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Amsterdam, The Netherlands

# OpenDaylight

## Current and Future Use Cases

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OpenDaylight Technical Steering Committee (TSC) Chair

Principal Architect / System Manager, Ericsson



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# Agenda

- OpenDaylight Overview and Architecture
- OpenDaylight Use Cases (Partial List)
  - I. Network Abstraction
  - II. ONAP
  - III. Network Virtualization
  - IV. AI/ML with OpenDaylight
  - V. ODL in OSS
- OpenDaylight: Getting Involved
- Acknowledgements
- Q & A



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# OpenDaylight Overview and Architecture



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## Past Two Days ...

- Dinner Discussion with Phil Robb, VP of Operations, Networking & orchestration, Linux Foundation
  - Topic: our first OpenDaylight Meetings
    - November 2012



Nostalgic post by Dave Meyer, first ODL TSC chair on Facebook about first release Hydrogen in Jan 2014

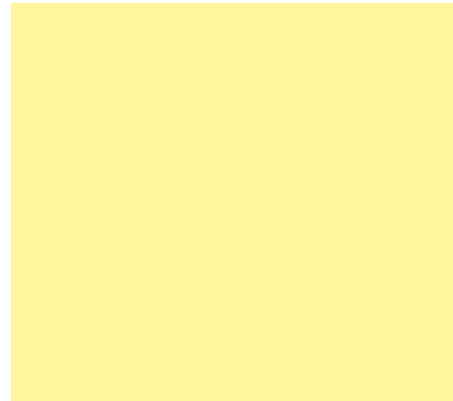


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## Realization: We're a bit old ...

- As far as open source communities go – 6 years is like 60 dog years!!!
  - But that's great!!
    - We've got old timers
- AND
- We've always been adding new developers

# OpenDaylight Project Goals



- **Code:** To create a robust, extensible, open source code base that covers the major common components required to build an SDN solution and create a solid foundation for Network Functions Virtualization (NFV)
- **Acceptance:** To get broad industry acceptance amongst vendors and users
- **Community:** To have a thriving and growing technical community contributing to the code base, using the code in commercial products, and adding value above and around.





# OpenDaylight Now

- Mature, Open Governance
- 900 Contributors
- Over 100 deployments
- Multiple use cases
- Dozens of ODL-based solutions
- Mature code base – continued robust contributions even after 5+ years
- Focus on performance, scale and extensibility

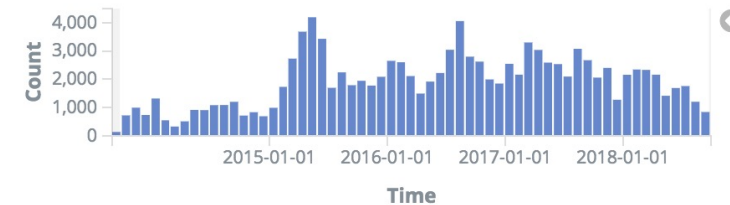
Git

**116,431**  
# Commits

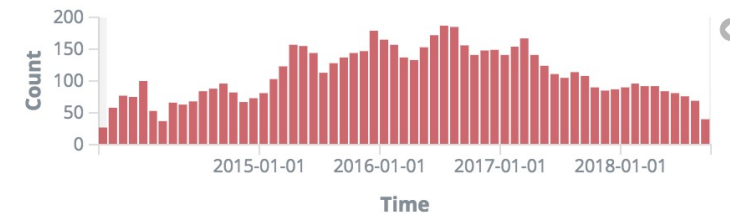
**900**  
# Authors

**86**  
# Repositories

Git Commits



Git Authors





# Service Abstraction Layer

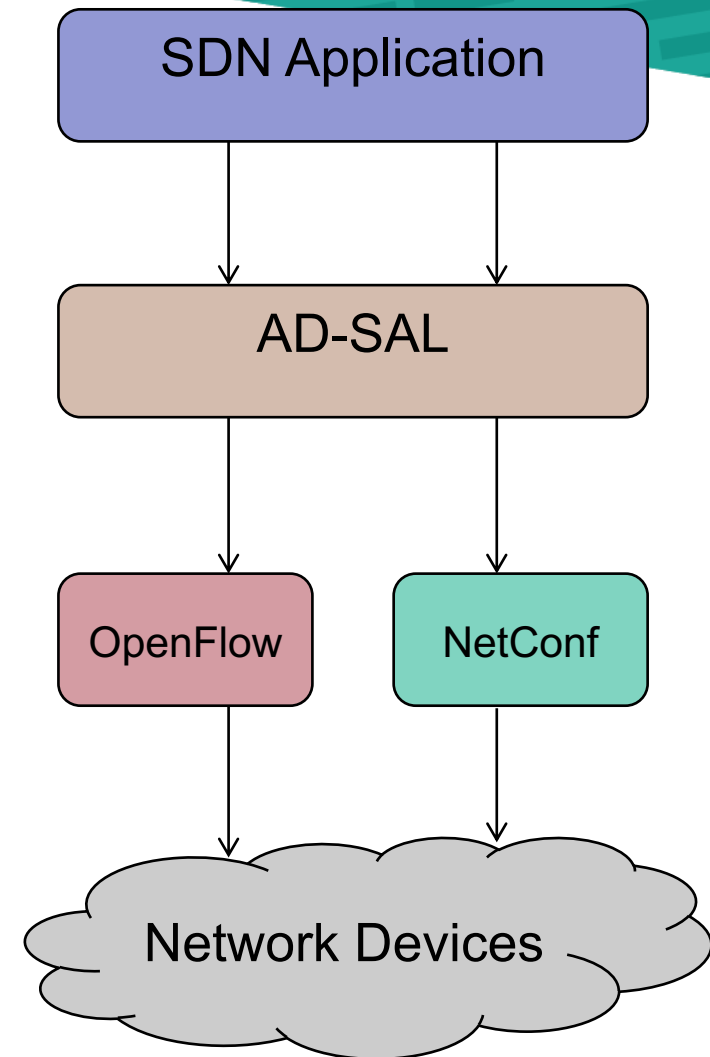
- Initial SDN controllers
  - Controller application APIs strongly tied to OpenFlow
  - Hence applications developed limited to a single southbound protocol
- OpenDaylight Goal
  - Decouple the application API from the southbound protocol plugins - be that Openflow, NETCONF, OVSDB, PCEP, BGP, SNMP, or whatever.
- How to achieve the goal?
  - Use an abstraction layer – or what is called by OpenDaylight as Service Abstraction Layer or SAL





## API Driven SAL (AD-SAL)

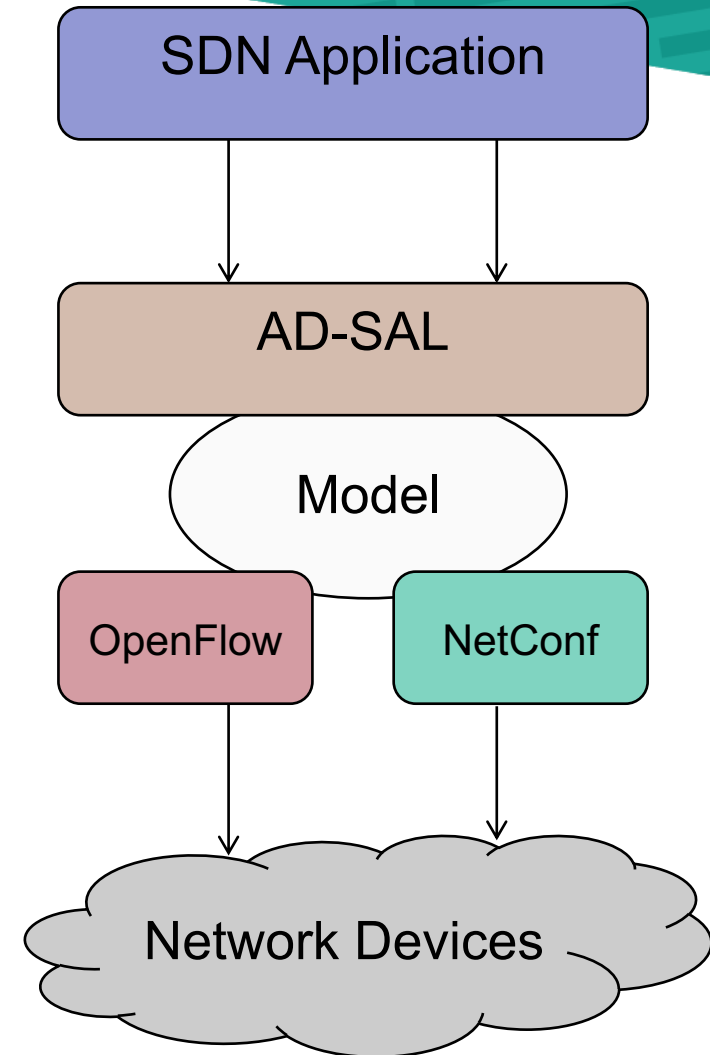
- Initial attempt at abstraction
  - API-Driven SAL, for communicating more directly with devices, using protocol(s) associated with the specific API.
- However abstraction difficult to realize in practice than it was in theory
  - AD-SAL became a collection of independent and discrete APIs, with one set of APIs for each and every southbound protocol
- AD-SAL was soon deprecated in OpenDaylight.





## So how to achieve true abstraction?

- Alternatives
  - Build a better SAL
    - Take the existing APIs for the different plugins, and attempt to come up with an API abstraction that meets all of their needs
  - Use models
    - Implement a model layer within the SAL which has SDN applications dealing with software models of network devices, rather than directly with the devices themselves.
    - This was the approach taken by OpenDaylight – to develop a **Model Driven SAL** or the **MD-SAL** built around **Yang models**





# YANG

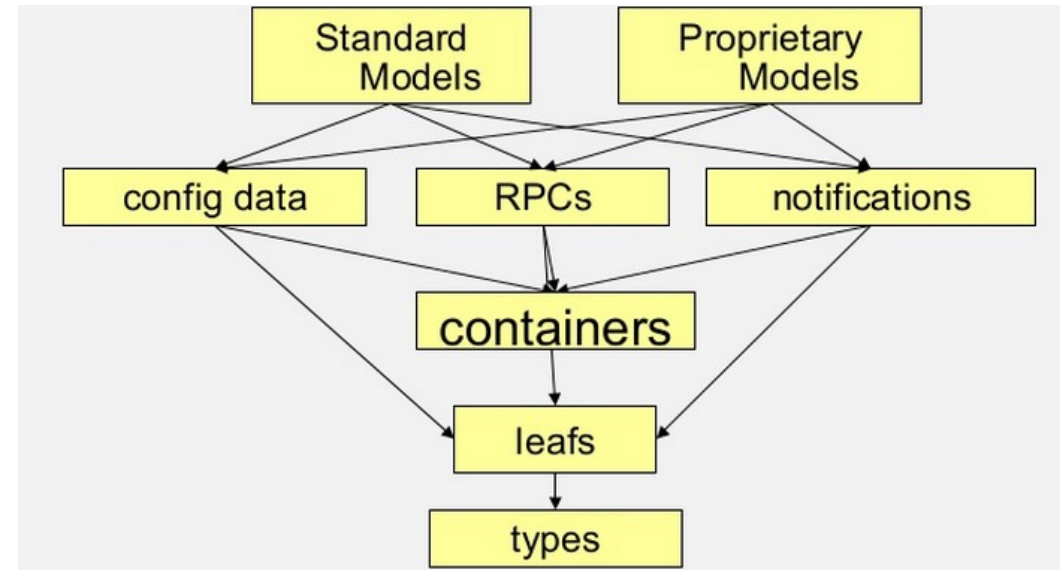
- Data modeling language that is also the preferred configuration language for NETCONF protocol
- Further reads:
  - [YANG introductory tutorial](#)
  - [RFC 6020 - YANG - A data modeling language for NETCONF](#)
  - [RFC 7950 – The YANG 1.1 Data Modeling Language](#)

```
module model1 {  
  
    namespace "urn:model1";  
    prefix model1;  
    yang-version 1;  
  
    revision 2015-04-06 {  
        description "Initial revision";  
    }  
  
    grouping A {  
        list B {  
            key id;  
            leaf id {  
                type uint32;  
            }  
            leaf D {  
                type uint32;  
            }  
        }  
    }  
  
    container C {  
        uses A;  
    }  
}
```

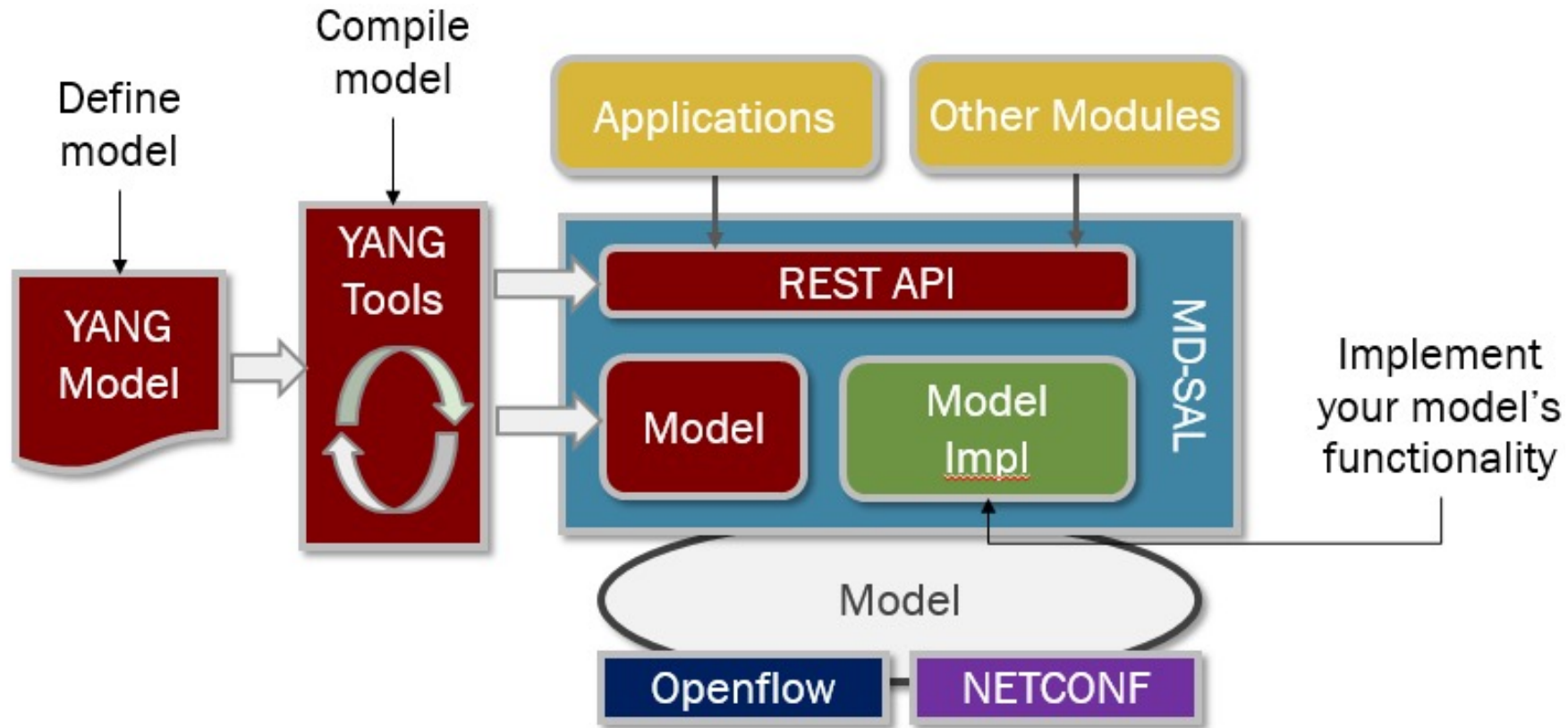


# What can YANG model?

- Data
- RPCs:
  - Perform procedure call with input/output, without worrying about actual provider for that procedure
- Notifications:
  - Publish one or more notifications to registered listeners



# MD-SAL Application Creation Process



- › Applications built defining models
- › YANG used for defining models
- › Compilation results in the skeleton of application: model, RESTCONF API, etc.

- › Elements in red color above is the app skeleton
- › The model implementation (green) is where you will write code to do whatever it is that your application or the model within your application does



# Yangtools – What does Yangtools do?

- Generates Java code from Yang
- Provides ‘Codecs’ to convert
  - Generated Java classes to Document Object Model (DOM)
  - DOM to various formats
    - XML
    - JSON
    - Etc
- ‘Codecs’ make possible automatic:
  - RESTCONF
  - Netconf
  - Other bindings



Java  
code

xml

json

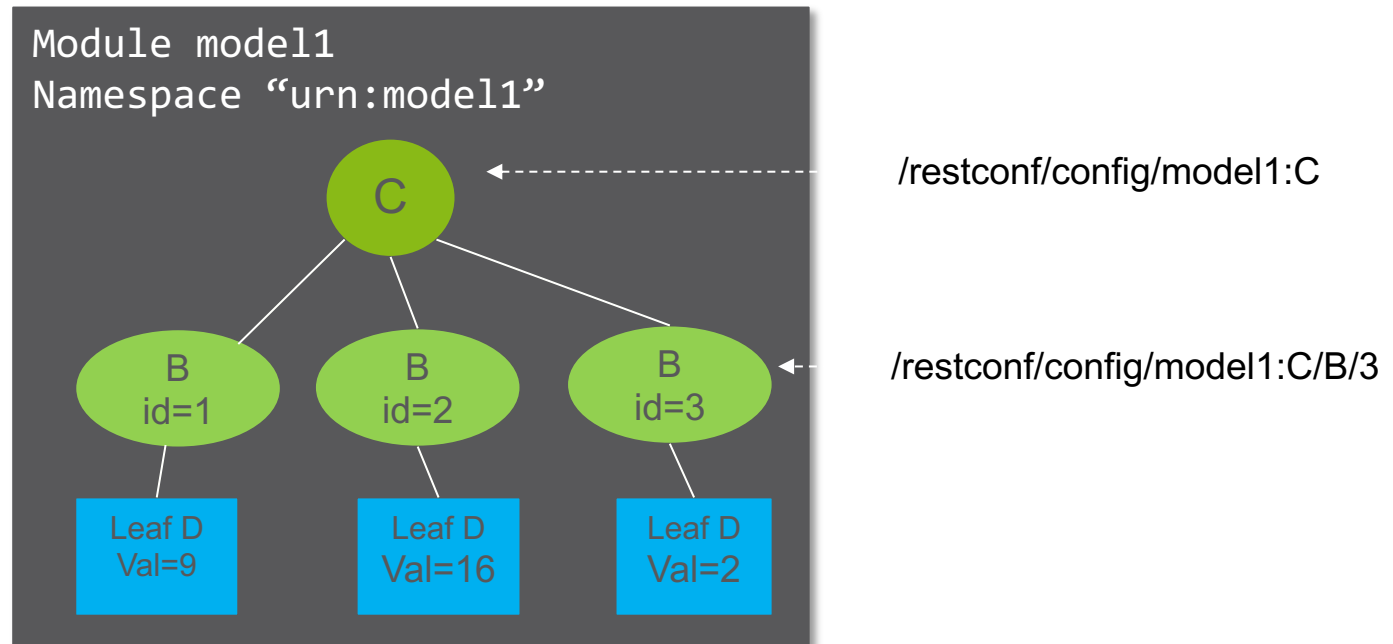


# Yang to Java benefits

- Consistent Data Transfer Objects (DTOs) everywhere
  - **Automated Bindings:**
    - restconf
    - netconf
  - **Consistent:** reduce learning curve
  - **Immutable:** to avoid thread contention
  - **Improvable** – generation can be improved and all DTOs get those improvements immediately system wide

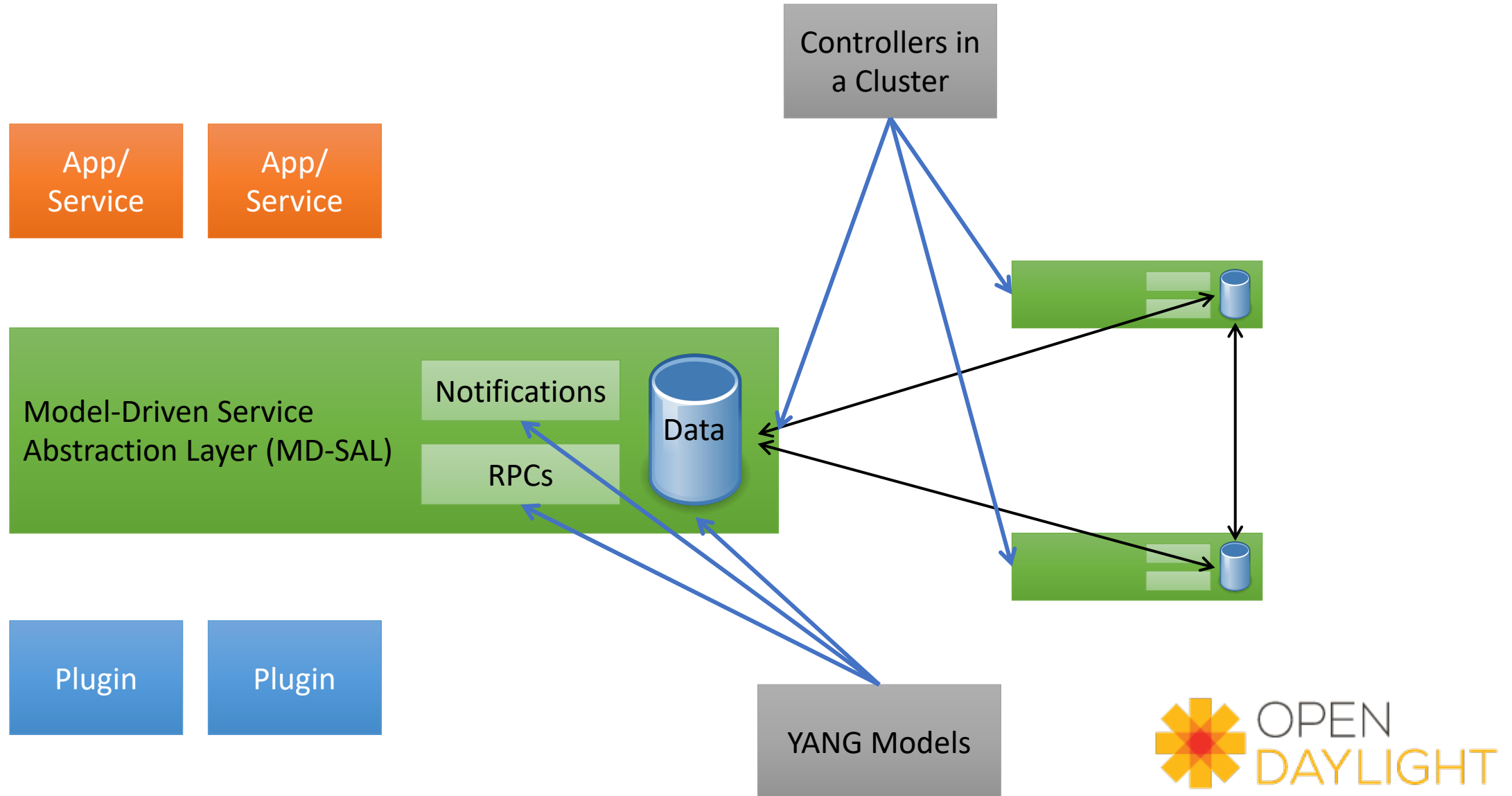
# MD-SAL

- › Model-driven SAL is the kernel of the OpenDaylight controller
- › It manages the contracts and state exchanges between every application. It does this adaptation by managing centralized state
- › Takes in the YANG model at runtime and constructs the tree in the data store

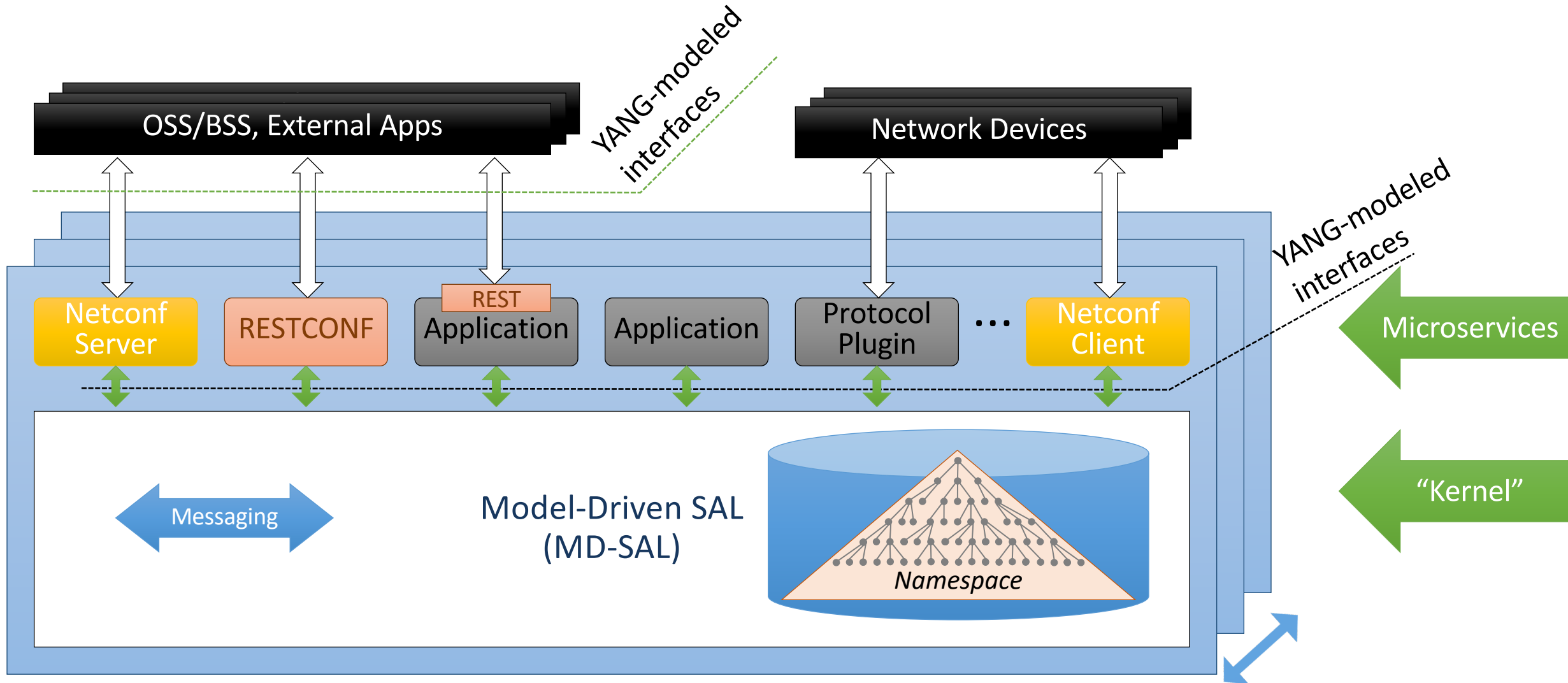




# OpenDaylight Architecture - Simplified View



# An Aspect of the architecture: ODL is a $\mu$ -services platform



Third Party Applications (Orchestration, Control Plane, UI, etc.)

OpenDaylight APIs

Platform Services

Network Services And Applications

Application (Processing)

Model

API

Data Store (Config & Operational)

OpenDaylight Platform

Messaging (Notifications / RPCs)

API

Protocol Plugin

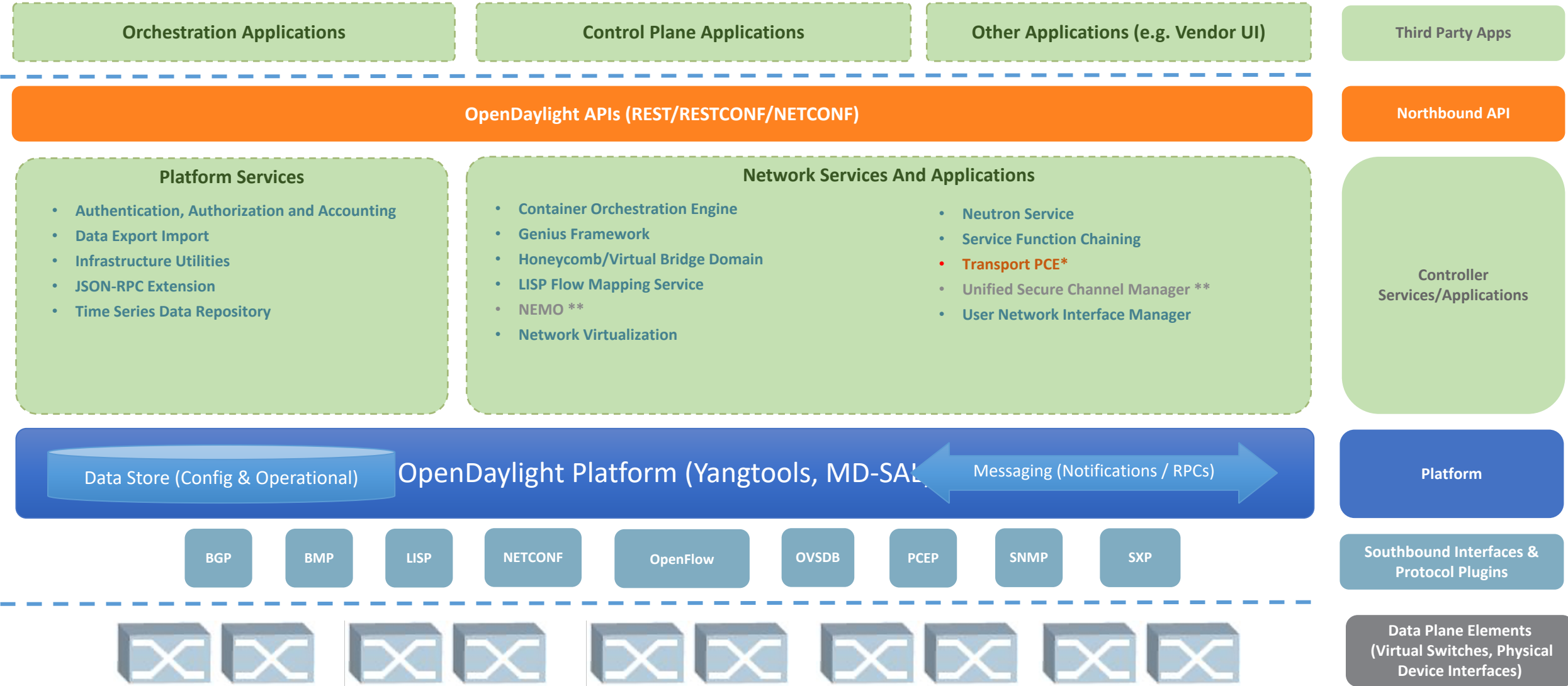
Model

Interfaces & Protocol Plugins

Data Plane Elements (Virtual Switches, Physical Devices)



# OpenDaylight Fluorine Release



\* First release for the project

\*\* Not included in Fluorine distribution - separate download



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# OpenDaylight Architecture: Key Takeaway

- OpenDaylight architecture is amenable to be applied to a variety of use cases as:
  - Not tied to a particular protocol
  - Modular, Extensible
  - Has built-in tools to simplify application development



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# OpenDaylight Use Cases (Partial List)



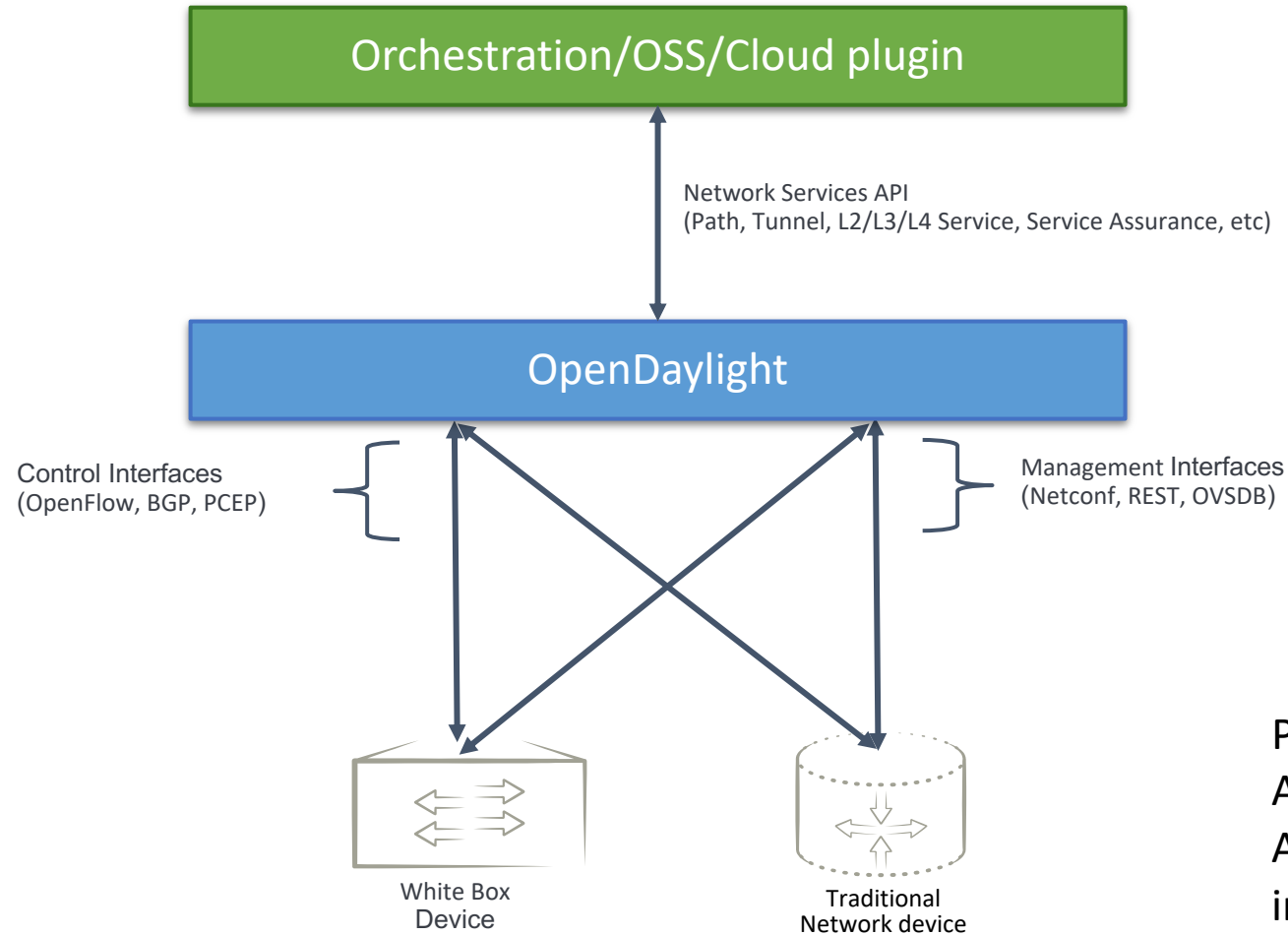
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## Note

- OpenDaylight architecture has been used in many use cases – not all covered here



# Use Case I Network Abstraction

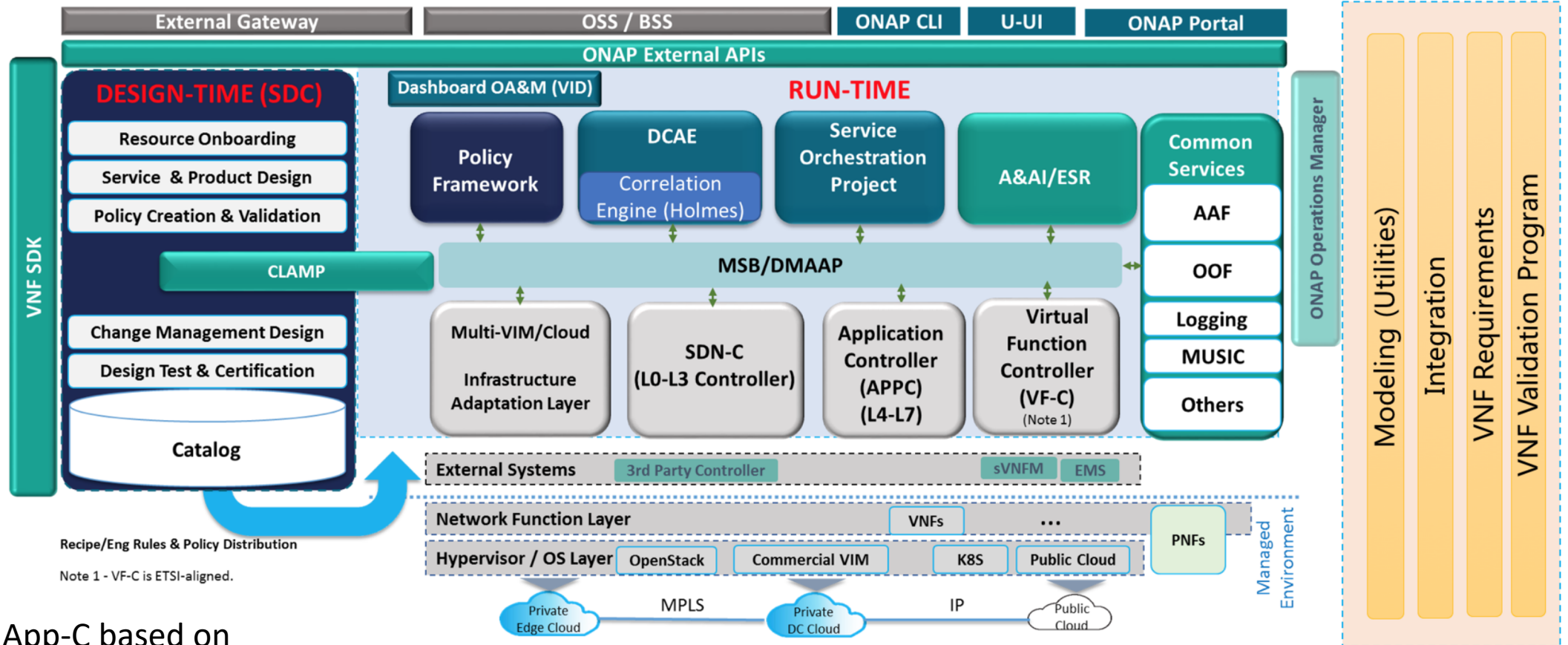


Provides Network Services API for Network Automation in a Multi Vendor Network





# Use Case II ONAP Project



Recipe/Eng Rules & Policy Distribution

Note 1 - VF-C is ETSI-aligned.

SDN-C & App-C based on OpenDaylight code



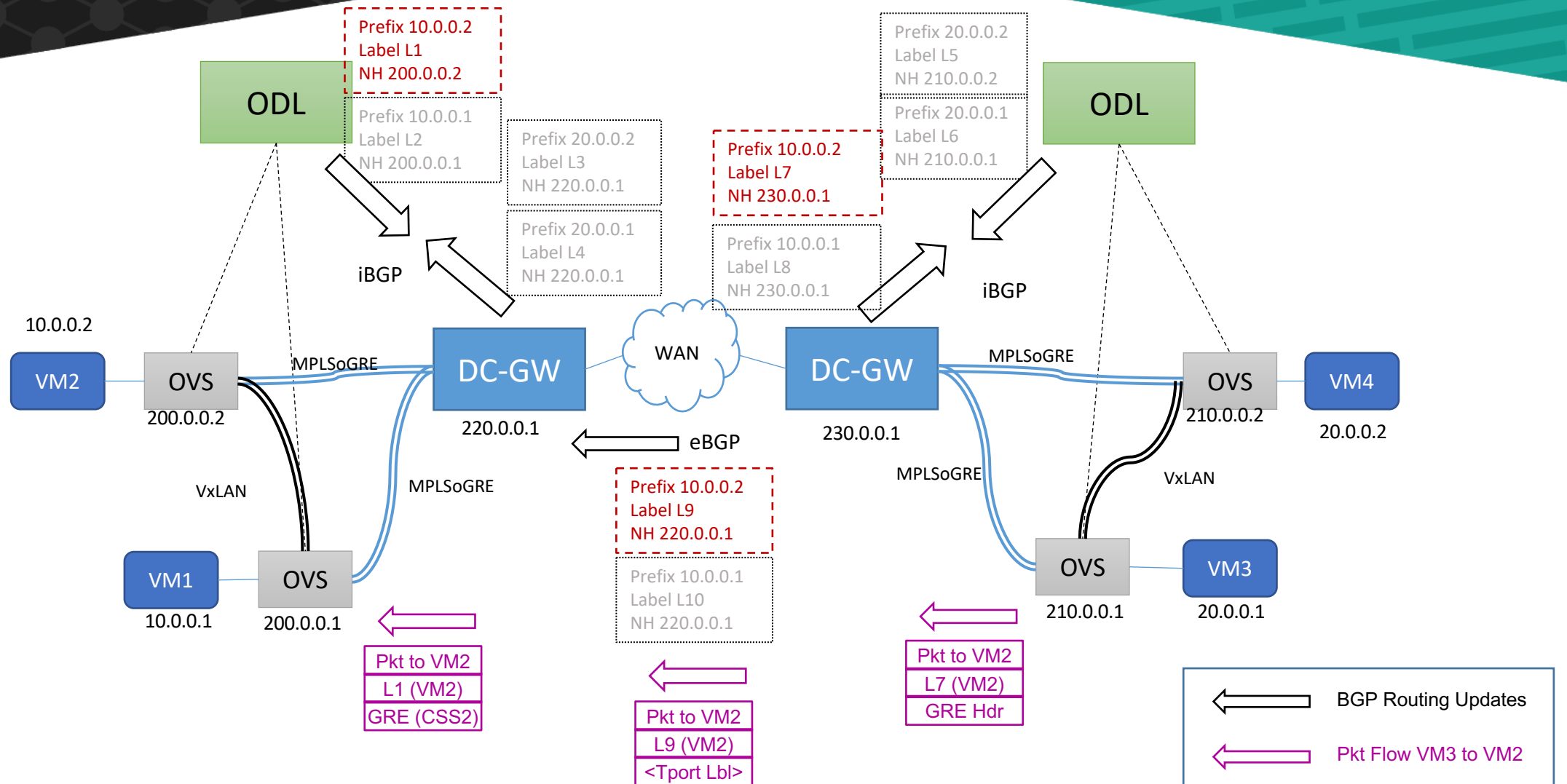
### Use Case III

## Network Virtualization

- A set of projects working in tandem to provide network virtualization (overlay connectivity) inside and between data centers for Cloud SDN use case
  - VxLAN within the data center
  - L3 VPN across data centers
- Integration with OpenStack Neutron and Kubernetes (in-progress)
- Uses Open vSwitch and hardware VTEPs (ToR) as the datapath

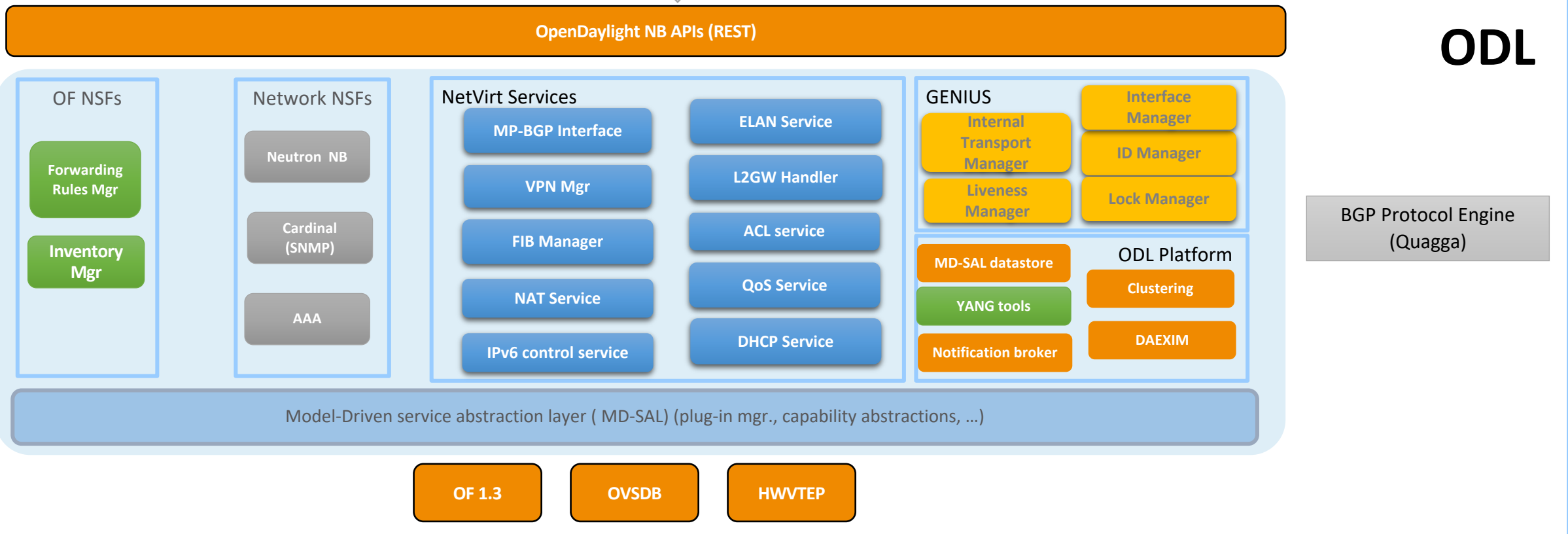
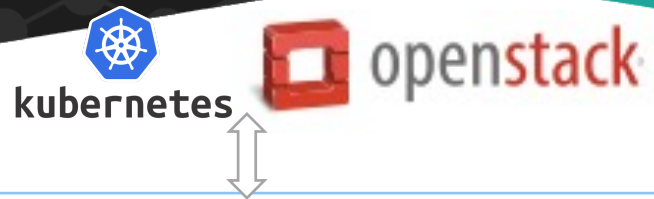


# NetVirt: L3 VPN & VxLAN Architecture Overview





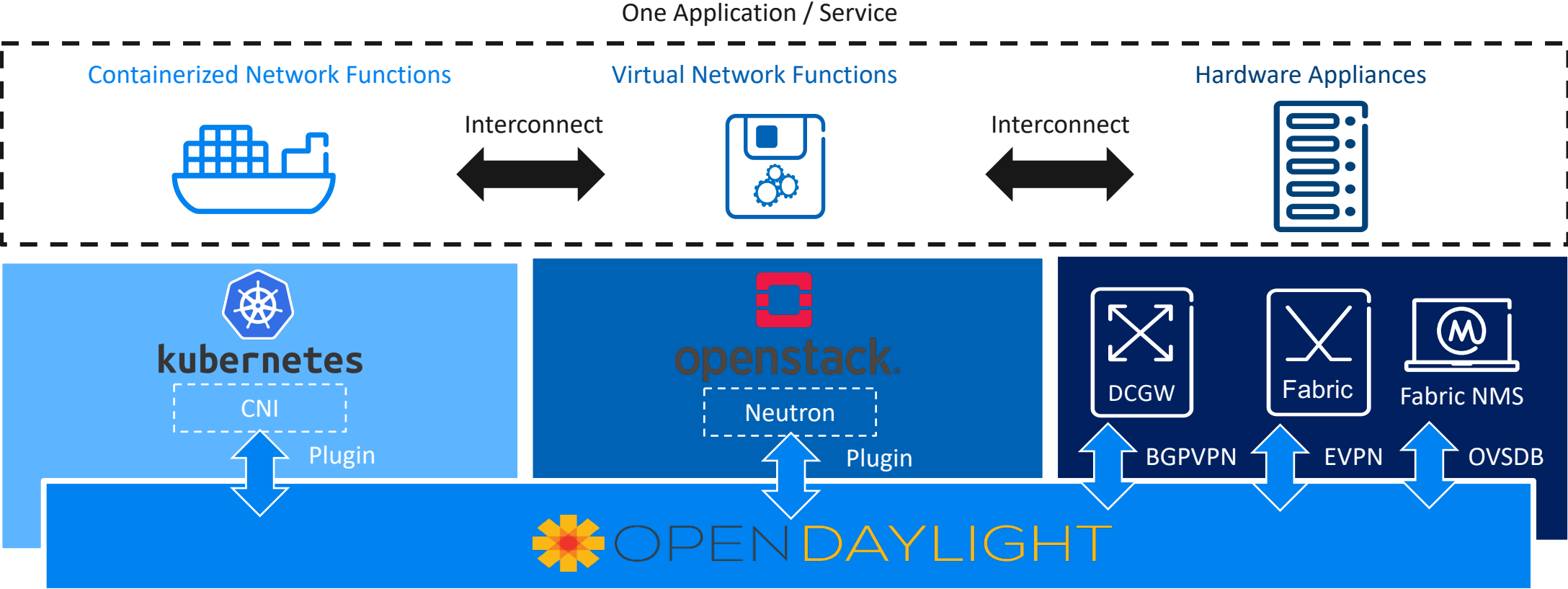
# Network Virtualization: OpenDaylight Components



Legend

- ODL GENIUS** (Yellow box)
- ODL Netvirt** (Blue box)
- ODL Infrastructure** (Orange box)
- Misc Services** (Grey box)
- External module** (Light grey box)

# A common controller platform



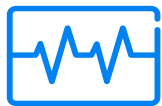
Uniform service capabilities



Simplified interworking



Reduced training And validation

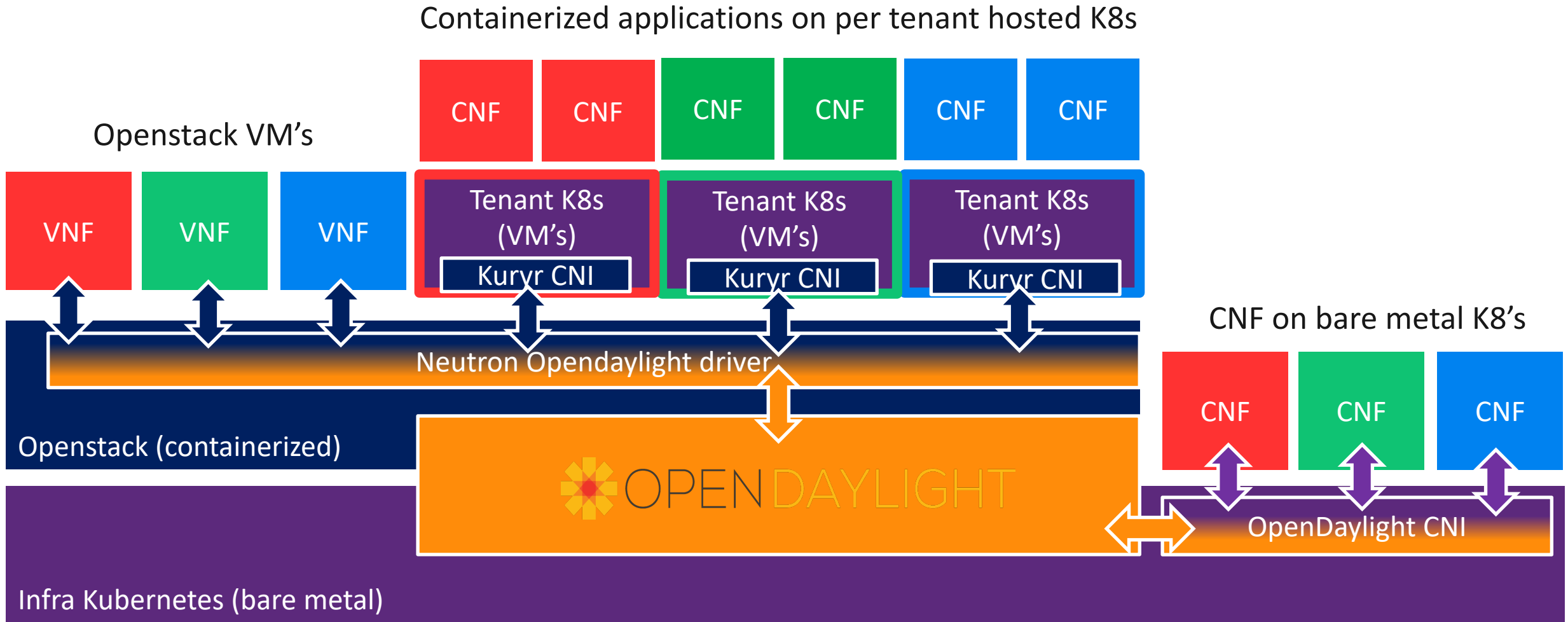


Simplified troubleshooting



Common dashboard

# OpenDaylight multi-instance controller





# OpenDaylight Container Orchestration Engine

- Current Status

- Hybrid scenario:
  - Openstack and Kubernetes side by side
    - Integration with ODL via Openstack Kuryr
    - Supports Multinode environment
    - Supports container in a VM scenario
- Baremetal scenario
  - Kubernetes only
    - Tight integration with ODL NetVirt
    - Supports Pod 2 Pod networking L2/L3

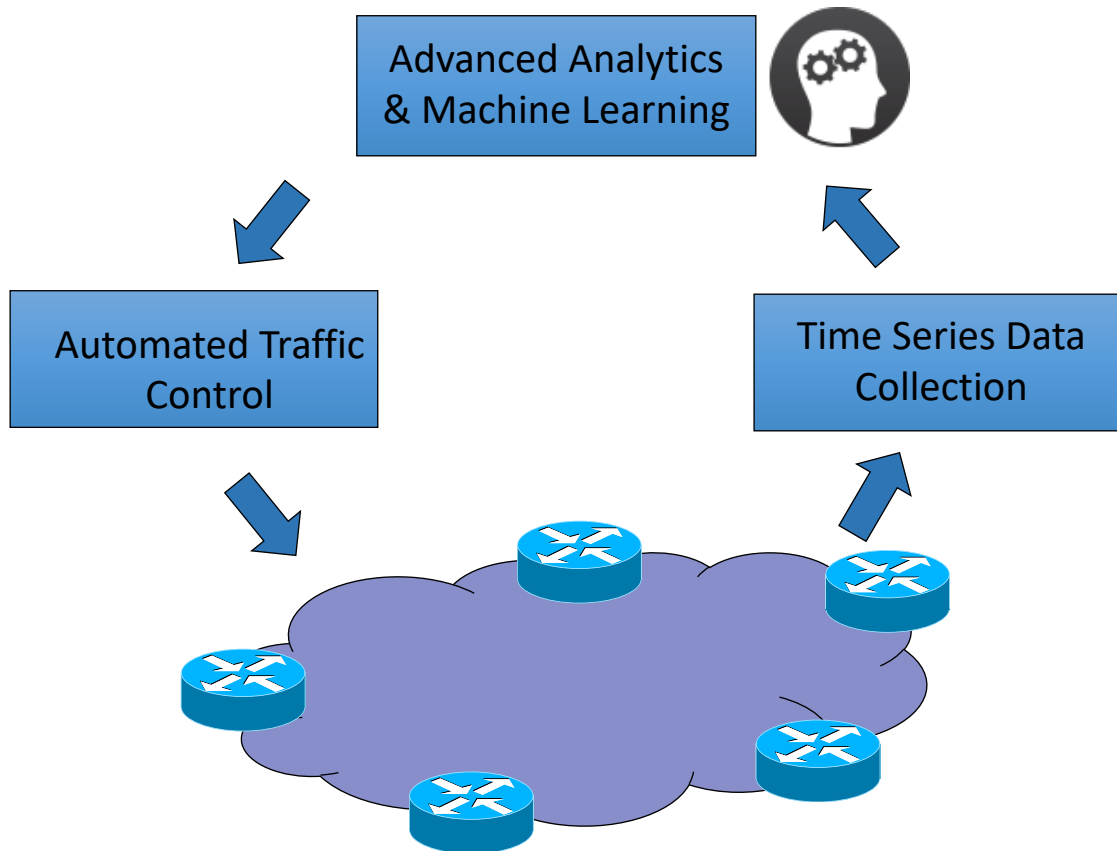
- Future Scenarios

- Support for non-OF southbound
  - NetConf
- Testing with L3VPN for multi-tenant scenarios
- Scale testing & improvement



## Use Case IV (future) AI/ML with OpenDaylight

### Smart SDN Controller



- Network status awareness
  - Rely on time series data collected from the network
- Traffic Control Policy Change decision making
  - Based on the advanced analytics and machine learning.
- Dynamic change of Control policies
  - Automatically change the traffic control policies based on the analytics results.





# Why we need Machine Learning in SDN

- Software Defined Networks needs to be intelligent.
  - To be aware of the runtime status of the network.
  - To make the right decisions that adjust the policies for traffic classification and traffic shaping.
  - To dynamically change the policies according to the analytics results.
    - AI / ML can be used to establish normalized profiles and dynamically update the profiles based on a set of predetermined or dynamically learned rules.

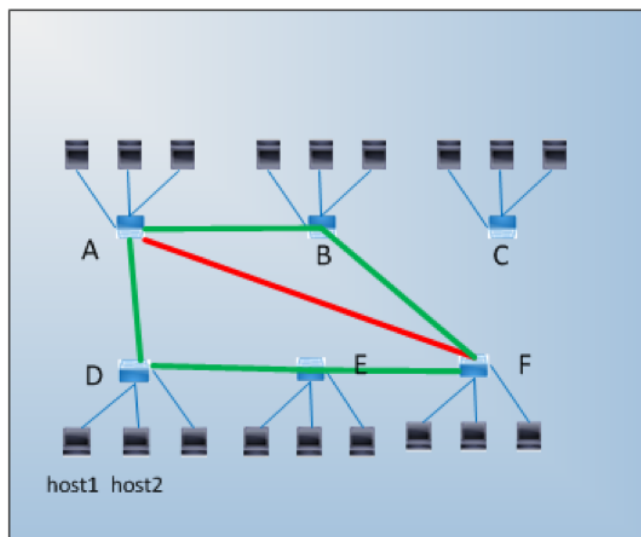


# Use Cases of a smart and intelligent SDN controller

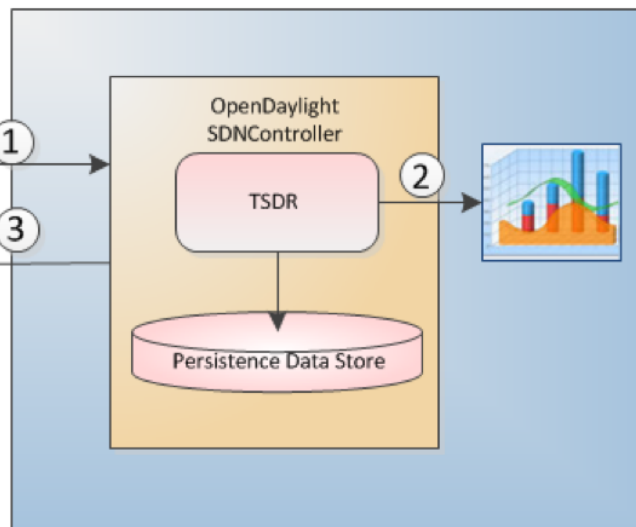
- Traffic Control and Routing Optimization
  - Congestion Control
  - Traffic Pattern Prediction
  - Routing Optimization
- Resource optimization
  - Networking resource allocation optimization
  - Cloud resource management optimization
- Security and Anomaly Detection
  - DDoS attack detection and mitigation
- Troubleshooting and Self-healing



## AI/ML Example Use Case – Traffic congestion prediction with automated control



SDN controlled network



OpenDaylight + TSDR

- ① Collect stats from the network and store into TSDR
- ② Data analysis through data analytics engines integration
- ③ Traffic flow redirection from A->F to A->B->F and A->D->E->F

- Predicted congestion path in the next 24 hours
- Healthy path in the next 24 hours

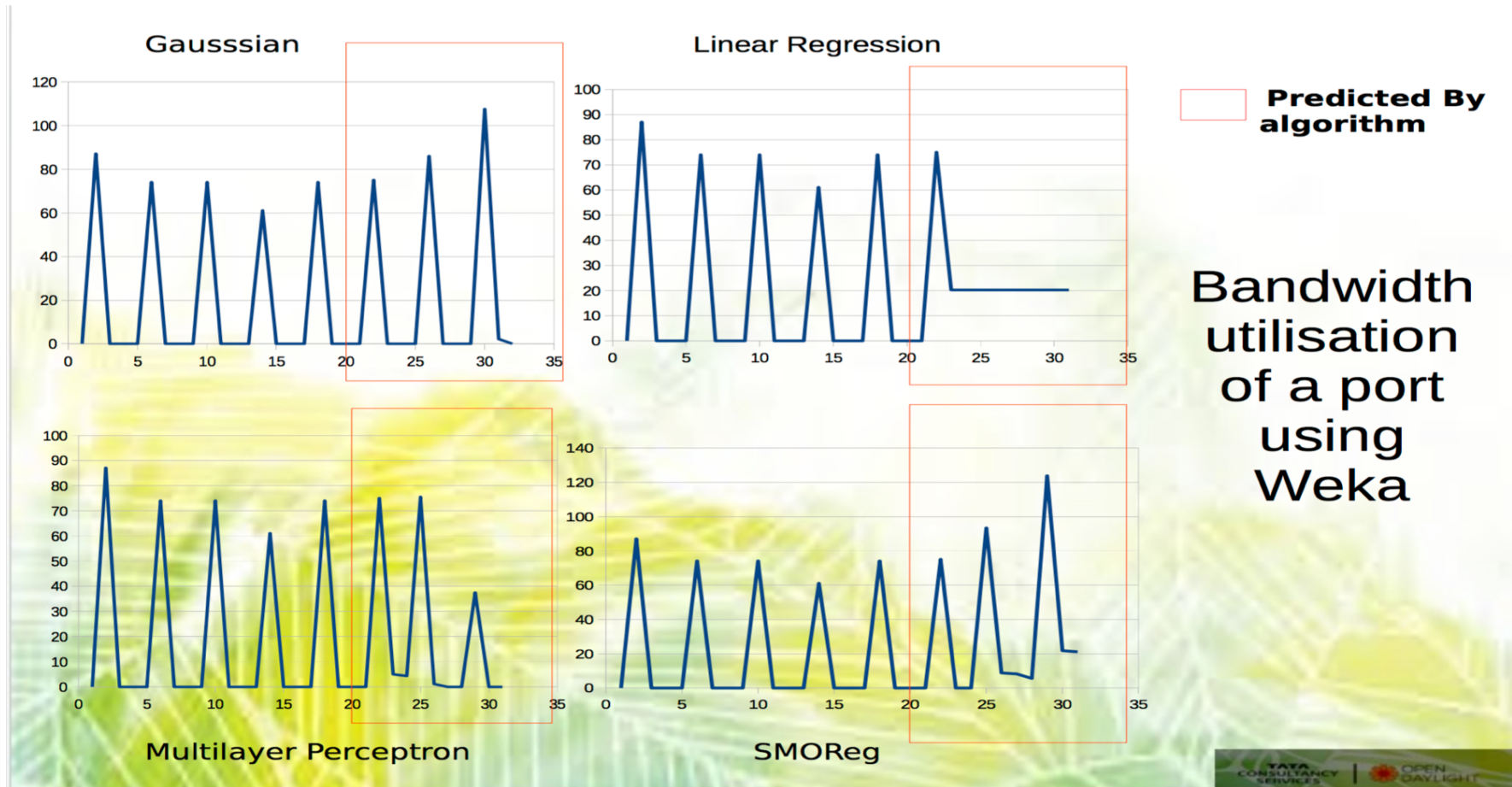


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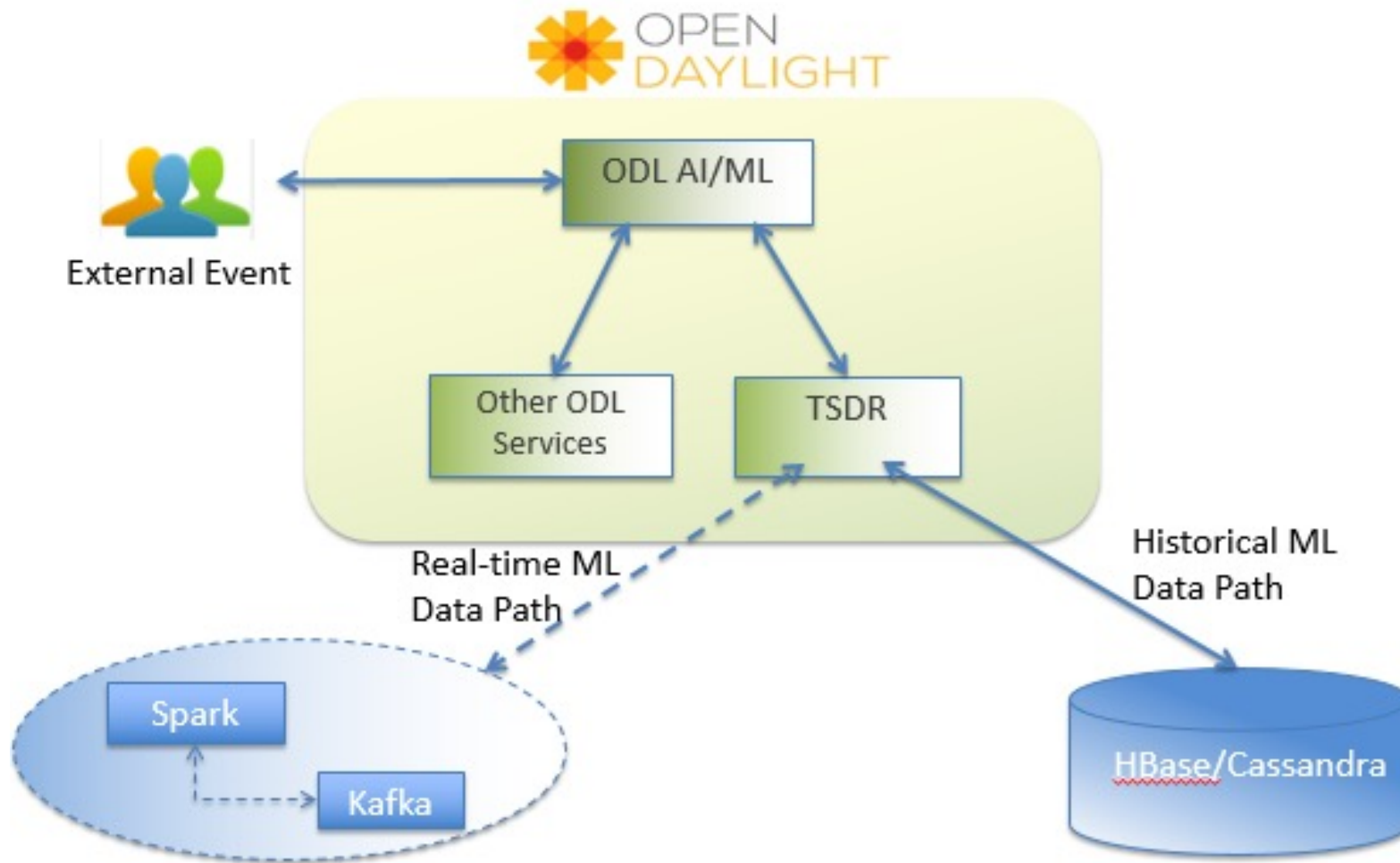
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## Prediction using Weka leveraging data collected in TSDR

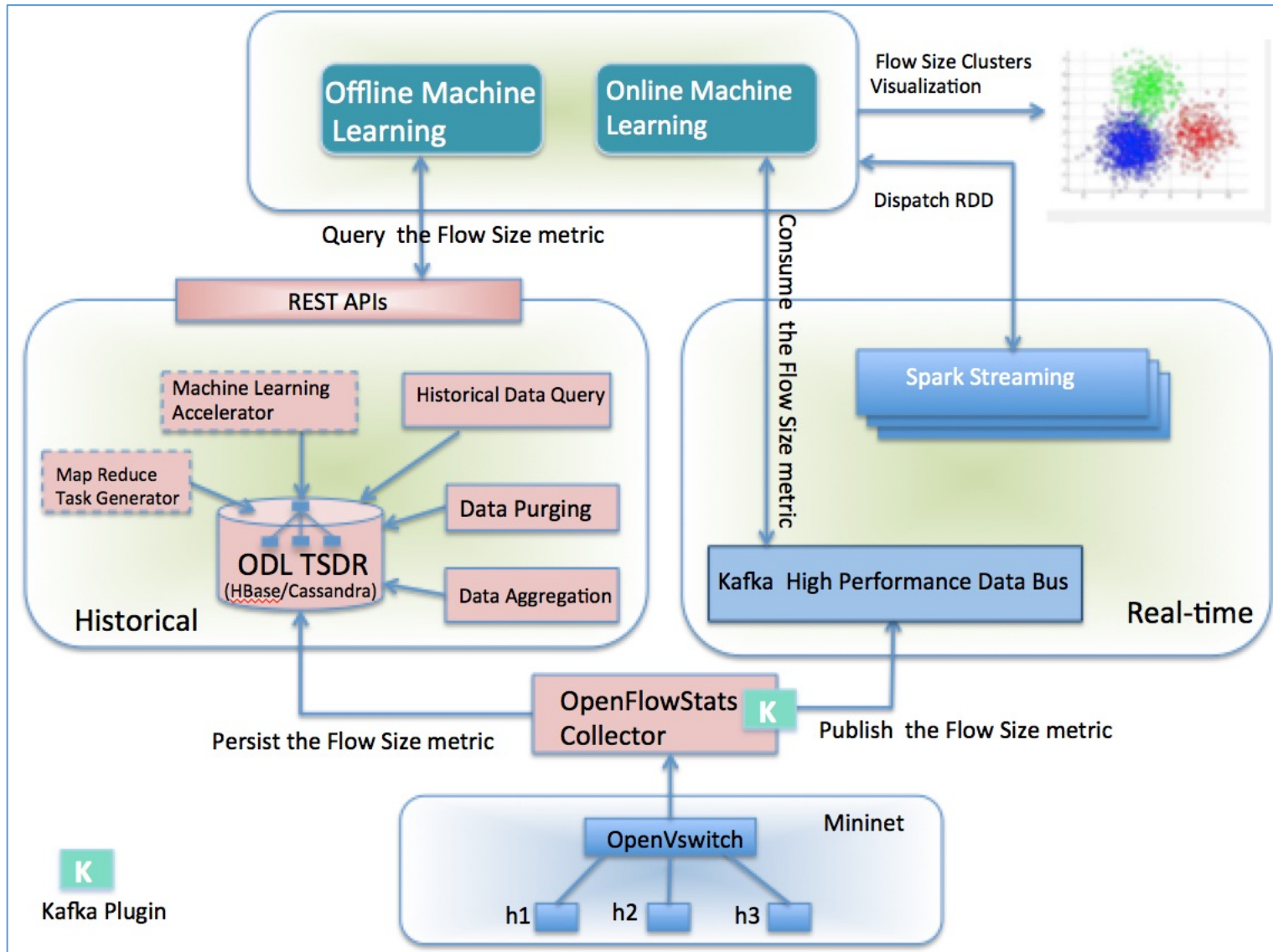


# ODL AI/ML framework in the ODL ecosystem



- Enable AI/ML on both historical and real-time data paths.
- Many use cases would require both offline and online ML on the time series data.
- External events could be additional input for accurate machine learning results.
- Feed back the results to SDN control path for automatic traffic steering and policy placement.
- Well-defined interface among the components towards future standardization of advanced analytics in SDN.

# ODL AI/ML framework PoC Architecture



- PoC of both historical offline machine learning and real-time online machine learning
  - Collect the time series data
  - Persist into scalable data storage
  - Publish to high performance data bus
- Integrate with external machine learning libraries
  - Spark MLlib
  - DeepLearning4J
- Collect OpenFlow Stats and apply machine learning algorithms
  - *k*-means clustering



Use Case V

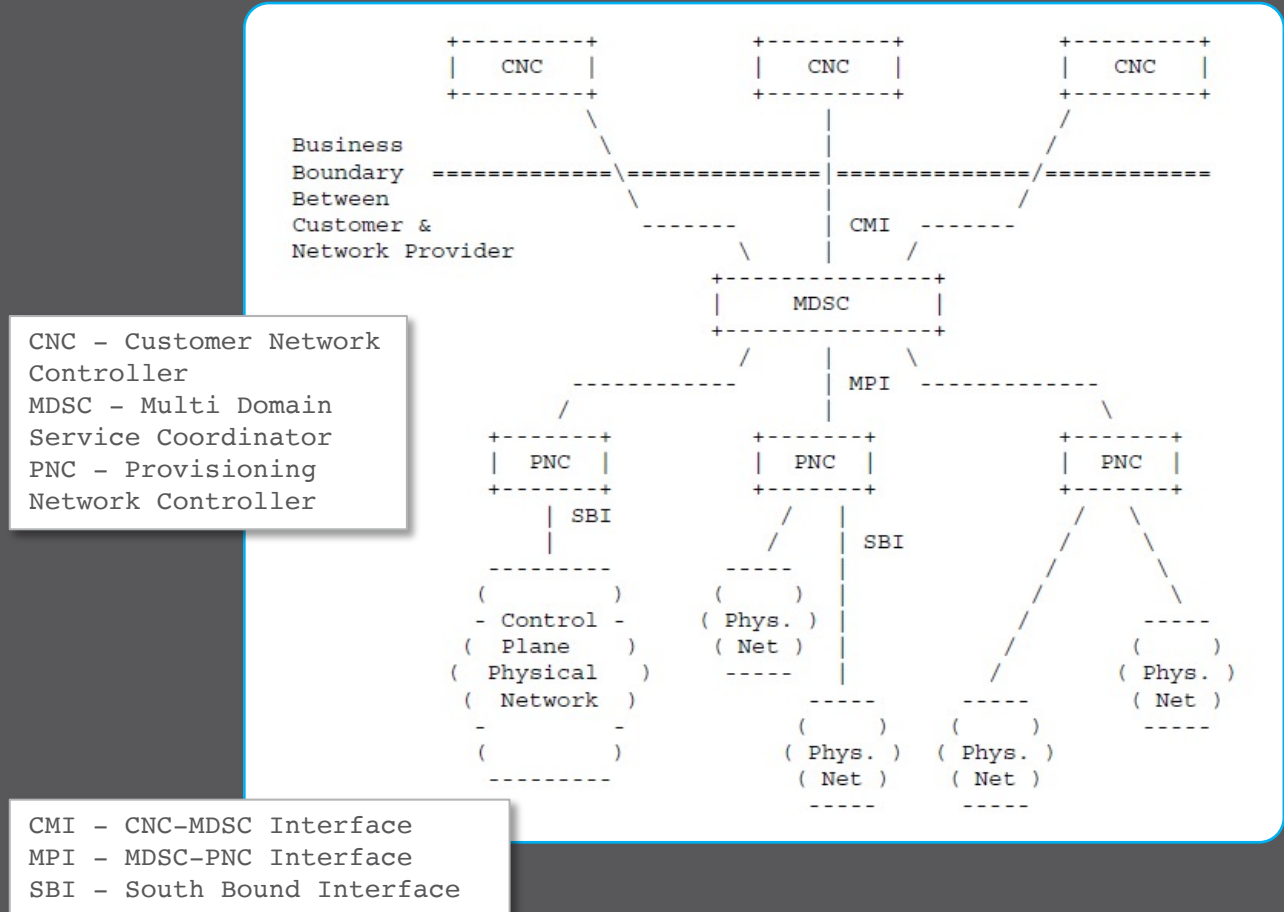
## OpenDaylight in OSS (future)

# WAN Transport Orchestrator (WAN-O)

- Based on ACTN (Abstraction of Control of Traffic Engineered Network) IETF Standard for realizing hierarchical SDN architecture
  - Yang Based (NetConf/RESTCONF) Models

# SDN Hierarchical architecture based on ACTN

- › Coordination of resources across multiple independent networks and multiple technology layers to provide end-to-end services
- › Layered operational model:
  - *Customer*: issuing a service request from catalog
  - *Service Provider*: dealing w/ Customer and providing the service (may or may not own the network(s) as such)
  - *Network Provider*: infrastructure providers owning the physical network(s) and building the infrastructure





# WAN-O as MDSC, interfaces

## MDSC NBI:

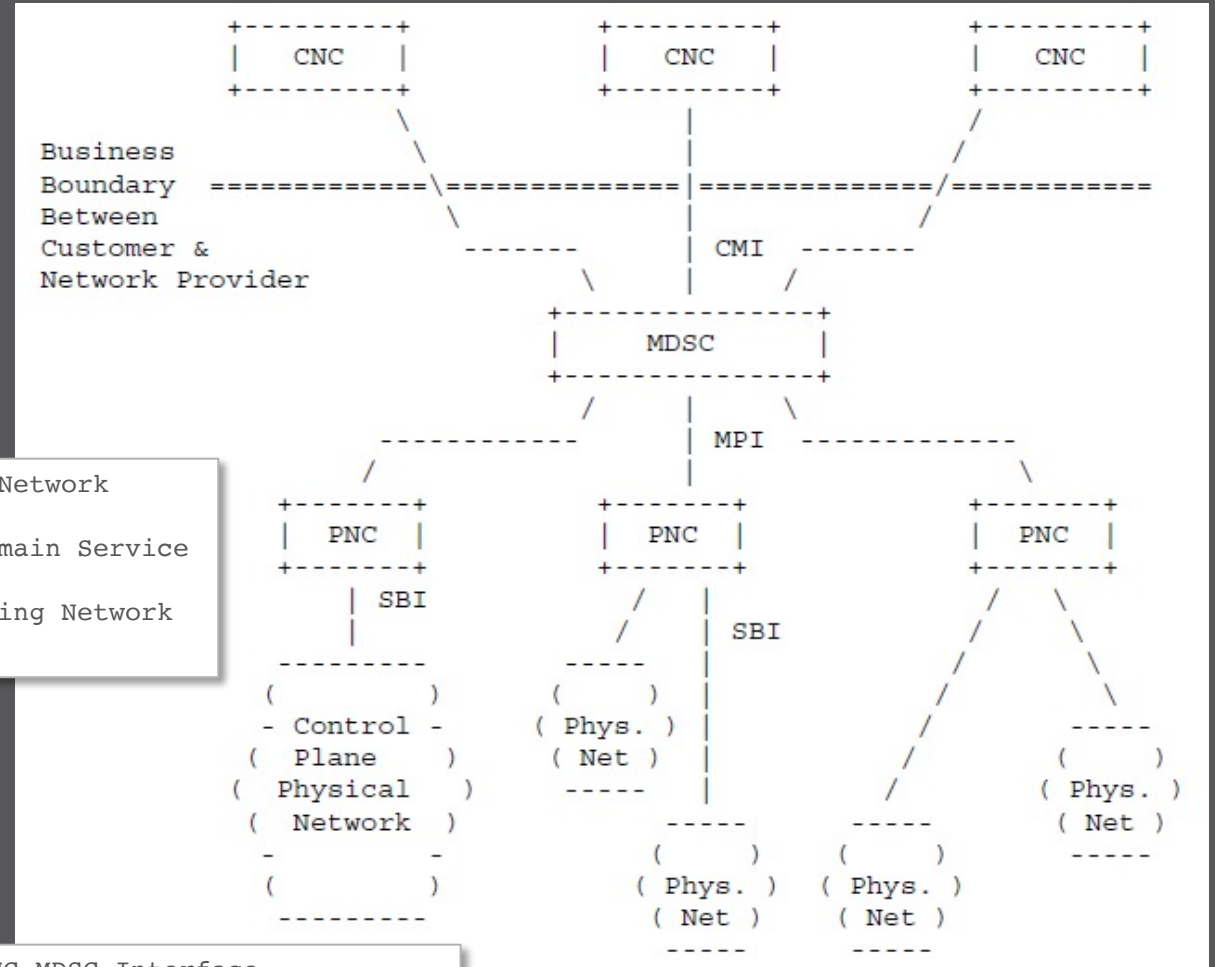
- CMI: CNC to MDSC interface
- YANG based (Netconf/Restconf)
- End to end Virtual Network concept
- Unified end to end topology

## MDSC SBI:

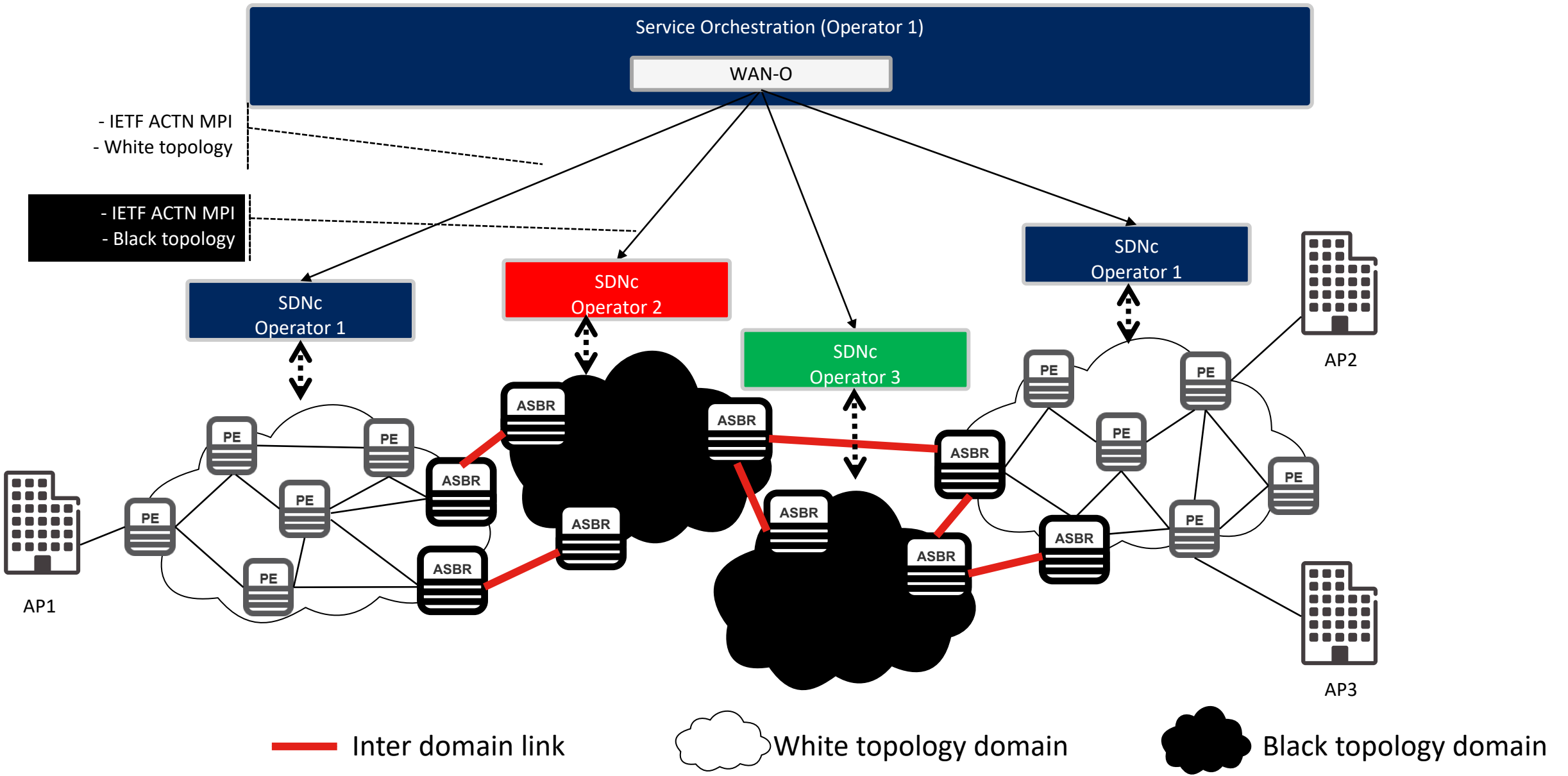
- MPI: MDSC to PNC interface
- YANG based (Netconf/Restconf)
- Per domain TE-Tunnels
- White or Black Domain topology

CNC - Customer Network Controller  
 MDSC - Multi Domain Service Coordinator  
 PNC - Provisioning Network Controller

CMI - CNC-MDSC Interface  
 MPI - MDSC-PNC Interface  
 SBI - South Bound Interface

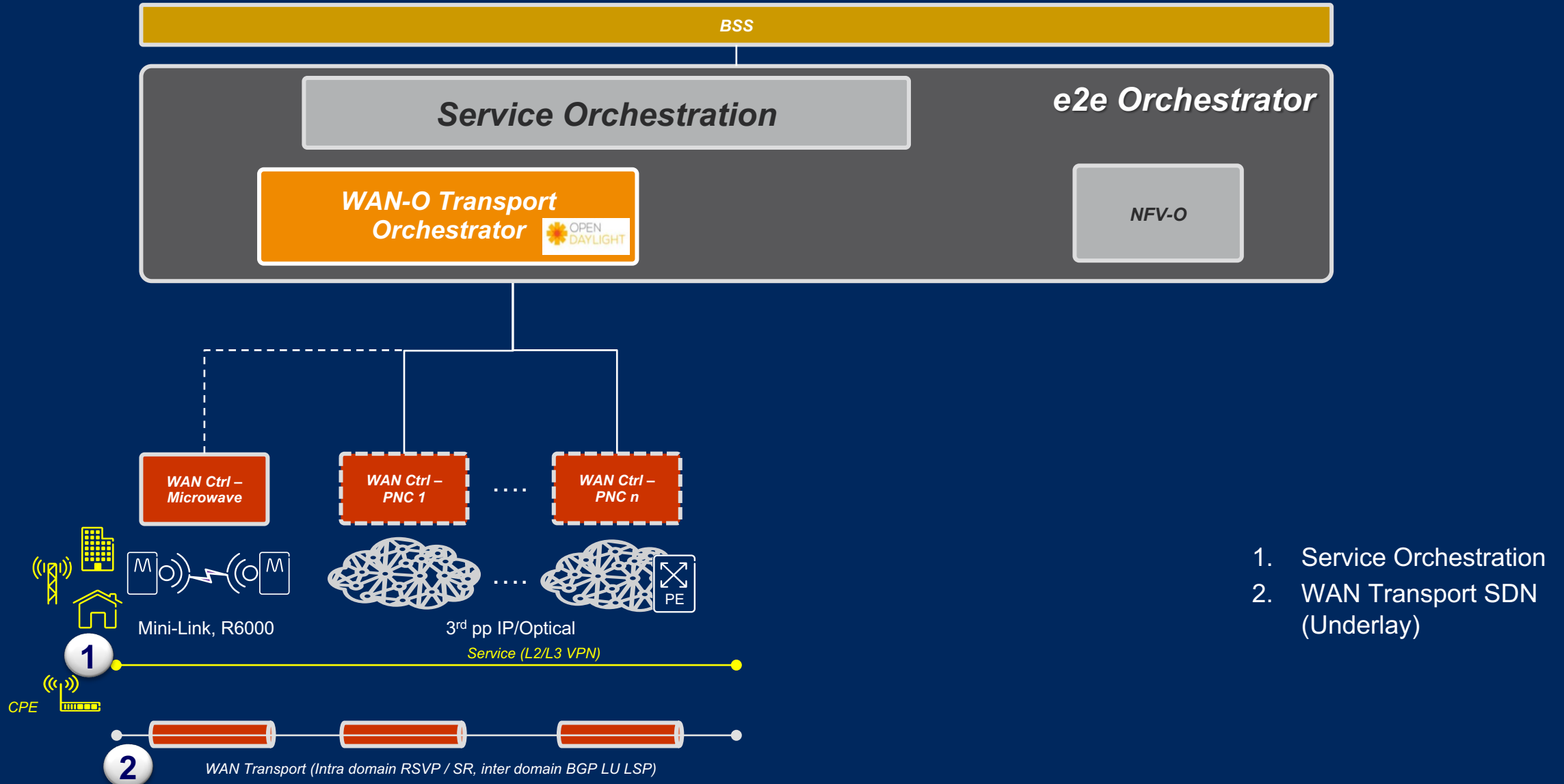


# Transport Network architecture



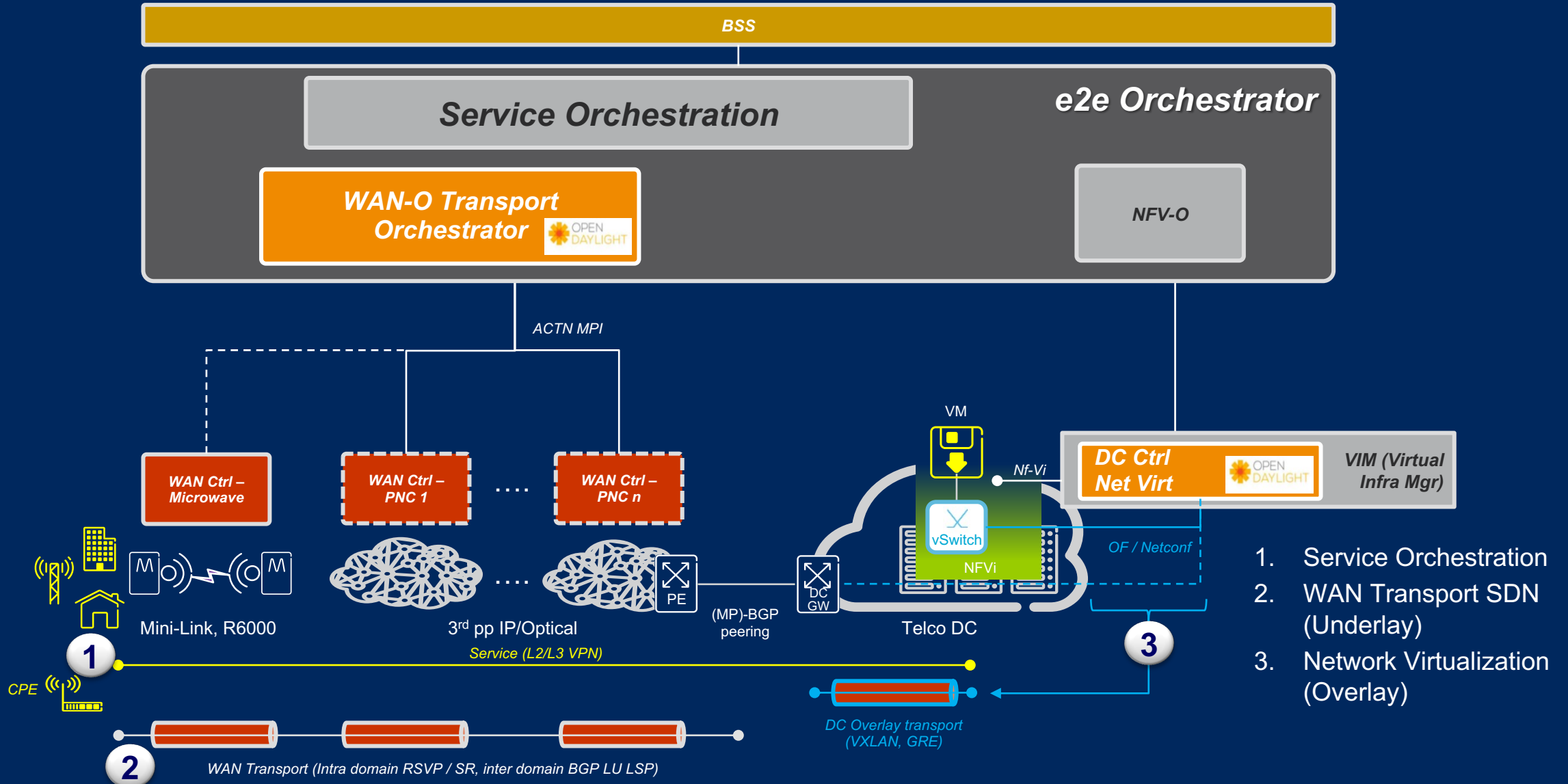
# END to END service orchestration

## Connectivity services



# END to END service orchestration

## VNF services





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# OpenDaylight: Getting Involved



## Avenues for getting involved

- OpenDaylight Wiki: <https://wiki.opendaylight.org>
- Mailing Lists:
  - Central / Cross Project: [https://wiki.opendaylight.org/view/Mailing\\_Lists](https://wiki.opendaylight.org/view/Mailing_Lists)
  - Complete List including individual projects: <https://lists.opendaylight.org/mailman/listinfo>
- Chat with developers via IRC: <https://wiki.opendaylight.org/view/IRC>
- Meetings:
  - Technical Steering Committee: <https://wiki.opendaylight.org/view/TSC:Meeting>
  - Technical Work Stream: [https://wiki.opendaylight.org/view/Tech\\_Work\\_Stream:Main](https://wiki.opendaylight.org/view/Tech_Work_Stream:Main)
  - Complete List including individual projects: <https://wiki.opendaylight.org/view/Meetings>



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## Areas to getting involved in

- OpenDaylight Documentation Project
- Project of your interest
  - [https://wiki.opendaylight.org/view/Project\\_list](https://wiki.opendaylight.org/view/Project_list)
  - Code Reviews
  - Bug Fixing
- MD-SAL & Clustering (Distributed Systems)
  - Experts
  - Enthusiasts: Improve your skills in these hot & in-demand area
- Scale & Performance
- Testing
- Architecture Improvements
  - Example: Scalable and Robust Data Replication using etcd.



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# Acknowledgements





- Contributors to slides

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- Prem Sankar Gopanan
- Scott Melton
- Srini Seetharaman
- YuLing Chen

- Reference

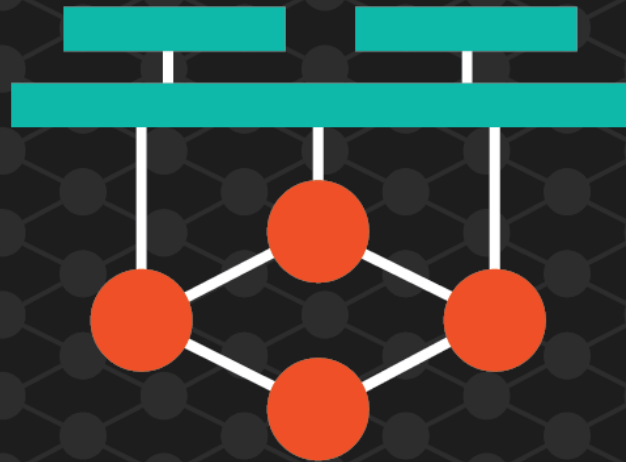
- <https://github.com/BRCDCcomm/BVC/wiki/MD-SAL>



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