The bridge to possible

Management of IP+Optical Networks Using an SDN Controller Architecture

SDN for SP Networks 2023 Edition

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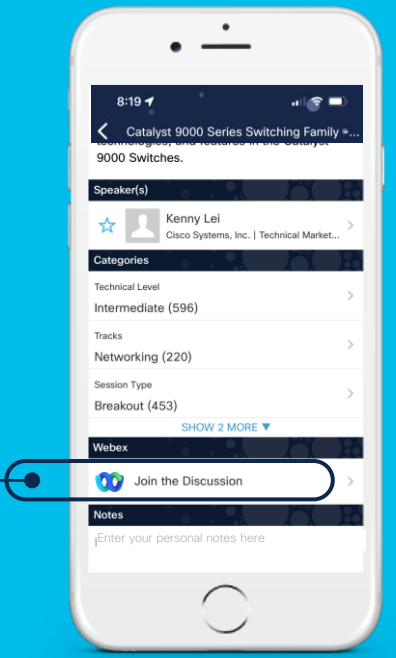


Agenda

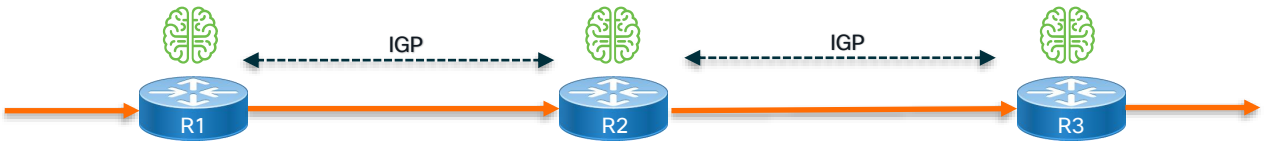
- SDN Background
- Industry Standards and Initiatives
- SDN Controller Data Collection
- Network Use Cases
- Cisco SP SDN Strategy

Caution! Industry buzzword alert!

SDN Background

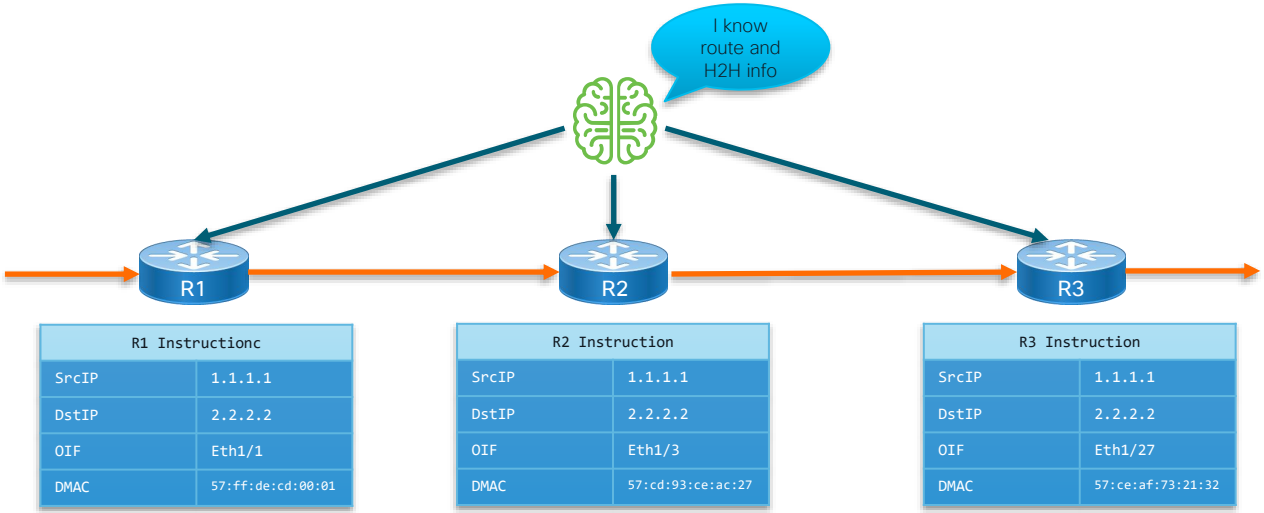
What is a ”non-SDN” network?

- What most networks are today and have been for the last several decades
- Network has a distributed control plane using protocols to communicate routing and forwarding information across the network
- This does not mean it is not intelligent, we’ve added all kinds of protocols and extensions to enhance distributed control planes and influence end-to-end forwarding
  - RSVP, RSVP-TE, Segment Routing, BGP-Flow Spec, onboard applications like Auto-Bandwidth
  - In some cases, the head-end node influences forwarding across the network, but the intelligence is still embedded within the device



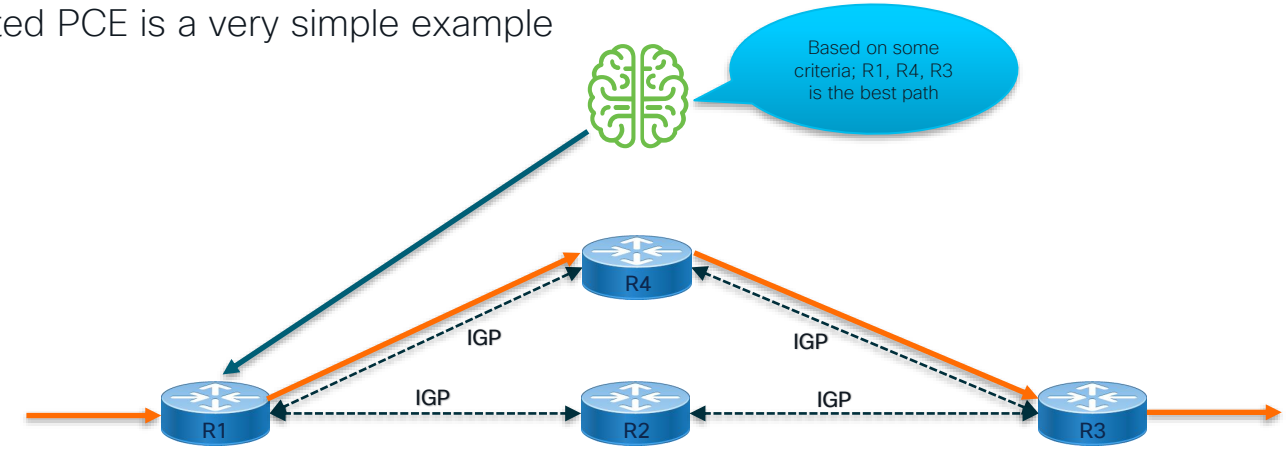
What is Software Defined Networking?

- Purist view: Physical separation of control and data plane, external control plane is responsible for all management and routing functions
- Centralized (off-box) control plane makes all routing and forwarding decisions
- Simplified hardware was one of the drivers
  - Standard interface for programming routing/forwarding tables at each hop
  - Standard languages to define forwarding mechanics: Openflow, P4



What is SDN? – ”Hybrid” SDN

- Pragmatic view: Common distributed networking with additional intelligence
- Network programmability through standard protocols and open interfaces
- Can augment different layers of the network: Service endpoints, overlay paths, device-level forwarding
- Delegated PCE is a very simple example



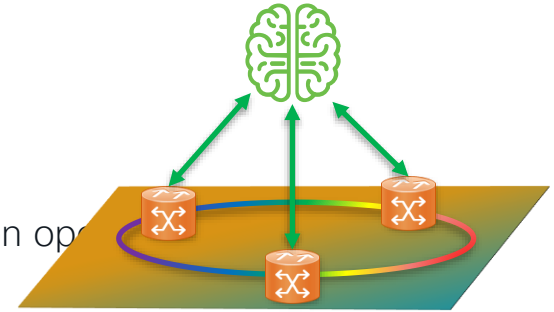
R1 Instruction	
SrcIP	1.1.1.1
DstIP	2.2.2.2
Path	R1, R4, R3

Intent Based Networking (IBN)

- Often goes hand in hand with “SDN”
- IBN drives network configuration from desired end goal
- Declarative configuration driven by higher layer requirements
- ”I need L2 connectivity between applications A and Z”
  - Software decomposes ask into network services and configuration
  - Each component is only responsible for the components it knows about
- Key is to create abstract representations of services and networks higher layer elements can consume

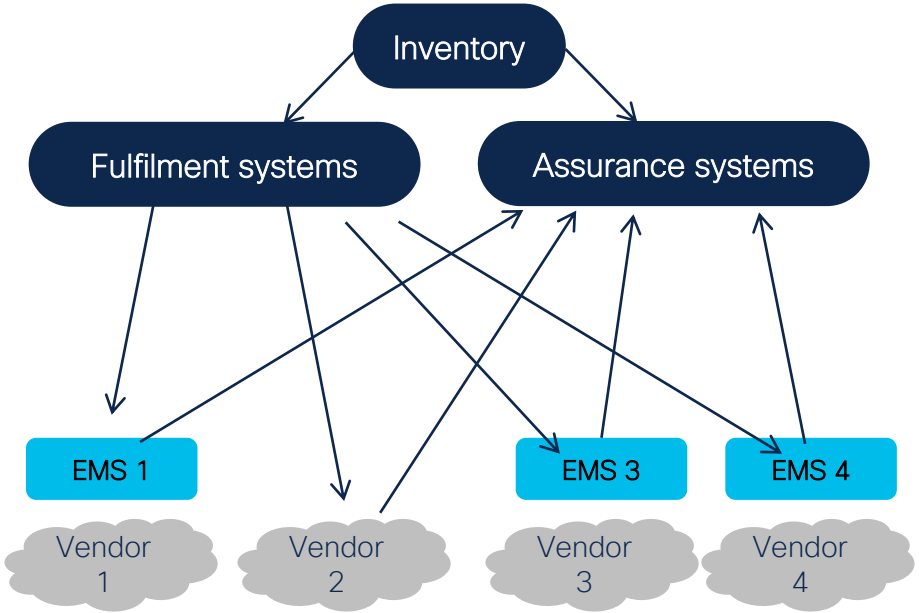
What is an “SDN controller”?

- A “controller” directs the actions or function of (something), in this case network devices or other network controllers
- Southbound adapters to interact with network or other controllers
- Aggregates standard and proprietary network data
  - Network data is the foundation of more intelligent networks
  - Consumed by controller applications
- Render north bound API interfaces
  - Allows other controllers to consume data or perform application op
    domain elements
- Contains intelligent network applications
  - Translate Intent into network configuration

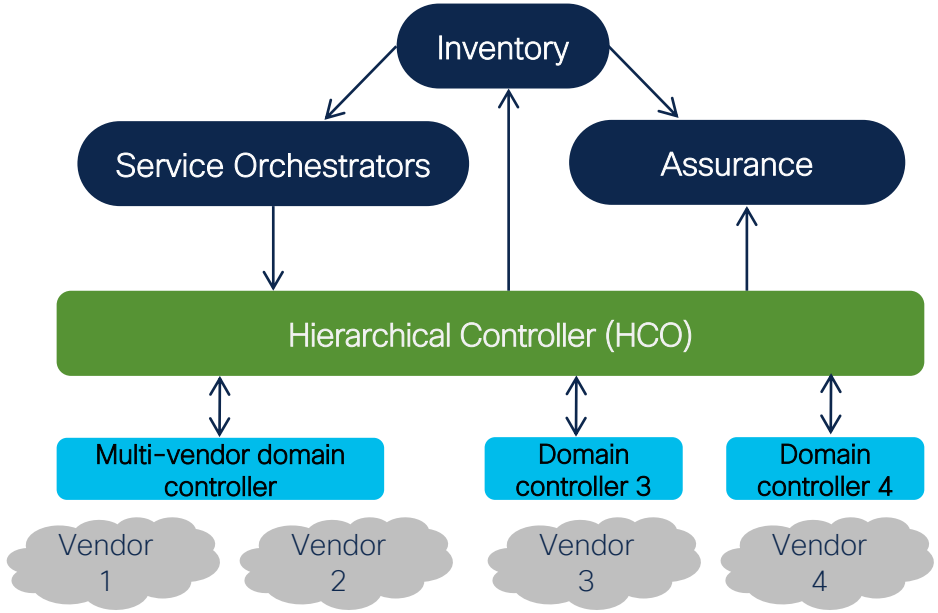


Legacy Network Management vs. SDN Hierarchy

Legacy mgmt stack



New SDN stack



Why use SDN?

- Enhance network decision making with data that's not feasible to use as input into a distributed on-box routing protocol
  - Embedding complex functions into device level software is difficult
  - Upgrading device software is still relatively painful

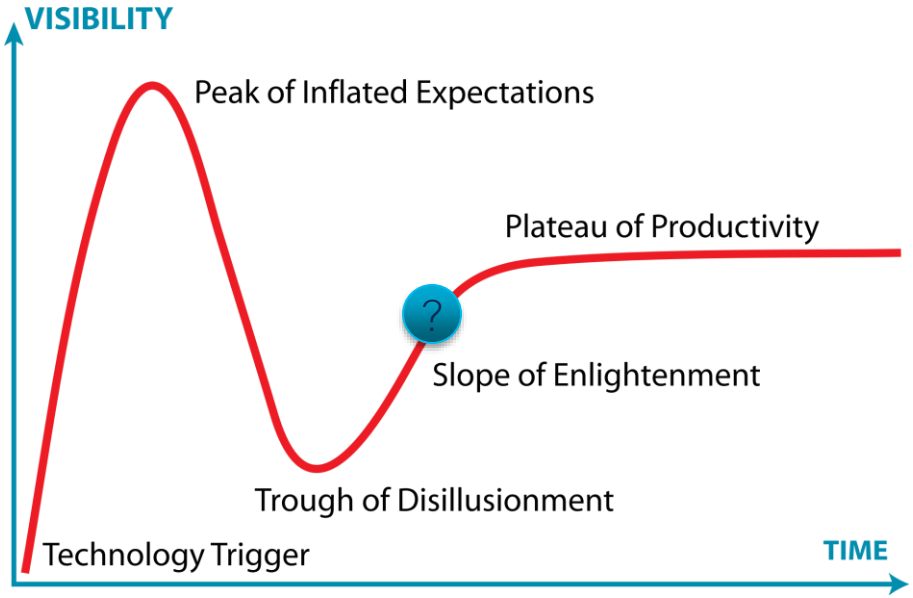
- Intelligent multi-layer networks
  - GMPLS is a distributed IP+Optical control plane but has not seen adoption
  - Is SDN the savior of failed device-level control plane interop?

- Optimize network resources

- Ancillary benefits include network visibility and fault identification/correlation

Who is using SDN today?

- Some have been using “SDN” for some time, EG: Content providers with more advanced automation
- Majority of SPs are not using what I would call “SDN”, but many are looking at it



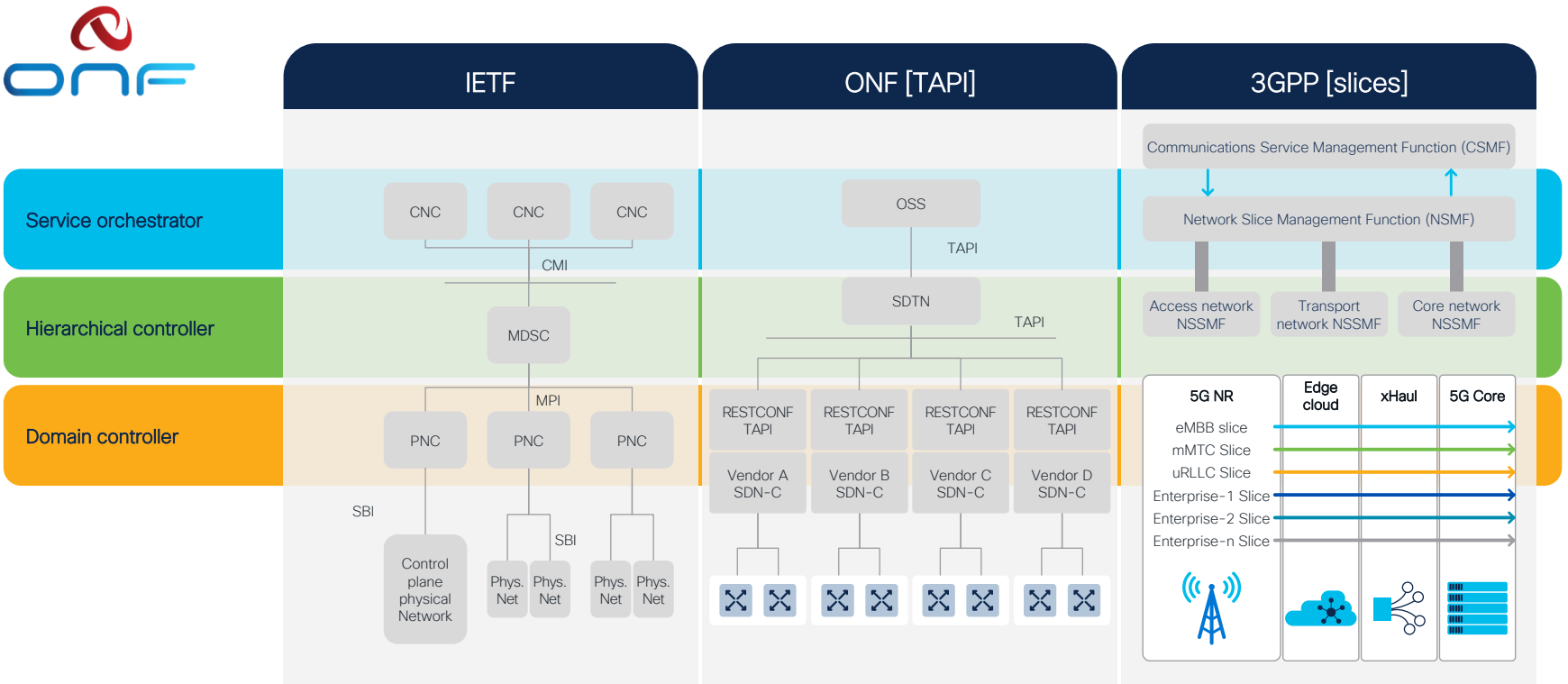
Gartner hype cycle

Gartner proclaimed purist

“SDN” dead in 2019

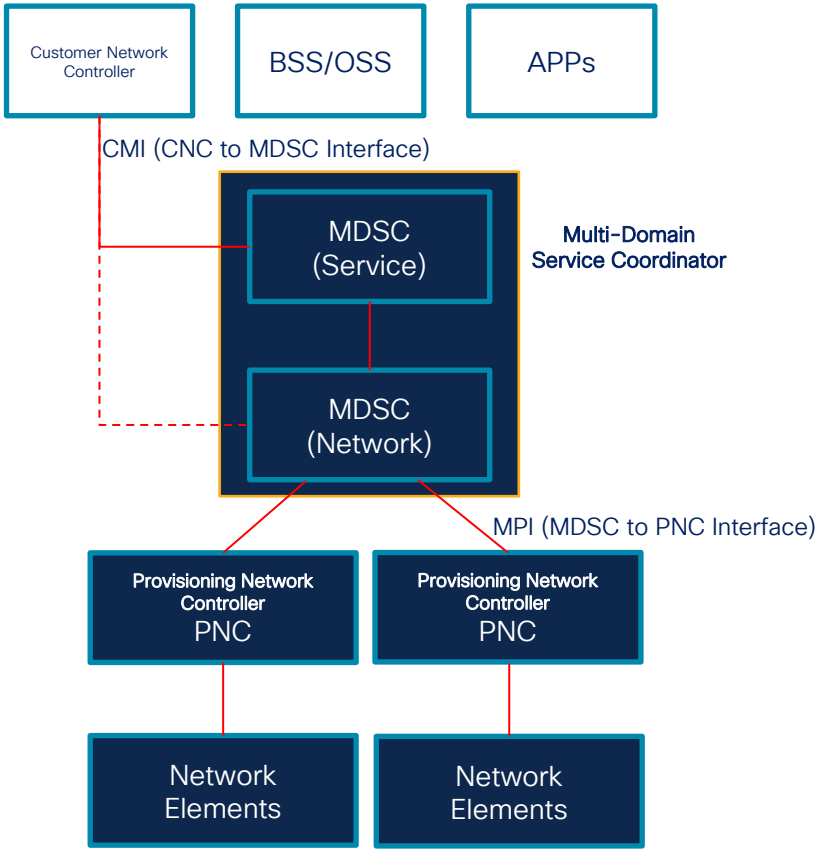
SDN Standards and Industry Initiatives

Hierarchical SDN Architecture – Standards Bodies



IETF ACTN

Abstraction and Control of Traffic Engineered Networks



- RFC8453 defines hierarchical framework of controllers
- Assigns roles and responsibilities to different elements
- Framework defines loose coupling between components but not interfaces and encoding

✅ HCO or “Hierarchical Controller” is a common name for MDSC

✅ ”Domain controller” is a common name for PNC

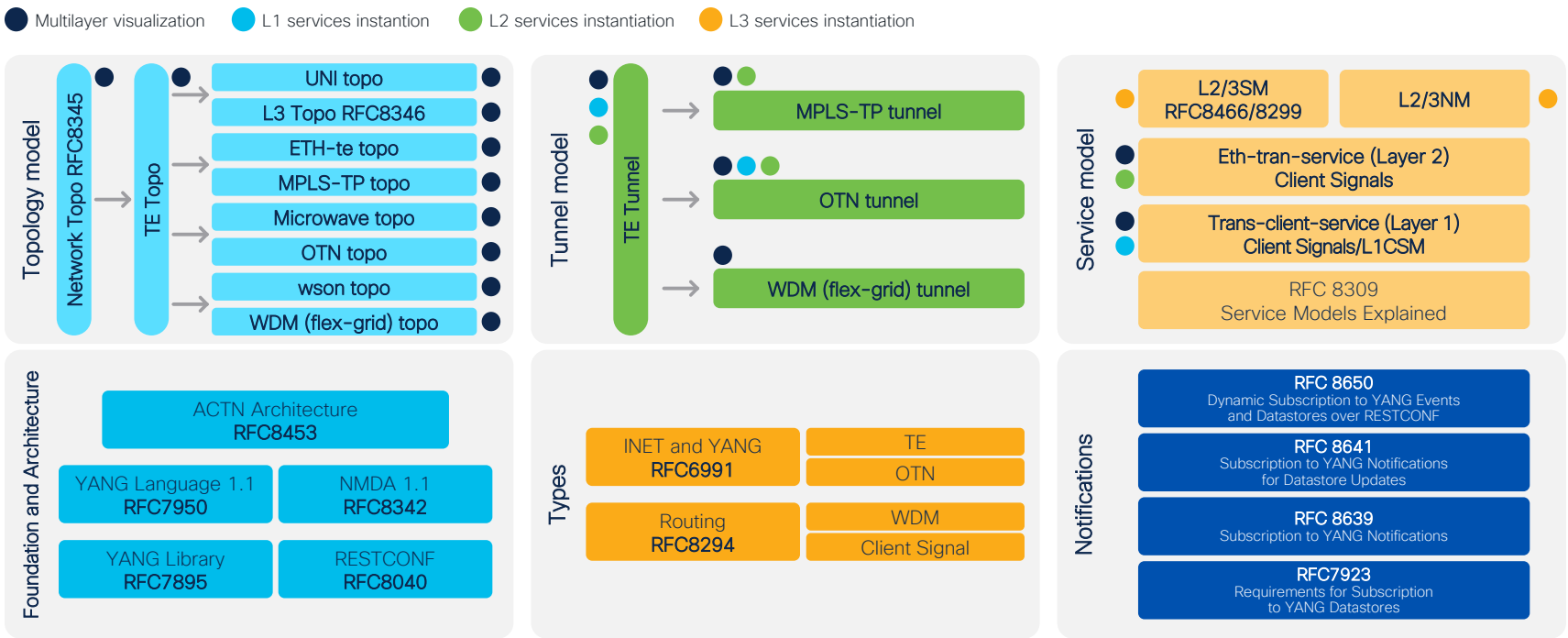
IETF ACTN – Controller roles

- CNC – Customer Network Controller
  - Highest level orchestration / workflow system defining intent
- MDSC (Multi-Domain Service Controller) or HCO
  - Aggregate information from downstream controllers to perform multi-domain tasks, for example IP+Optical provisioning or stitching a single service across two ASNs
- PNC – “Provisioning Network” aka ”Domain” controller
  - Communicates using SBI to network elements for provisioning, fault, and performance data collection
  - May be proprietary or standard SBI to devices

IETF – Additional Topics

- Service level standard models
  - IETF L2NM for L2VPN, L3NM for L3VPN
- Network models
  - Network topology, inventory, and TE models
- Continued work on enabling protocols such as PCEP, IS-IS, BGP-LS extensions, Network Telemetry Framework

IETF RFCs and Drafts



ONF Telecom Infra Project

TELECOM INFRA PROJECT

- OOPT – Open Optical & Packet Transport Project Group

- TIP OOPT MUST - Mandatory Use Case Requirements for Transport SDN
  - Focused on defining a SDN controller-based architecture like ACTN, but adds transport protocols, encoding, and model requirements based on industry s
  - MUST has generated controller requirements documents for the NBI/SBI models, interfaces, along with the use cases which must be supported

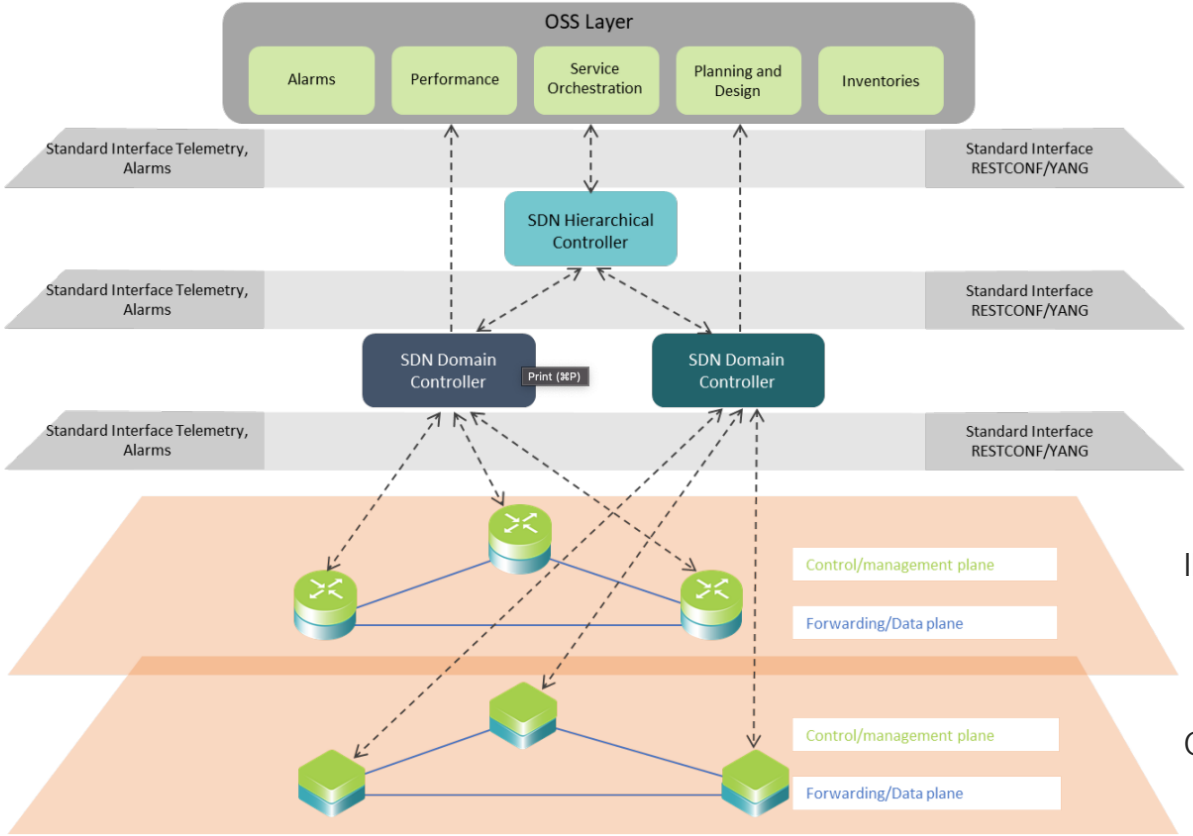
- TIP OPT MANTRA - Metaverse ready Architectures for Open Transport
  - Focused on multi-vendor Open Optical Networks including IP-over-DWDM using ZR/ZR+

- Driven primarily by operators, not vendors

https://telecominfraproject.com/oopt/

TIP MUST Open Transport SDN

TELECOM INFRA PROJECT



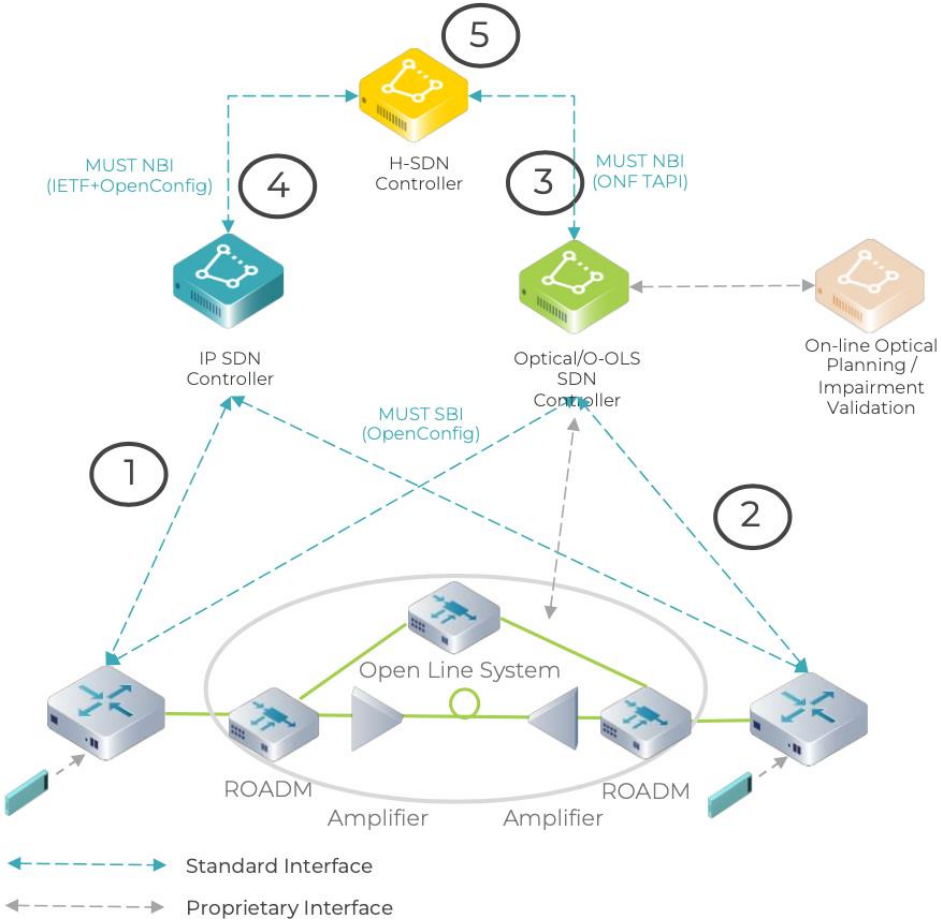
Similar structure to ACTN

Communication is not always hierarchical, only where it makes sense

IP/MPLS/SRv6 Network

Optical DWDM Network

TIP MANTRA Open Optical



1. IP SDN Controller to IP devices
2. Optical SDN Controller to optical devices
3. HCO to Optical SDN Controller
4. HCO to IP SDN Controller
5. Hierarchical Controller

Each has defined roles and responsibilities

ONF OTCC Project and Transport API (T-API)

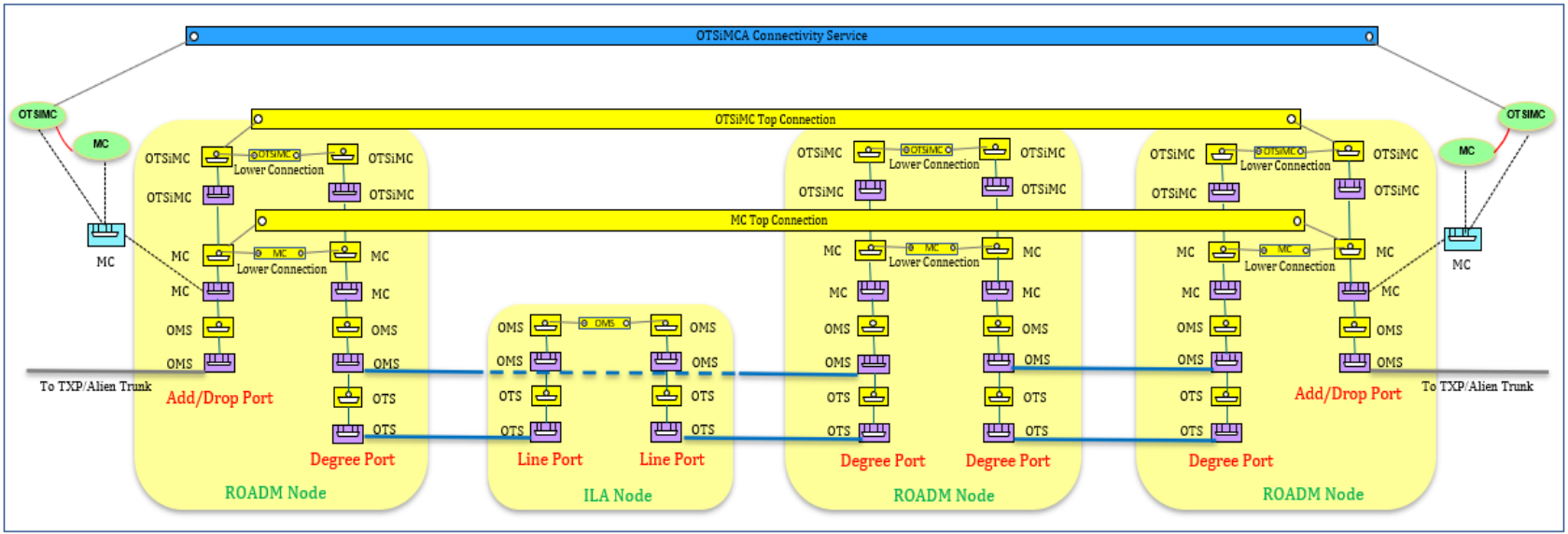
Open Transport Configuration and Control

- Defines a set of models for managing optical transport networks
  - Equipment inventory, topology, connectivity-service, fault, and performance covered in defined models
  - Used by external systems, T-API does not define SBI from controller to device

- Has become the de-facto standard for optical domain controllers
  - Still in early stages of implementation, many differences between implementations still
  - Version 2.4 recently released
  - OIF (Optical Interworking Forum) public interop events
  - Used by TIP MUST, MANTRA, and other groups defining architectural standards

https://wiki.opennetworking.org/display/OTCC/TAPI+Documentation

T-API Connectivity Service



- Hierarchical services definitions
- Hierarchical topology

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T-API Connectivity Service

Other important open automation initiatives

- Common **device** data models
- gRPC, gNMI, gNOI management protocols
- Subscription based streaming telemetry
- Vendor neutral testing and compliance

- YANG models for disaggregated DWDM systems *(covers DCO pluggables)*, RPCs and device templates
- Controller based architecture following similar architecture as TIP MANTRA

What allows SDN controller interop?

- Standard architecture definition for controller communication
- Standard data models
  - YANG is the de facto standard language today
  - Standards covering different domains and technologies
  - Device-level, controller-level, service-level
  - Necessary to normalize proprietary data into vendor-agnostic data
- Standard interface protocols
  - NETCONF to devices is widely implemented and deployed
  - gNMI, gNOI are additional standards for device-level interaction
  - RESTCONF has become the de facto standard for controller to controller interaction

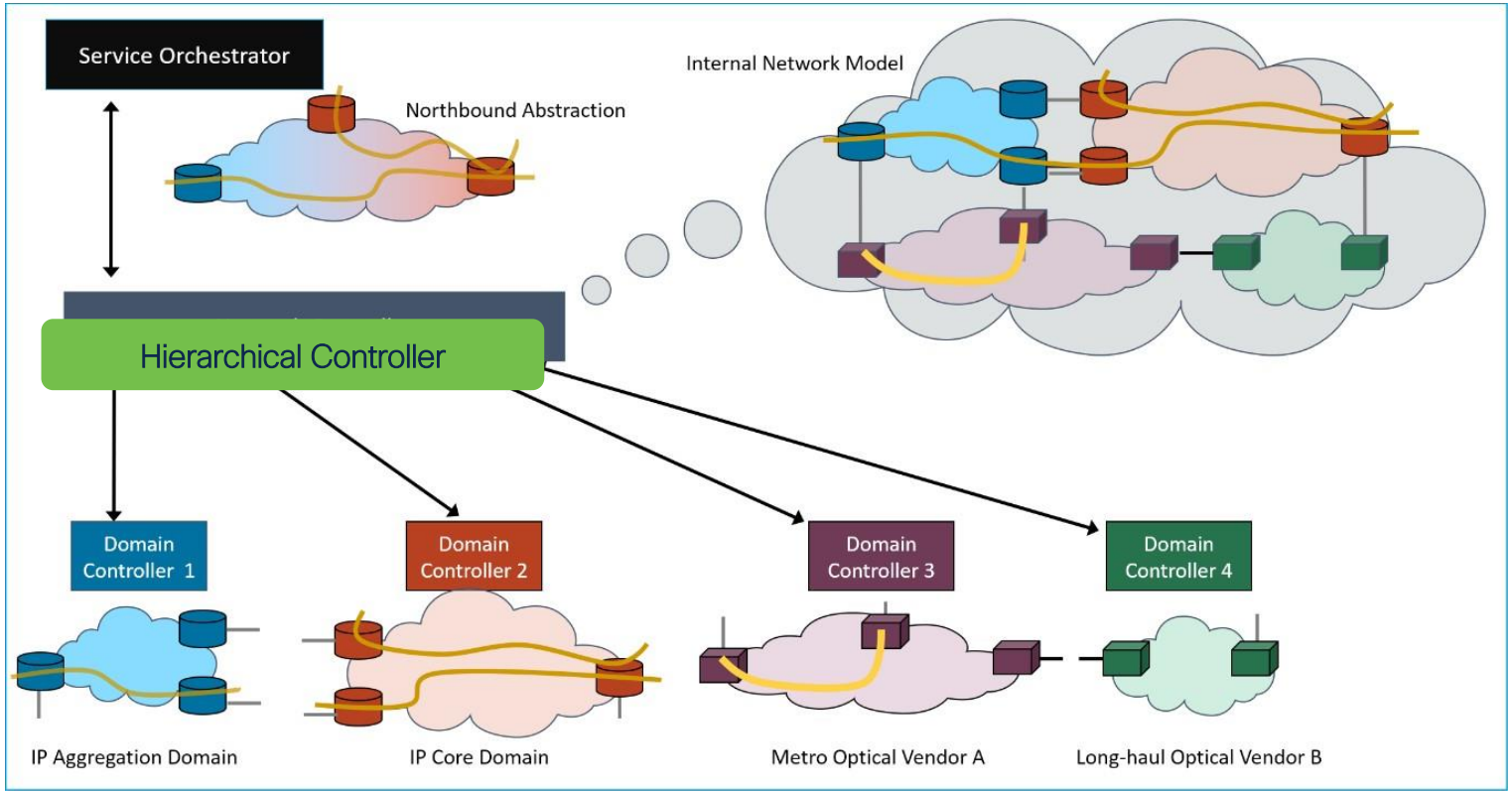
Popular open source controllers

- Open Daylight
  - Linux Foundation project initiated in 2013 by commercial networking vendors
  - Java OSGi based framework; applications for data collection, TE, orchestration, provisioning for various technologies
  - Base for various open source and commercial vendor controllers

- ONOS (Open Network Operating System)
  - Work initiated by ON.Lab in 2012, now driven by ONF (Open Networking Foundation)
  - Java OSGi based distributed framework using network and data abstractions to facilitate network application development
  - uONOS is the newer microservices based ONOS
  - Wide range of use cases: BNG, WAN, BGP EPE

SDN Controller Data Collection

What data is kept/exposed by each controller?



Network Data – Packet

- Realtime topology data is needed to make accurate traffic routing decisions
- Network to IP domain controller
  - BGP-Link State (BGP-LS) is de facto standard today for IGP data
  - PCEP is de facto standard for Traffic Engineering tunnel information (RSVP-TE/Segment Routing)
  - Direct device interrogation using CLI (screen-scraping) or SNMP, pushed from device using telemetry
- Controller to controller
  - RFC 8345 (Base network model) is used today for topology data
    - RFC 8346 covers L3 topology, 8944 L2 topology, 8795 Traffic Engineering
    - Drafts for Segment Routing and other attributes
  - Additional IP Traffic Engineering (RSVP-TE LSP, SR Policy) data is conveyed via IETF TEAS models
  - RESTCONF notification subscription over SSE (Server-side events) or Websockets

Network Data – IETF RFC8345 topo example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"lower-bound": 16000,
"upper-bound": 23999
}
],
"msd": 10,
"node-capabilities": {
"transport-planes": [
{
"transport-plane": "ietf-segment-routing-common:segment-routing-transport-mpls"
}
]
}
},
"router-id": [
"100.0.0.27"
],
"cisco-crosswork-isis-topology:isis-node-attributes": [
{
"system-id": "1000.0100.0027",
"level": "level-2"
}
]
}
},
```

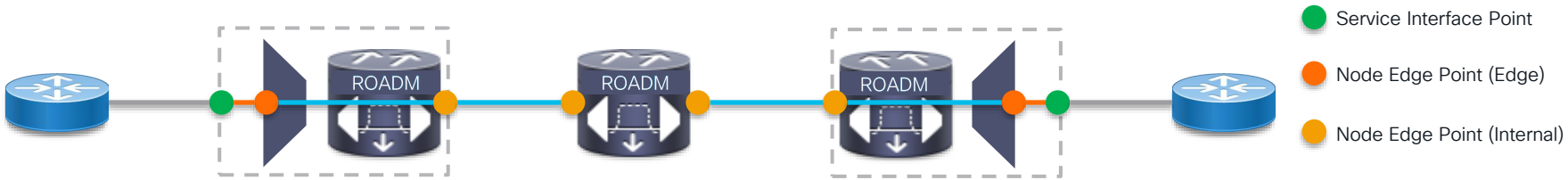
Network Data – Packet metric data

- Performance data
  - Typical network statistics, IE: Interface stats, resource utilization
- Flow data
  - If available Netflow / IPFIX can add additional detail to network level flows
  - Applications steering traffic to/from external destinations relyon flow information to make routing decisions
- Metric data is overlayed onto topology data to optimize routing and forwarding decisions

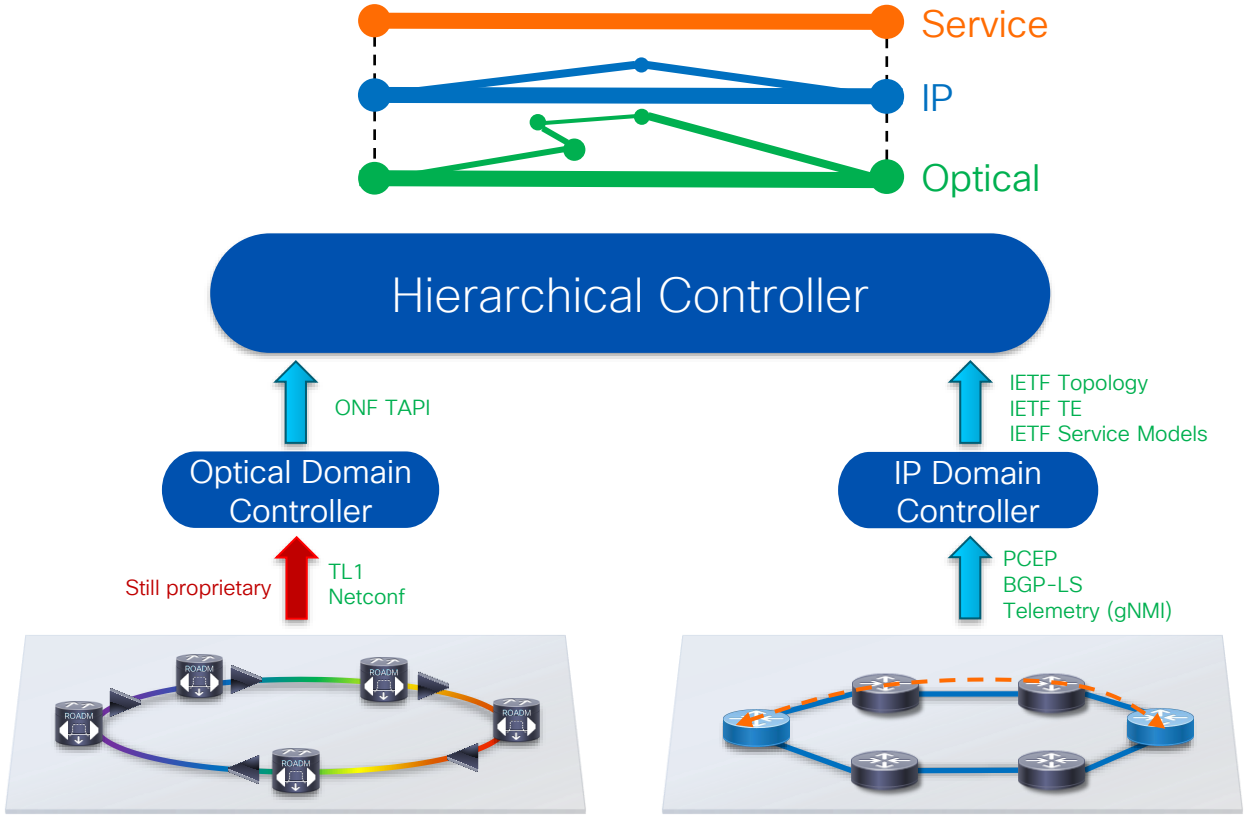
Network Data – Optical

- Controller to network
  - Typically, standard interfaces like TL1, SNMP, or NETCONF are used to the device but encoding and models are proprietary

- Controller to controller
  - T-API is the current de-facto standard
    - topology-context includes full internal optical topology with nodes, network-edge-points (NEP)
    - service-interface-point model contains all client facing interfaces that are a possible termination point for service creation
    - Topologies in TAPI can be recursive



Network Data



Standards gaps

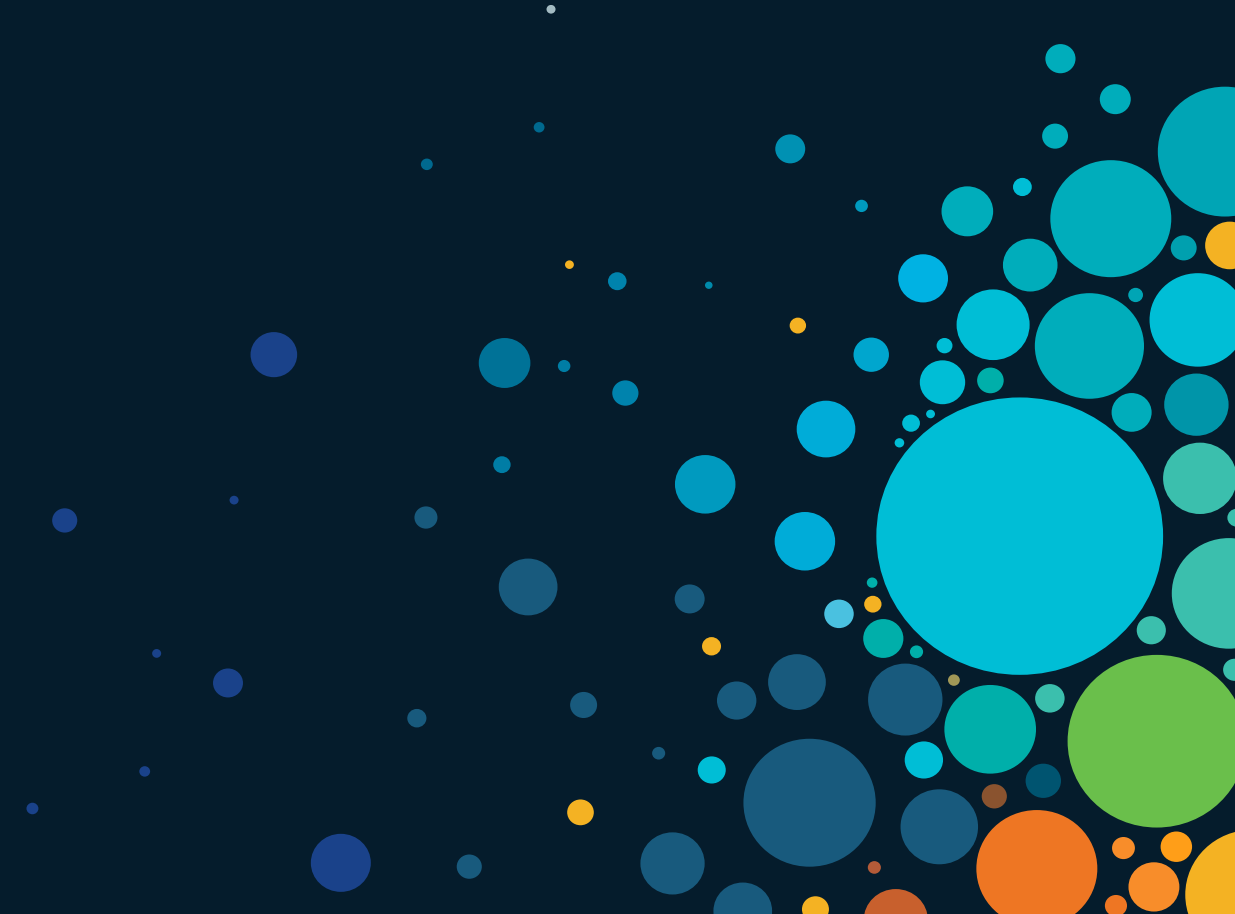
Packet Controller to HCO gaps

- Physical inventory model
  - draft-ietf-ccamp-network-inventory-yang is a recent proposal for a NBI controller model to carry aggregated inventory information for a domain it controls
  - draft-wzwb-opsawg-network-inventory-management is another recent model, augments the network inventory model with hardware inventory information

- Performance metric data

- In the IP world we typically get these direct from a device or proxy device-level data through an intermediate application. Proxy is still an option but not ideal

Network Use Cases



SDN Controllers – Real world view

- Controller can be considered a part of the network, managing network resources like an embedded device control plane
- Operational visibility is a good starting place for deployment
  - Provisioning and more advanced control functions can be added later
- Fully closed loop automation is rare

Use Case – Shared Risk Link Groups

- IP links over optical DWDM circuits often converge on a single fiber, conduit, node
- Traffic engineering and protection on the IP network requires it be seeded with information about shared resources, otherwise a single failure could take down working and protect paths
- Optical restoration requires dynamic updates of SRG information on the IP network
- GMPLS does solve some of this, but was complicated and not interoperable between vendors

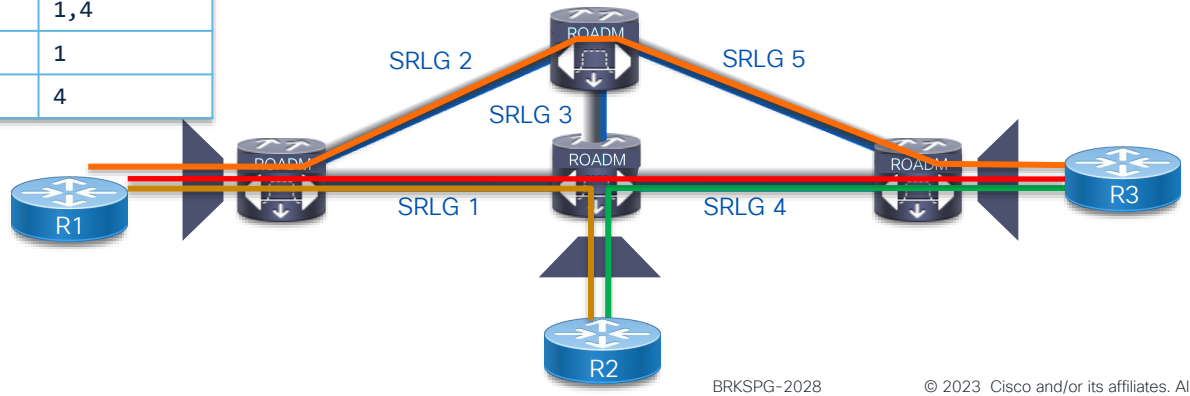
Use Case – Shared Risk Link Groups

- IP layer needs SRLG information for service and protection diversity
- Easier to solve by using intelligent software at hierarchical controller level
- Source of truth for SRLG information is optical network

HCO	
R1 Eth0	Circuit A
R1 Eth1	Circuit B
R1 Eth2	Circuit C

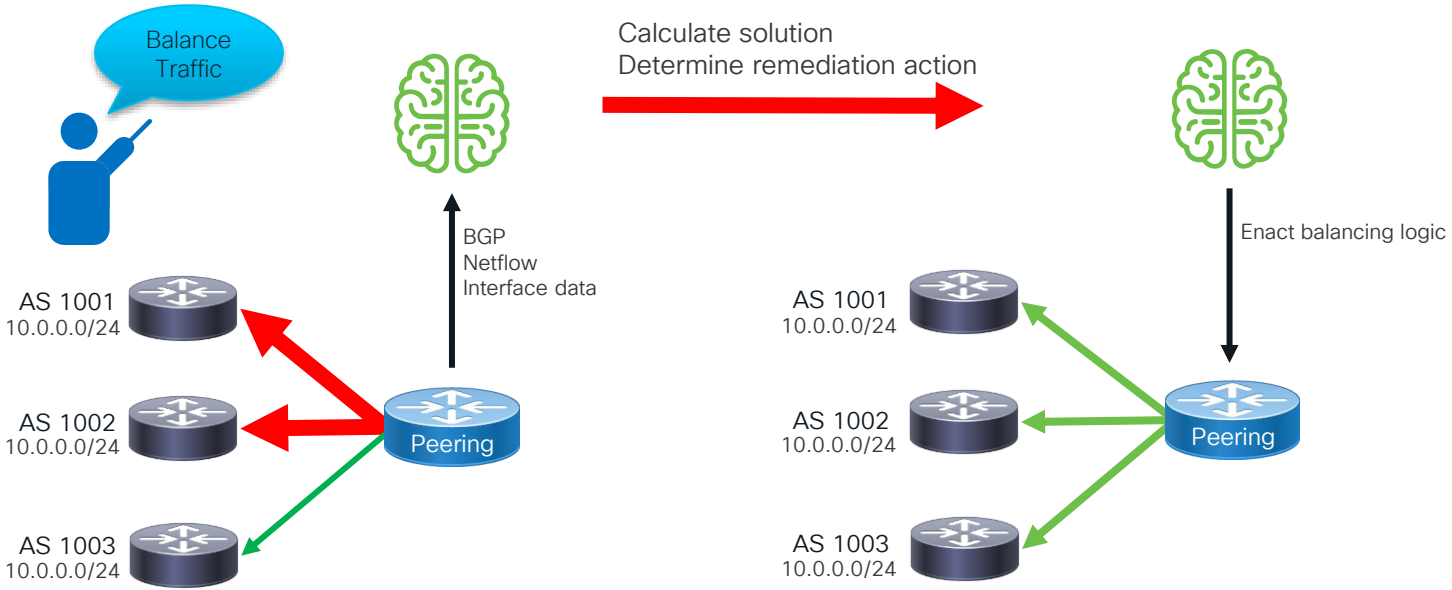
Optical Controller	
Circuit A	1,2,5
Circuit B	1,4
Circuit C	1
Circuit D	4

- HCO has discovered or manually entered Inter-Layer Link
- HCO programs SRLG information on each router, R1 will augment Eth1 protection to use Eth0 and not Eth2
- If underlying circuit path changes, SRLG information is updated dynamically



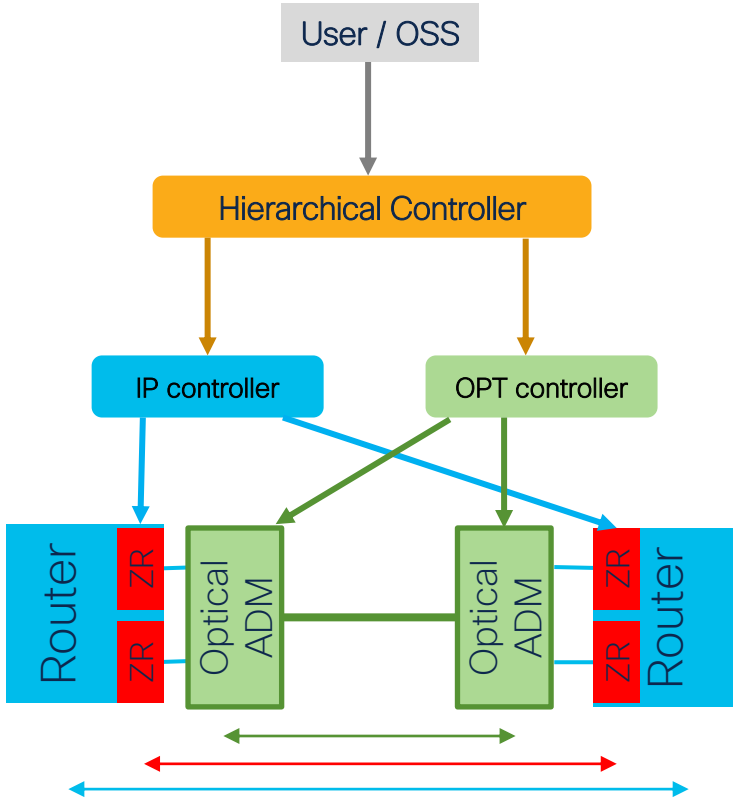
Use Case – Edge traffic balancing

- More of a true “SDN” use case of defining an end goal and using network data and intelligent software
- End state: Balance traffic to 10.0.0.0/24 across all possible peers

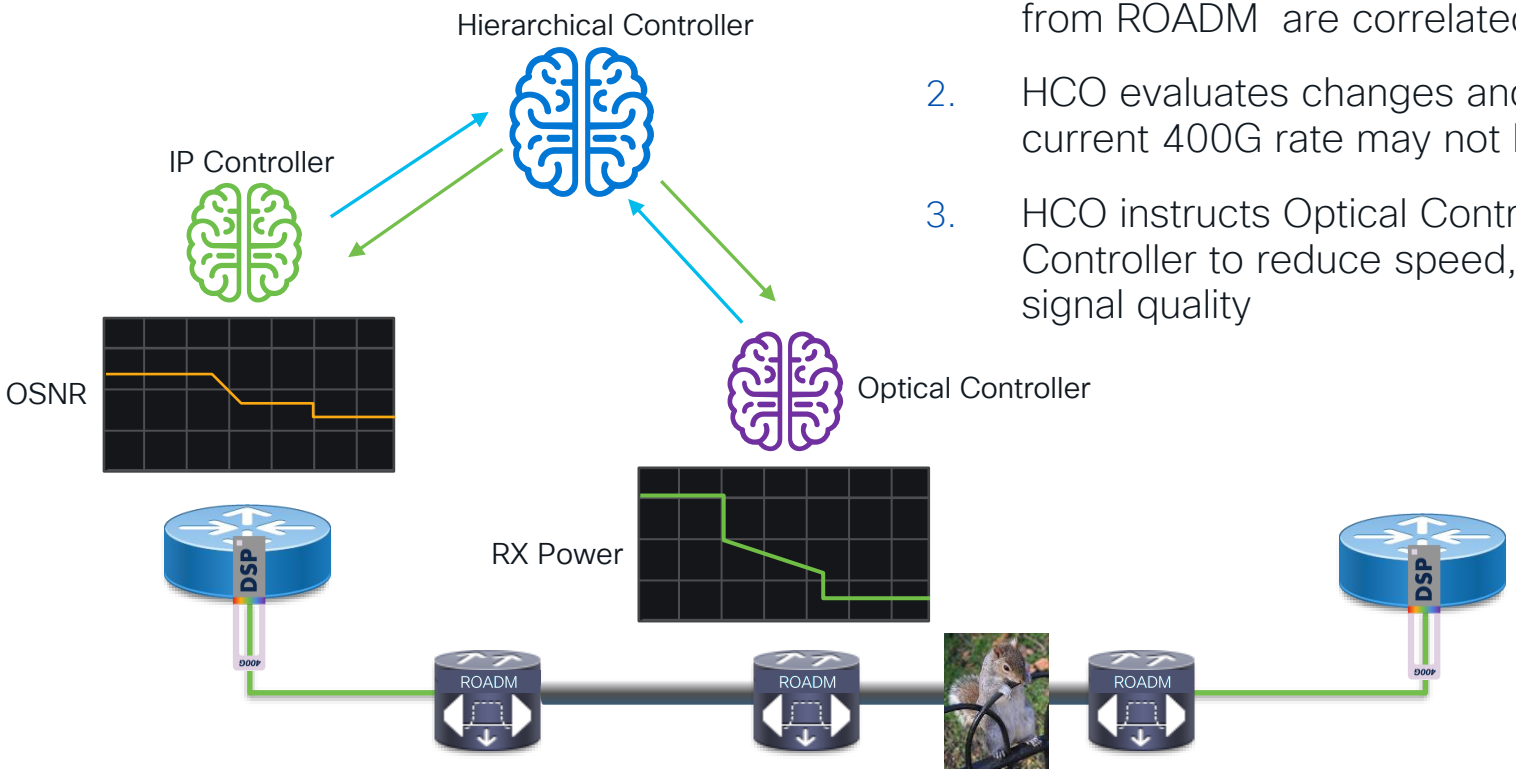


Routed Optical Networking
Link Provisioning

1. Router DCO and their capabilities discovered
2. A user or OSS request creation of a new RON link between 2 ZR ports
3. HCO identifies the ROADM ports at both ends
4. HCO requests the OPT controller to create a lightpath between the 2 ROADM ports using TAPI
5. The OPT controller checks feasibility of the new connection
6. It also determines the best modulation format, wavelength, power etc.
7. HCO read the recommended values from the OPT model via TAPI, sends a request to create a DCO link with computed values
8. The IP controller provisions the ZRs using OpenConfig Terminal Device Models



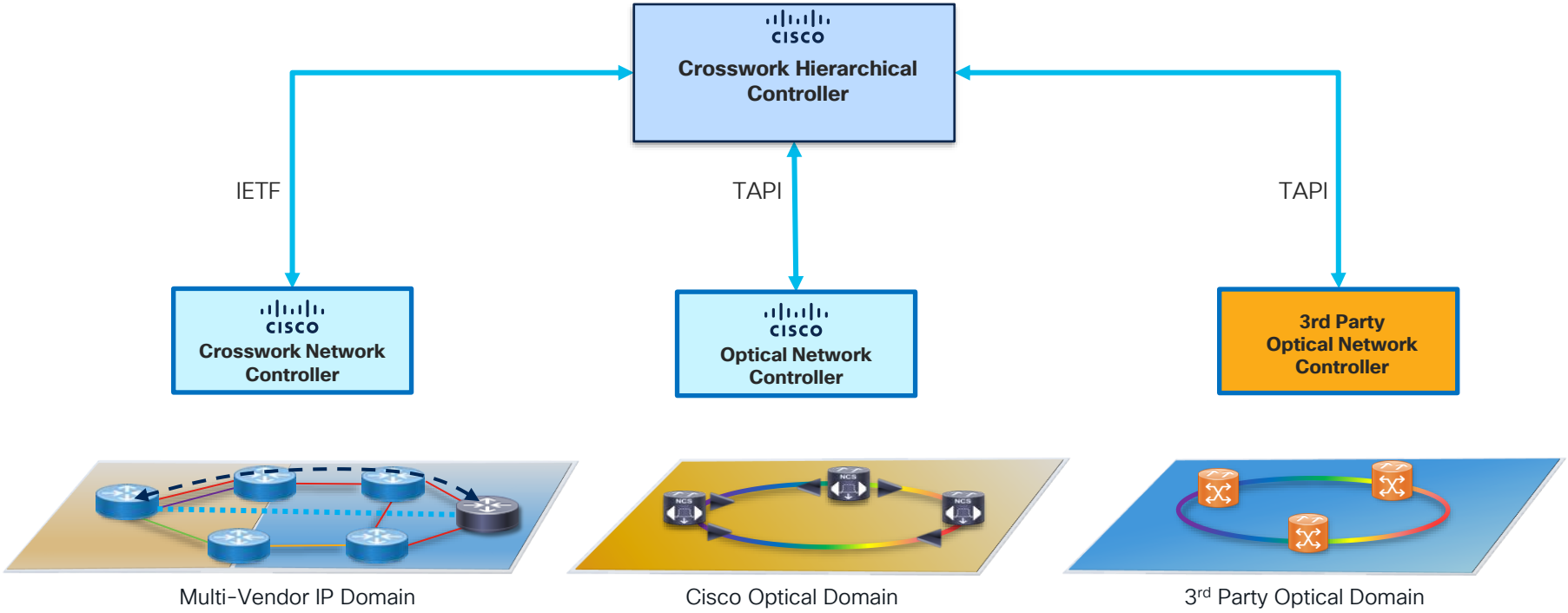
Routed Optical Networking
Dynamic Link Capacity



1. OSNR from router DCO and RX power from ROADM are correlated by HCO
2. HCO evaluates changes and determines current 400G rate may not be sustainable
3. HCO instructs Optical Controller and IP Controller to reduce speed, improving signal quality

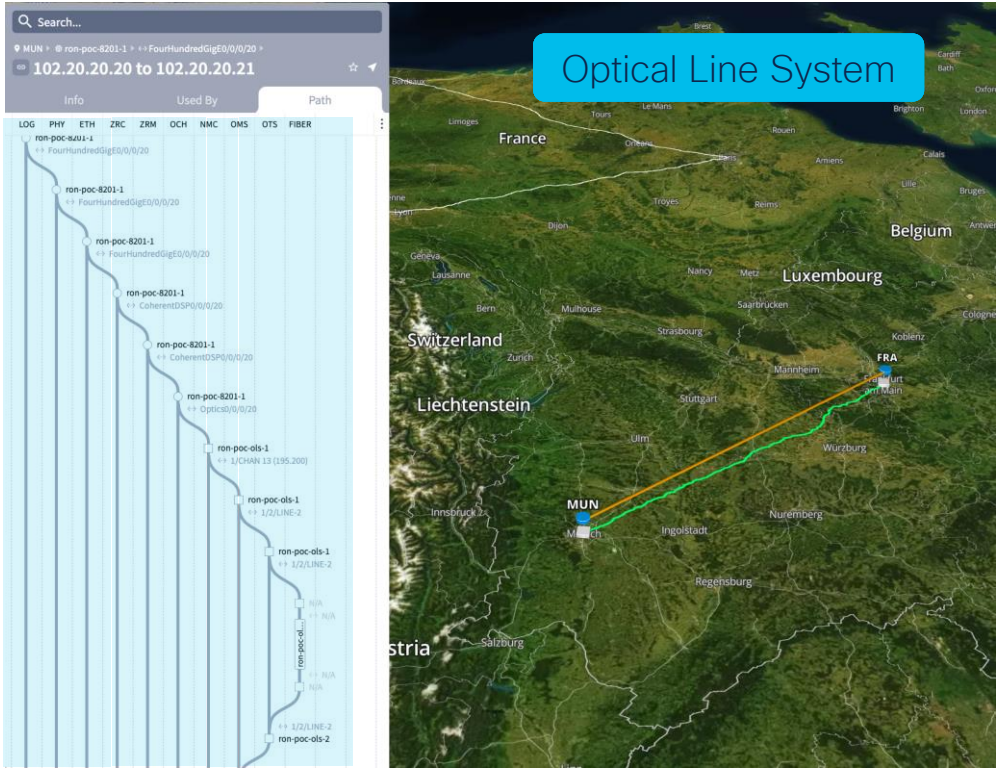
Cisco SP SDN Strategy

Cisco SP SDN Controller Framework
Alignment to Standards – IETF ACTN



Crosswork Hierarchical Controller

- IP & Optical Network Connectivity, Topology, Equipment Inventory
- Multi-Vendor Service to Fiber visibility
- Dynamically deducting cross-domain connectivity
- Risk Management / Diversity assurance



Crosswork Network Controller (CNC)
IP Converged SDN Transport automation

- Service Provisioning (L2VPN, L3VPN)
- Service-Oriented Transport Provisioning (SR-MPLS, RSVP-TE)
- Real-time Network Optimization
- Bandwidth Optimization
- Closed Loop Automation

- Service Topology Visualization
- Service Health Status
- Network State and Device Health Insights
- Local Congestion Mitigation
- Secured Zero Touch Provisioning

Cisco Optical Network Controller (CONC)

Optical Network Connectivity, Topology, Equipment Inventory

Optical Service Management

TAPI Open North Bound Interface

Service Restoration (Future)

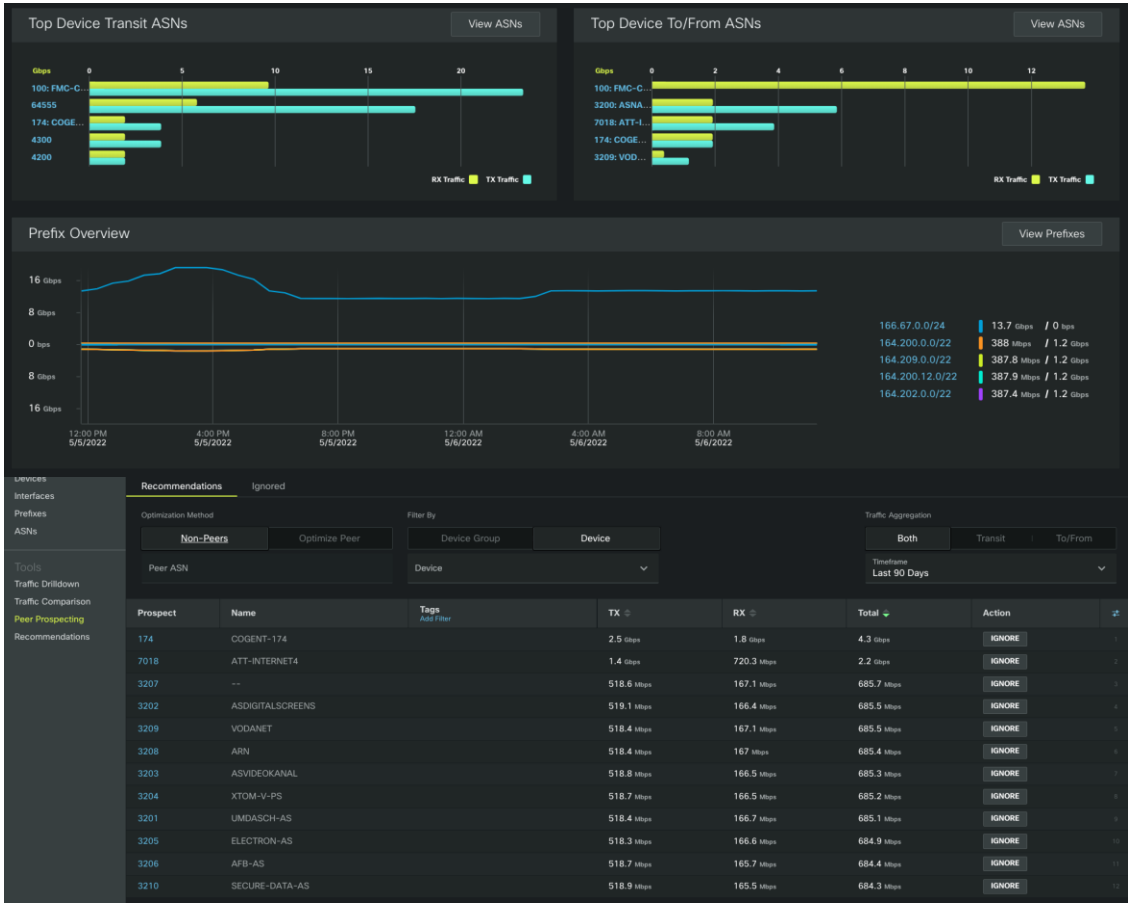
NCS 2000 12.x

NCS 1004

NCS 1010

Crosswork Cloud Traffic Analytics

- SNMP and Netflow data collection
- Recommendation engines for peer prospecting and traffic balancing



Resources

- Visit Routed Optical Network demo in World of Solutions to see Cisco SDN Controllers in action
- Routed Optical Networking Solution Guide
  https://xrdocs.io/design/blogs/latest-routed-optical-networking-hld
- Cisco Crosswork Network Automation
  https://www.cisco.com/c/en/us/products/cloud-systems-management/crosswork-network-automation/index.html

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Session ID	Title	Presenter(s)	Date	Time
BRKSP-2637	Network Automation with Routed Optical Networking (RON) Architecture	Domenico Zini	Tuesday, Feb 7	3:30 PM - 4:30 PM CET
BRKSPG-2263	Design, Deploy and Manage Transport Slices using SDN Controller and Assurance	Sujay Murthy	Tuesday, Feb 7	5:00 PM - 6:30 PM CET
BRKSPG-2028	**Management of IP+Optical Networks Using an SDN Controller Architecture**	**Phil Bedard**	**Wednesday, Feb 8**	**12:00 PM - 1:30 PM CET**
BRKSPG-2664	Automate 5G datacentre and transport components with NSO Cross-Domain Function Packs.	Shambhu Mishra	Wednesday, Feb 8	1:30 PM - 2:30 PM CET
BRKSPG-2474	Reduce Resolution Time with a Service-Centric Approach to Troubleshooting	Paola Arosio	Wednesday, Feb 8	4:45 PM - 5:45 PM CET
BRKMPL-2131	Deploying VPNs Over Segment Routed Networks Made Easy	Krishnan Thirukonda	Thursday, Feb 9	8:45 AM - 10:15 AM CET
PSOSPG-2011	Accelerating the Benefit of Router Optical Networking with Crosswork Automation	Domenico Zini	Thursday, Feb 9	12:30 PM - 1:00 PM CET
BRKSP-2250	Eliminate Congestion Surprises and Fire Drills Forever with Crosswork Cloud-Traffic Analysis as a Service	Dan Backman	Thursday, Feb 9	3:45 PM - 4:45 PM CET
BRKSPG-2031	Deploying XR Programmability in Production Networks	Mike Korshunov	Friday, Feb 10	11:00 AM - 12:30 PM CET

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