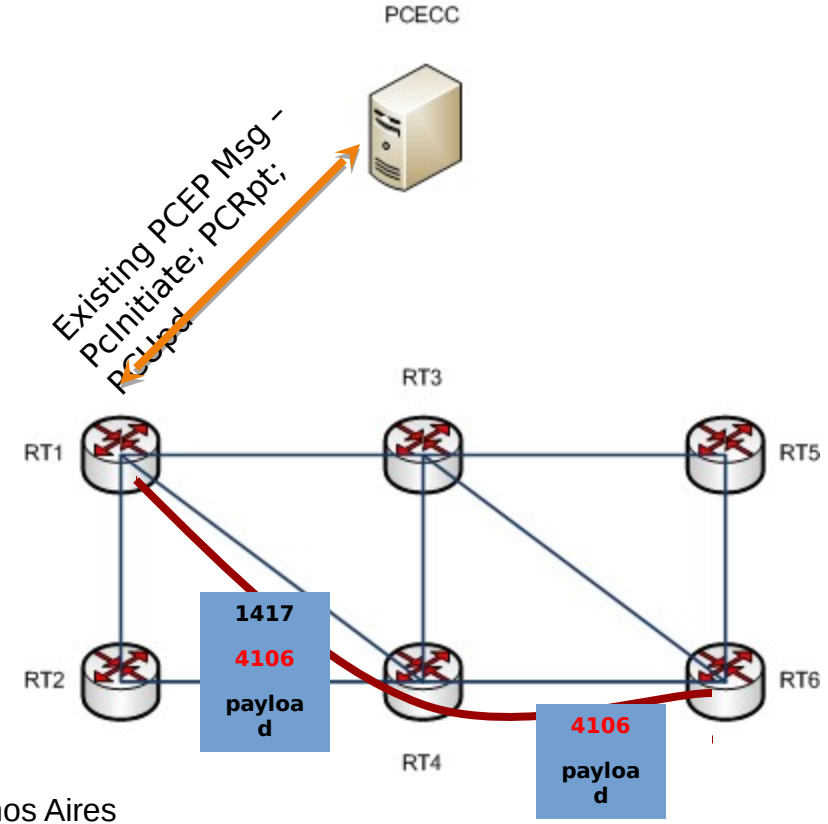
# PCECC – P2MP LSP

1. Request PCECC to initiate LSP
2. PCECC computes the path and allocates label along the path for each node
3. PCE sends PCInitiate message to the ingress and Ingress sends PCRpt message back
4. PCECC sends PCLabelUpd to each node (including the branch node) along the path with label information to download
5. PCECC sends PCUpd to the ingress and PCC sends PCRpt back with status-up.

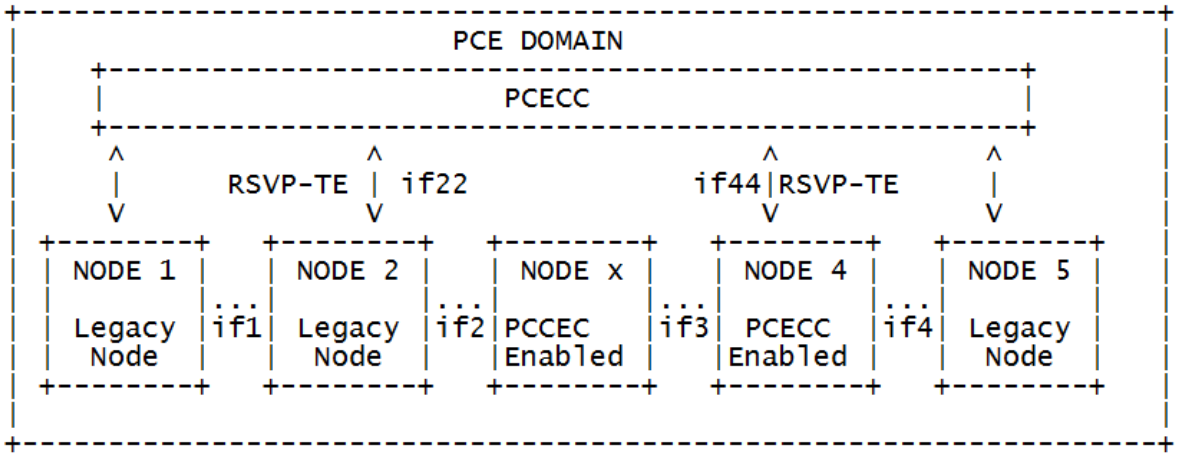


# PCECC - SR


PCECC
PCE allocates Labels (SID) for node, Adjacency.
LabelUpd for label mapping for node and adjacency.
RT1
RT2
RT3
RT4
RT5
RT6


PCECC
Existing PCEP Msg – PcInitiate; PCRpt; PCUpd
RT1
RT2
RT3
RT4
RT5
RT6
1417
4106
payload
4106
payload

# PCECC Use Case for SDN Migration




- Node1 sends a path request message for the setup of LSP which has destination as Node5.
- PCECC sends a reply message for LSP setup with path (node1, if1), (node2, if22), (node-PCECC, if44), (node4, if4), Nnode5.
- Node1, Node2, Node-PCECC, Node 5 will setup the LSP to Node5 normally using the local label as normal.
- Then the PCECC will program the out-segment of Node2, the in-segment of Node4, and the in-segment/out-segment for NodeX.

# Related Drafts

Experimental I-D. - PCEP Procedures and Protocol Extensions for Using PCE as a Central Controller (PCECC) of LSPs
http://www.ietf.org/id/draft-zhao-pce-pcep-extension-for-pce-controller-03.txt

I-D. - The Use Cases for Using PCE as the Central Controller(PCECC) of LSPs.
https://tools.ietf.org/id/draft-zhao-teas-pce-central-controller-use-cases-00.txt

# Thanks!