Path Computation Element (PCE) & its role in SDN.

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Who am I?

- Lead Architect at Huawei Technologies, India for Network Business
- 15+ years of experience
- Focus on Standards and Research
  - Chair of PCE WG at IETF
  - 10 RFC (main author) / 8 RFC (contributor)
- Area of interest –PCE, SDN, TE, Segment Routing (SR)
- Secretary at IIESoc (iiesoc.in)
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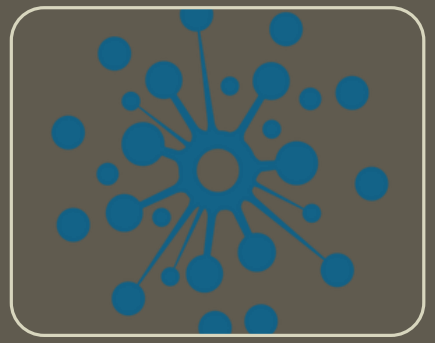
Some Background

TE (Traffic Engineering)

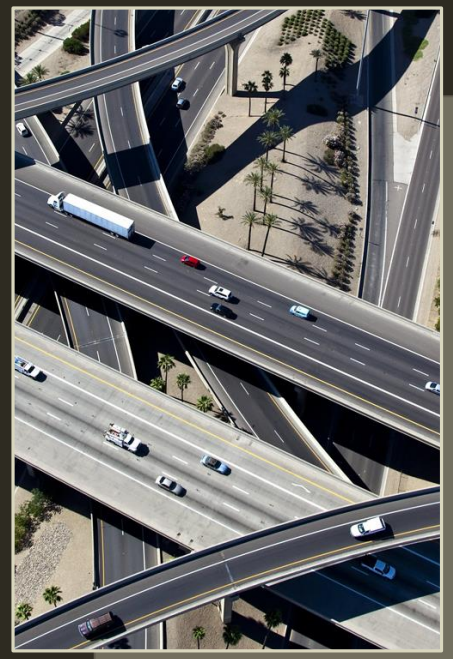
- Enable operators to control how specific traffic flows are treated within their networks



SDN (Software Defined Networking)

- Software-defined networking (SDN) is an approach to networking that allows administrators to manage network services through abstraction of lower-level functionality.
- Separation of control plane and forwarding plane

What is PCE?



A Path Computation Element (PCE) is 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.

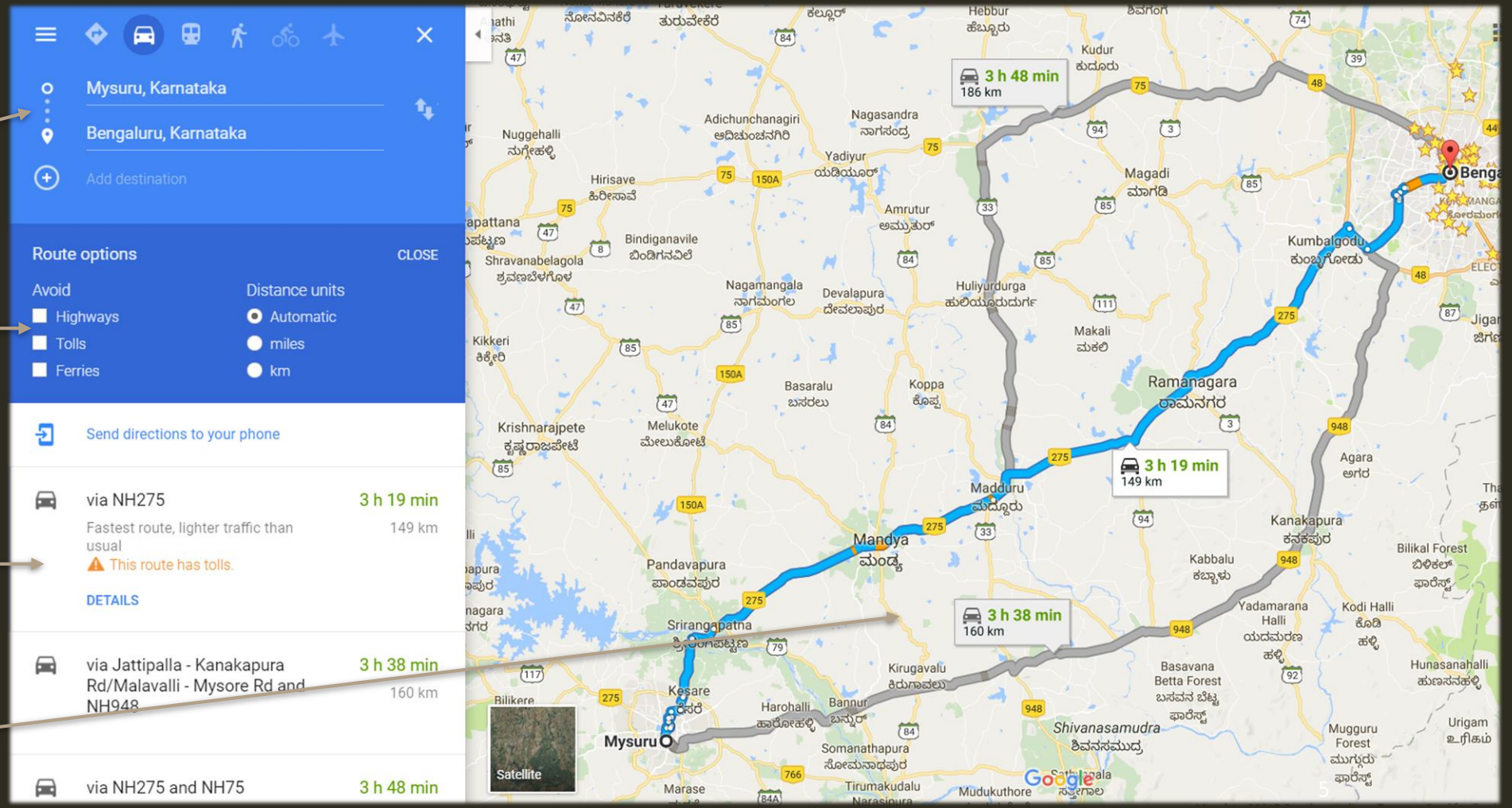
So, What is it?

Endpoints

Constraints

Path

Traffic Engineering Database

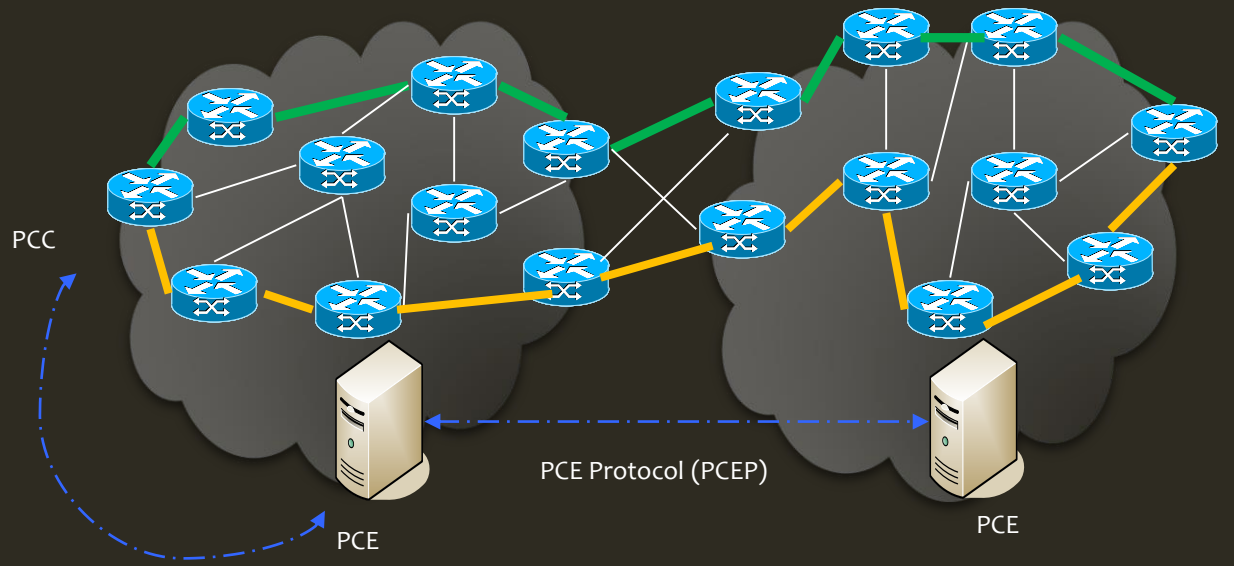


The Basics!

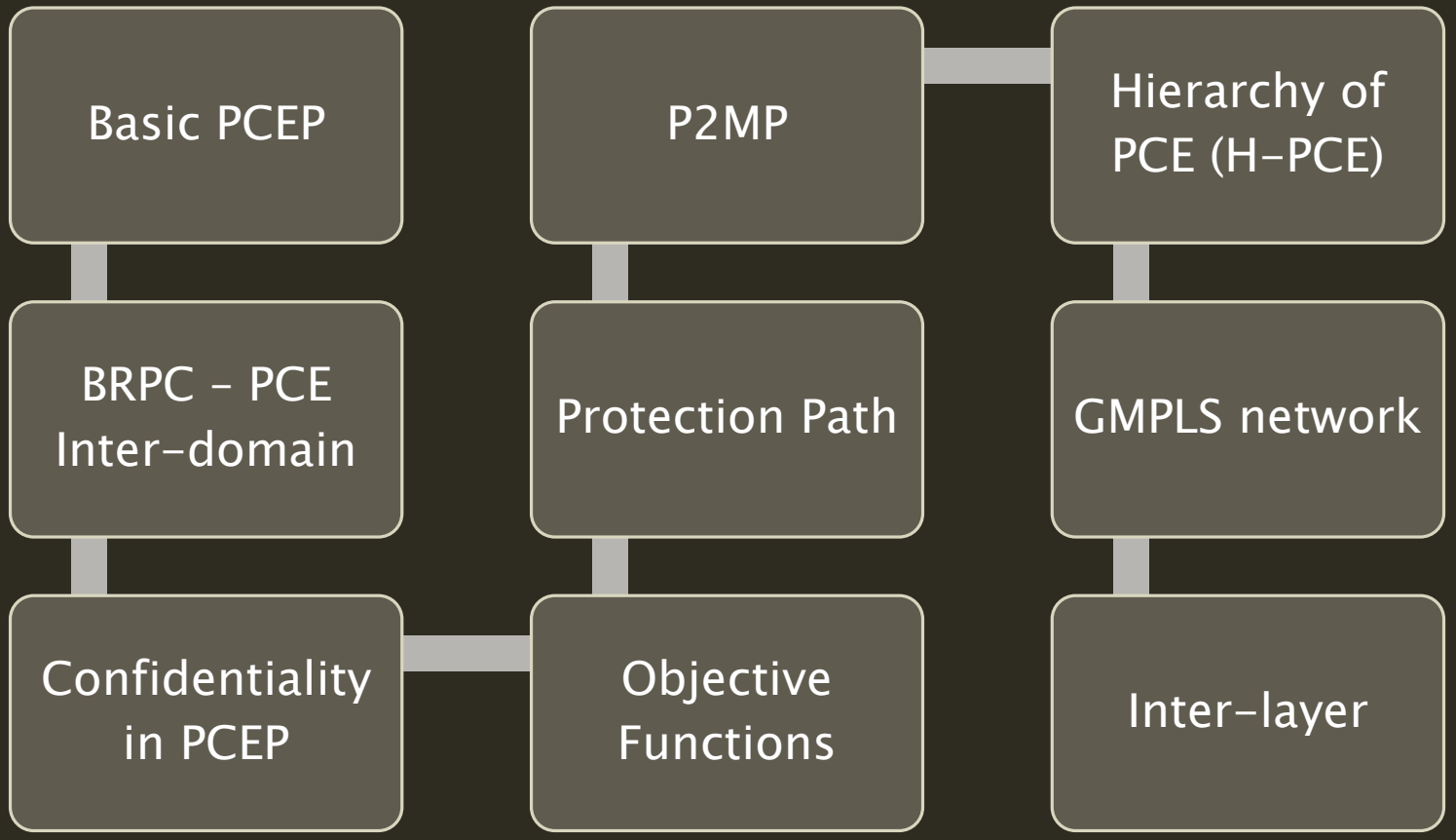
PCE	PCC	PCEP	PCE WG
• Path Computation Element • Part of SDN controller • Specializes in complex path computation on behalf of PCC	• Path Computation Client • Router offloads path computation to a specialized PCE	• PCE Protocol to communicate between PCC and PCE(s) using TCP	• Chartered in 2004 • Yes, its that old! • First RFC – RFC4655 (in 2006) • Since then 38 RFC further published!

But Why?

- The path is usually computed by the source node (Ingress)
- Does not have enough computation power or space
  - Low end devices (with MPLS moving towards edge!)
- Does not have all the information!
  - Inter-domain / Inter-layer path computation across domain boundaries!
- Special Path Computation algorithms



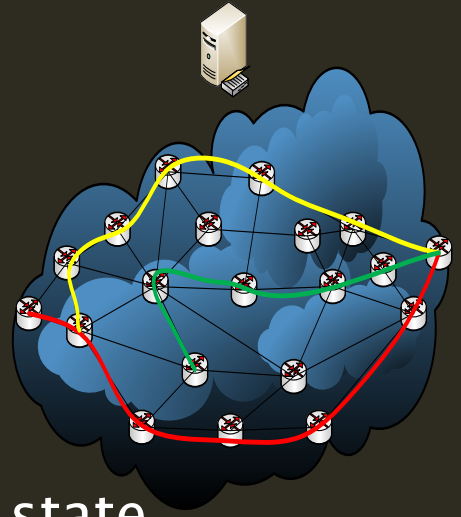
The History!


Basic PCEP
P2MP
Hierarchy of PCE (H-PCE)
BRPC – PCE Inter-domain
Protection Path
GMPLS network
Confidentiality in PCEP
Objective Functions
Inter-layer

But, Stateless!

- Even though PCE could do complex path computation by itself or by working with other PCEs
  - It could do that only when the PCC asks for it!
- Even when PCE learns of topology change
  - It cant do much!
- So far the PCEP was a simple client-server protocol
  - and stateless!
- Only TEDB – Traffic Engineering Database!

Stateful PCE



- Now, along with network state (TEDB), if the PCE also stores the state of all the computed paths or LSPs and their resources (lets call it LSP-DB)
  - We could do so much more and that is Stateful PCE!

Passive

- It uses the TEDB and LSPDB while path computation, but computation is done only when requested by PCC.

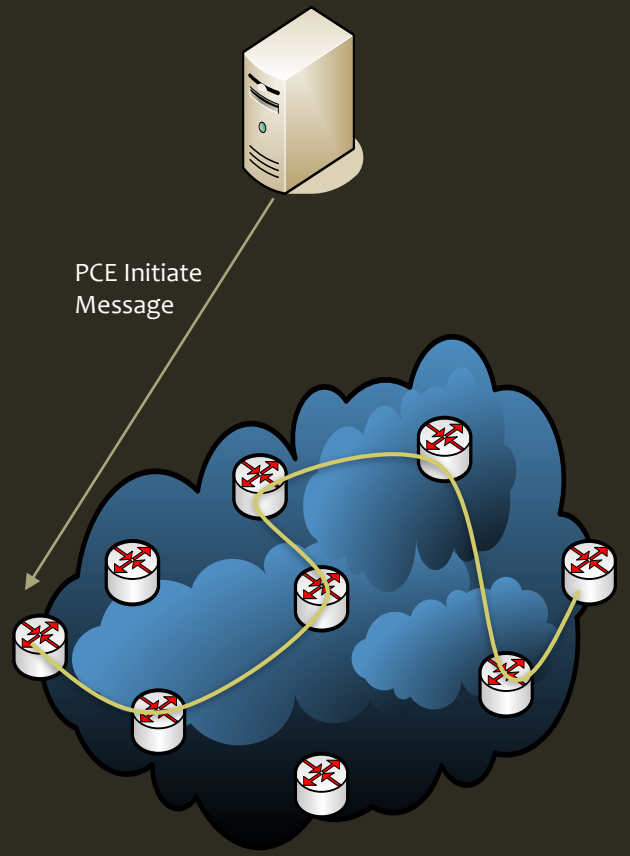
Active

- It allows the LSP to be delegated to the PCE where PCE becomes the owner of the LSP and can change any attribute of the LSP at anytime.

The Stateful PCE can do global re-optimization considering various LSPs to optimize the whole network!

PCE Initiated

- Setup, maintenance and teardown LSPs directly by the PCE!
  - No need for local configuration at the device!
- Allowing for a dynamic network that is centrally controlled and deployed.
- Useful when the LSP placement needs to change in response to application demands.
- Agile software-driven network operation, and can be seamlessly integrated into a SDN controller-based network architecture!!

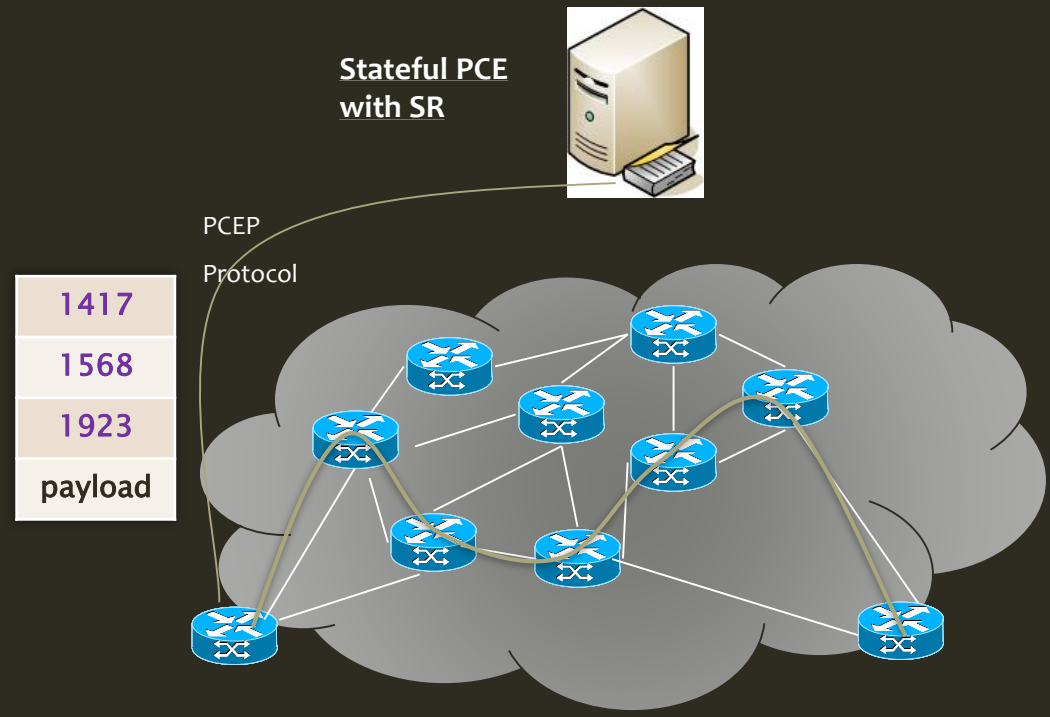


SR & PCE

- Segment Routing Path
  - PCE prepare label stack identifying node and adjacency labels
- PCE
  - PCE computes the SR Path and instructs the head-node with a label stack.
  - PCE can respond to network events like congested links and update the label stack
- PCE is the magic, that makes SR work!

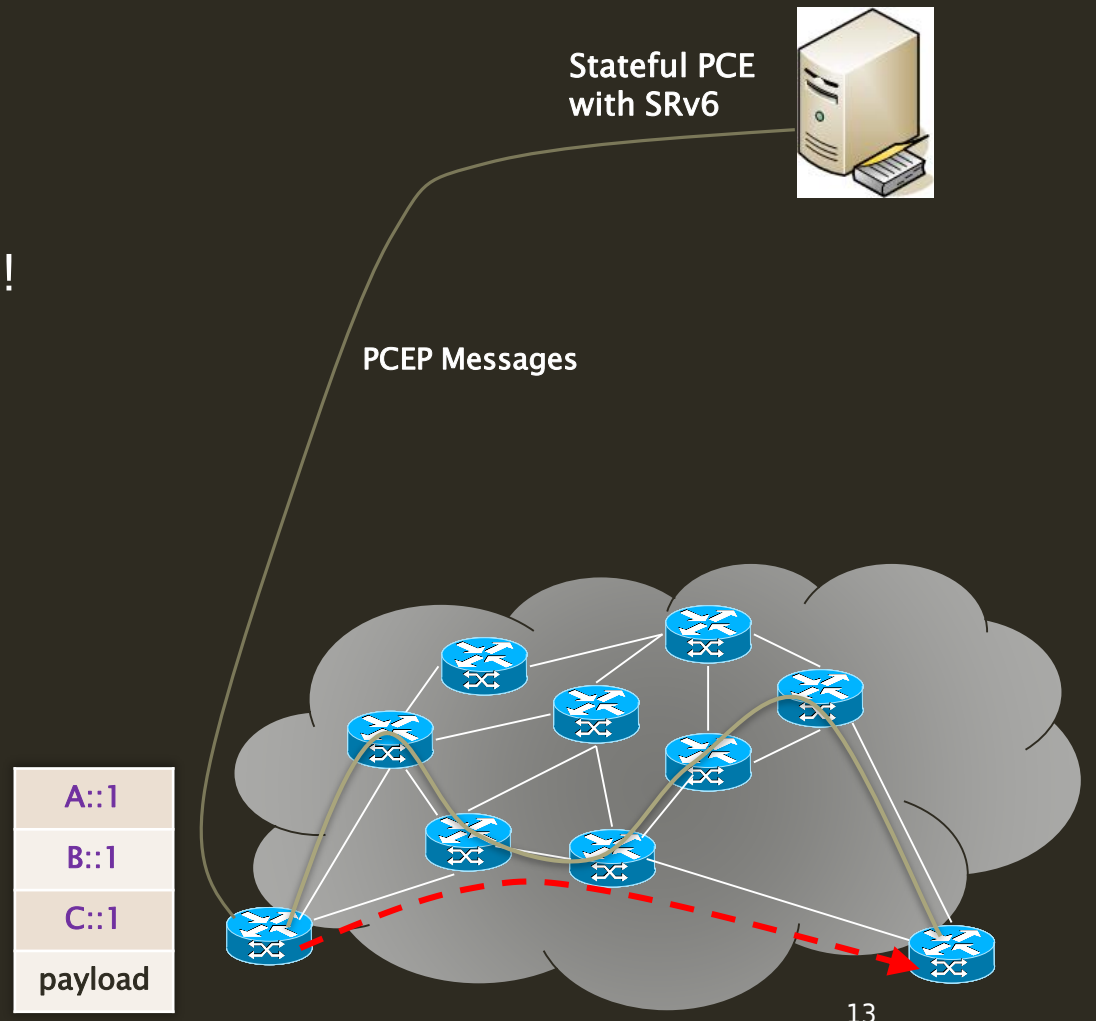
PCEP extensions

- draft-ietf-pce-segment-routing
- PCE capability advertisement
- New path setup type
  - "This is an MPLS-SR path"
- New sub-objects for SR paths
  - SR-ERO/SR-RRO



SRv6 & PCE

- For a PCE SRv6 looks quite a lot like MPLS-SR
  - The Segment Routing Path is a SID stack
- The PCE is still the magic that makes SR-TE work!
- A PCE can compute SR paths considering
  - Source and destination
  - Flow characteristics
  - Current network condition and loads
- PCEP extensions to support SRv6
  - draft-negi-pce-segment-routing-ipv6
  - PCE capability advertisement
  - Path type identifiers
    - "This path is used for SRv6"
  - Extended ERO and RRO for SR
    - Sub-objects for SRv6



Other Enhancements to Stateful PCE

Association

GMPLS

P2MP / Multicast

Inter-domain

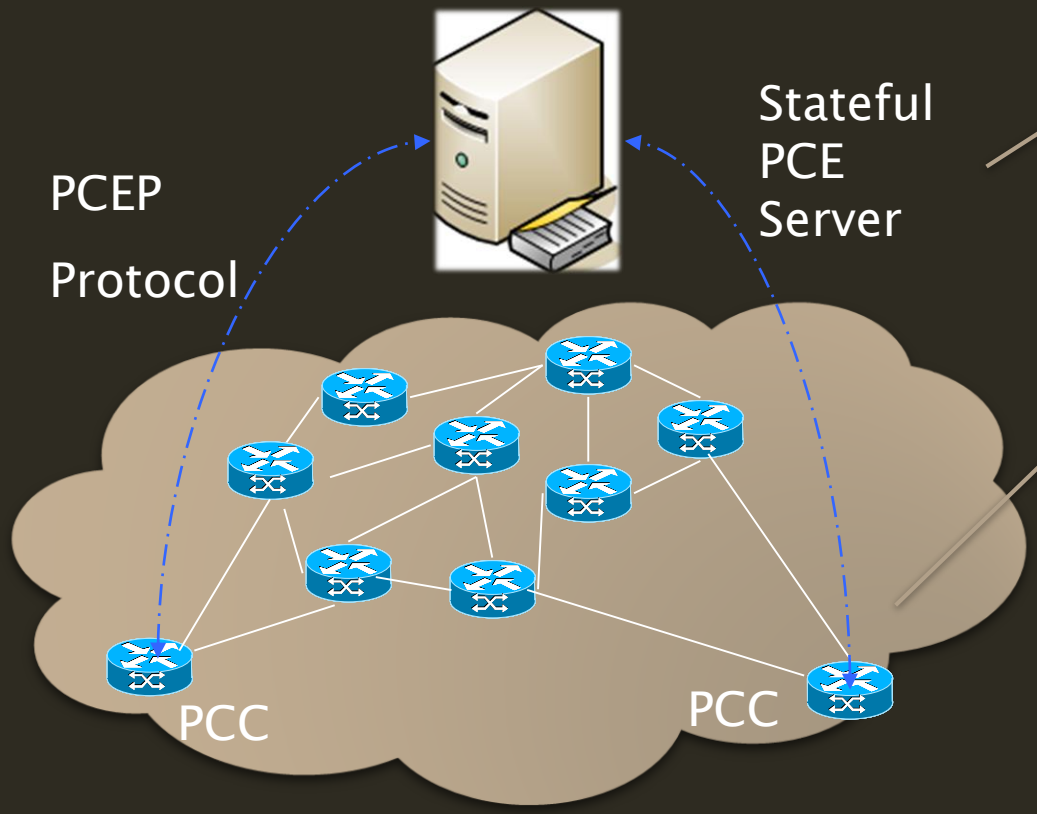
Hierarchy

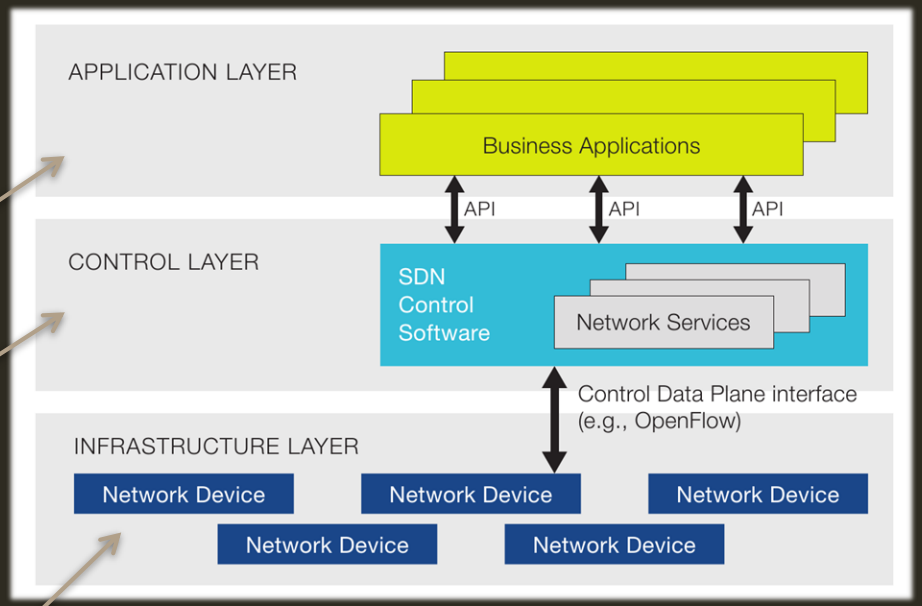
Auto-bandwidth

Scheduling

PCE & SDN

Abstraction & Algorithms over Stateful PCE





In some network with existing investment in IP/MPLS devices, active stateful PCE can offer centralized control over the LSPs as a simple evolutionary approach for SDN.

What is the relationship with SDN ?

PCEP can be considered the earliest SDN southbound protocol

- PCE is an SDN controller plus the application logic for path computation
- PCE provides end-to-end paths (when requested)
- PCC installs a received path specification

An MPLS-TE network could be considered to be an SDN-based network if:

- MPLS LSRs are built with full separation of control and forwarding planes
- LSR performs exact match on a single field in the packet header
- LSR processing is simple: stack operation and forward without routing protocols (e.g., MPLS-TP)
  - All paths are configured from a central platform via a control plane

PCEP as a SBI

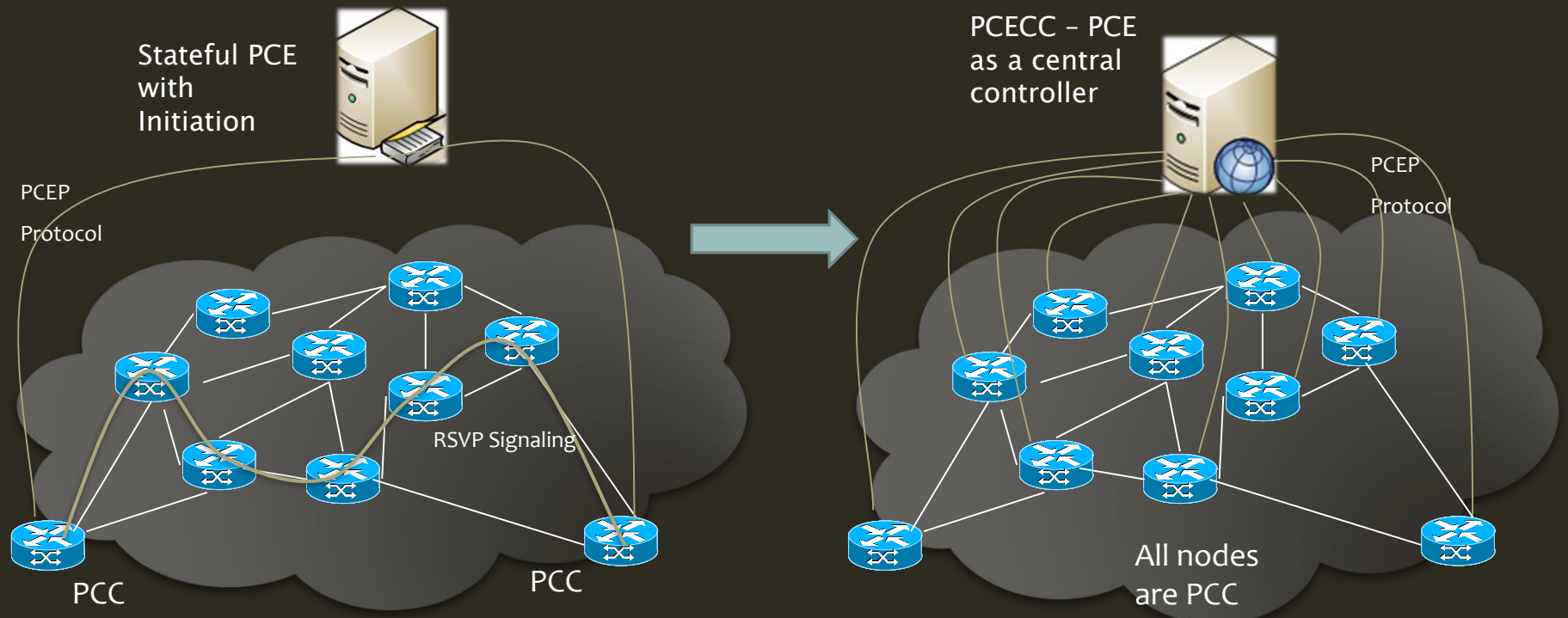
PCE is a core of a SDN controller

Should PCEP be upgraded to a full-fledged SBI?

What is needed to do that?

- Ability to use PCEP to program each node along the path of the LSP
- Ability to use PCEP for label dissemination for SR
- Ability to identify which traffic flows in the LSP
- Ability to use PCEP to learn topology changes
- Multicast / P2MP
- Coordinate between PCEs
- and so on….

PCE as Central Controller



Free from signaling protocols

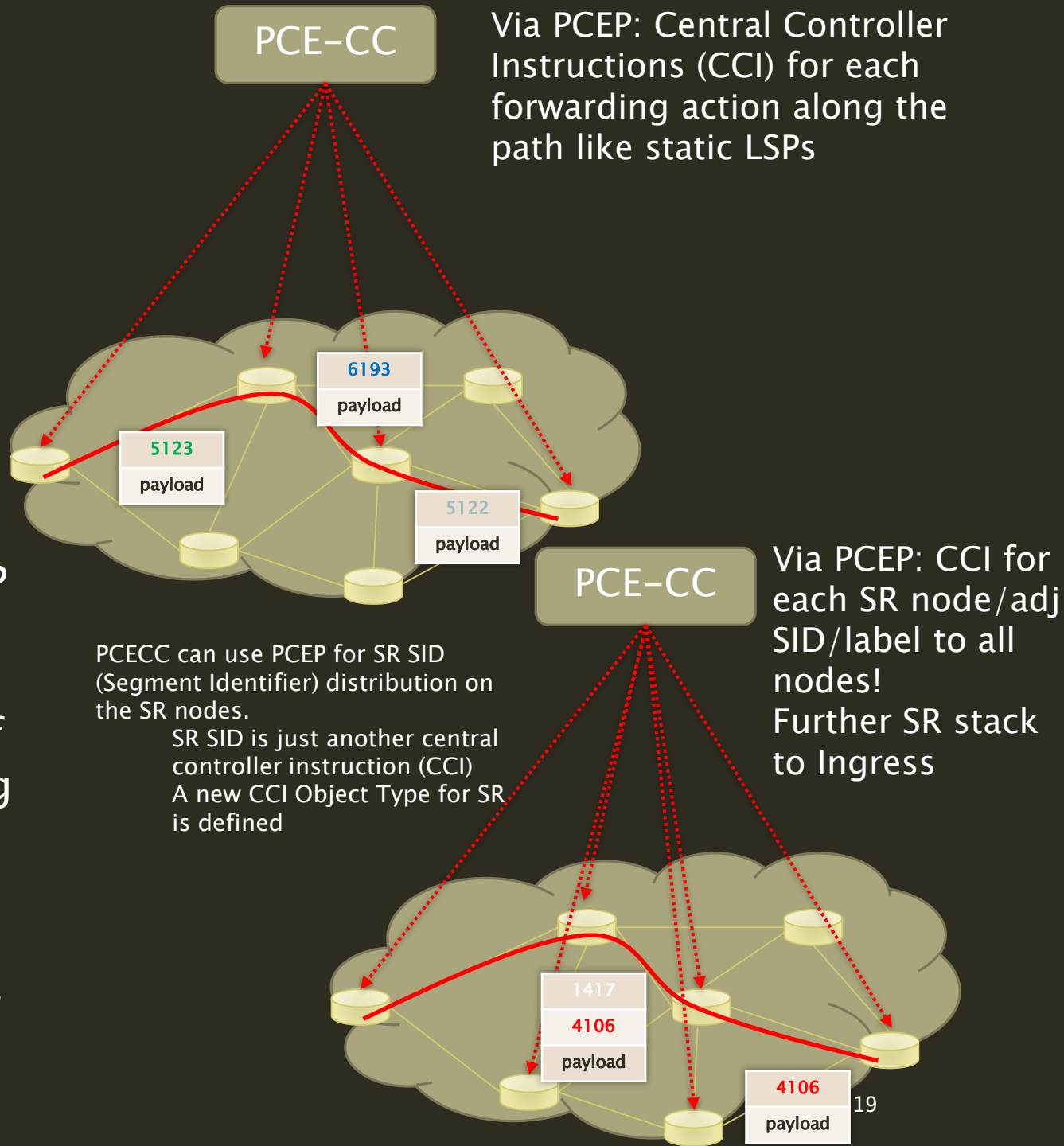
PCECC communicates to all nodes

PCECC responsible for label allocation

Central controller!

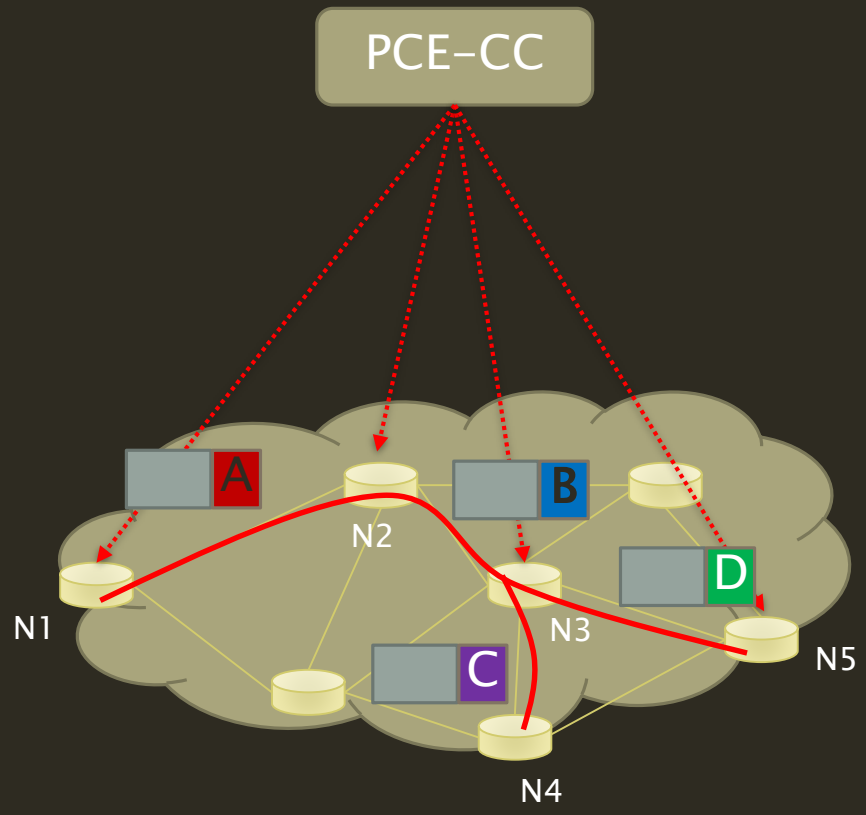
PCECC

- RFC8283 defines an architecture for use of PCE in a network with central control
  - Examines the motivations/applicability for PCEP as a control protocol in SDN
- A PCE-based Central Controller (PCECC) can simplify the processing of a distributed control plane by blending it with elements of SDN and without necessarily completely replacing it
- The PCECC programs forwarding instructions into the network and so is applicable to SR



PCECC for P2MP

- [I-D.ietf-pce-stateful-pce-p2mp] specify the extensions that are necessary in order for the deployment of stateful PCEs to support P2MP TE LSPs
- PCECC – P2MP additional requirement
  - A branch node is an LSR that replicates the incoming data on to one or more outgoing interfaces.
  - At the branch node N3
    - Incoming Label : B
    - Outgoing Label: (C, towards N4) and (D, towards N5)
    - 3 instances of CCI object in PCInitiate message for each label



PCEP - FlowSpec

- When a PCE is in control (active stateful, maybe PCE-initiated)
  - The head-end doesn't know why the LSP or SR-path was created
  - The PCE needs to tell the head-end what traffic to put on the path
  - Traffic Classification is a key part of TE
- draft-ietf-pce-pcep-flowspec
  - A new FLOWSPEC object with Flow Filter TLV with one or more Flow Specification sub-TLVs
  - Allow re-use of BGP TLVs
    - (But subtly different meaning from BGP FlowSpec!)

- PCE initiates a new P2P LSP and wants it to be used for all traffic destined to 198.51.100.0/24 and all traffic destined to 203.0.113.0/24
- It sends a PCInitiate message for the LSP and includes a Flow Spec Object containing a Flow Filter TLV
  - It includes two Flow Specification TLVs

    Type = 0x0001 (IPv4 destination prefix)
    Length = 0x0004
    Value = prefix length in bits (1 octet)
    prefix 0x18C63364

    Type = 0x0001 (IPv4 destination prefix)
    Length = 0x0004
    Value = prefix length in bits (1 octet)
    prefix 0x18CB0071

ACTN – Abstraction & Control Of TE Networks

				
Abstraction of underlying network resources	Virtualization of particular underlying resources	Network Slicing of infrastructure to meet customers requirements	Creation of abstract environment allowing operators to view and control multi-domain networks as a single abstract network	Presentation to customer of networks as a virtual network

Role of PCE in ACTN

- ACTN – Abstraction and Control of TE networks
- Multi-layered multi-domain Network
  - Technology, administrative or vendor islands
  - Interoperability
- Facilitate virtual network operations
  - Creation of a virtualized environment allowing operators to view and control multi-subnet multi-technology networks into a single virtualized network.
- Accelerate rapid service deployment of new services
  - including more dynamic and elastic services
  - improve overall network operations and scaling of existing services.

Controller

- PCE is a key function in a controller
- Stateful PCE
  - Initiation capability
- Application Based Network Operations [RFC7491]
- PCE based central control (PCECC)

Multi-Domain & Multi-Layer

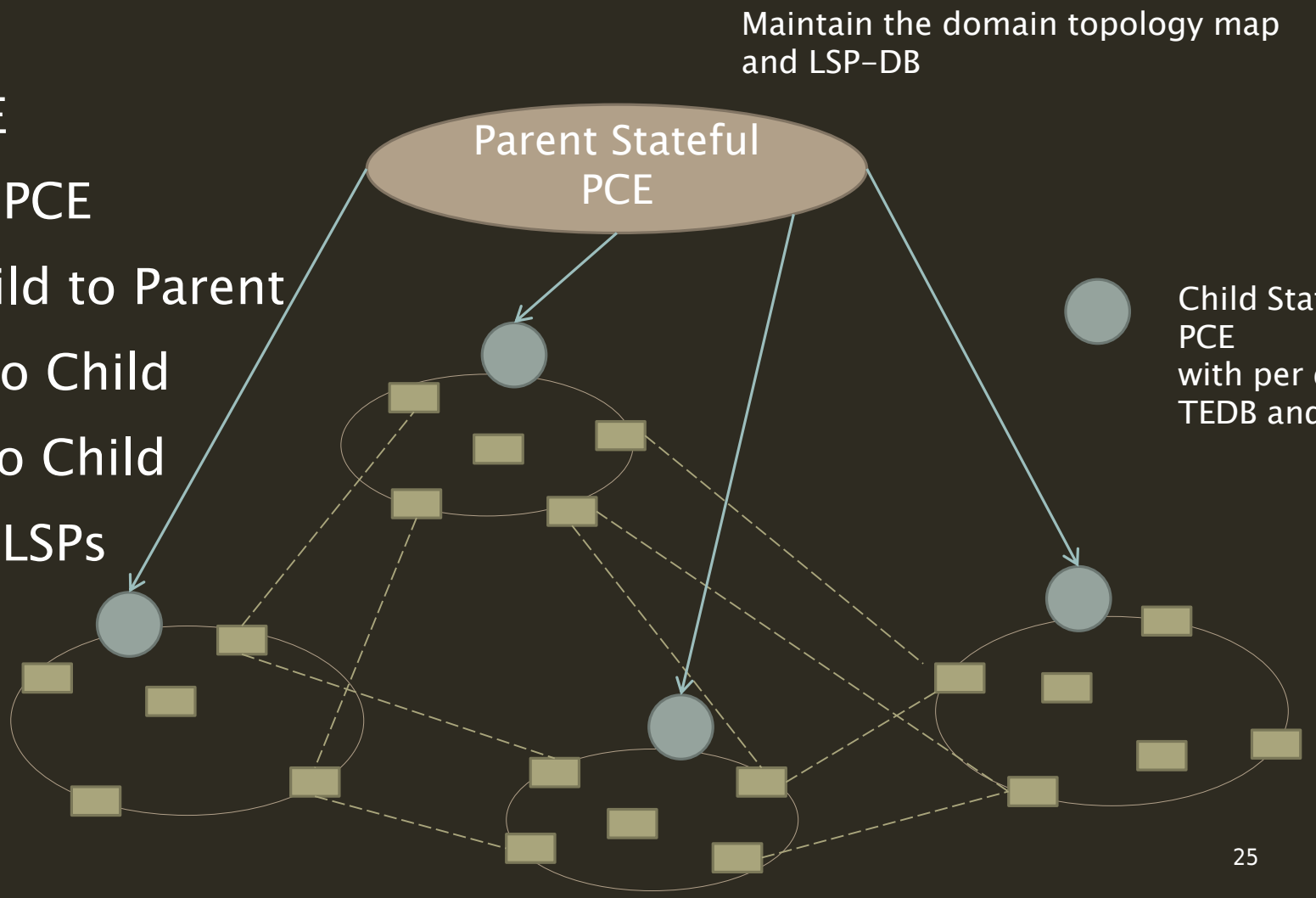
- Per-domain path computation [RFC5152]
- Backward Recursive Path Computation (BRPC) [RFC5441]
- Inter-Layer [RFC5623]
- Hierarchy of PCE (H-PCE) [RFC6805]
- Stateful H-PCE

Role of PCE (& PCEP) in ACTN

Stateful H-PCE	• Hierarchy of Stateful H-PCE fits into hierarchy of controllers! • VN Instantiation and Modifications •
VN Association	• Associate paths with a VN slice
PCEP-LS	• Use PCEP to inform link state and TE information between controllers • Building Domain Topology

Stateful H-PCE

- H-PCE + Stateful PCE
- Hierarchy of Stateful PCE
- State report from Child to Parent
- Update from Parent to Child
- Initiate from Parent to Child
- E2E and Per-domain LSPs



PCEP-LS

- PCEP can also be extended to support learning topology via PCEP-LS.
- In case of PCECC where a PCEP session exist between the controller and the nodes in the network, it would be wise to re-use this session to also learn the local topology information from all nodes and collected/correlated at the controller using PCEP-LS.
- Applicable also to optical network as well as between controllers.
- Allow encoding of only the attributes that have changed since the last reporting.

Making PCEP Secure

- Supported MD5 and TCP-AO
  - MD5 no longer used!
- Support for TLS – RFC 8253 published recently!
- Peer authentication, message encryption & integrity
- StartTLS approach

JOIN US AT PCE WG

pce@ietf.org

PCE WG work items

Stateless

- Initial work in PCE WG

Stateful

- Maintaining state at PCE and PCE-initiation

PCECC

- Towards SDN controller SBI

Inter-domain

- use of PCE for inter-domain path computation

ACTN/HIC

- Hierarchy of Controller

Segment Routing

- SR-MPLS and SRv6

Optical

- GMPLS, WSON etc