



- ◇ Open Transport Configuration & Control Lyndon Ong (Ciena)
- ◇ Config & control wireless networks with CIM & SDN-C Tracy Van Brakle (AT&T)
- ◇ First Joint ONF/ONAP Demonstration with SDN-R..... George Clapp (AT&T)

12 December 2017



Open Transport Configuration & Control

Lyndon Ong (Ciena)

New ONF – 200+ Members Strong Community Positioned for Success



Partner

at&t China unicom 中国移动 COMCAST Google
T-Mobile Türk Telekom NTT Group
verizon Operators

Vendors

ciena CISCO ERICSSON FUJITSU HUAWEI
intel NEC NOKIA radisys SAMSUNG

ONF Board

ONF (& Stanford)	Guru Parulkar
<u>Network Operators</u>	
AT&T	DT
Turk Telecom	Comcast
NTT Comm	Google
SK Telecom	Telefonica
Verizon	
<u>Research & Vendor Community</u>	
Nick McKeown	Stanford
Fabian Schneider	NEC

Innovator

- SK Telecom
 - China Mobile
 - Chunghwa Tel
 - CENX
 - China Telecom
 - Juniper
 - Infinera
 - Others
- Microsoft
 - DoD
 - TELUS
 - Tencent
 - Vodafone
 - ZTE
 - Ceragon

Collaborator

70+

Volunteers

100s



- **Mission**

- Promote common configuration and control interfaces for transport networks in SDN, defining these interfaces with open source software and software defined standards

- **Leadership – OTCC TST**

- Lyndon Ong, Ciena, OTCC project lead
- Giorgio Cazzaniga, SIAE, Wireless Transport sub-project lead
- Karthik Sethuraman, NEC, Transport API sub-project lead
- Kam Lam, Fiberhome, OT Info Model sub-project lead

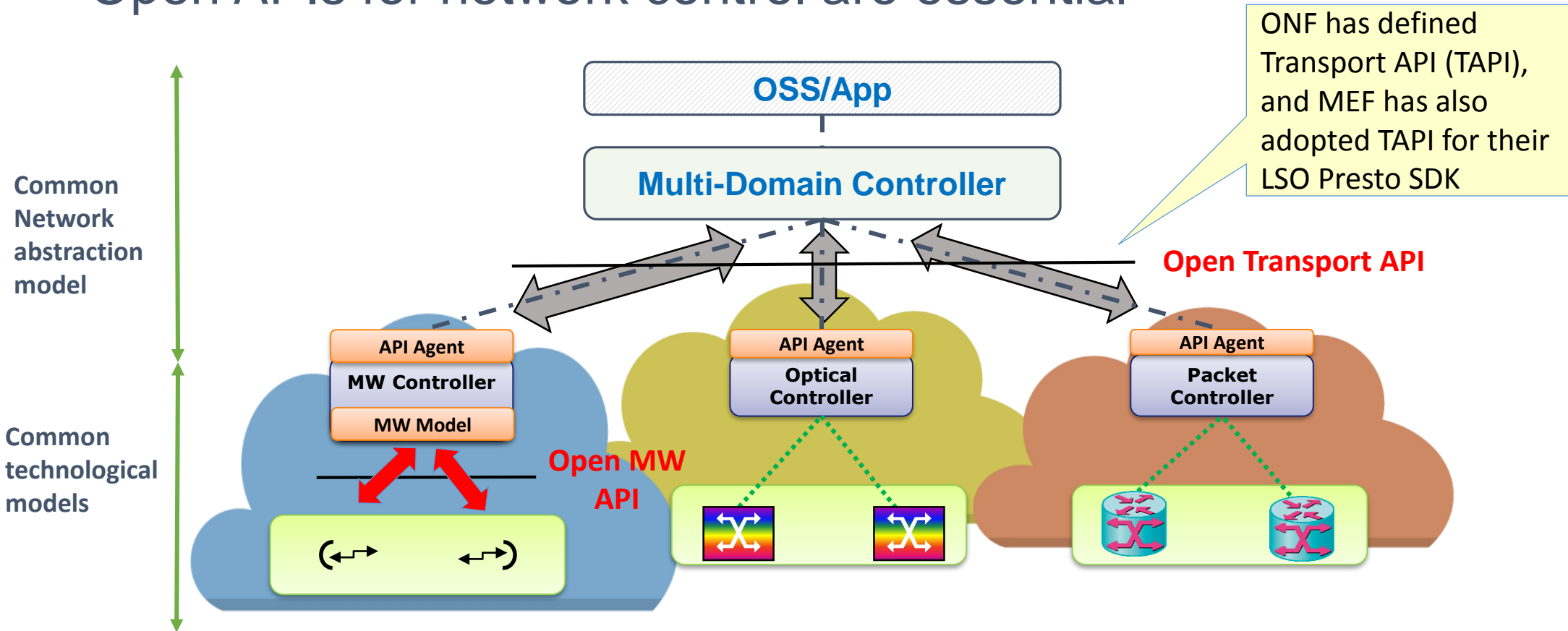
- **Results**

- OpenFlow extensions for optical
- Transport API Functional Requirements and SDK (related OIF and MEF demonstrations)
 - <https://github.com/OpenNetworkingFoundation/Snowmass-ONFOpenTransport>
- Wireless Transport Information Model (related WT PoCs)

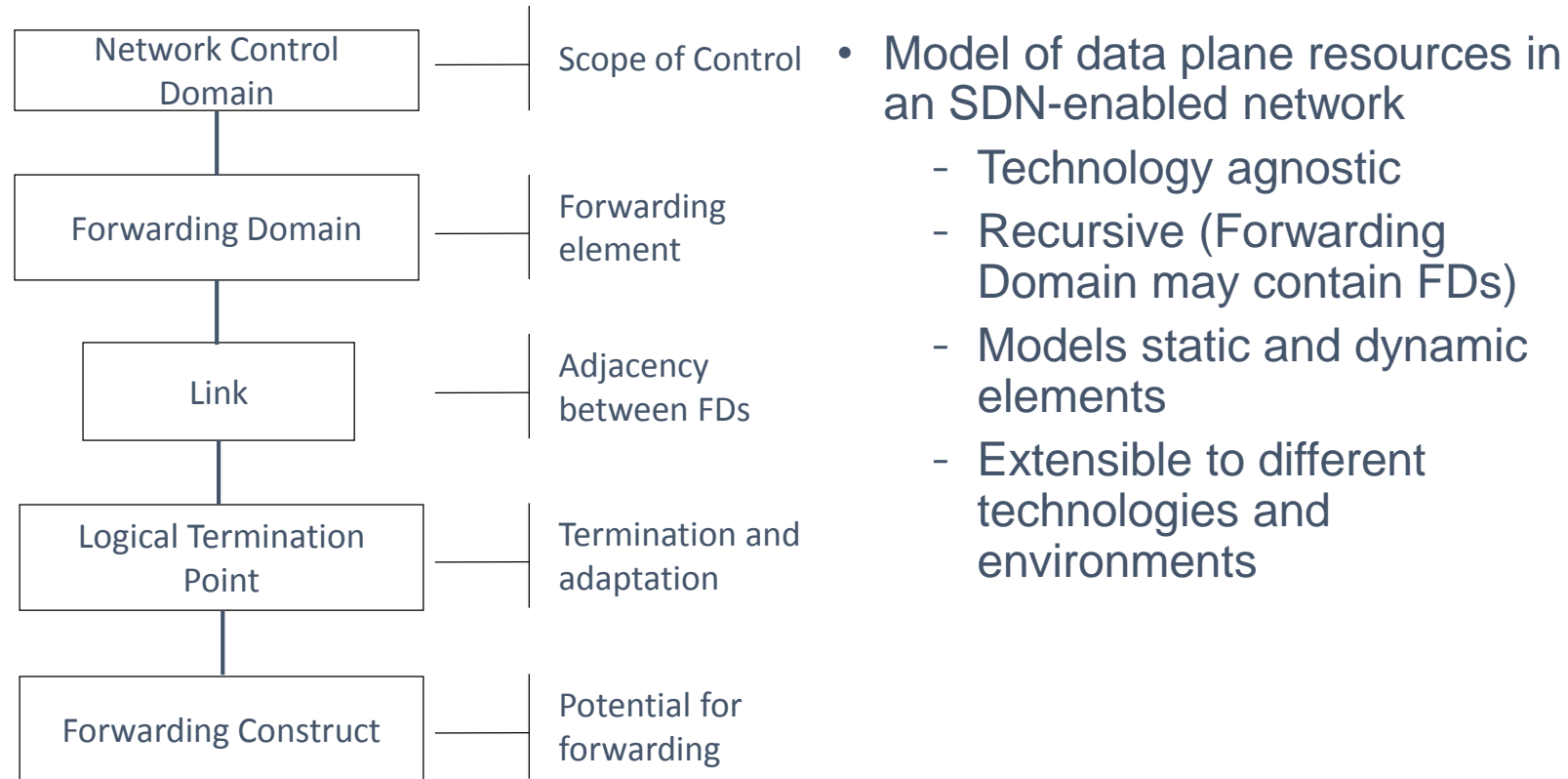
API Definition and Development



- Open APIs for network control are essential



Common Information Model (simplified)



Product of the ONF Information Modeling and Tooling Project

ONF TR-512 Core Information Model v1.3 – see

<https://wiki.opennetworking.org/display/OIMT/Ready+for+ONF+Approval>



Configuring and controlling wireless networks with ONF CIM & ONAP SDN-C

Tracy Van Brakle (AT&T)

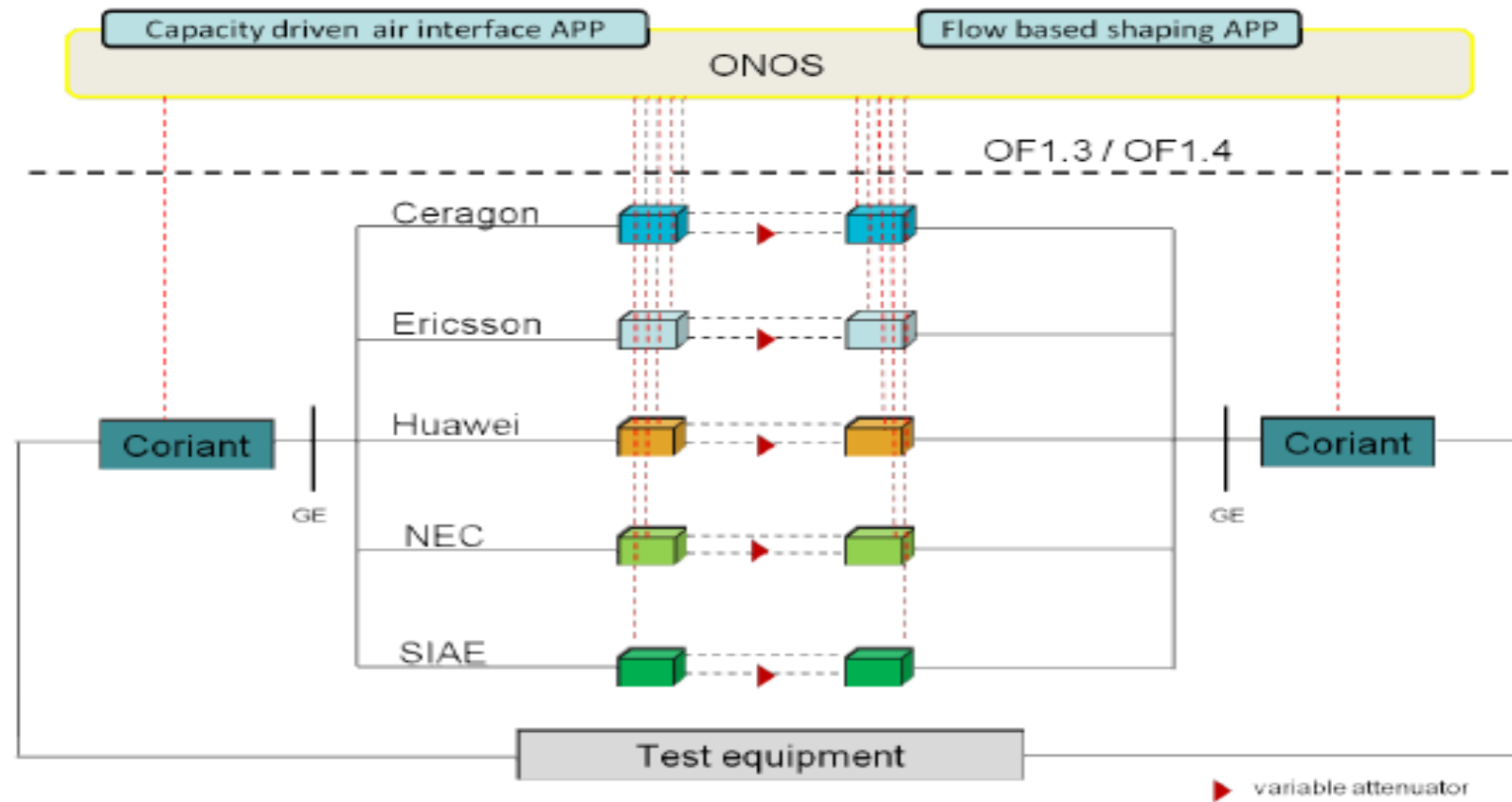
Overview and background



Proofs of Concept (PoCs) have been executed by the Open Networking Foundation Wireless Working Group(s) roughly every six months to demonstrate progress and to verify functionality and enhancements in a multi-vendor wireless network using real network devices, beginning with μ Wave/mmWave and now inclusive of eNB, RRH, DAS, IoT sensors. The work began with ONOS, then ODL stand-alone, and now ONAP SDN-C

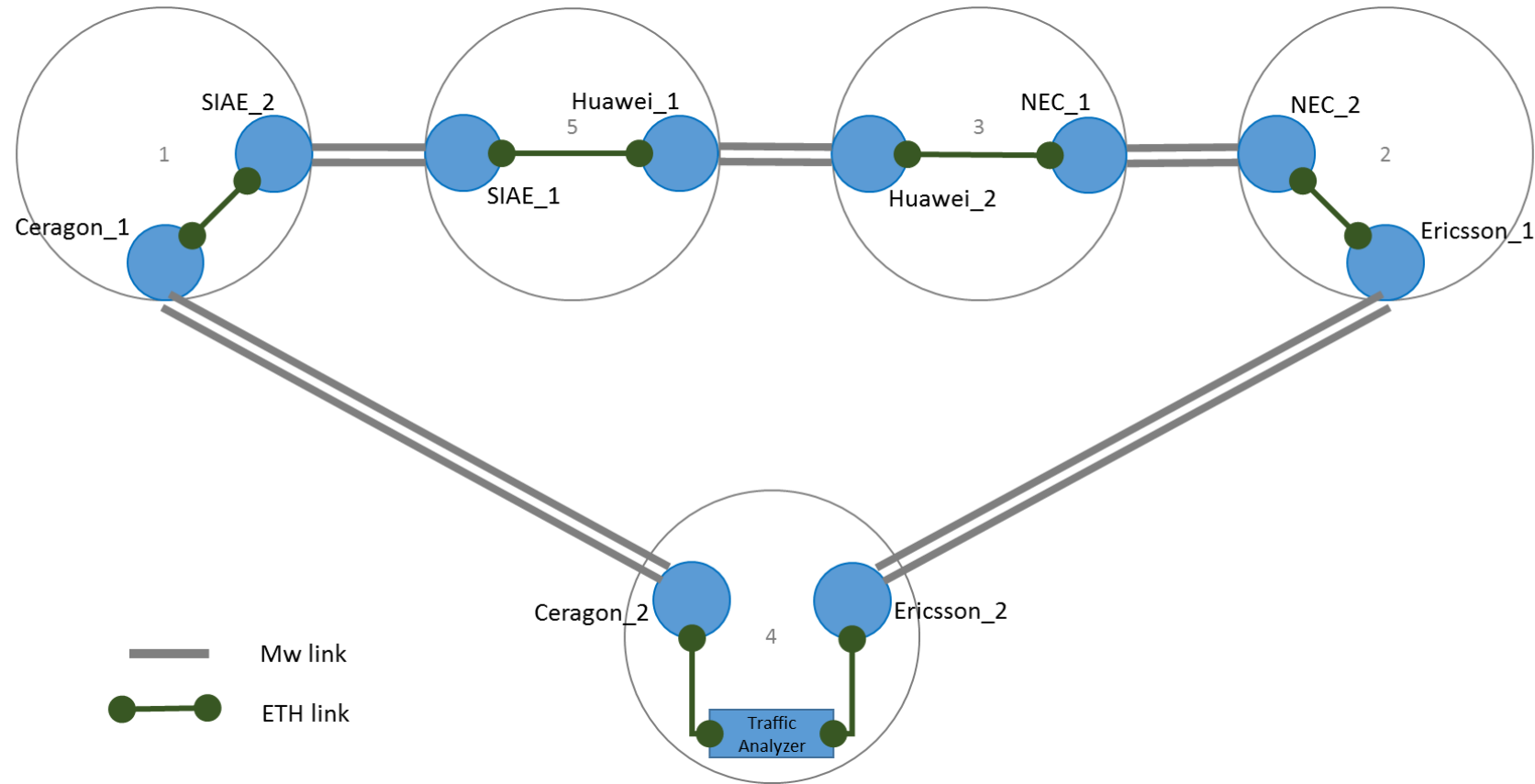
Date + Sponsor	SDN controller and platform	ONF CoreModel (TRs 512 & 532)	SBI protocol
1 st PoC; 4Q'15; Telefonica	ONOS	n/a	OpenFlow
2 nd PoC; 2Q'16; Telefonica	ODL Lithium SR4	n/a	Netconf/YANG
3 rd PoC; 4Q'17; AT&T	ODL Beryllium SR2 (ECOMP)	CM 1.1	Netconf/YANG
4 th PoC; 2Q'17; Deutsche Telekom	ODL Boron SR1 (ONAP release 0)	CM 1.2	Netconf/YANG
5 th PoC; 4Q'17; AT&T	ODL Boron / Carbon (ONAP "pre" Amsterdam)	CM 1.2	Netconf/YANG
6 th PoC; 2Q'18 - TBD	ODL Nitrogen (ONAP Beijing)	CM 1.3	Netconf/YANG

1st Proof-of-Concept → two basic SDN applications, OpenFlow – October 2015



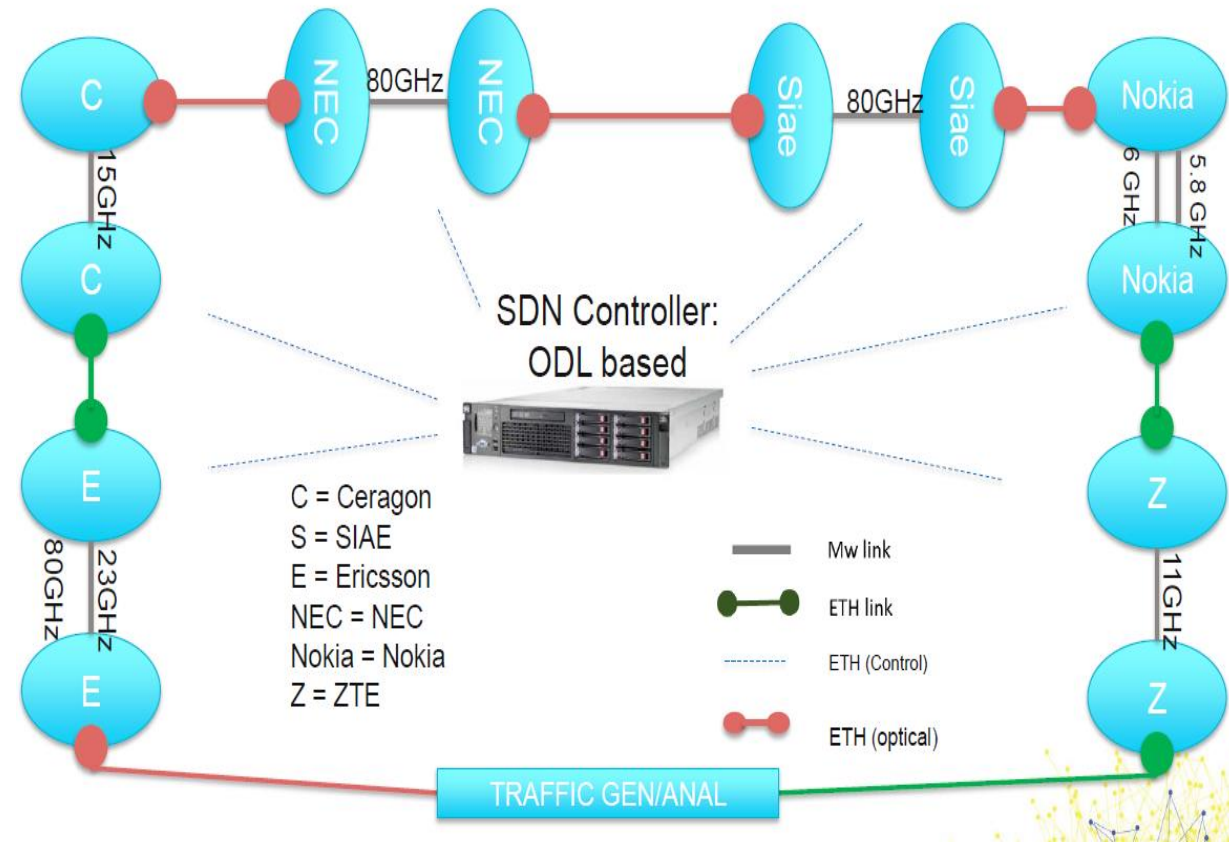
- 1st PoC took place in Madrid, Spain, October 2015
- Sponsor/Host = Telefónica and IMDEA Networks, AT&T (observer)
- Equipment vendors (in alphabetical order): Ceragon, Coriant, Ericsson, Huawei, NEC and SIAE

2nd Proof-of-Concept → FCAPS, ODL – April 2016



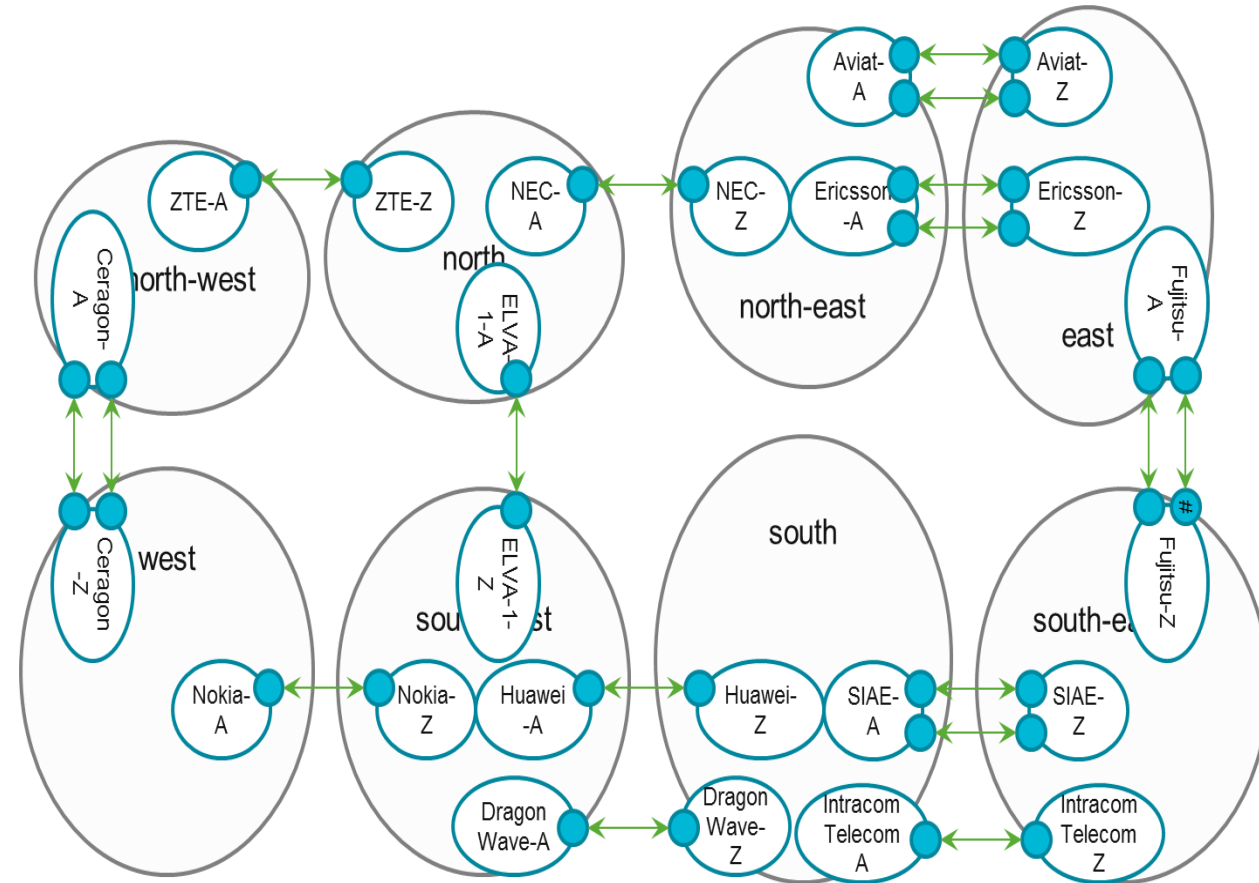
- **2nd PoC took place in Munich, Germany, April 2016**
- **Service Providers / Operators: Telefónica (lead), AT&T, Deutsche Telekom (observer)**
- **Equipment vendors (in alphabetical order): Ceragon, Ericsson, Huawei, NEC and SIAE**

3rd Proof-of-Concept → ECOMP (closed loop), Spectrum Access System inter-op



- 3rd PoC took place in Rutgers University Winlab, October 2016
- Service Providers / Operators: Telefónica, AT&T (lead), Deutsche Telekom
- Equipment vendors (in alphabetical order): Ceragon, Ericsson, Huawei, NEC, Nokia, SIAE, ZTE

4th Proof-of-Concept → 1588v2, connection-oriented Ethernet with re-routing

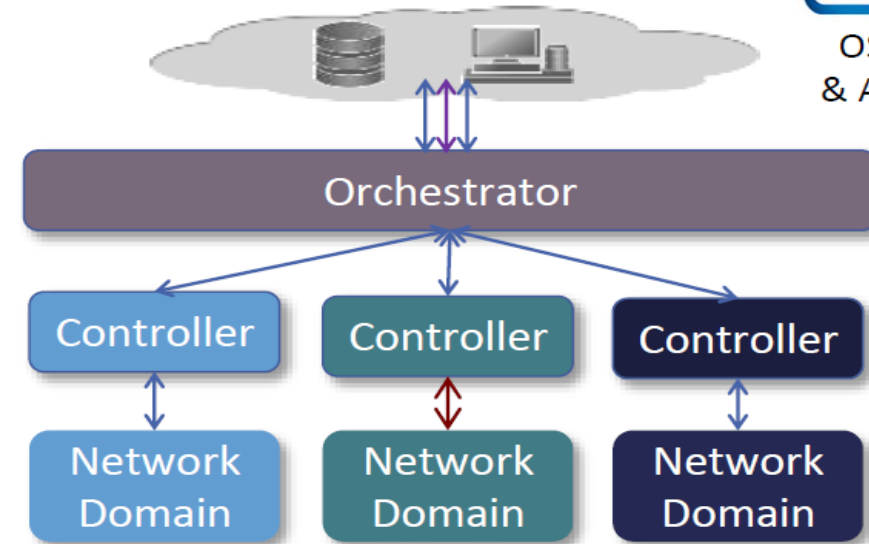
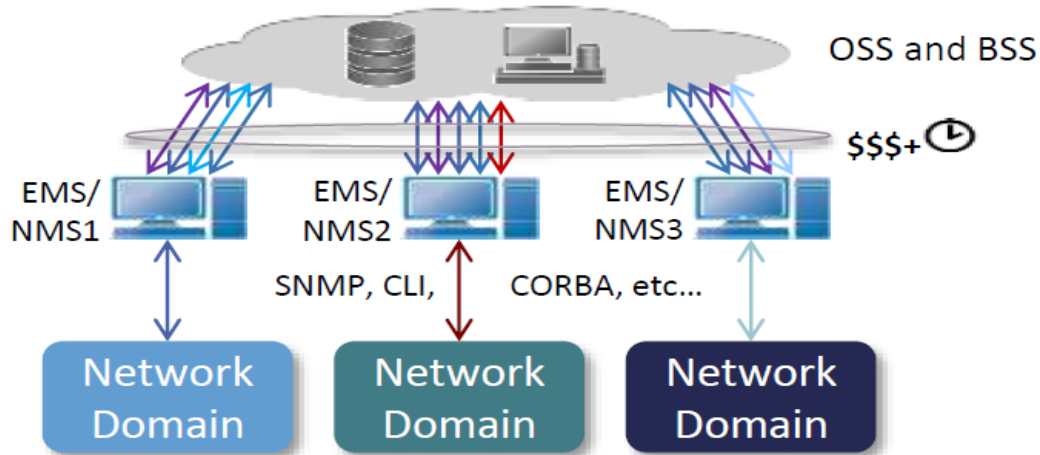


		Netconf/YANG (ONF-TR-512, 532)	Ethernet model	PTP (1588) model
Vendors	ADVA		X	X
	Aviat	X		
	Ceragon	X	X	
	DragonWave	X		
	ELVA-1	X		
	Ericsson	X	X	X
	Fujitsu	X		
	Huawei	X		X
	Intracom			
	Telecom	X		
	NEC	X	X	X
	Nokia	X	X	X
	SIAE	X	X	X
	ZTE	X	X	X

- **4th PoC took place in Bonn and Prague, June 2017**
- **Service Providers / Operators: Deutsche Telekom (lead), Telefónica, AT&T, Orange (observer)**

Overarching objectives for PoCs 2/3/4

Use Case: Multi-Vendor network integration



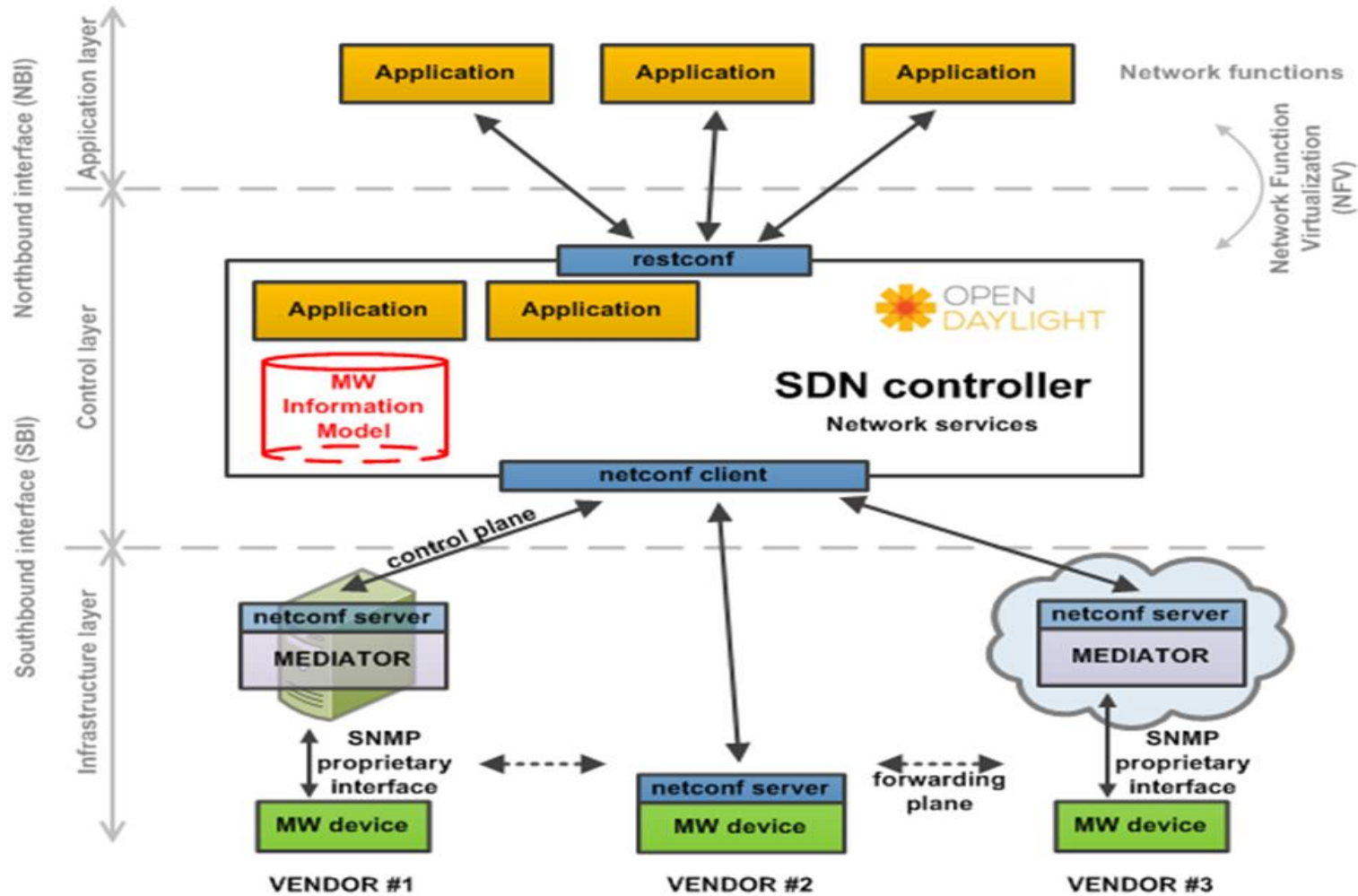
Current Situation:

- Individual EMS/NMS per vendor
- Huge complexity and cost in building/maintaining OSS/BSS – EMS/NMS interfaces
- Complex and slow for introducing new services spanning multiple network domains

SDN:

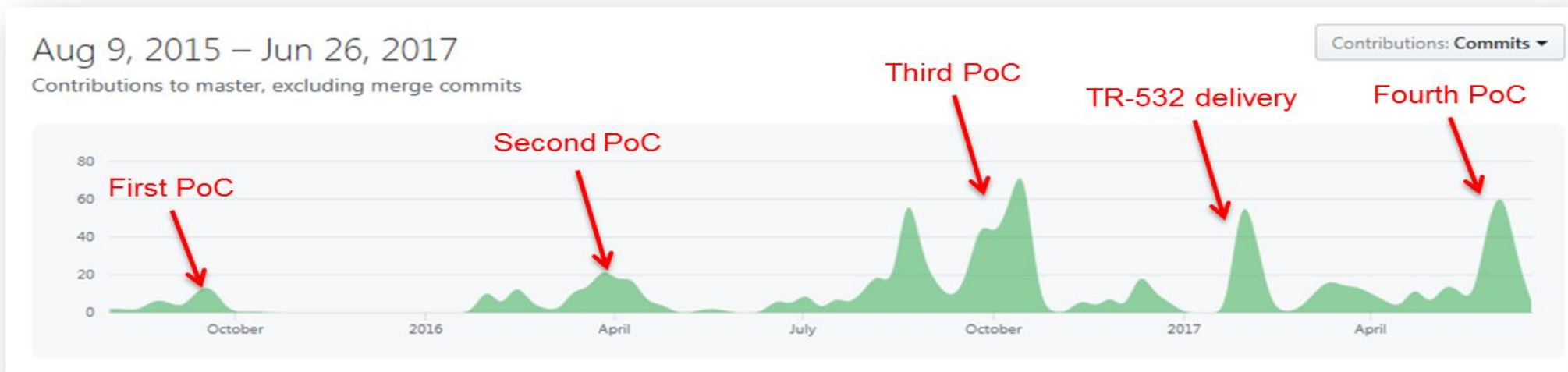
- New level of programmability on top of orchestrator
- EMS/NMS bypassed for service creation – standardised & simplified workflow
- Open Source based orchestrators for project speed up
- Reduced complexity through abstraction & virtualization in controller / orchestrator NBI

Basic architecture for ONF Wireless PoCs 2,3,4



CENTENNIAL

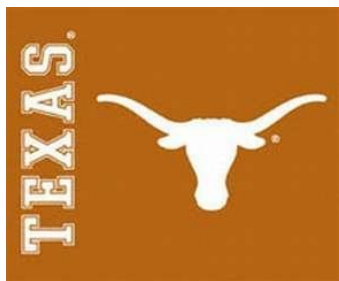
- CENTENNIAL is the open source project being used for (and by) the ONF Wireless Project to deliver code that implements the microwave (and now more generalized model) defined by the ONF Wireless WGs.
- Applications developed in the context of the PoC are also available in CENTENNIAL project repository.





Special thanks to the Community!

ALTIOSTAR

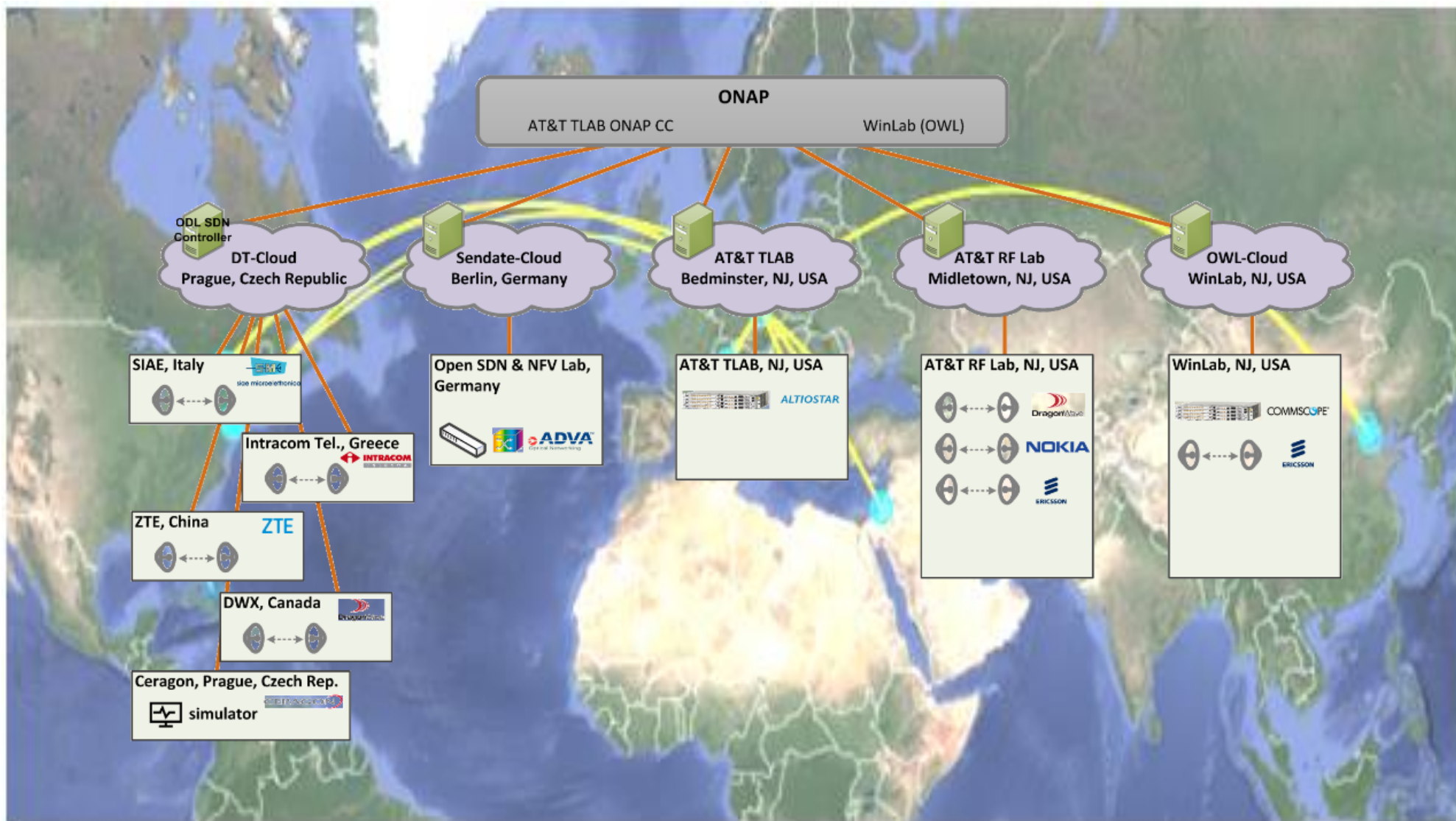




First Joint ONF/ONAP Demonstration with SDN-R

George Clapp

ONF Open Transport Working Group - Wireless Transport Project – Proof-of-Concept Demo



ONF / ONAP joint PoC participants and locations

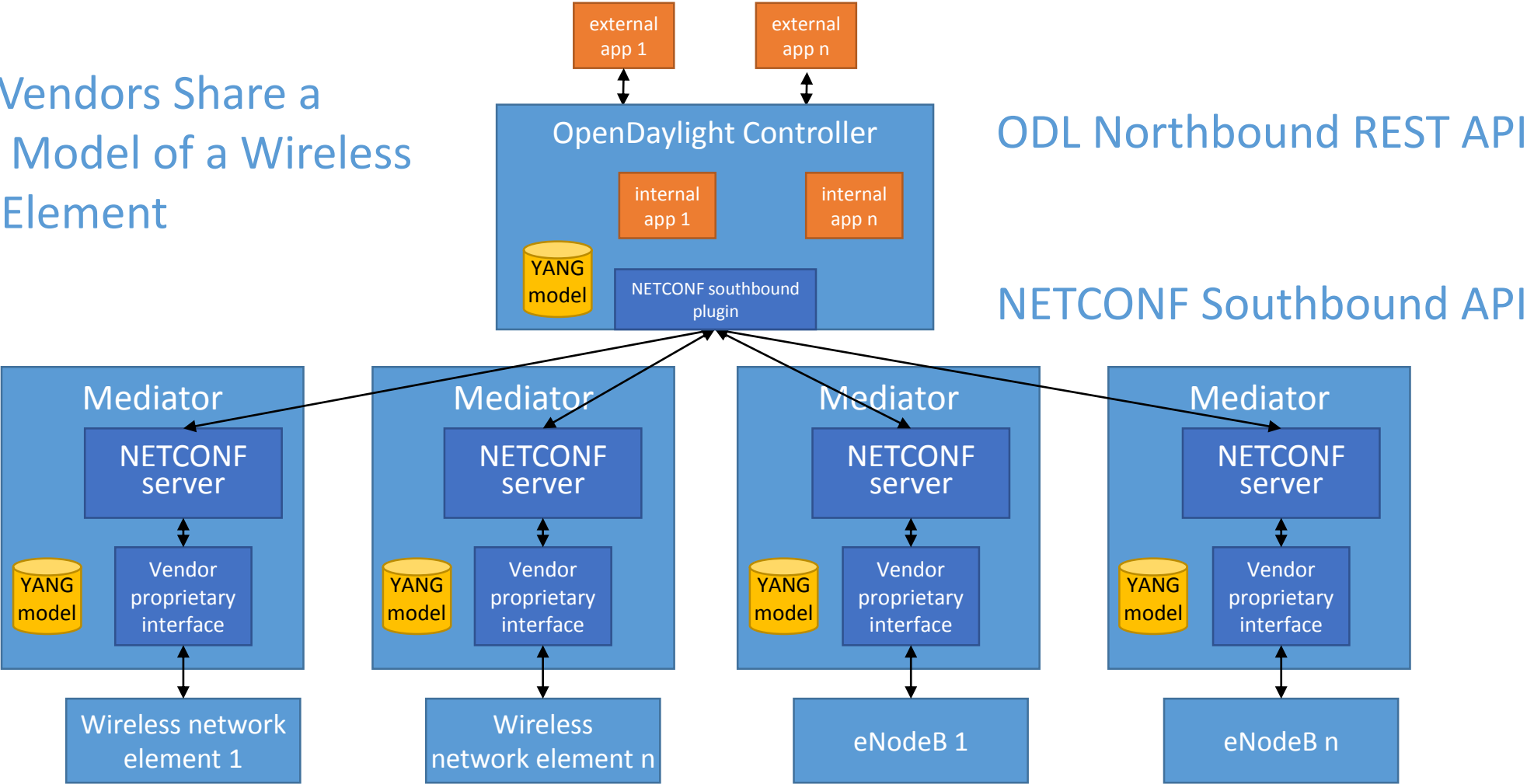


Vendor	Type of test devices	Location of test devices	Connected via (location of ODL SDN controller)
ADVA	2x ETH switch	Open SDN & NFV Lab, Berlin, Germany	Sendate-Cloud in Berlin, Germany
	3x ROADM <small>Reconfigurable Optical Add-Drop Multiplexer</small>		
AltioStar	RRH Remote Radio Head	WinLab, NJ, USA	OWL-cloud (WinLab) in NJ, USA
Ceragon	Simulator	VM inside DT-Cloud, Prague, Czech Republic	DT-Cloud in Prague, Czech Republic
CommScope	DAS Distributed Antenna System	WinLab, NJ, USA	OWL-cloud (WinLab) in NJ, USA
DragonWave-X	6x MW devices 4x Horizon Compact Plus (HC+) 2x Horizon Quantum	Ottawa, Canada	DT-Cloud in Prague, Czech Republic
	2x MW devices	AT&T Lab, NJ, USA	AT&T-cloud in NJ, USA
Ericsson*	4x MW devices	WinLab, NJ, USA	OWL-cloud (WinLab) in NJ, USA
Intracom Telecom	2x MW devices OmniBAS OSDR ODU	Athens, Greece	DT-Cloud in Prague, Czech Republic
Nokia*	2x MW devices	AT&T Lab, NJ, USA	AT&T-cloud in NJ, USA
SIAE	2x MW devices AGS20 IDU split-mount	Milan, Italy	DT-Cloud in Prague, Czech Republic
ZTE*	2x MW devices	Tianjin, China	DT-Cloud in Prague, Czech Republic

Basic Architecture for ONF Proof-of-Concept Demo's



Multiple Vendors Share a Common Model of a Wireless Network Element



Common Information Model



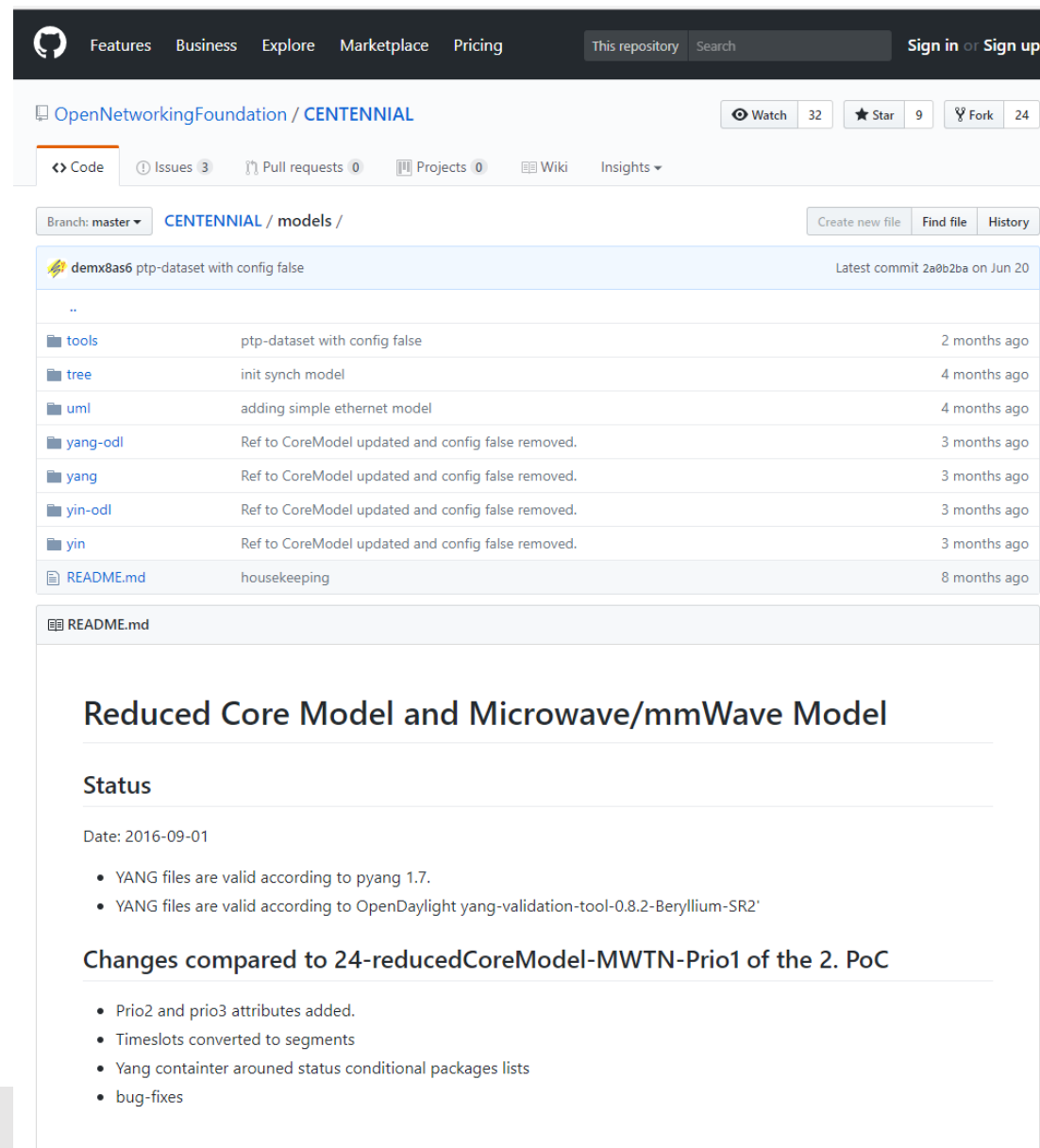
Microwave Information Model

Version 1.0
December 2016

TR-532



ONF Technical Recommendation (TR) 532



The screenshot shows the GitHub repository page for 'OpenNetworkingFoundation / CENTENNIAL'. The repository is on the 'master' branch and contains a directory named 'models'. The 'models' directory includes several sub-directories and files:

File/Directory	Description	Last Commit
..		Latest commit 2a0b2ba on Jun 20
tools	ptp-dataset with config false	2 months ago
tree	init synch model	4 months ago
uml	adding simple ethernet model	4 months ago
yang-odl	Ref to CoreModel updated and config false removed.	3 months ago
yang	Ref to CoreModel updated and config false removed.	3 months ago
yin-odl	Ref to CoreModel updated and config false removed.	3 months ago
yin	Ref to CoreModel updated and config false removed.	3 months ago
README.md	housekeeping	8 months ago

The 'README.md' file content is as follows:

Reduced Core Model and Microwave/mmWave Model

Status

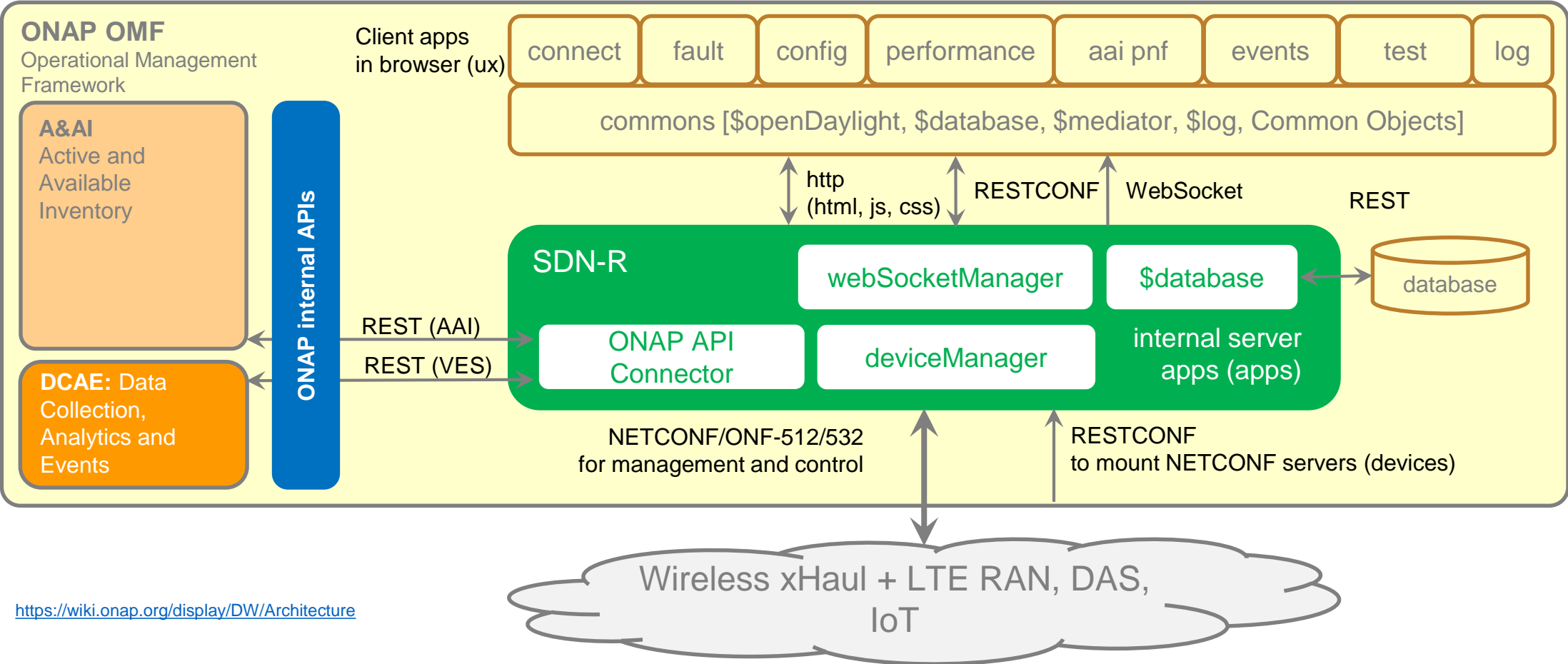
Date: 2016-09-01

- YANG files are valid according to pyang 1.7.
- YANG files are valid according to OpenDaylight yang-validation-tool-0.8.2-Beryllium-SR2'

Changes compared to 24-reducedCoreModel-MWTN-Prio1 of the 2. PoC

- Prio2 and prio3 attributes added.
- Timeslots converted to segments
- Yang container around status conditional packages lists
- bug-fixes

Simplified Architecture for ONF / ONAP Joint PoC



<https://wiki.onap.org/display/DW/Architecture>

SDN-R Web-based GUI Using OpenDaylight DLUX



A screenshot of the OpenDaylight DLUX web-based GUI. The browser address bar shows the URL: localhost:8181/index.html/#pnfTopology/site?lat=35.785139661293705&lng=21.258477625000086&zoom=3. The page title is 'pnf Topology'. The left sidebar contains a navigation menu with items: Topology, Nodes, Yang UI, Yang Visualizer, SDN-C Connect, ONAP AAI, ONAP DCAE, ONAP MSO, pnf Fault, pnf Config, pnf PM Current, pnf PM History, pnf PM Link, pnf Inventory, pnf Topology (selected), and pnf Mediator. The main content area shows a map of the world with several blue circular nodes and yellow curved lines representing network connections. The map is titled 'Map (35 of 35 sites loaded)'. In the top right corner of the main area, there is a status bar: 'Nodes: 16 || Alarm status: 0 | 0 | 0 | 36 | Sum: 36'. The top right of the page has a 'Logout' button. The bottom left of the map area shows the 'Google' logo.

SDN-R Functions



The screenshot shows the OpenDaylight Dlux web interface. The browser address bar displays `localhost:8181/index.html/pnfTopology/site?lat=35.785139661293705&lng=21.25847762500008662`. The page title is "pnf Topology". A sidebar on the left lists various menu items, with "pnf Topology" selected. The main content area shows a map of Europe with several blue circular markers and yellow lines connecting them, representing network topology. The map is titled "Map (35 of 35 sites loaded)".

- Topology
- Nodes
- Yang UI
- Yang Visualizer
- SDN-C Connect
- ONAP AAI
- ONAP DCAE
- ONAP MSO
- pnf Fault
- pnf Config
- pnf PM Current
- pnf PM History
- pnf PM Link
- pnf Inventory
- pnf Topology
- pnf Mediator

This screenshot shows the same OpenDaylight Dlux web interface as the previous one, but with a different zoom level on the map. The map shows a wider view of Europe and the Mediterranean region. The status bar at the top right indicates "Nodes: 16 | Alarm status: 0 | 0 | 0 | 36 | Sum: 36". The "pnf Topology" menu item is highlighted in the sidebar.

Inventory



OPEN DAYLIGHT pnf Inventory Nodes: 6 || Alarm status: 9 | 0 | 4 | 0 | Sum: 1

AltioStar-RRH-1

▼ ibbu | ibbu

Manufacturer:	Serial:	Version:	Date:	Description:	Part Type Id:	Model Identifier:	Type Name:
AltioStar	C1L23DFE2989	1.4.0	Sep 9, 2017	intelligent Baseband Unit	PLHP13B2SXR1	ibbu	ibbu

▼ irrh1 | irrh1

Manufacturer:	Serial:	Version:	Date:	Description:	Part Type Id:	Model Identifier:	Type Name:
AltioStar	PLW39160042	V2.0-Build 360	Sep 9, 2017	intelligent Remote Radio Head #1		irrh1	irrh1

▼ spm | spm

Manufacturer:	Serial:	Version:	Date:	Description:	Part Type Id:	Model Identifier:	Type Name:
AltioStar	PLW39150094	8	Sep 9, 2017	Signal Processing Module	330-01-0068	spm	spm

▼ tla | tla

Manufacturer:	Serial:	Version:	Date:	Description:	Part Type Id:	Model Identifier:	Type Name:
AltioStar	PLW39160042	21	Sep 9, 2017	tla	340-00-0058	tla	tla

▼ radio | radio

Manufacturer:	Serial:	Version:	Date:	Description:	Part Type Id:	Model Identifier:	Type Name:
AltioStar	PLW37160009	2	Sep 9, 2017	radio	330-01-0078	radio	radio

Drill Down to Components within a Network Element



OPEN DAYLIGHT pnf Inventory Nodes: 6 | Alarm status: 0 | 2 | 0 | 0 | Sum: 2

Nokia-62

- ▼ SHELF-1.1.0.0 | Microwave Service Switch Shelf
 - Manufacturer: VG Serial: VG113460439 Version: BACK2U Date: Aug 26, 2011 Description: MSS-8 Part Type Id: 3DB18485ABAA01 Model Identifier: CRMLB10HRA Type Name: MSS-8
 - ▼ CARD-1.1.9.0 | E-FANS Card in MSS Shelf, Slot 9
 - Manufacturer: SAN Serial: TH1528Q015B Version: FANS Date: Jul 11, 2015 Description: MSS/E-FANS Part Type Id: 3EM23911BBAA01 Model Identifier: CRCCASZJAA Type Name: E-FANS
 - > CARD-1.1.3.0 | P8ETH Card in MSS Shelf, Slot 3
 - > CARD-1.1.4.0 | P8ETH Card in MSS Shelf, Slot 4
 - > CARD-1.1.1.0 | CorEvo Card in MSS Shelf, Slot 1
 - ▼ CARD-1.1.7.0 | P32E1DS1_A Card in MSS Shelf, Slot 7
 - Manufacturer: SAN Serial: TH1122Q01V0 Version: P32E1DS1 Date: Jun 8, 2011 Description: MSS/DS1 Part Type Id: 3DB18126AEAB01 Model Identifier: CRG2ABUDAA Type Name: P32E1DS1_A
 - > CARD-1.1.5.0 | MPTACC Card in MSS Shelf, Slot 5
 - > CARD-1.1.6.0 | MPTACC Card in MSS Shelf, Slot 6

NETCONF Connected Network Elements



OPEN DAYLIGHT | ONAP | SDN-C Connect | Logout

Nodes: 6 | Alarm status: 9 | 0 | 4 | 0 | Sum: 13

Required network elements

Name	Connection status	IP address	Port	Radio signal ids	Actions
AltioStar-RRH-1	connected	10.31.1.141	14001	["41"]	[Network, Refresh, Info, F, C, A, P, S, I]
CommScope-DAS	connected	10.100.0.18	14005	["Test01"]	[Network, Refresh, Info, F, C, A, P, S, I]
Ericsson-A1	connected	10.100.0.11	8301	["INT3"]	[Network, Refresh, Info, F, C, A, P, S, I]
Ericsson-A2	connected	10.100.0.11	8302	["INT4"]	[Network, Refresh, Info, F, C, A, P, S, I]
Ericsson-B1	connected	10.100.0.11	8303	["RUBY_low"]	[Network, Refresh, Info, F, C, A, P, S, I]
Ericsson-B2	connected	10.100.0.11	8304	["RUBY_high"]	[Network, Refresh, Info, F, C, A, P, S, I]

ONAP Active and Available Inventory



Active and Available Inventory

Topology

Nodes

Yang UI

Yang Visualizer

SDN-C Connect

ONAP AAI

ONAP DCAE

ONAP MSO

pnf Fault

pnf Config

pnf PM Current

pnf PM History

pnf PM Link

pnf Inventory

pnf Topology

pnf Mediator

ID	Name	Type	Vendor	Model	If OAM	Maintenan...
12345-123-12345-22	ADVA-ROADM-B	ROADM	ADVA	FSP 3000R7	10.20.4.12	false
192.168.2.33:14007	DragonWave-A3	WirelessTransport	DragonWav...	Horizon Quantum	0	false
192.168.2.33:14006	DragonWave-Z2	WirelessTransport	DragonWav...	Horizon Compact Plus	0	false
12345-123-12345-23	ADVA-ROADM-C	ROADM	ADVA	FSP 3000R7	10.20.4.13	false
10.10.240.53:4060	Quantum_FarEnd	Wireless Transport	DragonWave	Horizon Quantum	0	false
192.168.2.7:33002	SIAE-S2	WirelessTransport	SIAE	AGS-20	0	false
192.168.2.18:830	Intracom-A	WirelessTransport	Intracom	OSDR-13H13	0	false
10.10.235.10:40011	Nokia-62	WirelessTransport	Nokia	Nokia 7.1	0	false
192.168.2.51:830	ZTE-24	WirelessTransport	ZTE	ZXMW NR8120A	0	false
10.100.0.11:8303	Ericsson-B1	WirelessTransport	Ericsson	MINI-LINK 6352	0	false
12345-123-12345-21	ADVA-ROADM-A	ROADM	ADVA	FSP 3000R7	10.20.4.11	false
10.100.0.11:8304	Ericsson-B2	WirelessTransport	Ericsson	MINI-LINK 6352	0	false
192.168.1.4:13001	Ceragon-A1	WirelessTransport	Ceragon	Simulator	0	false
192.168.1.4:13003	Ceragon-Z1	WirelessTransport	Ceragon	Simulator	0	false
10.10.232.30:8307	Ericsson-23	WirelessTransport	Ericsson	MINI-LINK 6352	0	false
192.168.2.33:14005	DragonWave-A2	WirelessTransport	DragonWav...	Horizon Compact Plus	0	false
192.168.2.33:14008	DragonWave-Z3	WirelessTransport	DragonWav...	Horizon Quantum	0	false

Total Items: 33

SDN-R Subproject

Subproject Name:

- SDN controller for Radio (SDN-R)

Subproject description:

The SDN-R subproject adds features/functionality to the OpenDaylight-based controller SDN-C (Core) that is built on the Common Controller Framework to configure and control wireless resources.

Scope:

The following features are in scope for the SDN-R subproject for ONAP release 2...

Community Labs in North America



TLAB	AT&T Advanced Technologies		Rich Bennett (RB2745@att.com) John Murray (JM2932@att.com)
Multi-Geo Labs via an IPSec GRE VPN tunnel	Wind River		Stephen Gooch (stephen.gooch@windriver.com)
WINLAB ONAP Wireless Lab (OWL)	Rutgers University/AT&T		Ivan Seskar (seskar@winlab.rutgers.edu) Tracy Van Brakle (tv8394@att.com)



WINLAB Tech Center Facility

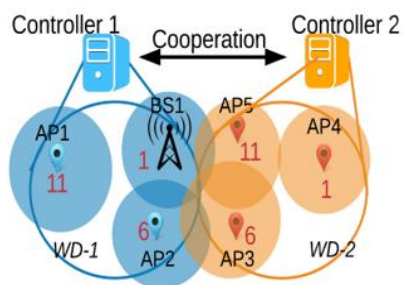
WINLAB founded in 1989 as a collaborative industry-university research center with specialized focus on wireless networking



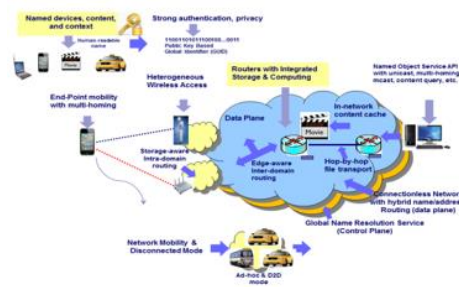
~25 faculty/staff, most from the ECE and CS departments at Rutgers

~40-50 grad students (80% PhD, 20% MS)

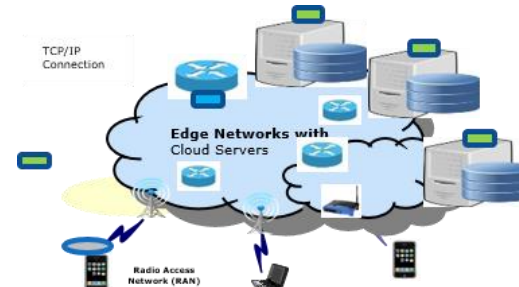
Center's research portfolio spans information theory, radio technology, wireless systems, mobile networks and computing



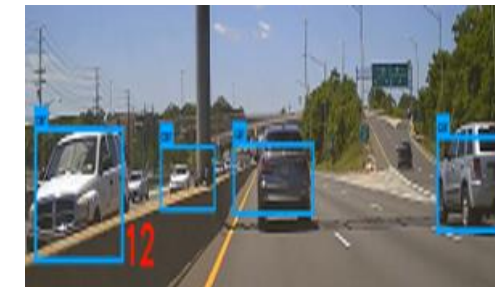
Dynamic Spectrum



Future Internet Arch.



Edge Cloud



Connected Vehicle

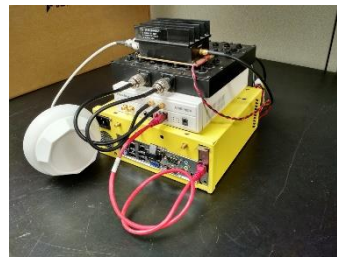
Extensive experimental research infrastructure including ORBIT & GENI testbeds, SDR, SDN, ...



Low Power IoT Device



Massive MIMO



SDR



ORBIT Radio Grid Testbed



GENI Rack



SDN



CloudLab Rack

Thank You!



ONAP

OPEN NETWORK AUTOMATION PLATFORM

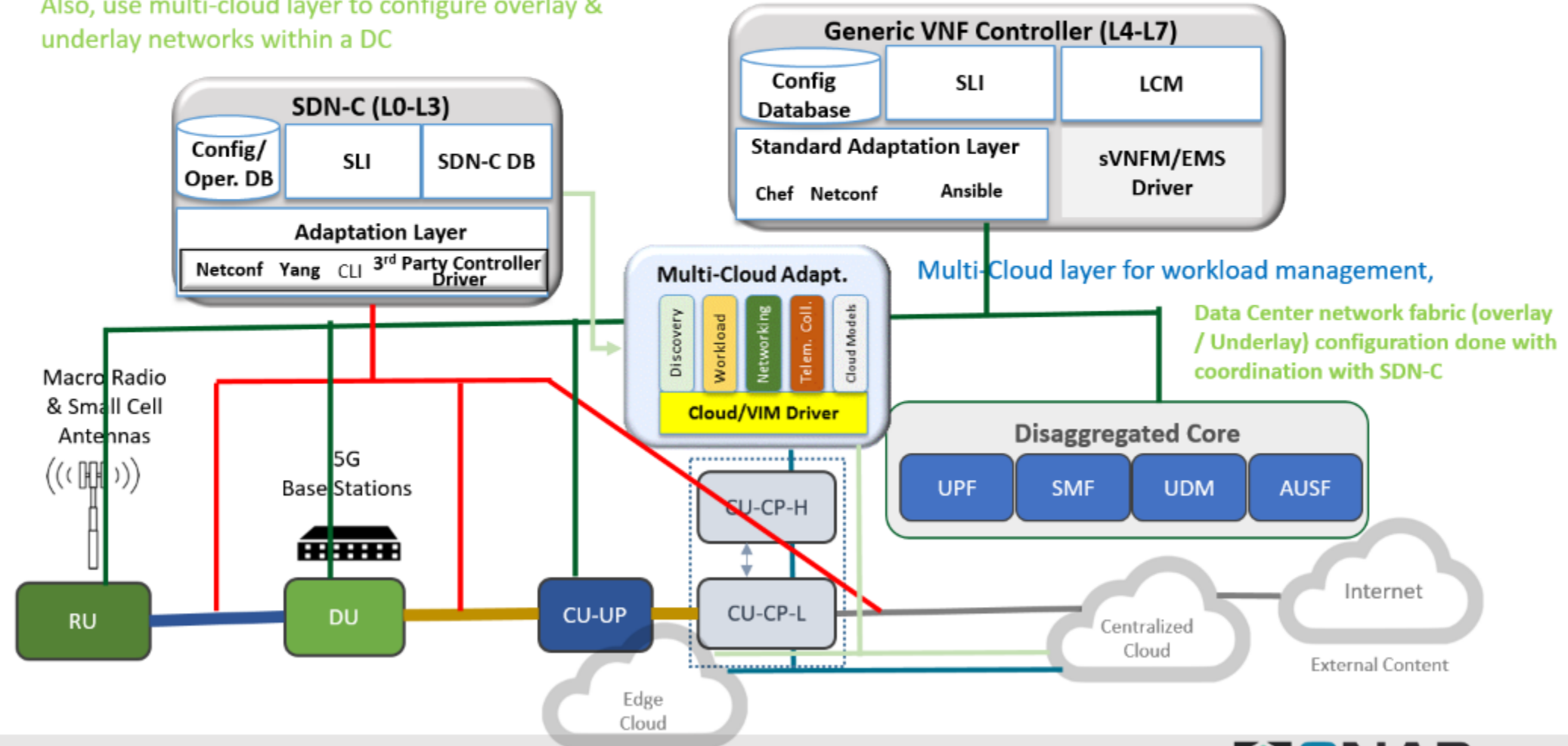
BACKUP SLIDES

Controller Scope to support anticipated 5G use cases

SDN-C (and possibly 3rd party controller) will be used for transport configuration – Front Haul, Mid Haul, Back Haul, etc.

Also, use multi-cloud layer to configure overlay & underlay networks within a DC

App-C (now Generic VNF Controller) is responsible for various network application configuration (PNF / VNF) – DUs, CUs, Disaggregated core, etc.



New Challenges in 5G Use Case

- Support a hybrid network consisting of PNF & VNF across RAN, WAN and EPC
- Support Design, Deploy, Monitor and Management of Network Slice(s)
- Design studio (SDC) enhancement
- Component models: e.g., RAN VNFs, Core VNFs, PNFs, etc.
- E2E model(s): e.g. service chain (tosca) topology, policy model(s)
- AAI enhancements to capture topology & inventory
- SO / App-C / DCAE / Policy enhancements to support for PNF and slice lifecycle management, slice deployment and management
- DCAE / Policy enhancements to support open framework for near-real time network optimization, conflict resolution during design time as well as run time across multiple microservices
- OOF enhancements to support multi-cloud and 5G network optimizations