

Security Level:

# SDN and the role of PCE

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*SDN - Software Defined Networks*

*PCE - Path Computation Element*

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# Content

Huawei

SDN - Software Defined Networks

PCE - Path Computation Element

Role of PCE in SDN

# Huawei - A quick glance...



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# Huawei at a Glance



**180,000**

Employees



**80,000**

R&D  
employees



**170+**

Countries



**15**

R&D institute  
and centers



**No. 72**

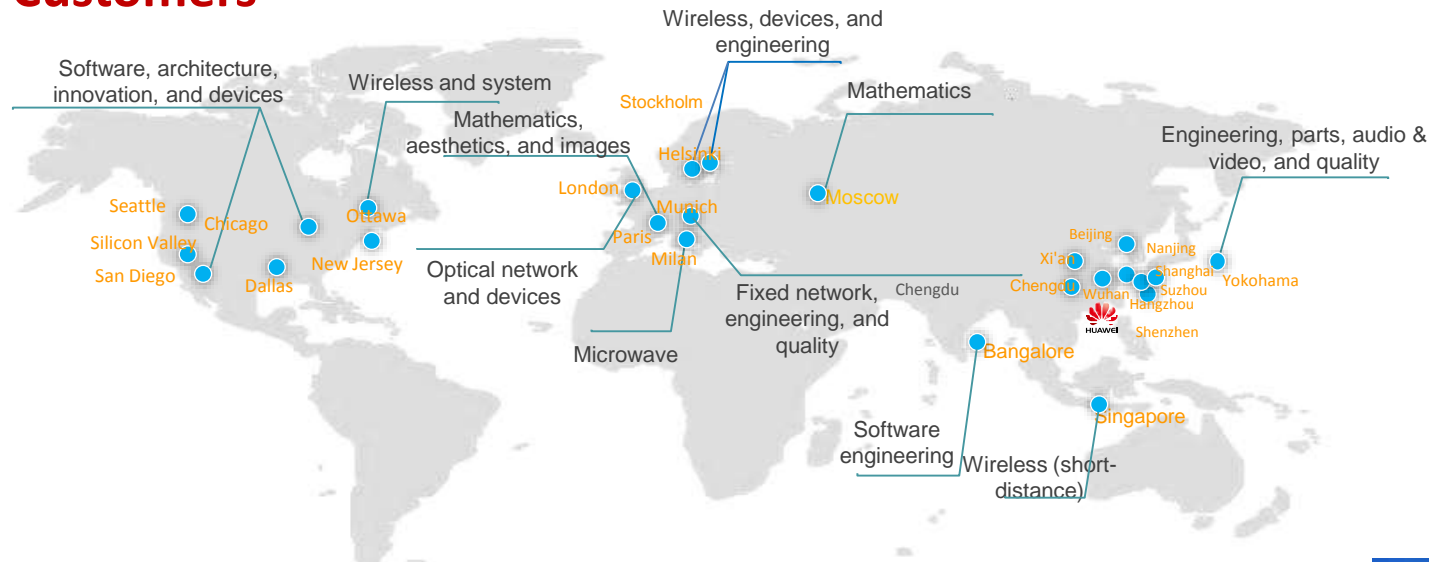
Interbrand's Top  
100 Best Global  
Brands



**No. 129**

Fortune Global  
500

# R&D Centers Worldwide: Using the Best Innovation Resources to Better Serve Customers



Sweden



UK



Bangalore, India



Russia



Shanghai, China



Hangzhou, China

**Huawei India R&D Center is First and Largest Overseas R&D Center of Huawei, focus on the business domains below:**

- One of important Platform Delivery Base
- One of competency centers for overseas market for the end-to-end business and solution delivery
- Cutting edge exploration of software engineering methodology/practice



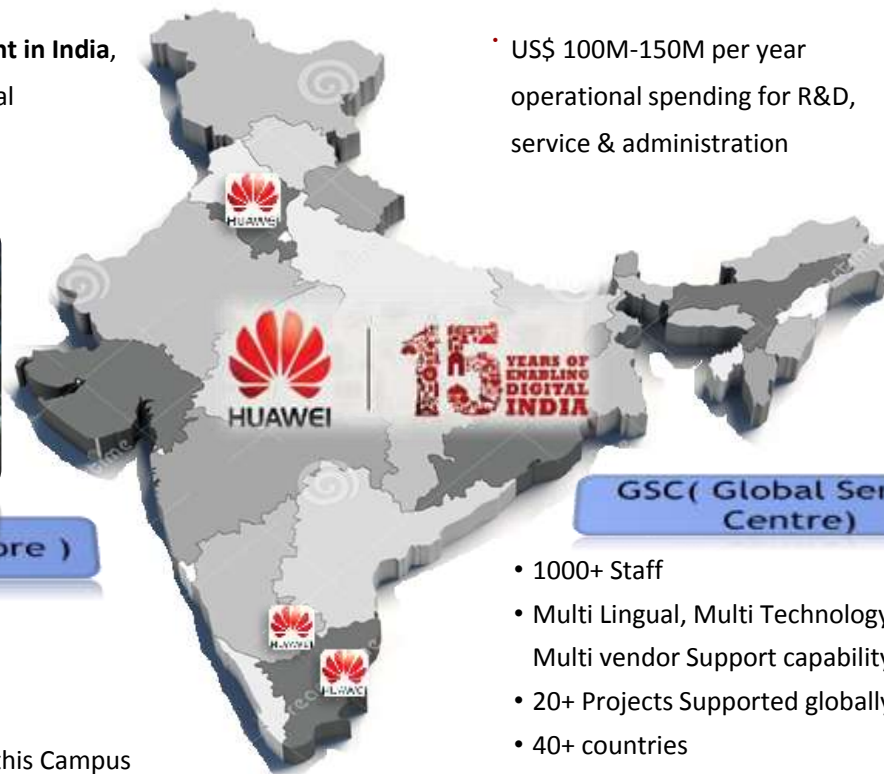
# Huawei India Strategy: Long Term player and continued investments

- 16 years presence and commitment in India, ~7000 employees in India; 93% local technical and professional staff .



R&D Centre ( Bangalore )

- Since 1999
- ~3000 local software engineers.
- Investment of ~170 Mn USD in this Campus



- US\$ 100M-150M per year operational spending for R&D, service & administration

GSC( Global Service Centre)

- 1000+ Staff
- Multi Lingual, Multi Technology, Multi vendor Support capability
- 20+ Projects Supported globally
- 40+ countries (India, Japan , UAE, Qatar, S Africa )

Local manufacturing (Chennai)

Since 2011

## Product Range:

- Microwave Series (RTN905/950A)
- Wireless - DBS 3900
- SDH & DWDM OSN Series(OSN 1800 Series)



# Huawei India Customers & Partners



TATA COMMUNICATIONS



Partners in Various Businesses

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Huawei Confidential



# SDN - Software Defined Network



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# Why SDN?

## Computing Trends are Driving Network Change

Changing traffic patterns

The “consumerization of IT” (BYOD)

The rise of cloud services - Virtual Desktop etc

“Big data” means more bandwidth



## Limitation of Current Networks

### Complexity that leads to stasis

- Add/Move devices
- Implementing network wide policy
- Time consuming & Manual
- Prone to errors

### Inability to scale

- Link oversubscription to provision scalability

### Vendor dependence

- Lengthy vendor equipment product cycles
- Lack of standard, open interfaces

# SDN - Definitions

[Common Definition] - The physical separation of the network control plane from the forwarding plane, and where a control plane controls several devices.

[The one that I like] - Software-defined networking (SDN) is an approach to computer networking that allows network administrators to manage network services through abstraction of lower-level functionality.

**Directly programmable:**  
Network control is directly programmable because it is decoupled from forwarding functions.

**Agile:** Abstracting control from forwarding lets administrators dynamically adjust network-wide traffic flow to meet changing needs.

**Centrally managed:**  
Network intelligence is (logically) centralized in software-based SDN controllers that maintain a global view of the network.

**Programmatically configured:** SDN lets network managers configure, manage, secure, and optimize network resources very quickly via dynamic, automated SDN programs.

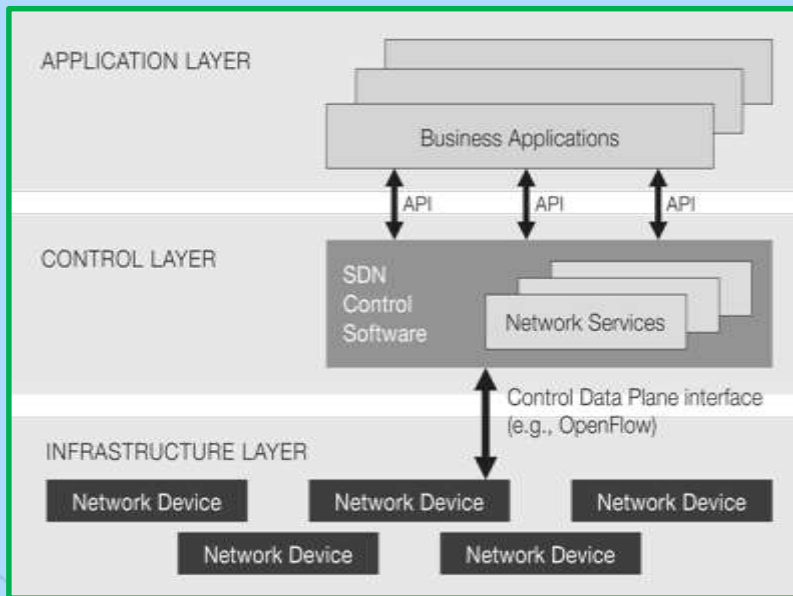
**Open standards-based and vendor-neutral:**  
When implemented through open standards, SDN simplifies network design and operation because instructions are provided by SDN controllers instead of multiple, vendor-specific devices and protocols.

# SDN @ ONF



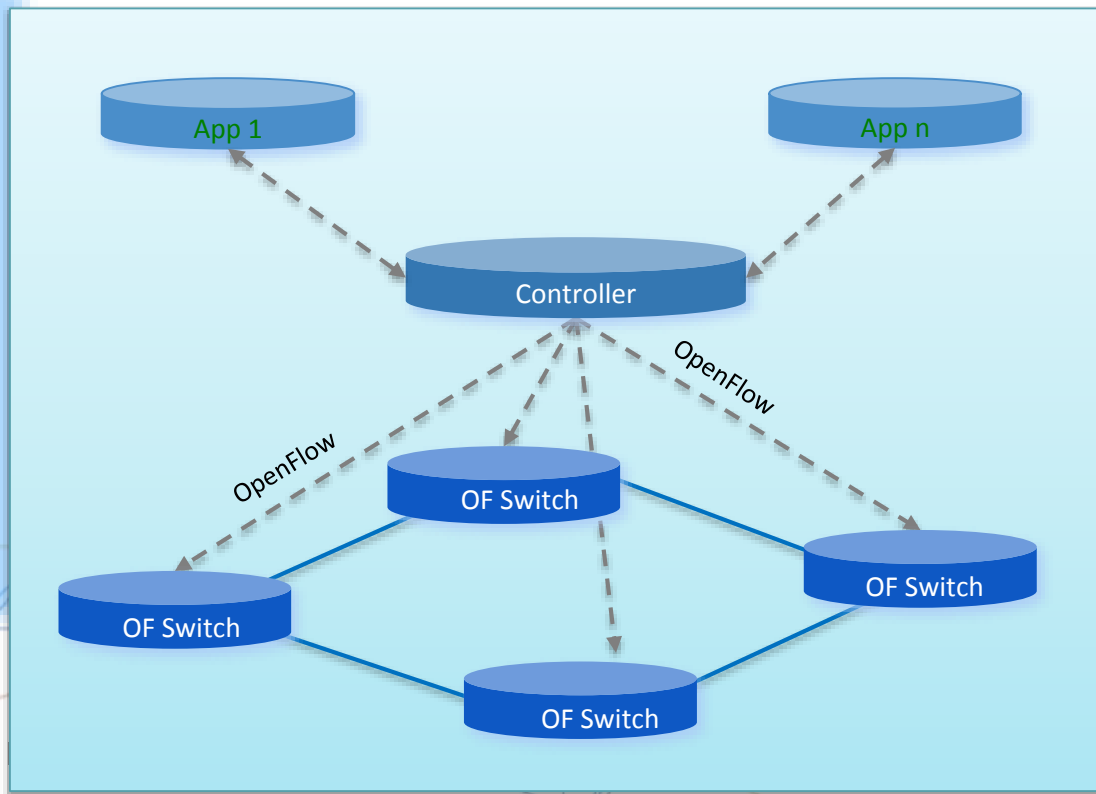
OPEN NETWORKING  
FOUNDATION

## ONF's SDN Architecture



**Characteristics: separate control and forwarding planes, centralized controller, programmable, open network, and forwarding plane abstraction**

## OpenFlow Deployment



# OpenFlow

- Openflow provides an open protocol to program the flow-table in different switches and routers
- Openflow allows direct access to and manipulation of the forwarding plane of network devices such as switches and routers, both physical and virtual.
- Use concept of flows to identify network traffic based on pre-defined match rules that can be statically or dynamically programmed by the SDN control software

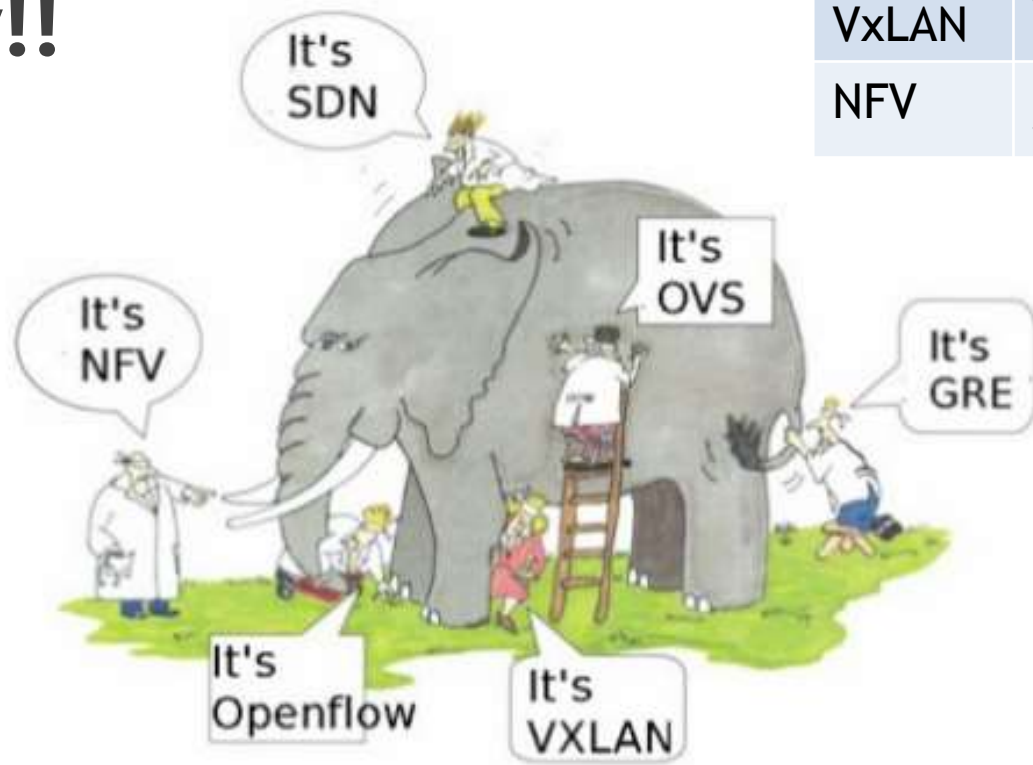
FIGURE 2  
Example of OpenFlow  
Instruction Set



# SDN Is Business, OpenFlow Is Technology!!

SDN emphasizes applications that drive network usability and business requirements, while OpenFlow is a technology to link an SDN controller and network devices.

OVS	Open vSwitch
GRE	Generic Routing Encapsulations
VxLAN	Virtual Extensible LAN
NFV	Network Function Virtualization





# Deployments



## DC

- Flexible and Dynamic Virtual Machine (VM) requires changes in networks.
- Virtual Switches
- Overlays
- Data Center Interconnect (DCI)



## Campus

- Changing networks with mobility, Bring your own device (BYOD)
- Accelerate the deployment
- Policy and access control



## Optical

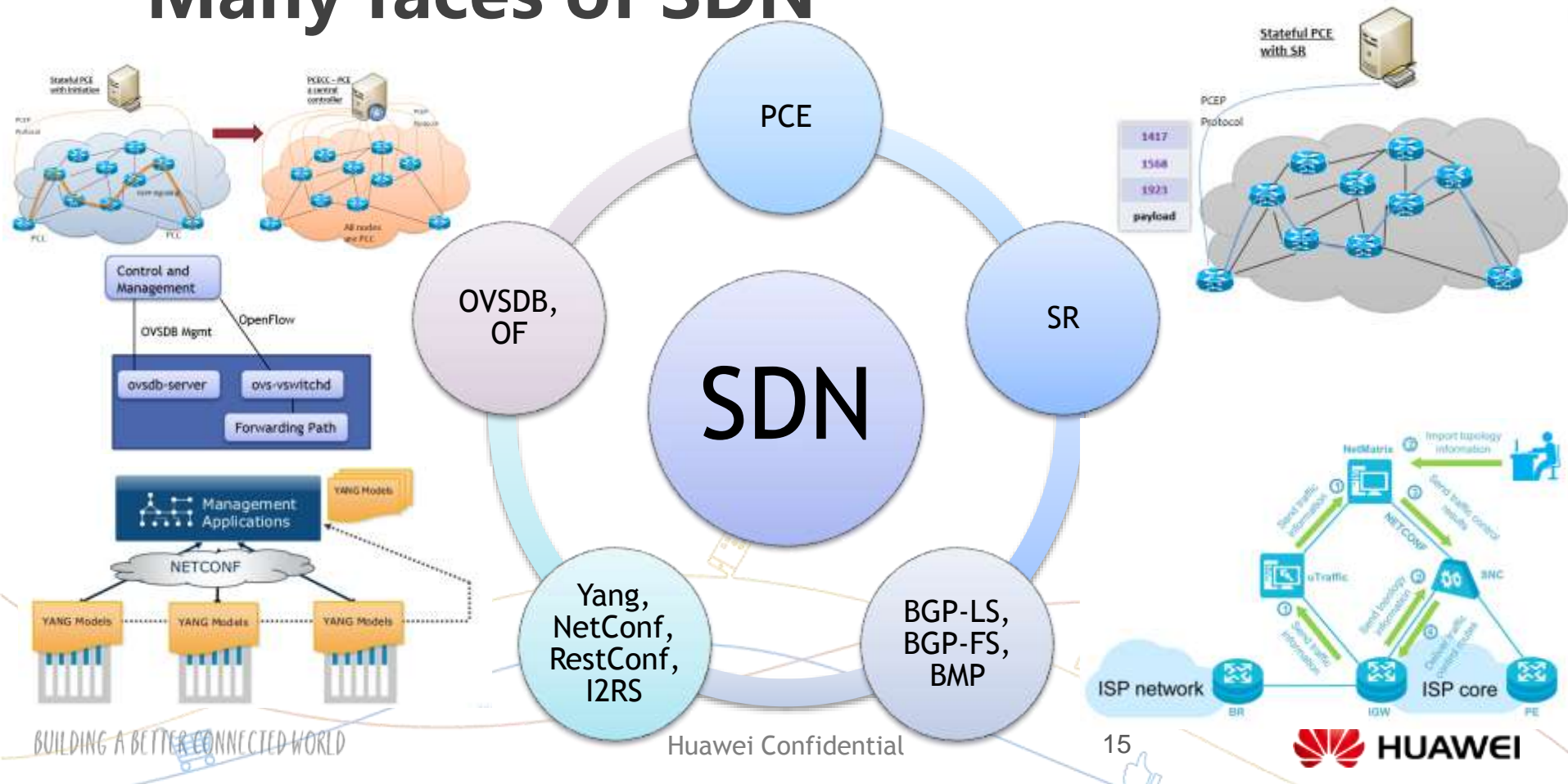
- T-SDN (Transport SDN) for various transmission network
- Multi-Layer optimization



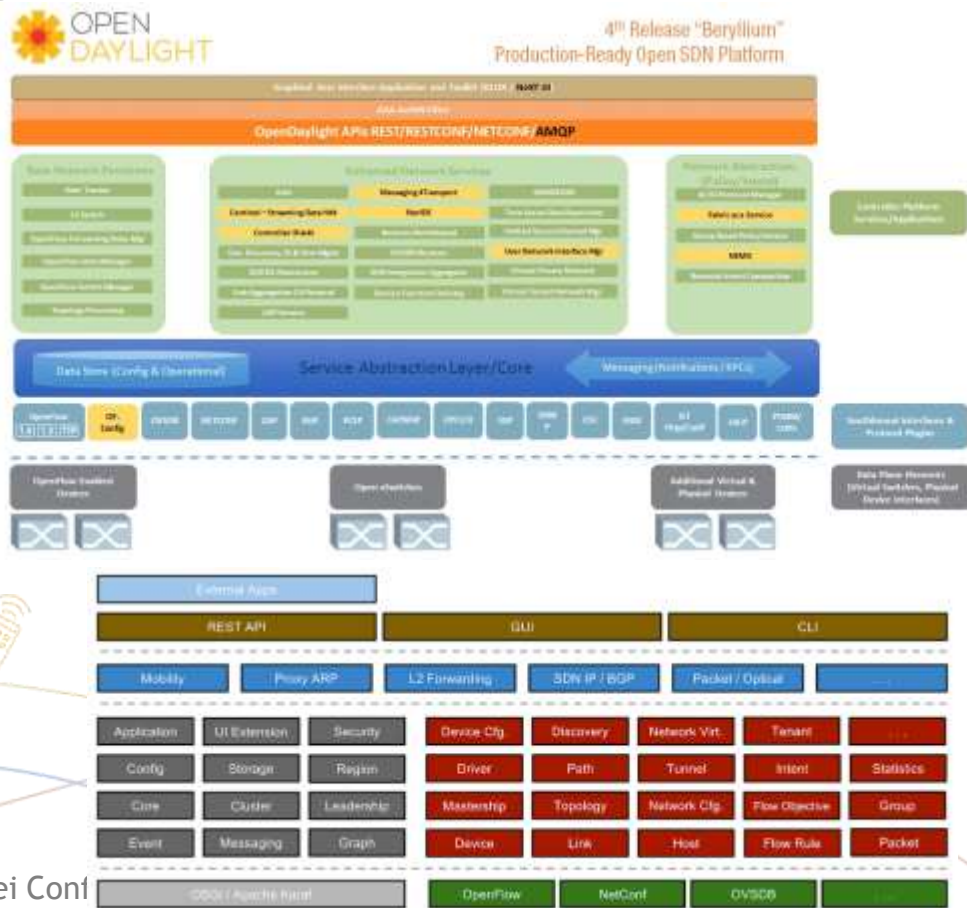
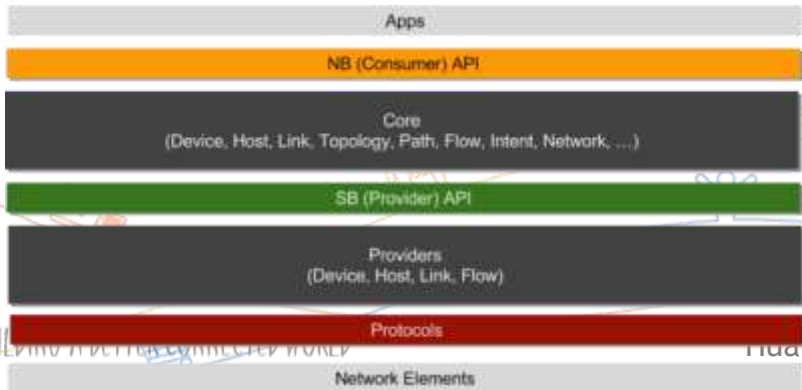
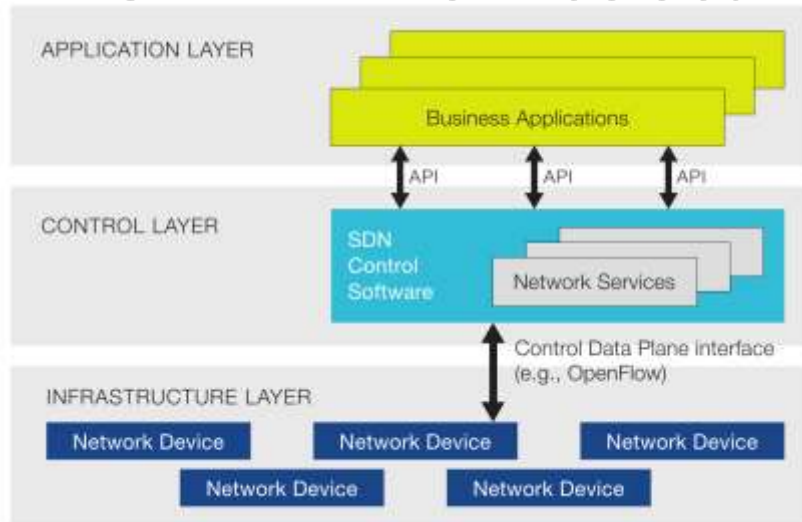
## Core

- IP/MPLS network
- Reusing existing protocols for SDN
- Path Computation Element (PCE) , Route Reflector (RR), IP+Optical
- InstantVPN

# Many faces of SDN



# SDN Architecture



# PCE - Path Computation Element



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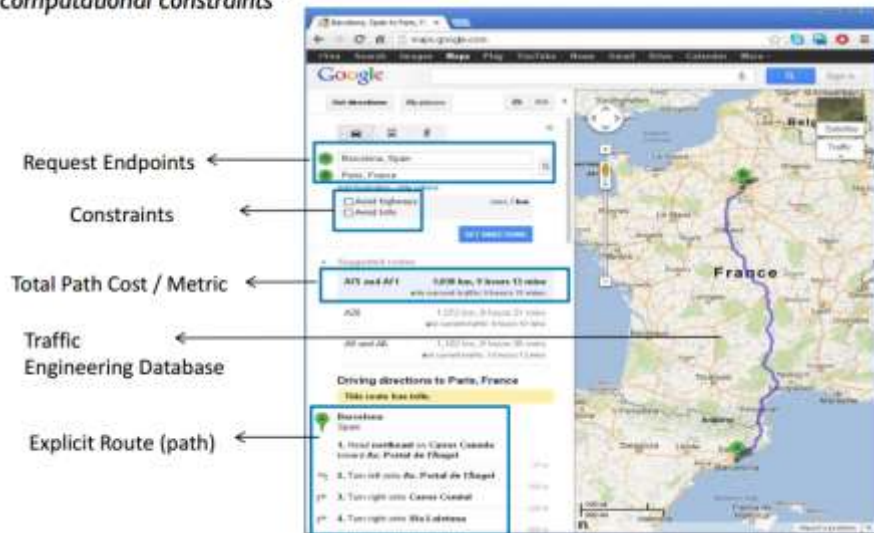


# PCE

- 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.
- PCE specializes in complex path computation across various domains on behalf of its path computation client (PCC) with enhanced scalability.
- Instead of head-end router doing the path computation, it is ask PCEs to cooperate and obtain end to end path.

## Path Computation Element / Function: what is it?

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



### PCE

- Path Computation Element
- Server or high end router

### PCC

- Path Computation Client
- Ingress, Network Management System(NMS)

### PCEP

- PCE Protocol to communicate between PCC and PCE(s)
- A TCP based protocol



# Drive for PCE

Central  
Control over  
Network

Innovative  
Algorithm

Application  
Awareness

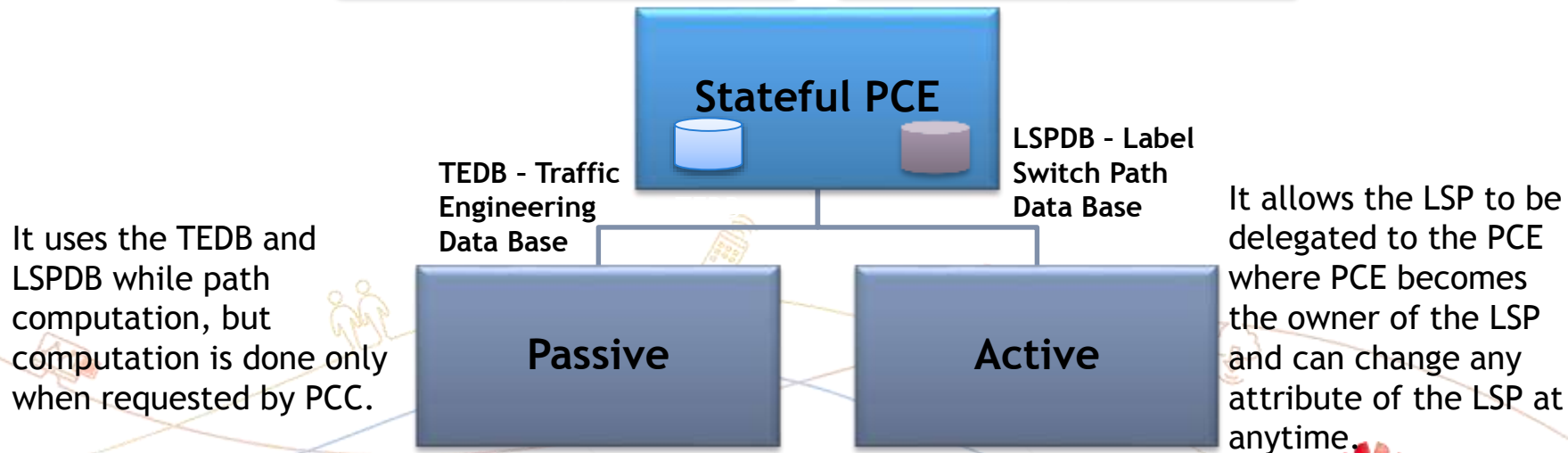
Globally  
Optimized

Dynamic  
and Agile

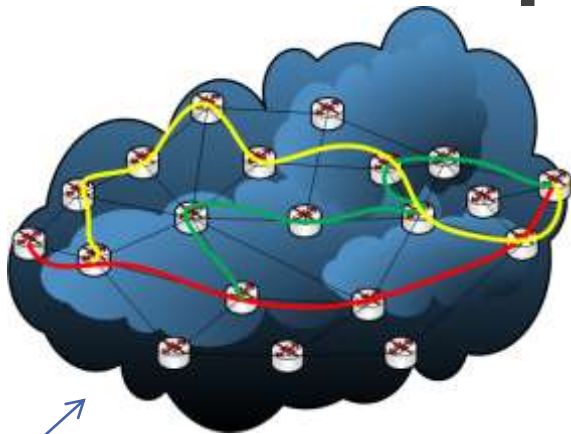
# Stateful PCE

Stateless PCE provides mechanisms to perform path computations in response to PCC requests. It utilized only the Traffic Engineering database (TEDB) to do this computation.

Along with network state (TEDB), Stateful PCE also stores the state of all the computed paths or LSPs and their resources (LSP-DB).

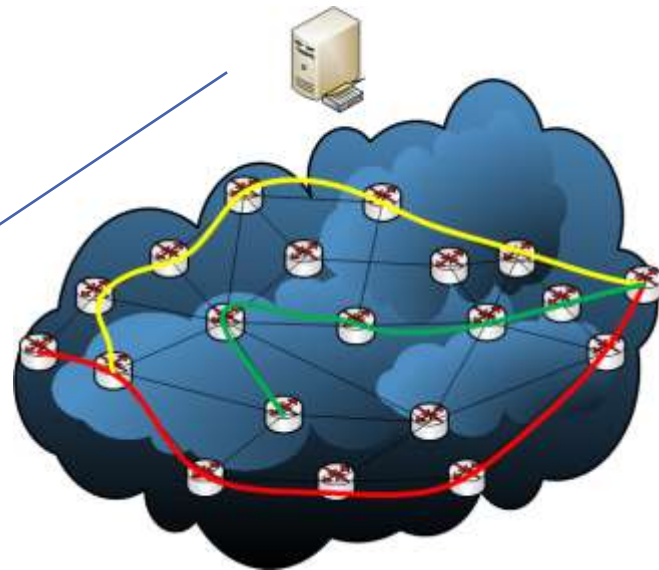


# Global Reoptimization



LSP path taken completely depend on the order of tunnel configuration.

Stateful PCE automatically re-optimize the network paths such that overall network gets optimized...



## Problems

- The order in which LSP are setup can lead to blocking resources for other LSPs.
- To resolve such deadlock, the administrator intervention is required.
- Many links in the network remain unutilized

## PCE Solution

- Active Stateful PCE can modify the LSP path at any time
- This allow stateful PCE to automatically re-optimize the global network without traffic disruption

# PCE-Initiated

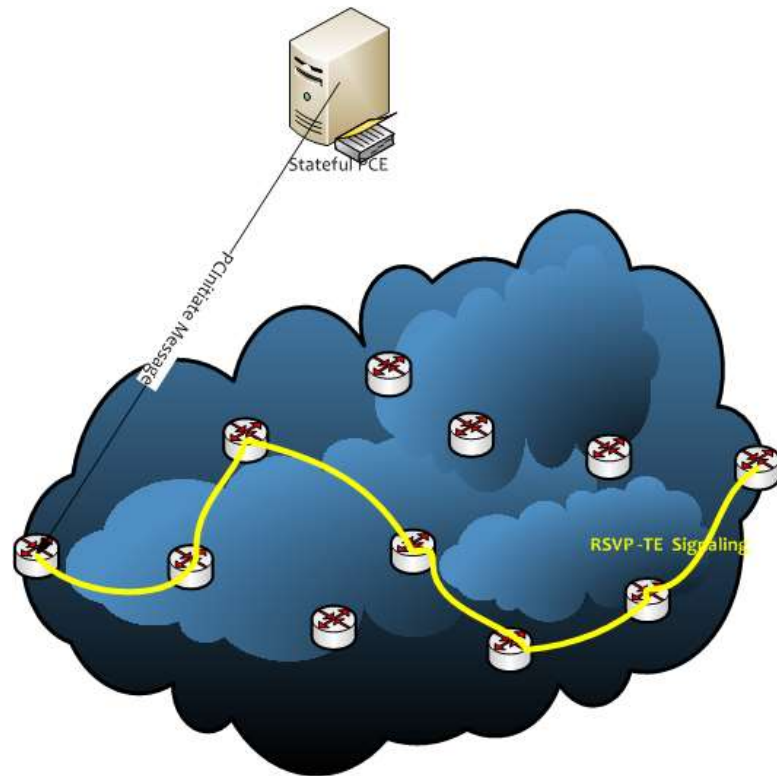
Setup, maintenance and teardown of PCE-initiated LSPs

Under the stateful PCE model, without the need for local configuration on the PCC...

Allowing for a dynamic network that is centrally controlled and deployed...

Environments where the LSP placement needs to change in response to application demands...

Agile software-driven network operation, and can be seamlessly integrated into a controller-based network architecture...



## LSP Initiate via PCEP

- A new PCInitiate Message

# PCE with Segment Routing (SR)

## SR Path

- PCE prepare label stack of node and adjacency labels

## PCE Optimization

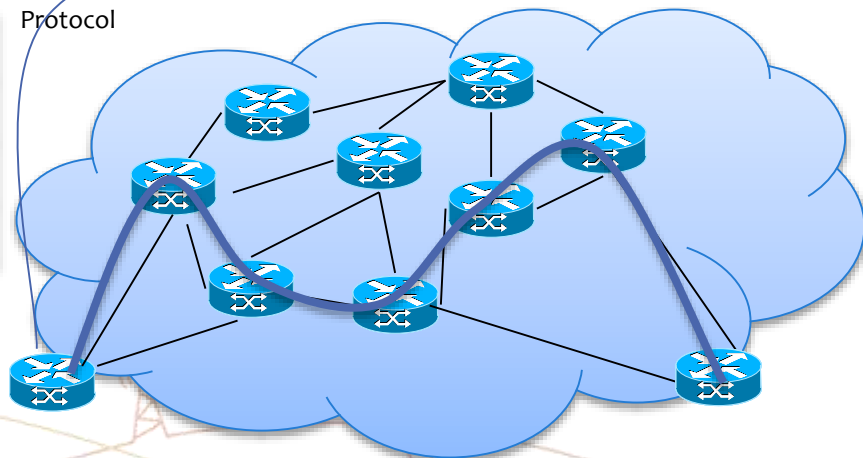
- PCE can respond to network events like congested links and update the label stack - no RSVP-TE signaling

Stateful PCE  
with SR



PCEP  
Protocol

1417
1568
1923
payload



PCE is the magic  
component of SR!!



# Stateful PCE Extn

## Optical

GMPLS controlled Networks

Support for flex-grid,  
WSN

Inter-Layer, VNTM - virtual  
network topology manager

## P2MP (point to multipoint)

Support for Multicast  
Service - MVPN, IPTV

Delegating P2MP Path  
Computations and  
optimizations

## Others

Sync Optimization

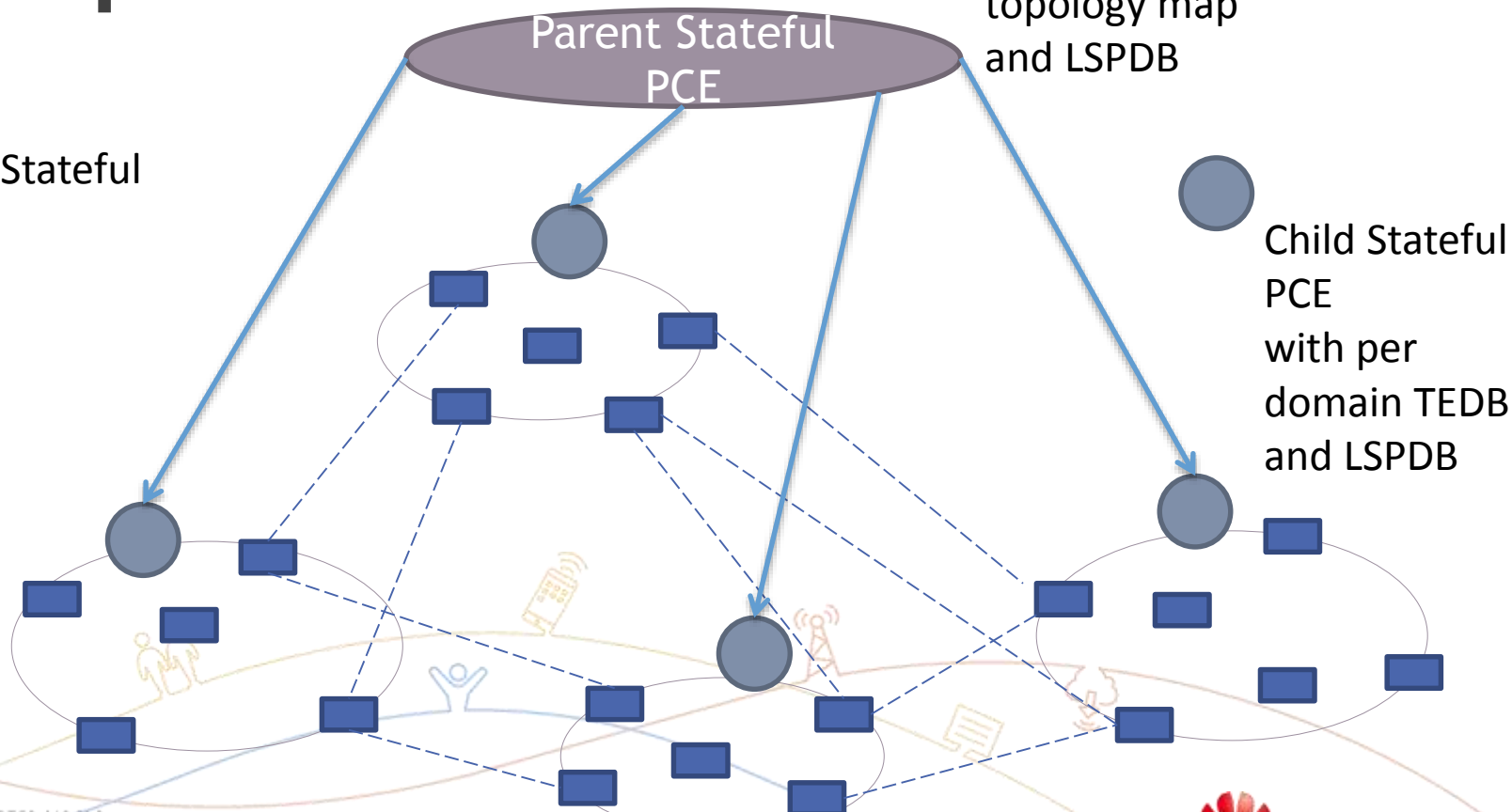
Backup Stateful PCE

Inter-domain and Inter-  
layer considerations

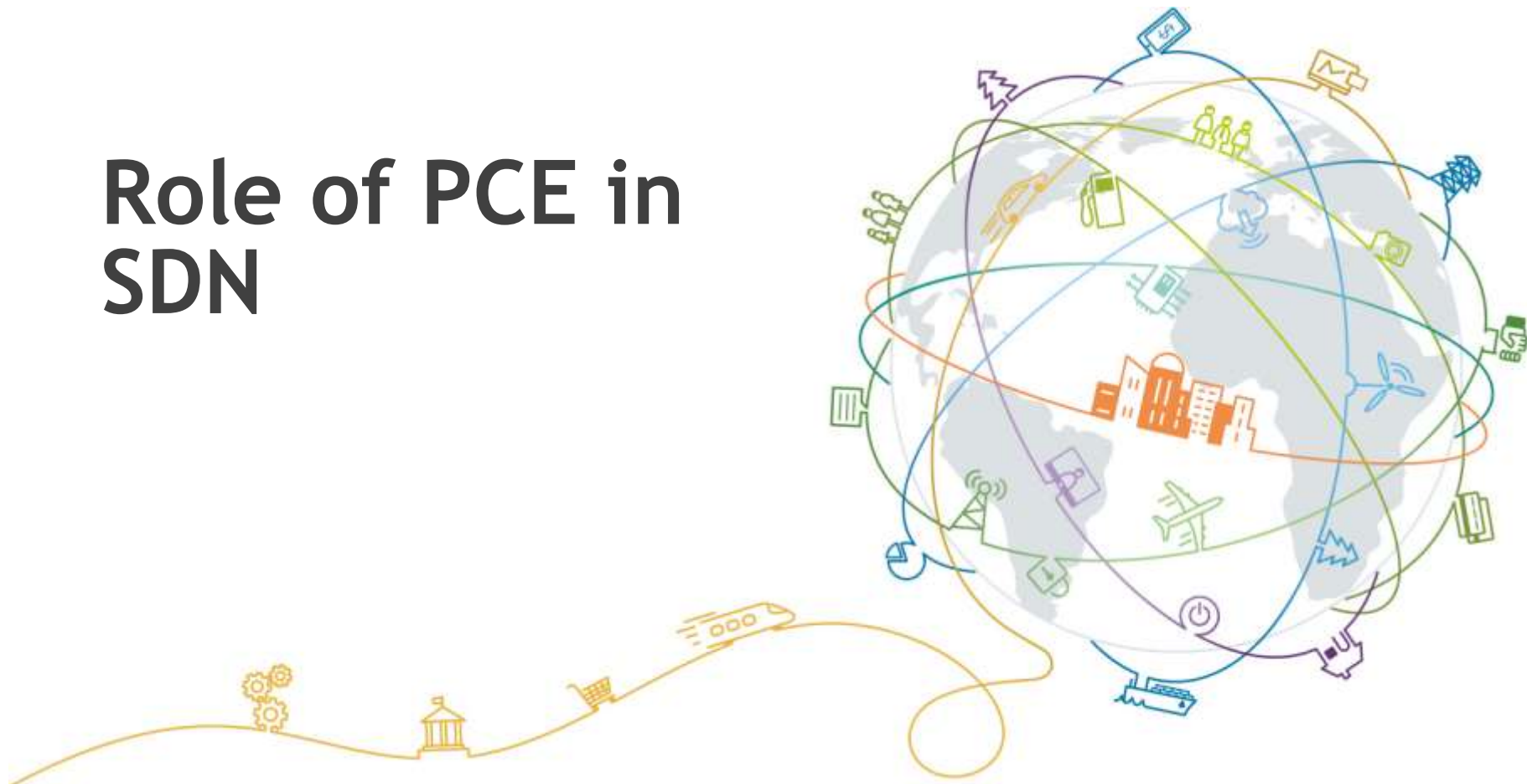
# Multiple Domains

Maintain the domain topology map and LSPDB

Hierarchy of Stateful PCE



# Role of PCE in SDN



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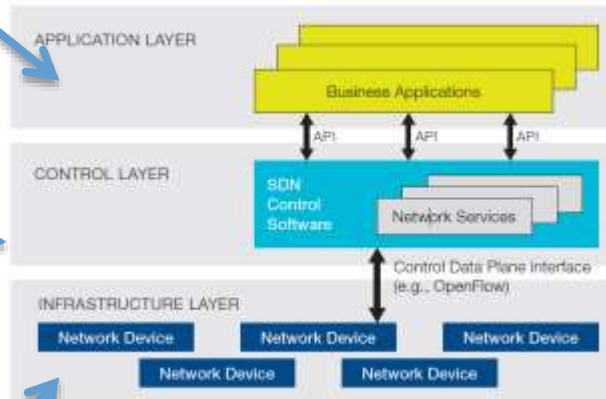
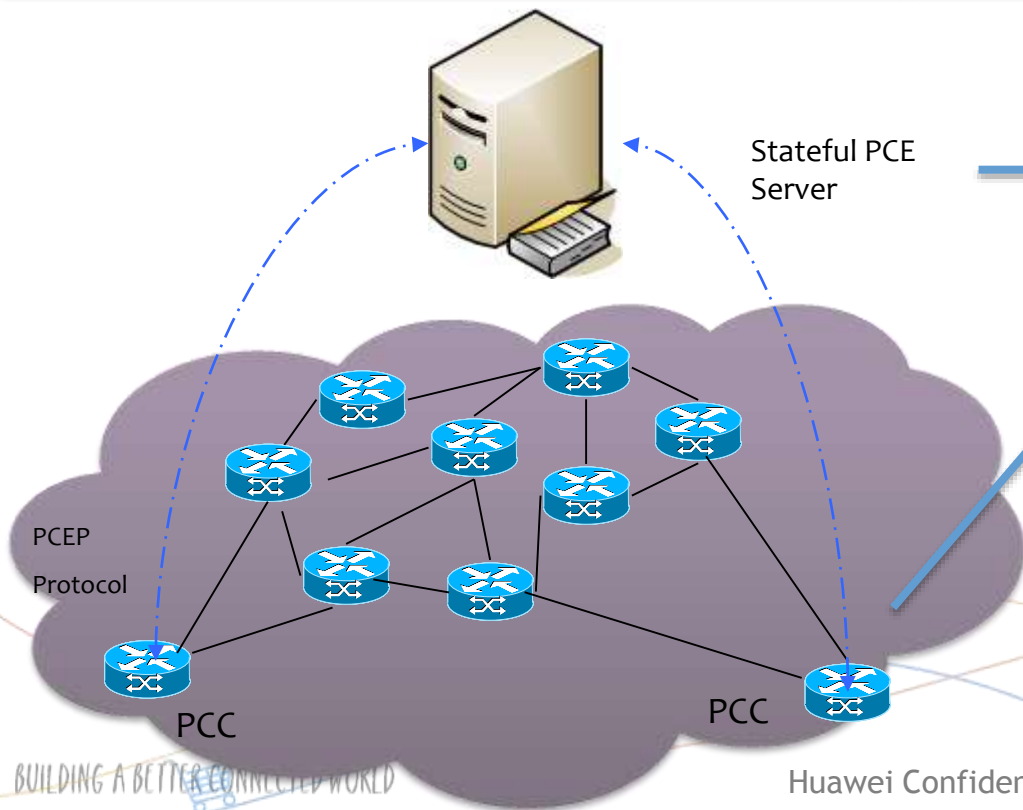




# Use of PCE as a Central Controller

# Stateful PCE

## Abstraction & Algorithms over Stateful PCE



### Stateful PCE as evolutionary approach to SDN.

In SP 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.



# PCE as Central Controller (PCECC)

PCE function is an integral part of any network controller

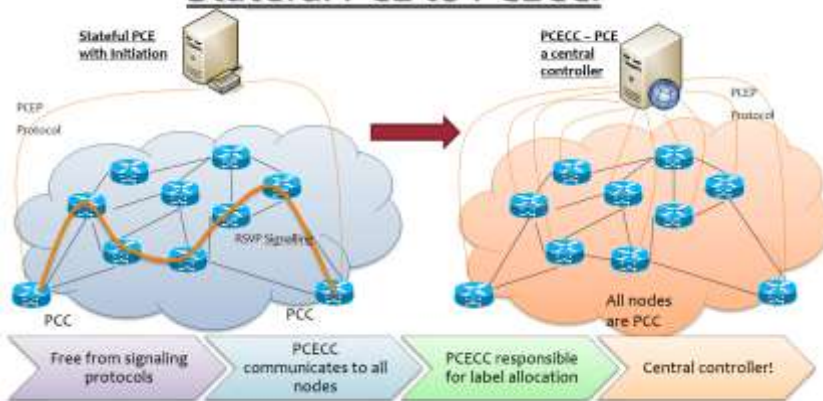
The controller can communicate with a conventional router using PCEP and can also use the same protocol to program individual routers

Each router along the path is told what label forwarding instruction to program and what resources to reserve

PCE-based controller is responsible to manage some part of label space

Move PCE towards SDN controller with label allocation and download

## Stateful PCE to PCECC!



Orchestrator / Service Manager / OSS / NMS

PCE based Controller

Topology and LSP Database

PCEP as SBI

# Modes

## Basic

- 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
- Rest processing similar to stateful PCE

## SR-BE

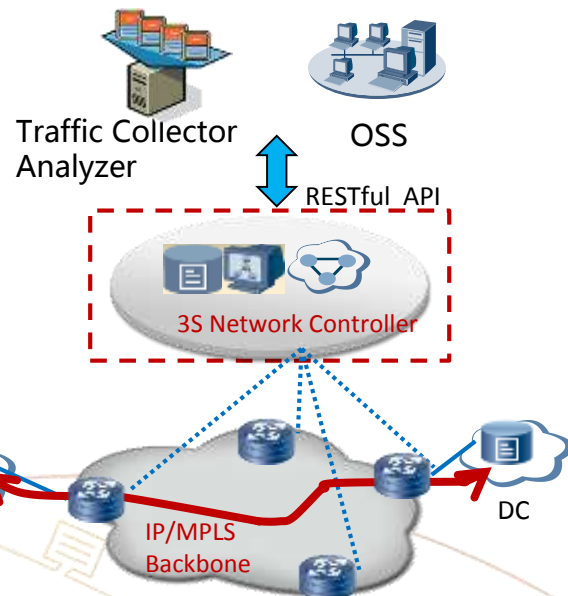
- Forwarding similar to LDP without LDP/IGP-SR signaling
- Use of SR Node label (global) to distribute label map
- PCECC allocates global label and distribute them
- Each LSR rely on local IGP for the next hop

## 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

# Why PCECC?

- OPEN-Flow Based SDN technologies are not deployable within the current network
- Huawei leads the industry by coming up a simple, smart and scalable SDN solution while having all the advantages
- Multiple Patents and IETF drafts
- Source Routing Based Forwarding
- Multi-topology for NV;
- Path Computation;
- LSP monitoring;
- IP+Optical PCE;
- H-PCE;
- Network Resiliency;
- Application-Aware Smart TE;

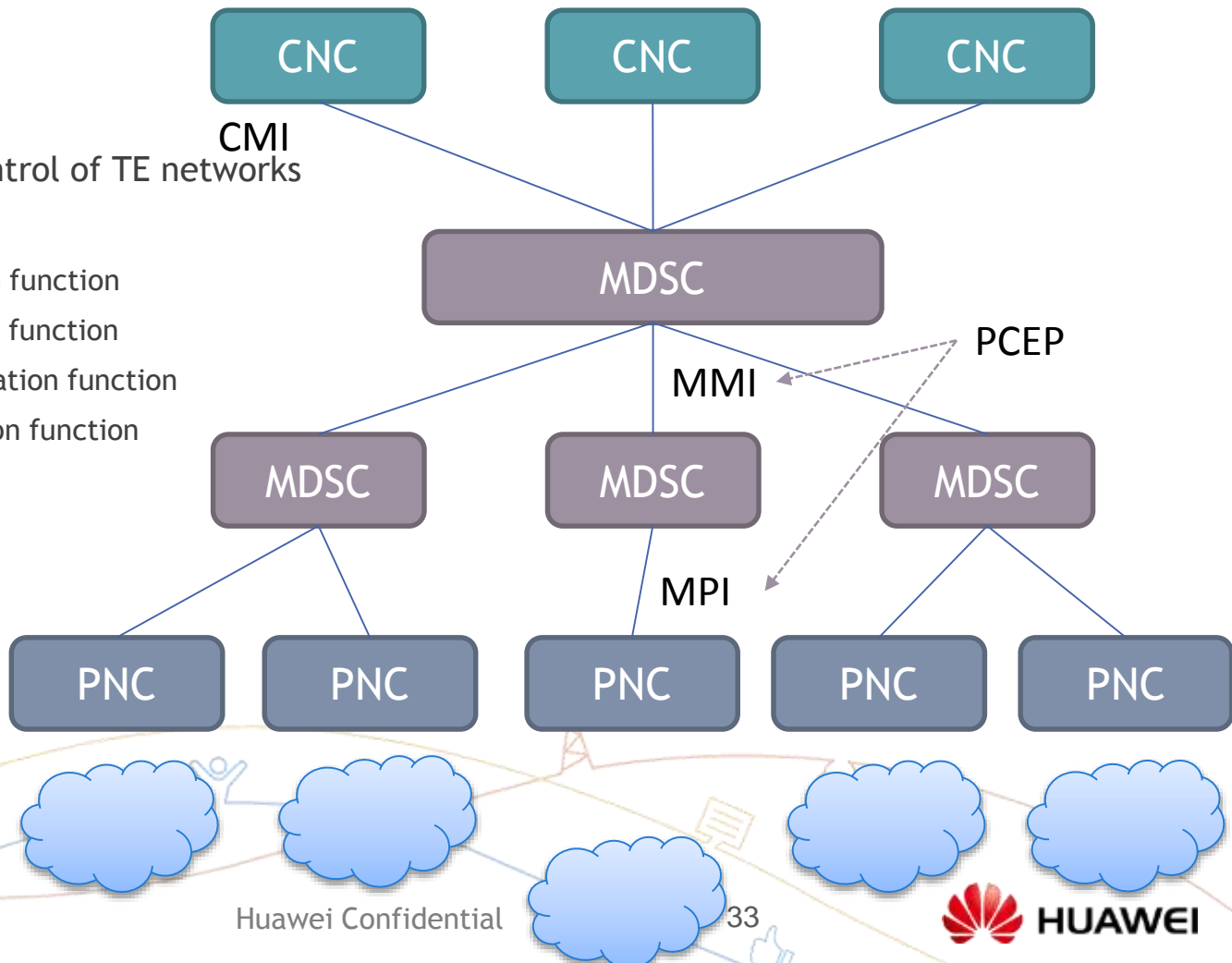




# Use of PCE in multi-domain, multi-layer

# ACTN

- ACTN - Abstraction and Control of TE networks
- Four Functions in ACTN
  - Multi domain coordination function
  - Virtualization/Abstraction function
  - Customer mapping/translation function
  - Virtual service coordination function



CNC	Customer Network Controller
-----	-----------------------------

MDSC	Multi-Domain Service Coordinator
------	----------------------------------

PNC	Physical Network Controller
-----	-----------------------------

CMI	CNC-MDSC Interface
-----	--------------------

MMI	MDSC-MDSC Interface
-----	---------------------

MPI	MDSC-PNC Interface
-----	--------------------

# ACTN

## Multi-layered multi-domain Network

- Technology, administrative or vendor islands
- Interoperability for dealing with different domains is a perpetual problem for operators.

## New service introduction with connections that traverse multiple domains

- Need significant planning
- Manual operations to interface different vendor equipment and technology across IP and Optical layers.

## 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.



# ACTN – Why?

Provide customer's ability to create VNS (Virtual Network Service) based on their service requirement and policy.

Connectivity spans multiple transport network domains due to the distributed nature of customer end points (e.g., data centers).

Recognize heterogeneous control/management technologies (e.g., GMPLS/ASON, PCE, EMS/NMS, OF, etc.)

- Hierarchy of controllers is a must to meet these requirements.

Controller - Controller interface is the key!

- Ability to build virtual network operation infrastructure based on multi-layer, multi-domain topology abstracted from multiple physical network controllers (e.g., GMPLS, OpenFlow, PCE, NMS, etc.)
- Ability to provide service requirement/policy (Between Customer and Network) and mechanism to enforce service level agreement.
- Ability to request/respond VN Query and ability to request/confirm VN Instantiation with VN lifecycle management/operation
- Coordination of multi-destination service requirement/policy to support dynamic applications such as VM migration, disaster recovery, load balancing, etc.
- Ability to Coordinate multi-domain and multi-layer path computation and setup operation
- Ability to perform E2E Path Restoration Operation

## Requirements for ACTN



# ACTN – usecases!

## Transport

- Interconnecting multi-domain vendor islands
- Global abstract topology

## Multi-tenant VN

- On-demand VN service creation
- Monitoring and Fault Management

## Packet & Optical

- Support for Network Planning, Monitoring, congestion management, and automatic adjustments
- Protection and Restoration
- Service awareness and coordination

## Carriers of Carrier

- One ISP can provide abstract topology and services to another ISP for dynamic operations

## Data Center Interconnect

- Multi-domain DCI
- VM migration
- Global Load Balancing
- Disaster Recovery
- Real-time on-demand VN setup!

## Mobile Back Haul

- End-to-End Enterprise Services Provisioning including access / metro / core
- Multi-layer coordination Requirement in L2/L3 Packet Transport
- Virtual Network Support

# What can PCE offer?



## Controller

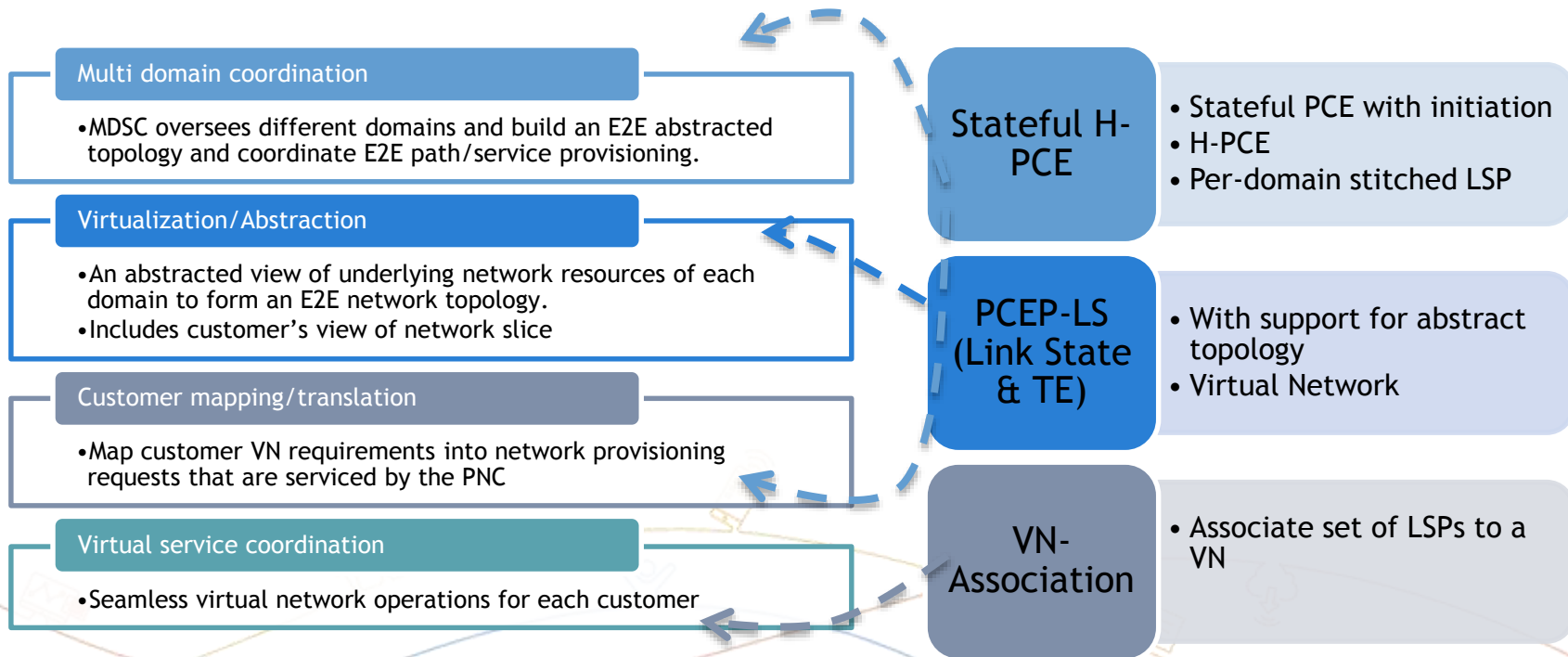
- PCE is a key function in a controller
- Stateful PCE
  - Initiation capability
- Application Based Network Operations [RFC7491]
- PCE based central control (PCECC)



## 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

# Architectural Considerations



Security Level:

# Towards a software driven world...



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# New work in these areas

Using Machine Learning and Artificial Intelligence for Network Operations

Using advanced path computation algorithm that optimizes the network as a whole

Interactions between controllers

Interactions with applications (North Bound Interfaces - NBI)



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THANK YOU

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