



CORD: A Platform for “The New Network Edge”



“70% of operators worldwide are planning to deploy CORD”

Michael Howard
IHS Markit

“Nearly 40% of all end-customers (residential, wireless and enterprise, collectively) will have service provided by COs or their equivalents using CORD by mid-2021”

Roz Roseboro
Heavy Reading

Service Provider Traction

North America

- **AT&T:** R-CORD, M-CORD (Multi-Service Edge), vOLTHA
- **Verizon:** M-CORD
- **Sprint:** M-CORD
- **Comcast:** R-CORD
- **CenturyLink:** R-CORD
- **Google:** CORD

Asia & Australia

- **China Unicom:** M-CORD, E-CORD
- **China Mobile:** M-CORD and E-CORD
- **NTT:** R-CORD
- **SK Telecom:** M-CORD
- **Telstra:** M-CORD
- **Reliance Jio:** M-CORD

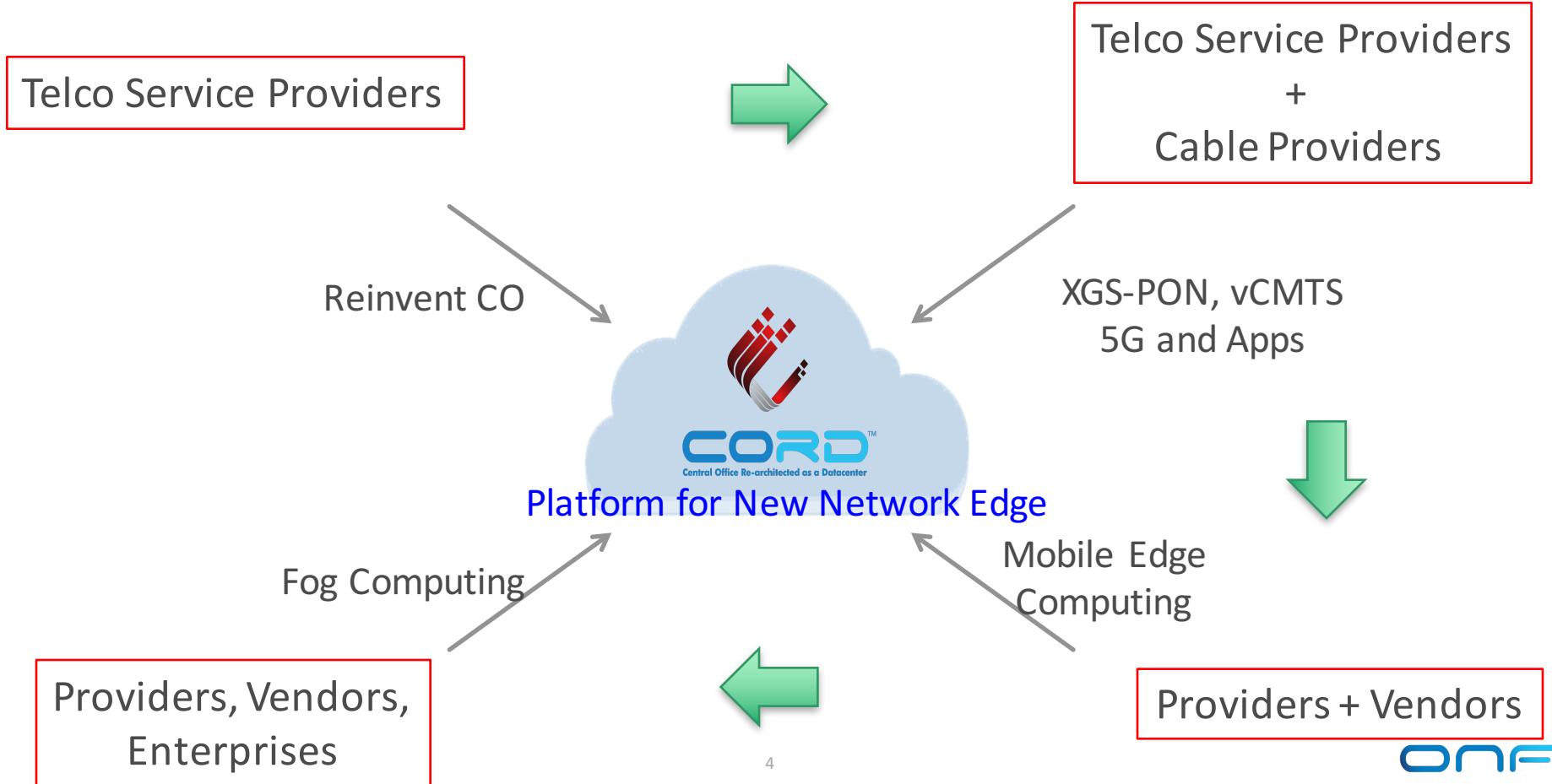
Europe

- **Deutsche Telekom:** R+M-CORD (Hybrid CORD)
- **Telefonica:** R-CORD, M-CORD
- **Telecom Italia:** M-CORD
- **Colt:** R-CORD
- **Turk Telekom/Netsia:** M-CORD & ONOS SDN Control

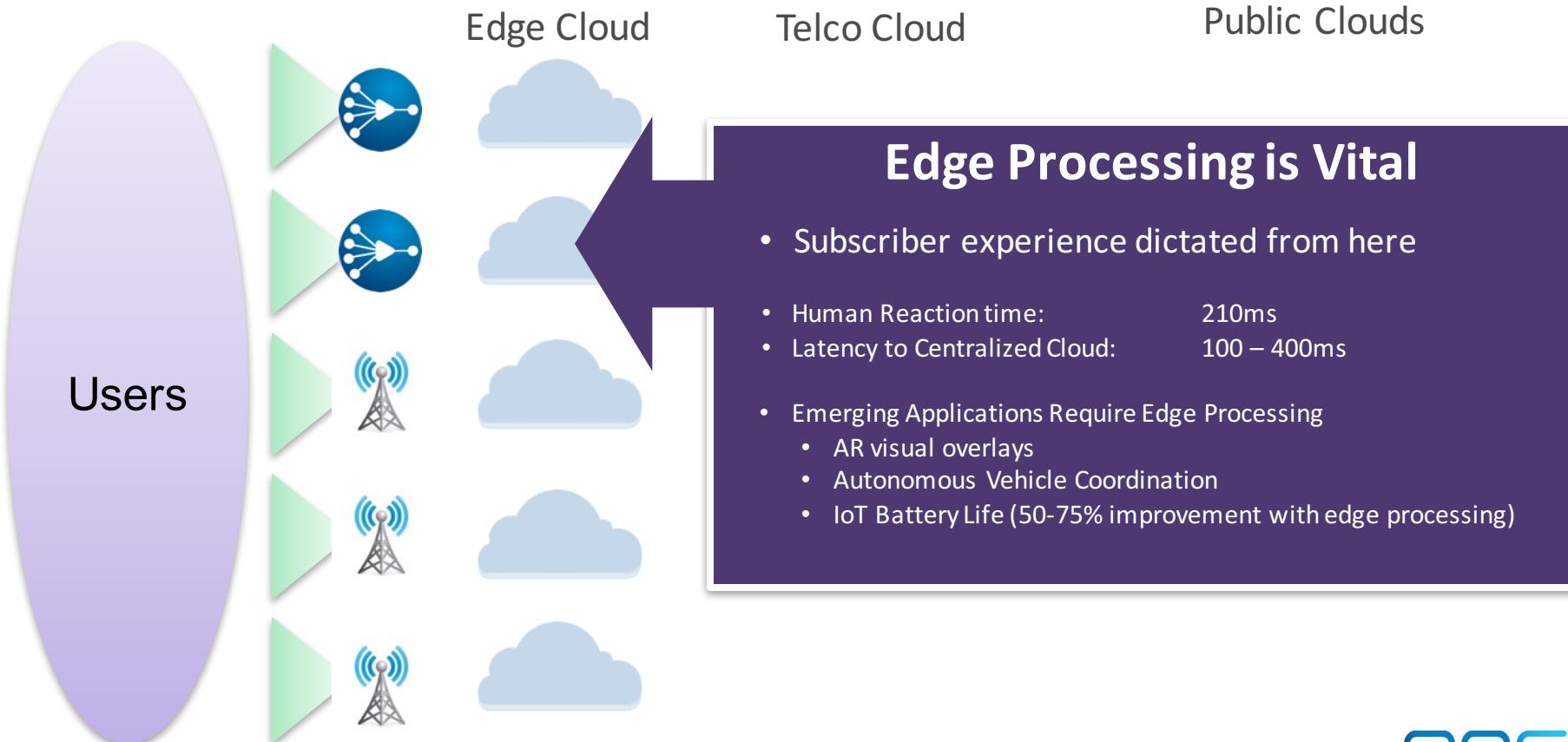
Interest continues to grow on a monthly basis.

Many successful POCs and lab trials and a few field trials

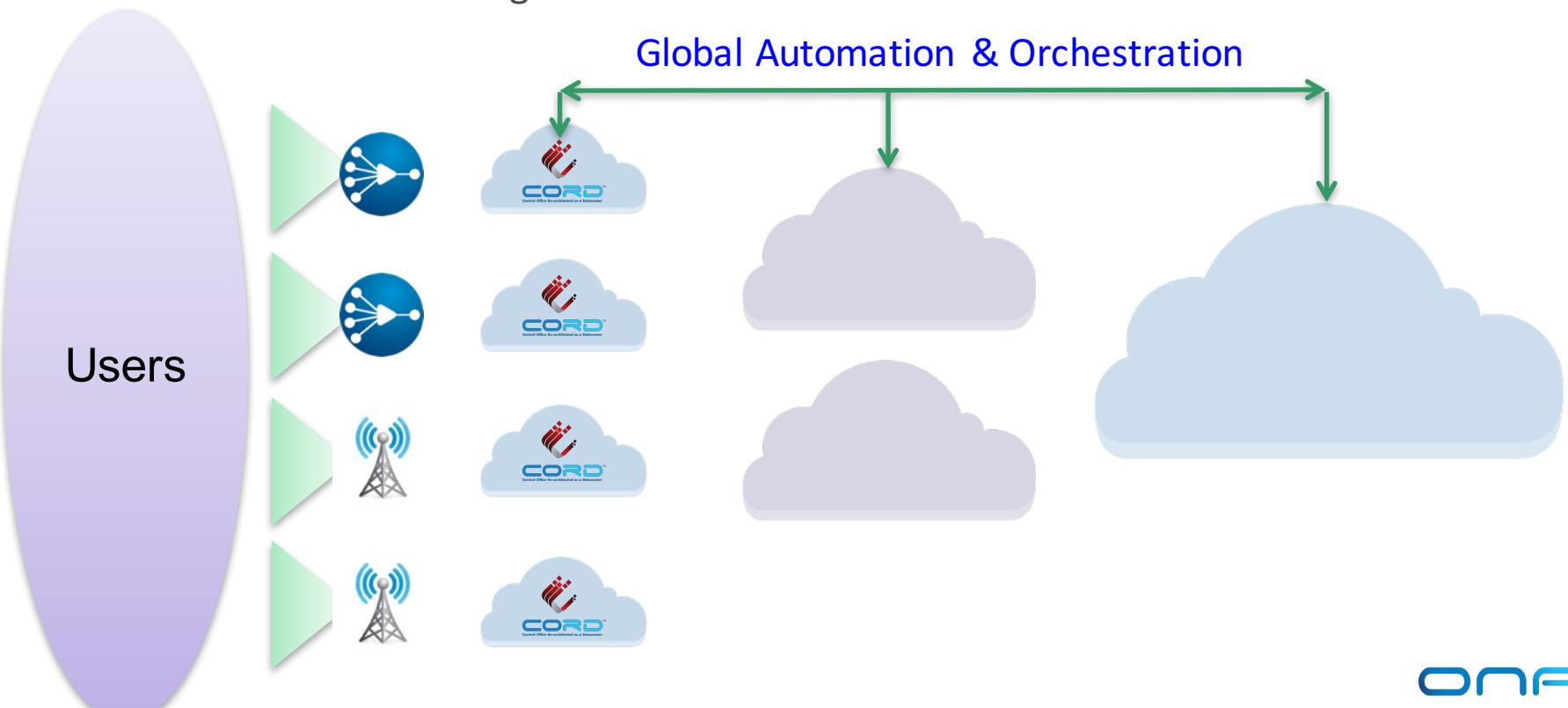
Why is CORD a Big Deal?



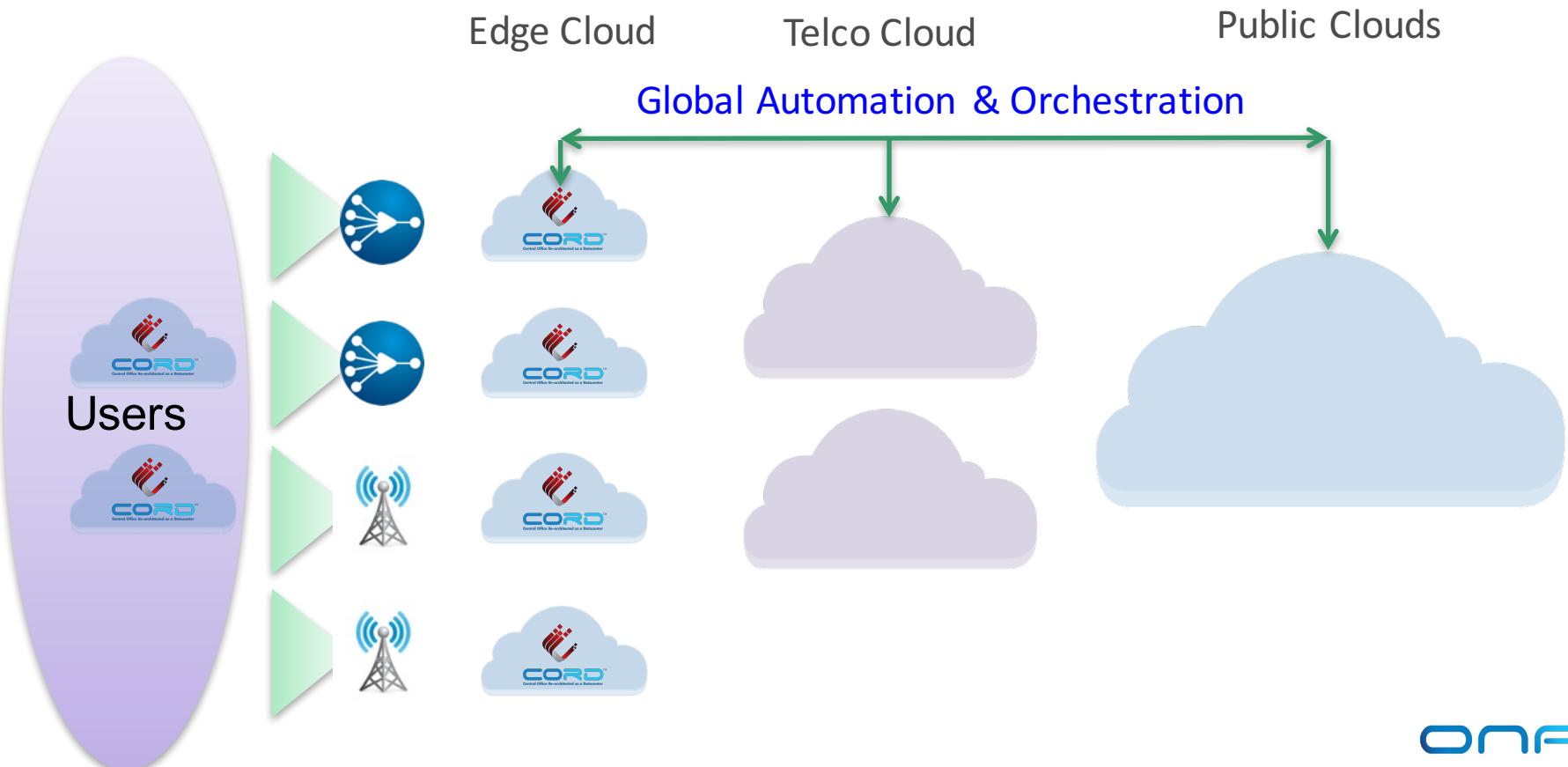
Emerging Multi-Tier Cloud with New Network Edge



Multi-Tier Cloud Needs: CORD for the Edge & Global Automation and Orchestration



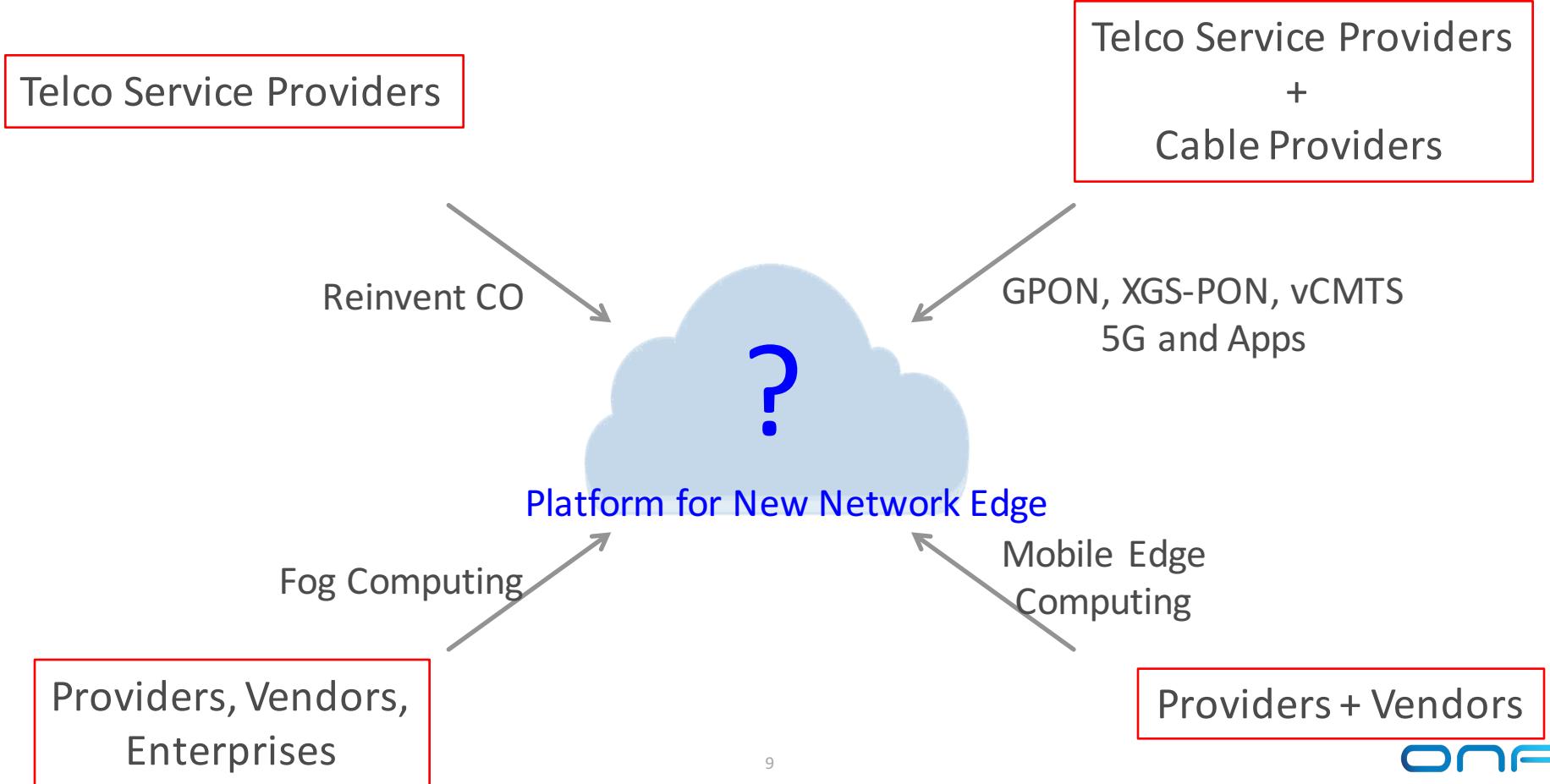
Network Edge Extending into Enterprises





CORD as a Platform for New Network Edge

What does the New Network Edge require?



What does the New Network Edge require?

Functionality

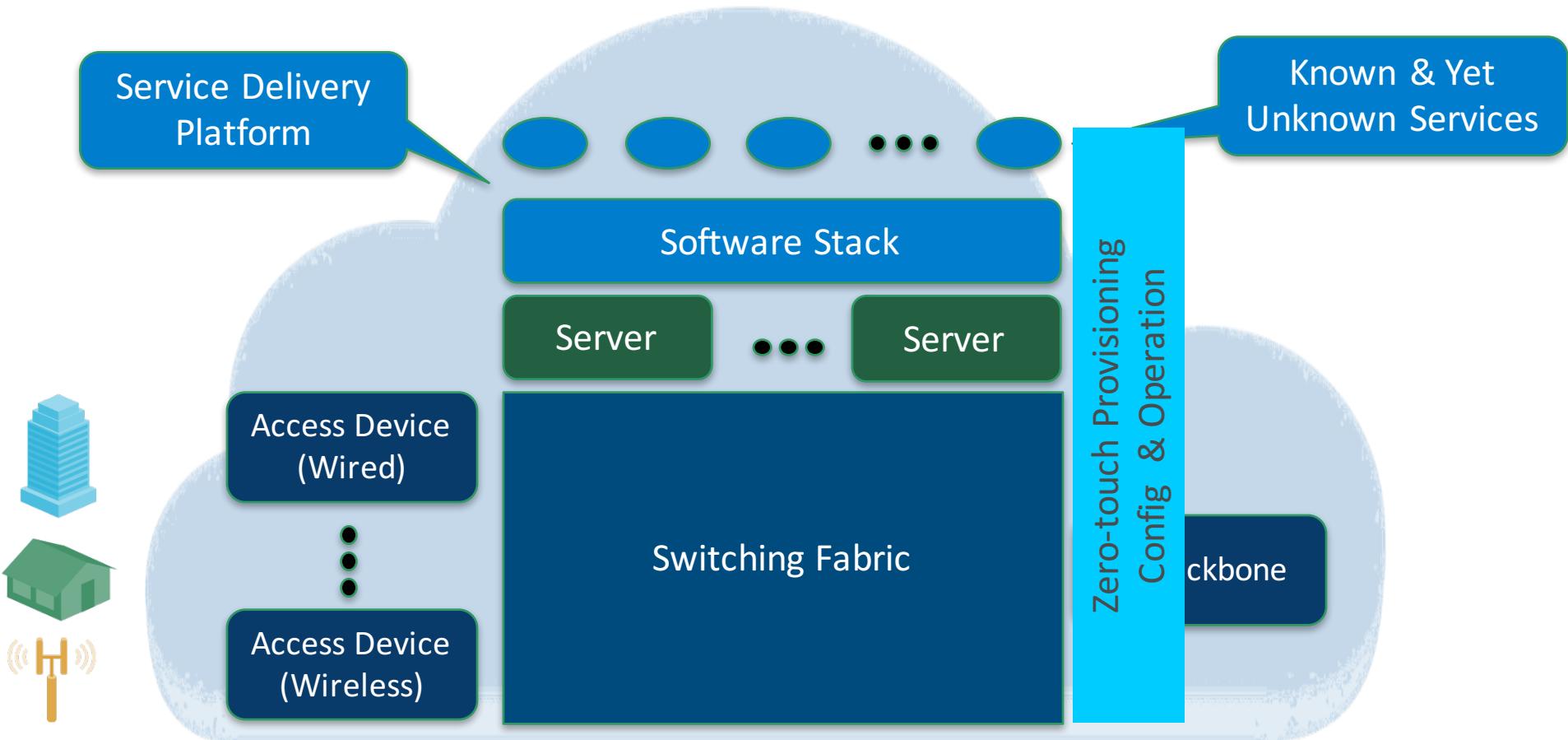
- A service delivery platform
 - For known & yet unknown services
- Many different configurations
 - Small to large
- Ability to plug-in different access devices/technologies
- Programmable control & monitoring
 - Millisecond control loops
- Economics of a datacenter
 - Space and power efficient
- Zero-touch/automated provisioning, config, & operation



Approach

- Built with
 - Merchant silicon
 - White boxes
 - Open source
- Vibrant community
- Future proof
 - Hard to predict services & access technologies
- Proprietary components as “tabasco sauce”

New Network Edge Platform Generic Architecture



CORD as the New Network Edge Platform: Specifics

~25 services
residential, mobile, &
enterprise use cases



- Software Stack:
- OpenStack/Docker/Kubernetes
 - ONOS, XOS

OCP
Server

OCP
Server

Metro-Ethernet

GPON OLT

XGS-PON OLT

RAN

eNB w/ xRAN

- Switching Fabric:
- Leaf-Spine Fabric
 - OpenFlow/P4 enabled
 - White Boxes
 - ONOS as SDN OS
 - Fabric Apps on ONOS

ROADM

Disaggregated
ROADM

Zero-touch Provisioning
Config & Operation
With MAAS, Ansible, Docker,
Kubernetes, XOS

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Metro-Ethernet

GPON OLT

XGS-PON OLT

RAN

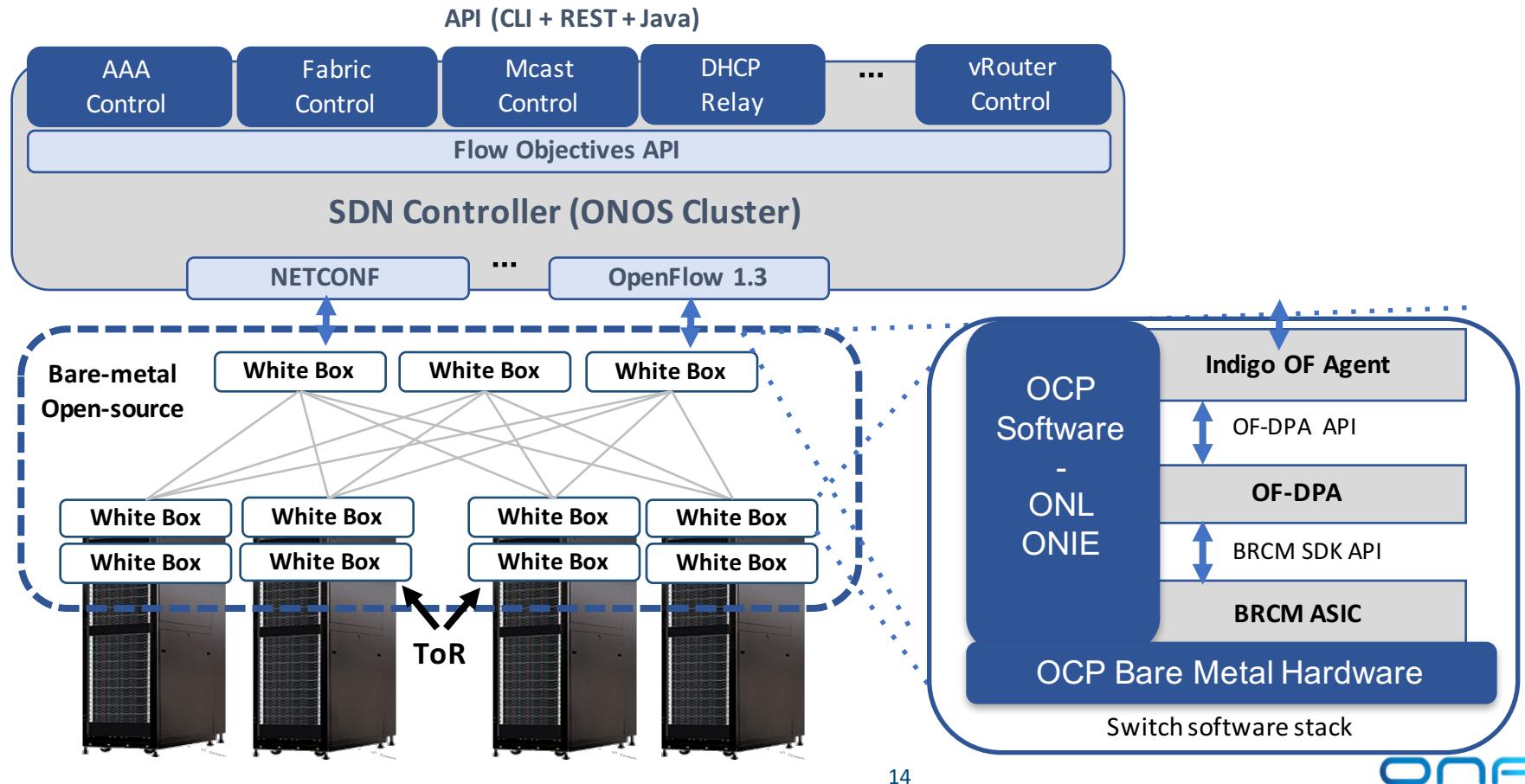
eNB w/ xRAN

ROADM

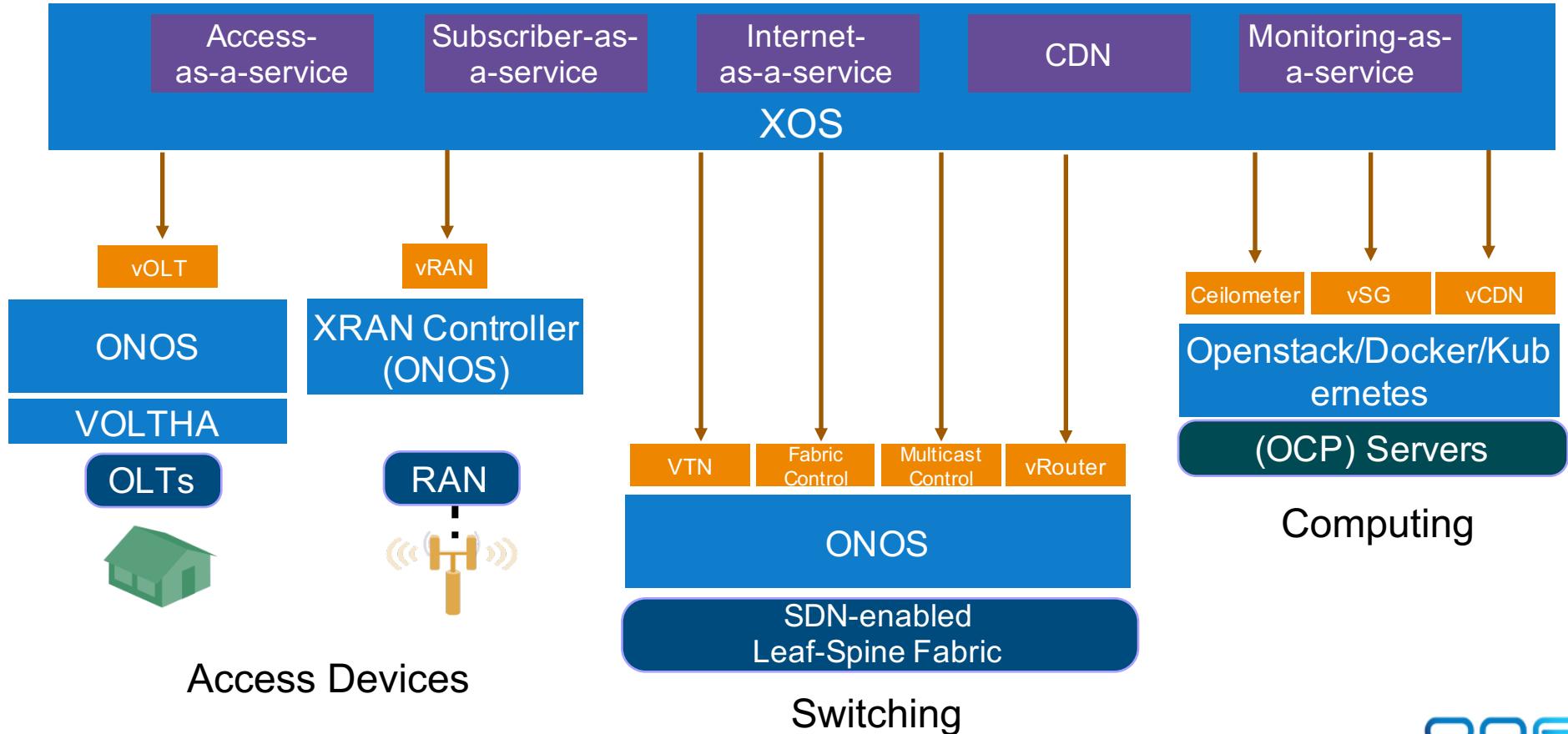
Disaggregated
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With MAAS, Ansible, Docker,
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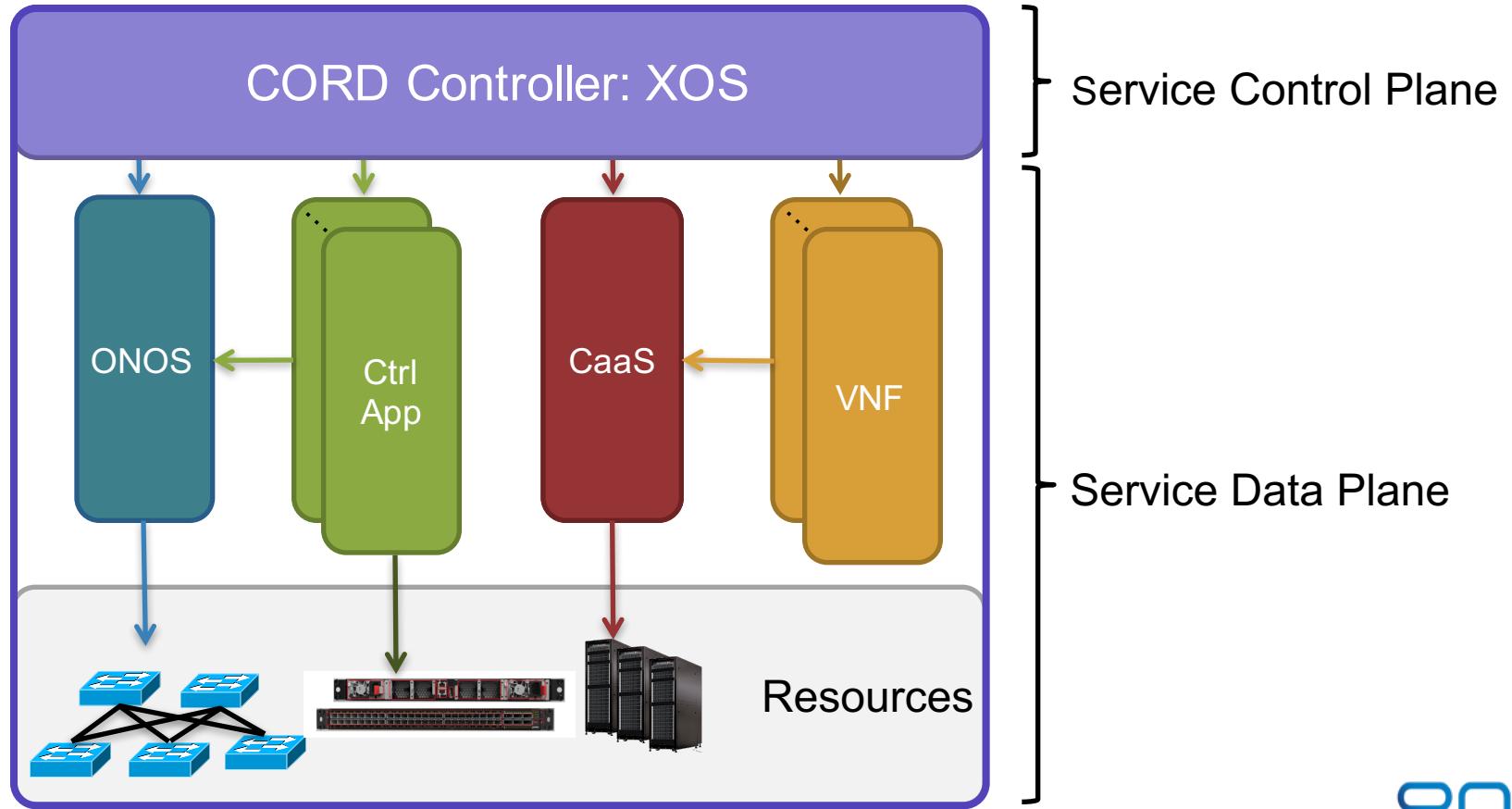
Trellis Fabric – Bare-metal + Open-Source + SDN



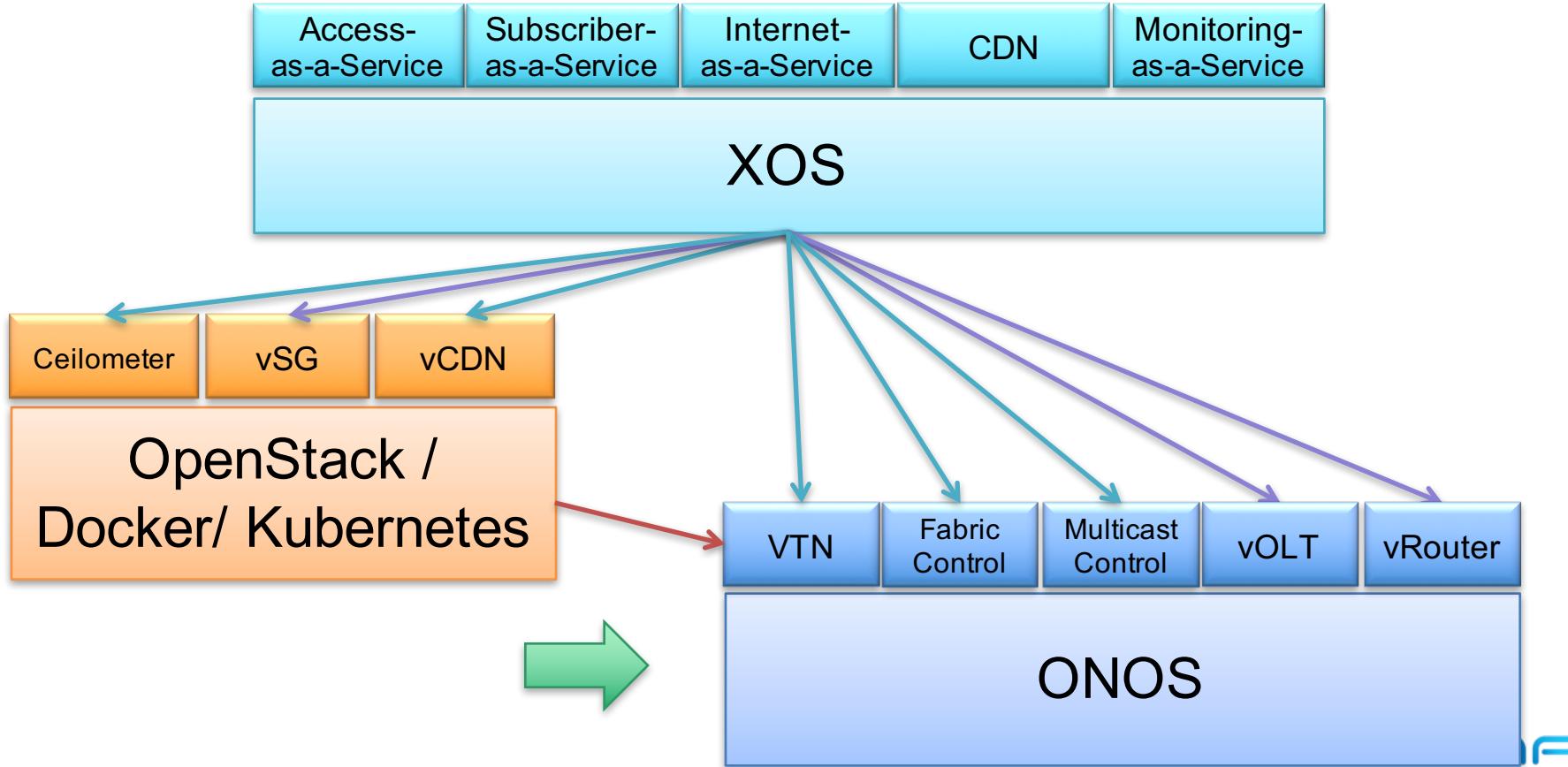
CORD Software Stack: Everything as a Service



CORD Software Architecture: Everything as a Service

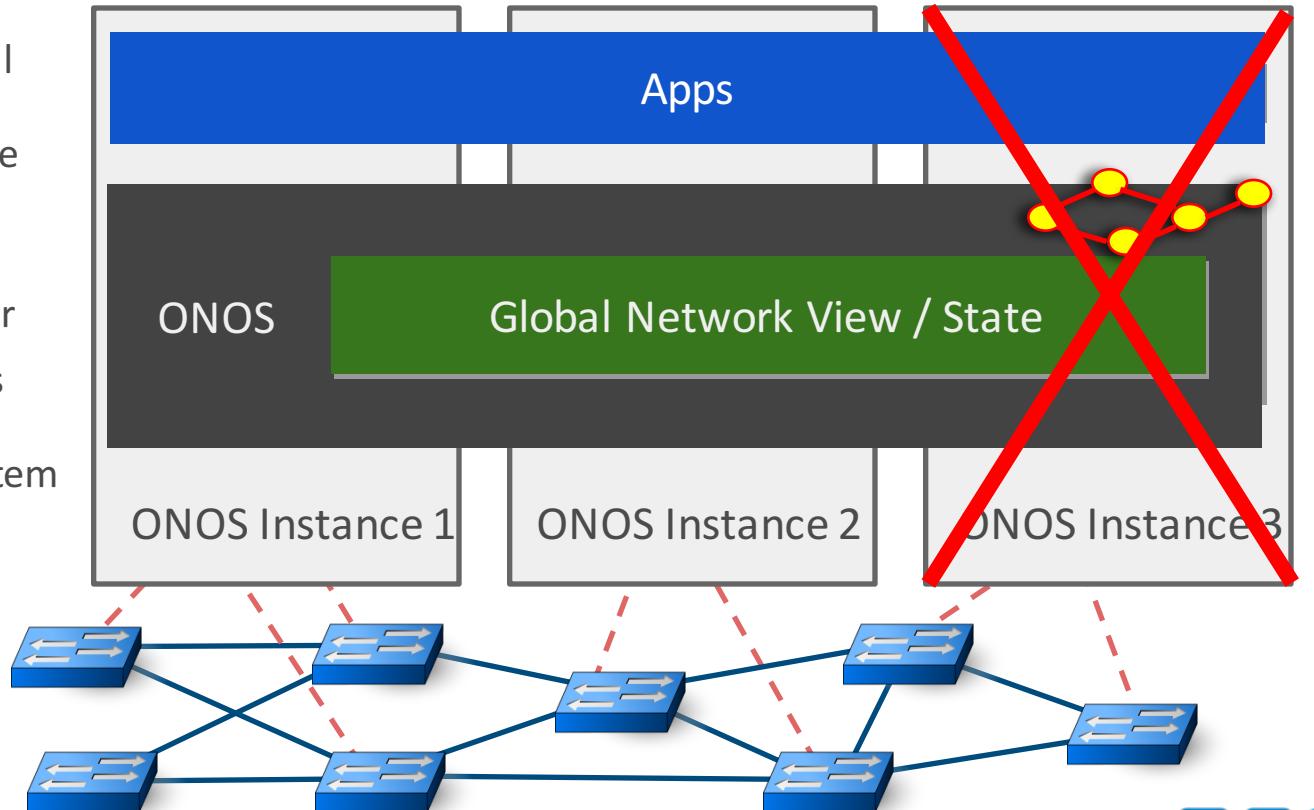


XOS: Service OS or CORD Controller



ONOS: SDN OS for Service Providers

- Each instance is identical
- One can add and remove instances seamlessly
- Each instance is a master for a sub-set of switches
- It works like a single system for apps and network devices



ONOS Architecture Tiers

Northbound Abstraction:

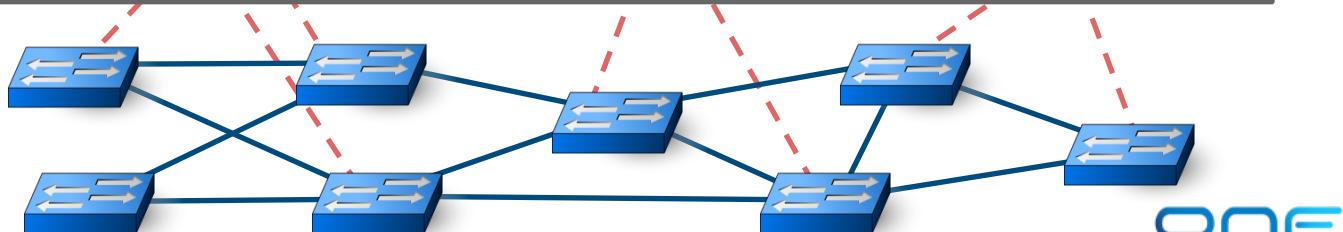
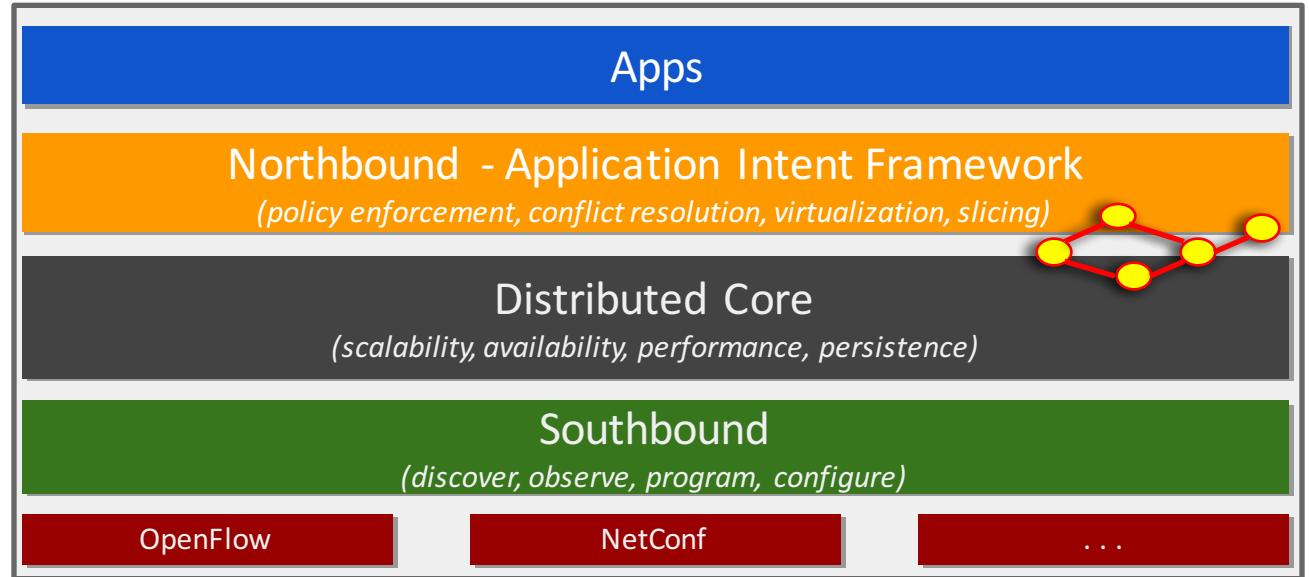
- network graph
- application intents
- virtualization & slicing

Core:

- distributed
- protocol independent

Southbound Abstraction:

- generalized OpenFlow
- pluggable & extensible



State of ONOS : Core

- Proven out its strong architecture foundation for scalability, performance, HA, modularity
- Model based dynamic configuration of devices and services
 - Late to the party compared to ODL, but now have several benefits beyond ODL
 - Ready for vendors and use case developers to start using ONOS for dynamic config
 - Will be ready for prime time in next release in Jan 2018
- In-service software upgrade (ISSU) – taking ONOS HA to the next level
 - Basic mechanisms in place
 - Will be ready for use in next release in Jan 2018
- Performance and Scalability
 - 12 consecutive releases: maintained or improved performance
 - ~3M flow ops/sec, ~225k intents/sec, less than 10ms latency to react to network events, ...

State of ONOS: South Bound

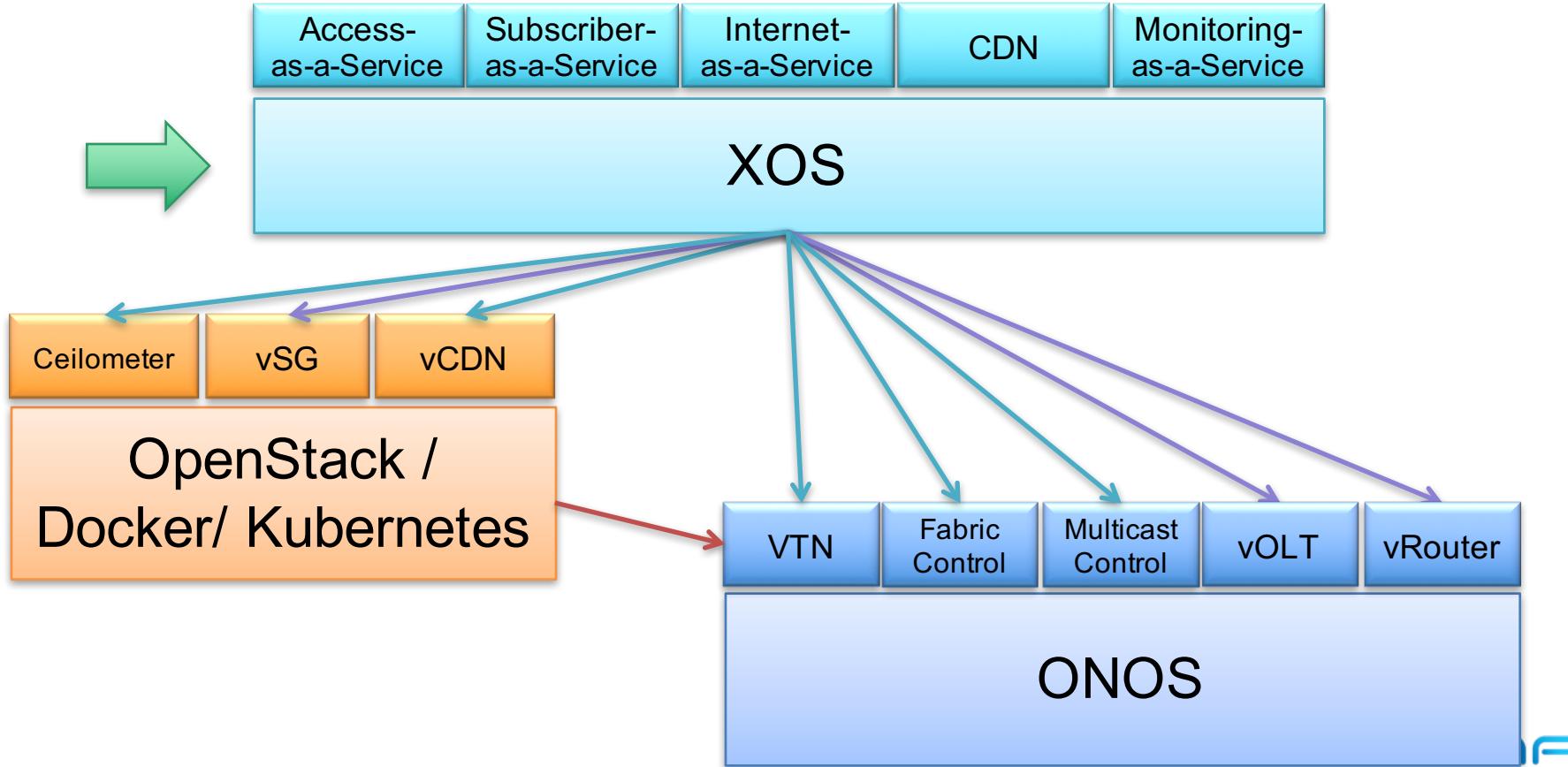
- ONOS first few releases
 - Focus on OpenFlow
- ONOS subsequent releases
 - Focus (led by vendors) on legacy protocols – most legacy protocols supported
- ONOS recent and future releases – “back to the future”
 - Focus is on device disaggregation: packet switches (P4), OLT (VOLTHA), eNB/RAN (xRAN), ROADM

**Validates wisdom and power of protocol and device independence
of the ONOS architecture**

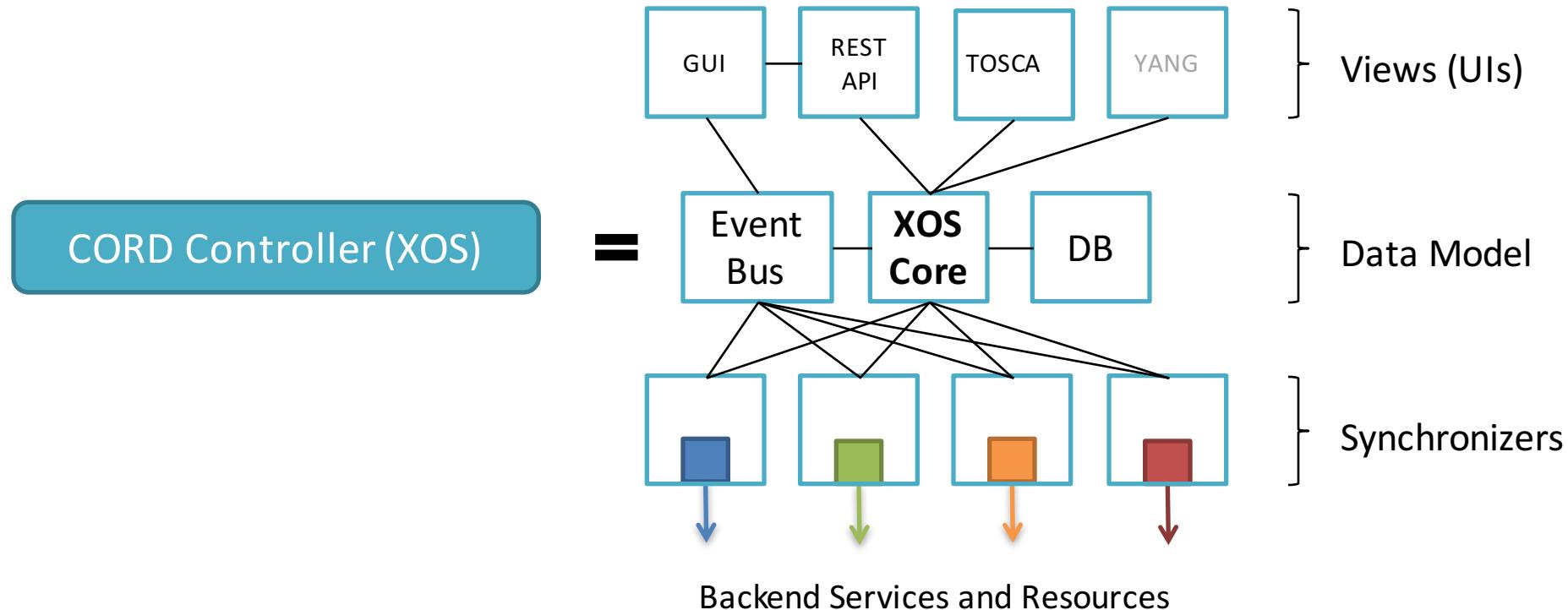
State of ONOS: Applications

- ONOS platform now supports 125 applications
 - Small platform extensions & larger user apps
 - Contributed by ONF as well as many community members
- ONOS build will allow a user/vendor to build ONOS with specified services for a given use case or a solution
- Categories of apps include
 - Device Drivers
 - Protocols & Providers
 - Models
 - Traffic Steering
 - Monitoring
 - Security
 - Utilities
 - Test Utilities

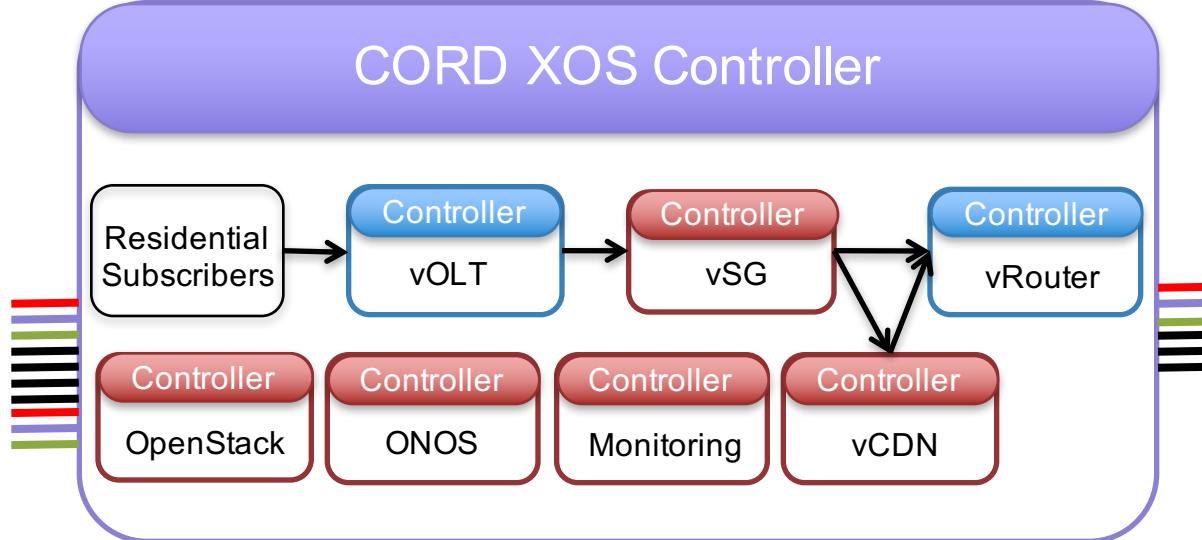
XOS: Service OS or CORD Controller



XOS Constructed from Micro-Services



CORD: Everything as a Service and Service Graphs



CORD: Automated Provisioning, Config, & Operation



- Power up hardware
- MASS to discover hardware and initial component boot



- Ansible to install & configure foundational software (e.g., Docker)



- Docker to install & configure CORD-specific management software (e.g., XOS, ONOS)
 - Working on getting k8s working with Docker



XOS

- XOS/ONOS install & configure services (k8s will play a role here too)
- XOS defines the "Service Control Plane" from which operators control & manage (i.e., operate) CORD

CORD POD Builds for CI

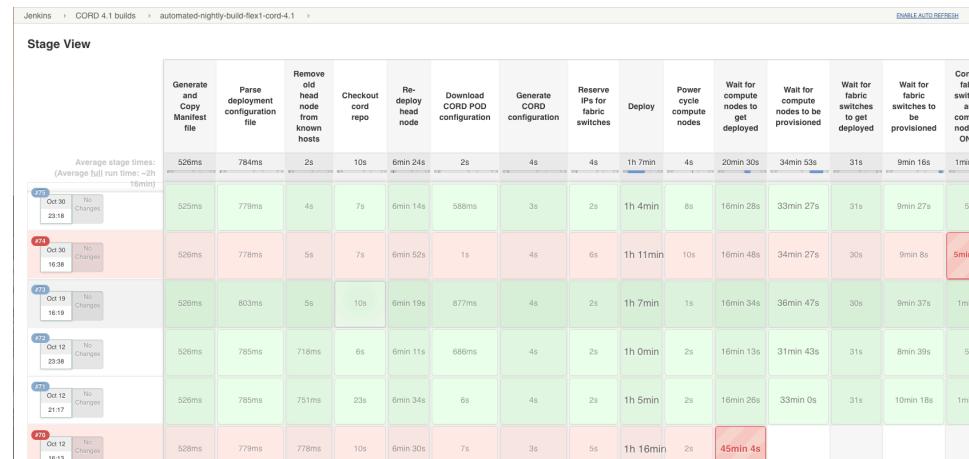
- All Nightly Jenkins Jobs: <https://jenkins.opencord.org/>

- Cord-in-a-Box (CiaB) Virtual Builds:

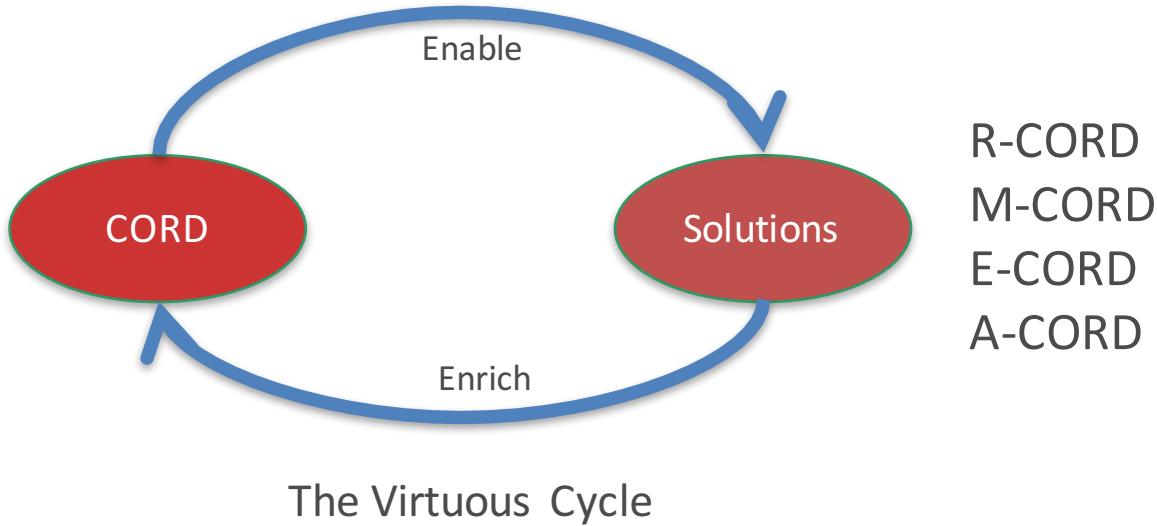
- Cord 3.0: <http://tinyurl.com/nightly-ciab-3-0>
- Cord 4.0: <http://tinyurl.com/nightly-ciab-4-0>

- Physical Pod Builds (Calix, Flex, QCT):

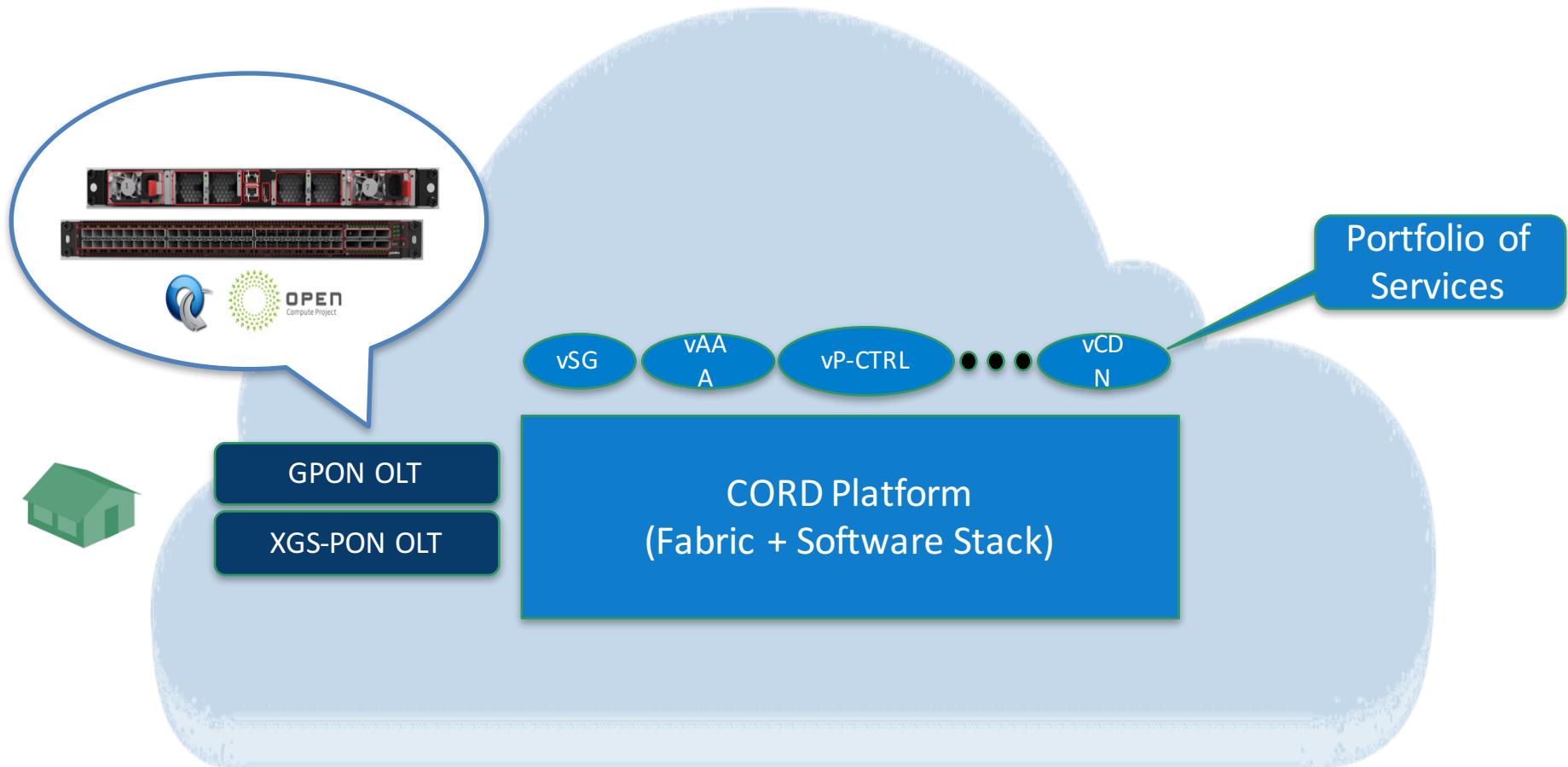
- Cord 3.0: <http://tinyurl.com/nightly-3-0>
- Cord 4.0: <http://tinyurl.com/nightly-4-0>
- Cord 4.1: <http://tinyurl.com/nightly-4-1>



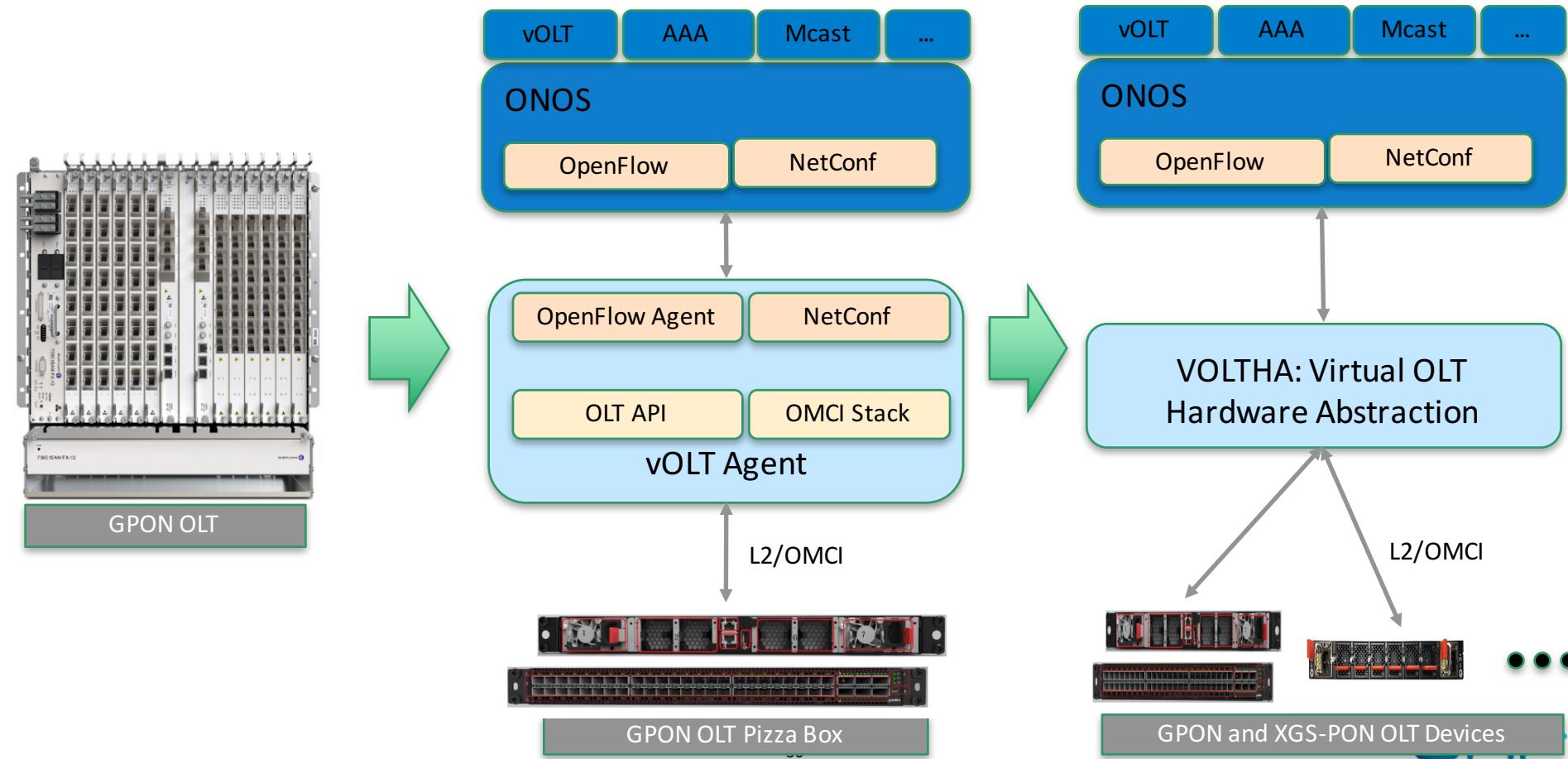
CORD Journey: 2015-Now



R-CORD: GPON and XGS-PON for Residential Customers

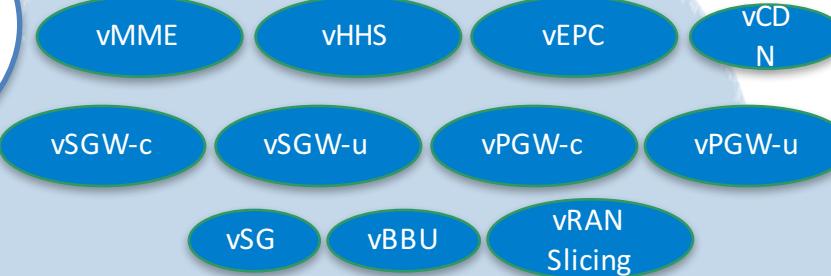


Approach to Access Devices: OLT Disaggregation



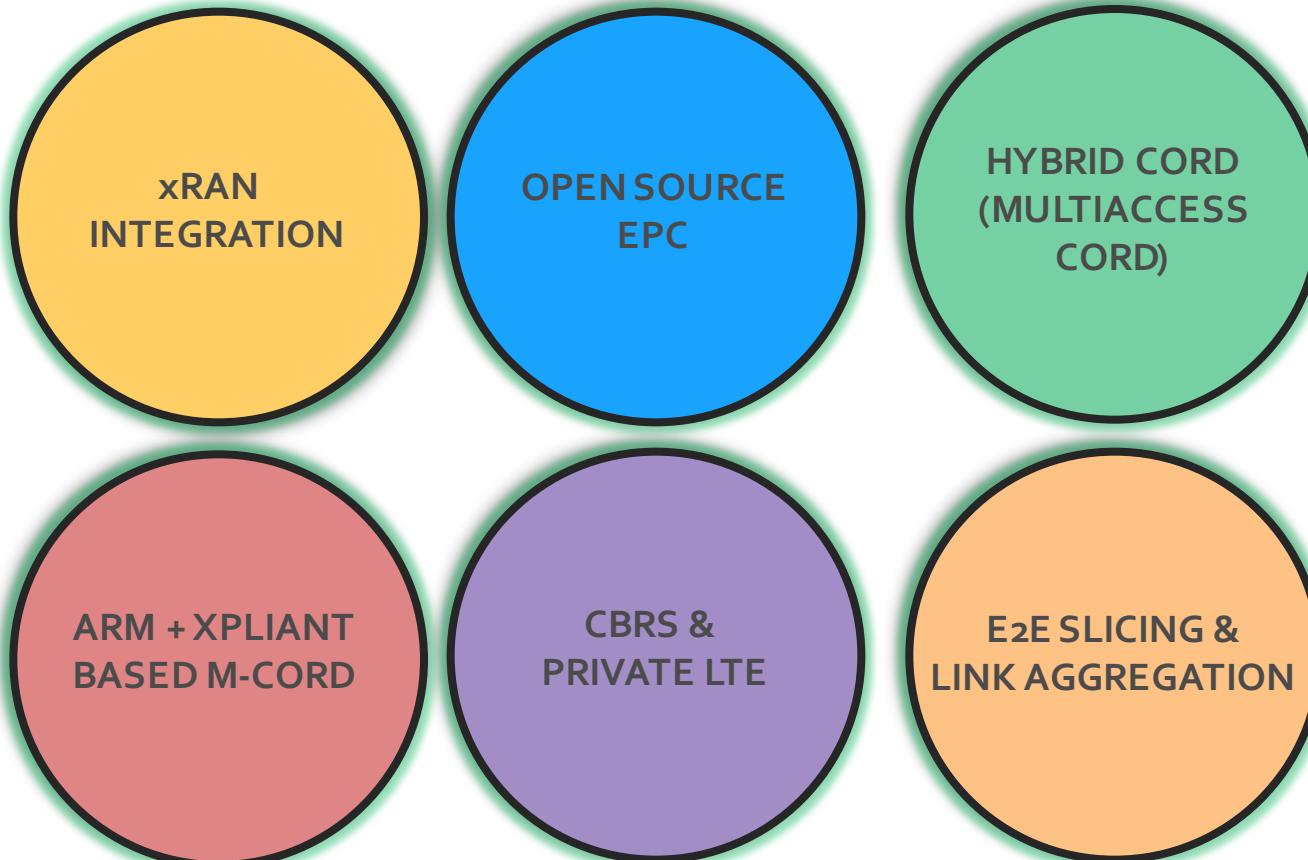
M-CORD: Enabling 5G

Disaggregated &
Virtualized RAN
With RAN Slicing

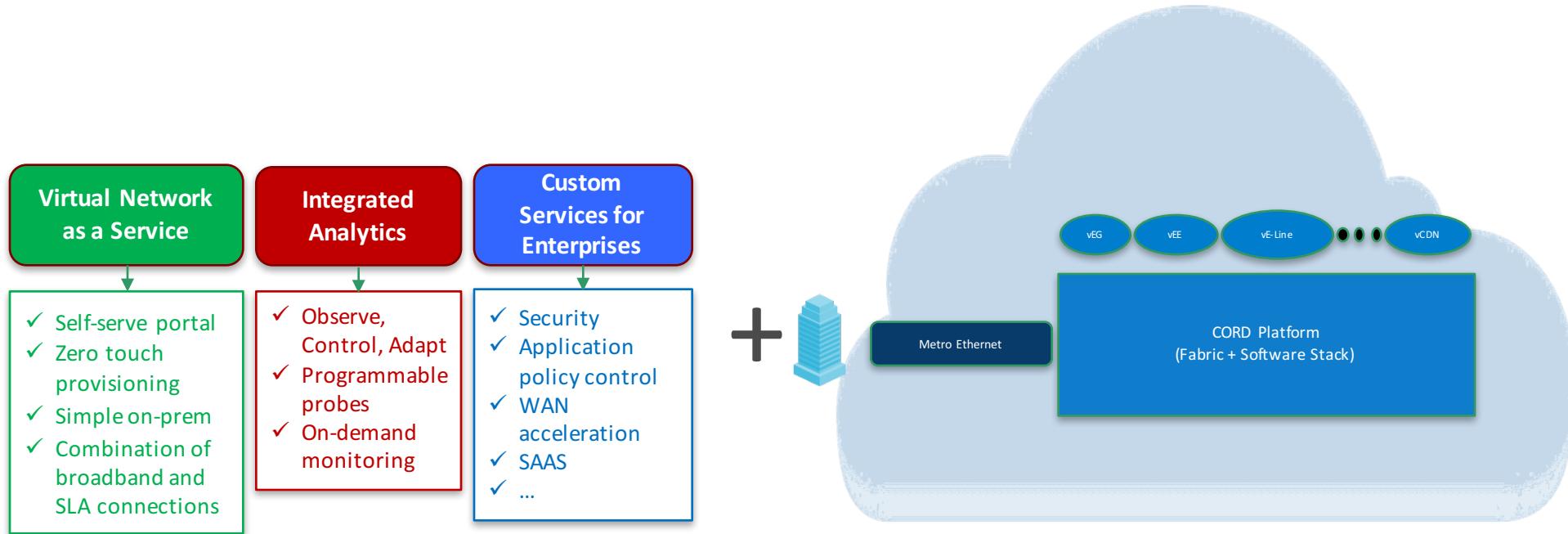


Disaggregated &
Virtualized EPC
EPC Slicing
MEC

M-CORD Capabilities Demonstrated at MWC San Francisco



E-CORD: For Enterprise Services



**Carrier-grade Network as a Service
Built on an open platform**

Bring data center economy and cloud agility

[R, E, M] CORD Service/VNF Portfolio

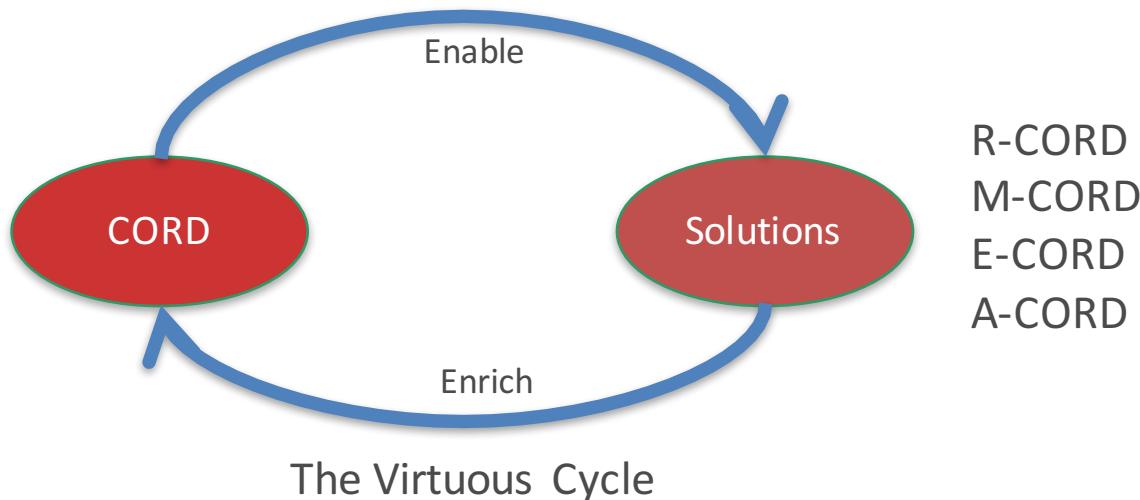
All Open Source But Many POC/Trial Quality

- Common Infrastructure Services
 - Monitoring-as-a-service, vRouter, Virtual-tenant-networking & Service-chaining (VTN)
- R-CORD services
 - vOLT (VOLTHA), vSubscriberGW (vSG – NAT, QoS, Access-control), IPv4 multicast-video, AAA (802.1x), DHCP

Bring your favorite (even proprietary) VNF!
Love to demonstrate on CORD!

- CORD-based control of CPE and Ethernet Edge (vCPE & vEE)
- Connectivity services for Carrier Ethernet remain in hardware datapath (pseudo wire service)
- Virtual Enterprise Gateway(vEG) container for DHCP, NAT, DNS and firewall
- Edge services
 - CDN, Parental-control

CORD Journey: 2015-Now



POCs/Demos



ONS-2015



ONS-2016



BBWF-2016



MWC-2017



ONS-2017



MWC-A-2017



BBWF-2017

CORD Releases



R 1.0



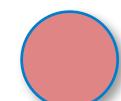
R 2.0



R 3.0



R 4.0



R 4.1

CORD 4.0 and 4.1 Releases

CORD individual subsystems and the integrated platform moving

- From POC to developer friendly to operator friendly
- From POC quality to field trial ready
- On-boarding of services (VNFs): From hand crafted complex process to an easy to follow
- [R,E,M]-CORDs: From separate to integrated R, M and E (services on same platform)
- Services (VNFs): From a small set to a portfolio of rich services for R, M, E CORDs

Timing is Perfect!

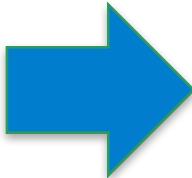


CORD is Taking Off!

Lot of Opportunities to
Contribute

We want to do everything to
help you contribute!

CORD's Appeal to Developers?



Intellectually Challenging & Rewarding

Latest Technologies

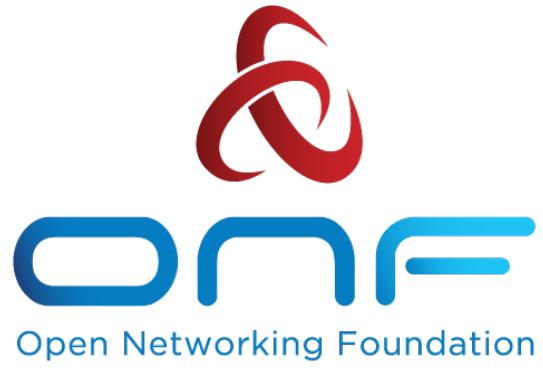
Transformative Impact

Shortest Time to Impact

Fun Global Community

CORD Summary

- Network edge is undergoing a major transformation
 - Represents a huge opportunity
- CORD has emerged as a compelling platform for the new network edge
 - Leverages disaggregation, open source and white boxes
 - Puts SDN, NFV and cloud technologies into a compelling solution
 - Many service providers experimenting and have plans for trials and deployment
 - CORD has a growing community of 60+ companies representing various stakeholders
- CORD has been demonstrated to support all three domains of use
 - Residential (R-CORD)
 - Mobile (M-CORD)
 - Enterprise (E-CORD)



The ONF Ecosystem

Operator Led Consortium

Partner

Operators (8)

Vendors (10)



ONF Board

ONF (& Stanford) Guru Parulkar

Network Operators

AT&T	Andre Fuetsch – CTO
China Unicom	Shao Guanglu - SVP
Comcast	Rob Howald– VP
DT	Jochen Appel -- VP
Google	Amin Vahdat – Fellow
NTT Comm	Dai Kashiwa – Director
Turk Telekom	Cengiz Dogan, CTO
Verizon	Srini Kalapala – VP

Research & Vendor Community

Nick McKeown	Stanford
Fabian Schneider	NEC

Innovator (110+)

Including 13 Operators:

China Mobile	Swisscom
SK Telecom	Telecom Italia
ECI Telecom	Telefonica
Facebook	TELUS
Globe Telecom	Vodafone
Goldman Sachs	Yahoo
Microsoft	

Collaborator (70+)

Volunteers

100s



ONF Mission

Transforming Networks into Agile Platforms for Service Delivery

Leveraging Disaggregation and Open Source to
Build Innovative Solutions for Operator Networks and
Catalyze our industry to accomplish this transformation

ONF Open Innovation Pipeline

Enabling Solution Customization

1 Different pieces can be plugged together to build solutions

2 Software Defined Standards solidify interfaces to enable easy integration of components from the broader ecosystem

Disaggregated Devices/White Boxes
Packet switches
OLT
eNB/RAN
ROADM

Controllers

Solution

VNFs
Micro-Services

Solutions

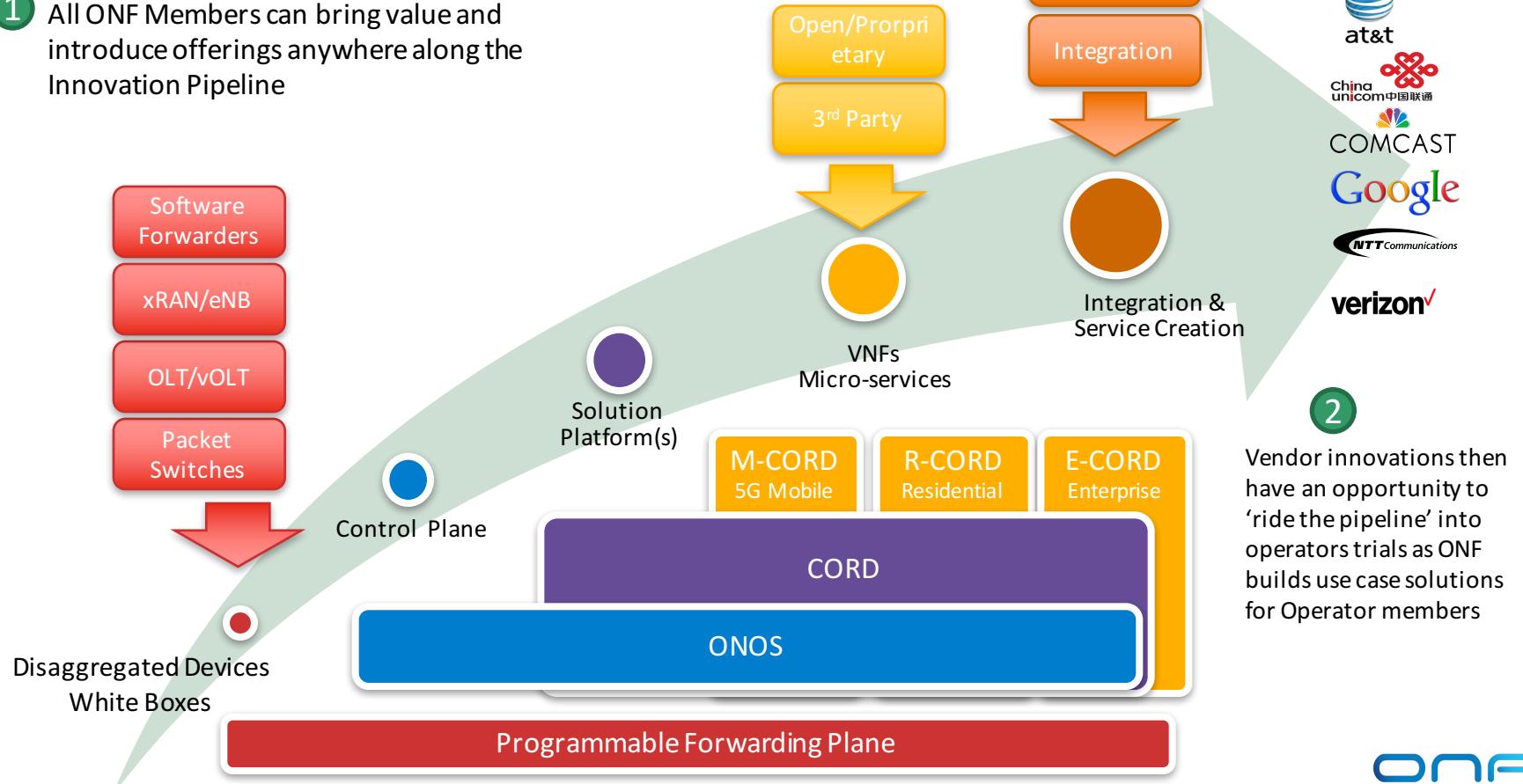
Building solutions for different use cases



3 Solutions are easier to build, customize and consume

Open Innovation Pipelines

- 1 All ONF Members can bring value and introduce offerings anywhere along the Innovation Pipeline



ONF Unique Approach

- A strong partnership with service providers
 - Complemented by rest of the ecosystem
- A small and strong independent engineering team
 - For architecture shepherding and core engineering
 - To pursue disruptive technologies & business models: white boxes, open source
- An open source developer community
 - With the “brigade model” to scale with focus and accountability
- Focus on the virtuous cycle of platforms and solutions
 - Platforms enable new solutions; and new solutions help platforms
- Work at the leading edge of technology, take risks, and demonstrate potential of innovative technologies/platforms
- A combination of open source and software defined standards (to be proven)

The approach is necessary & working to move our industry forward and we want to build on it

