



# 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

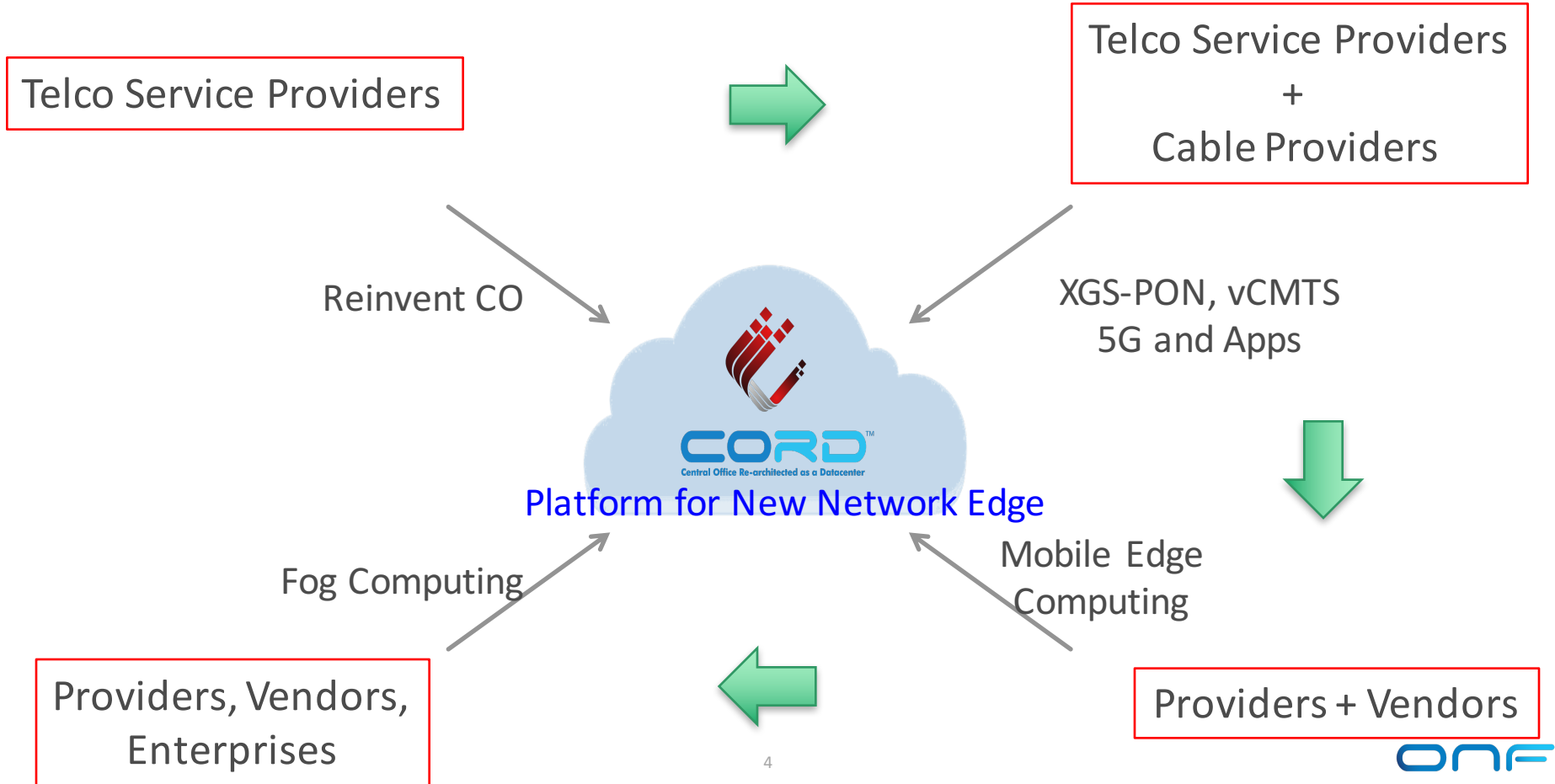
## Europe

- **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

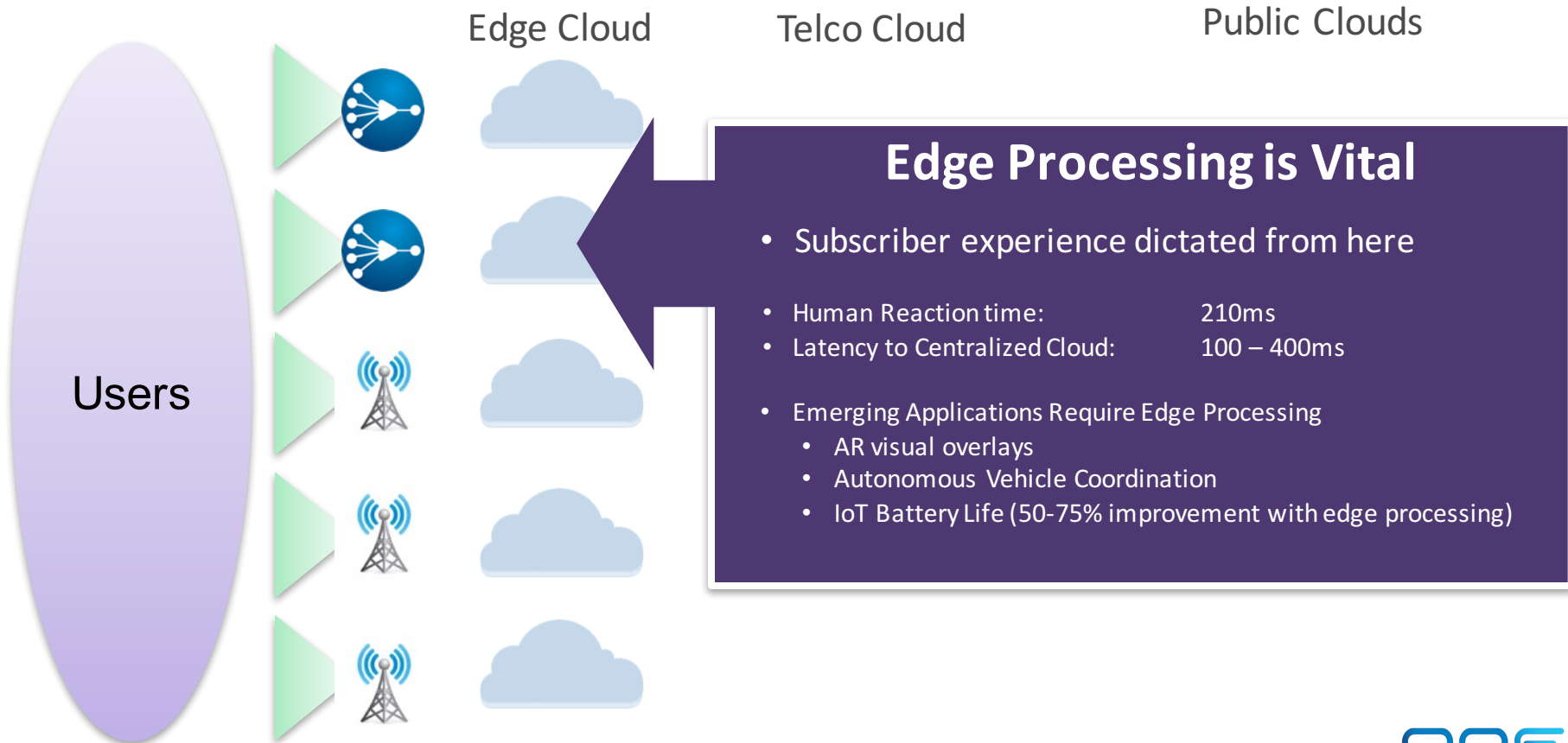
**Interest continues to grow on a monthly basis.**

**Many successful POCs and lab trials and a few field trials**

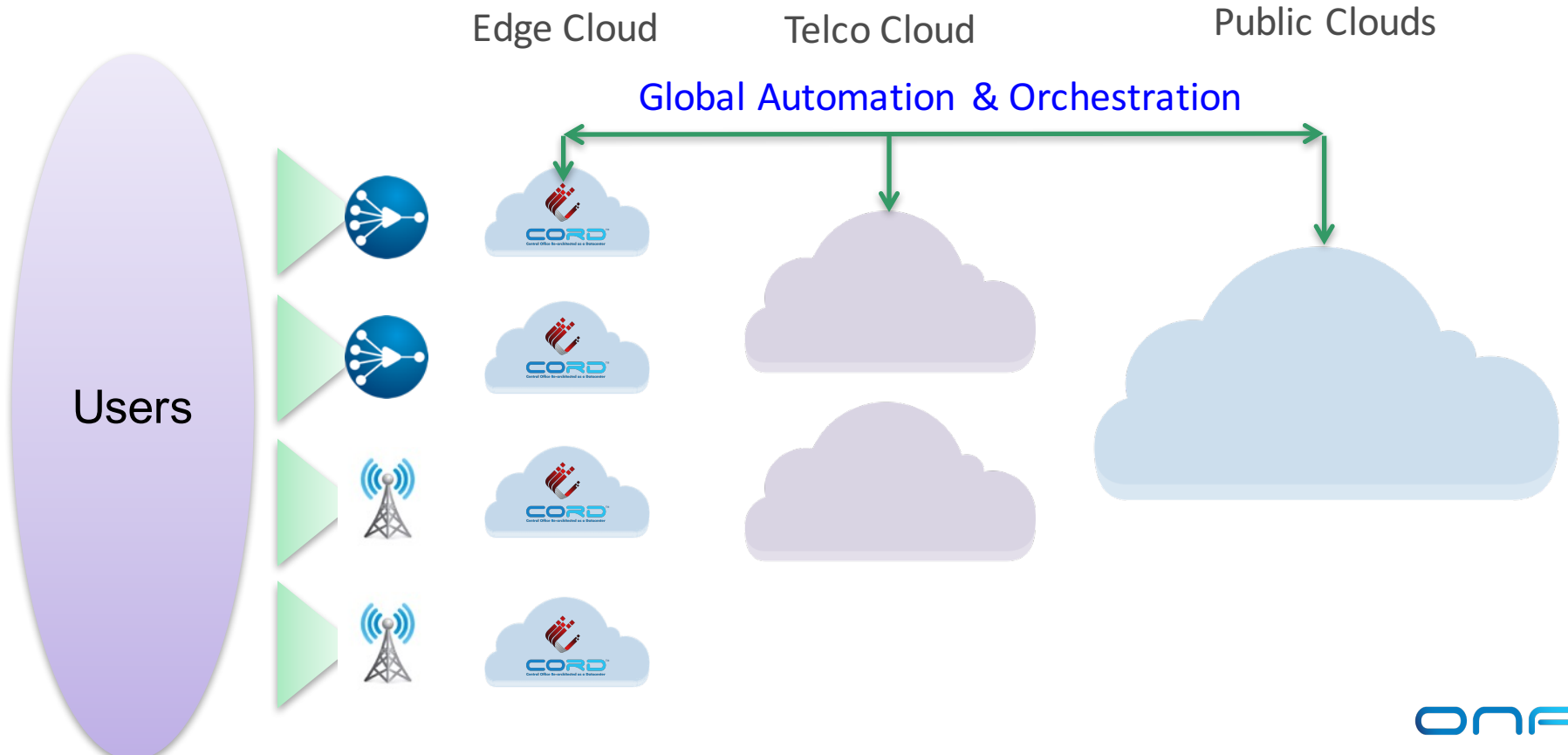
# Why is CORD a Big Deal?



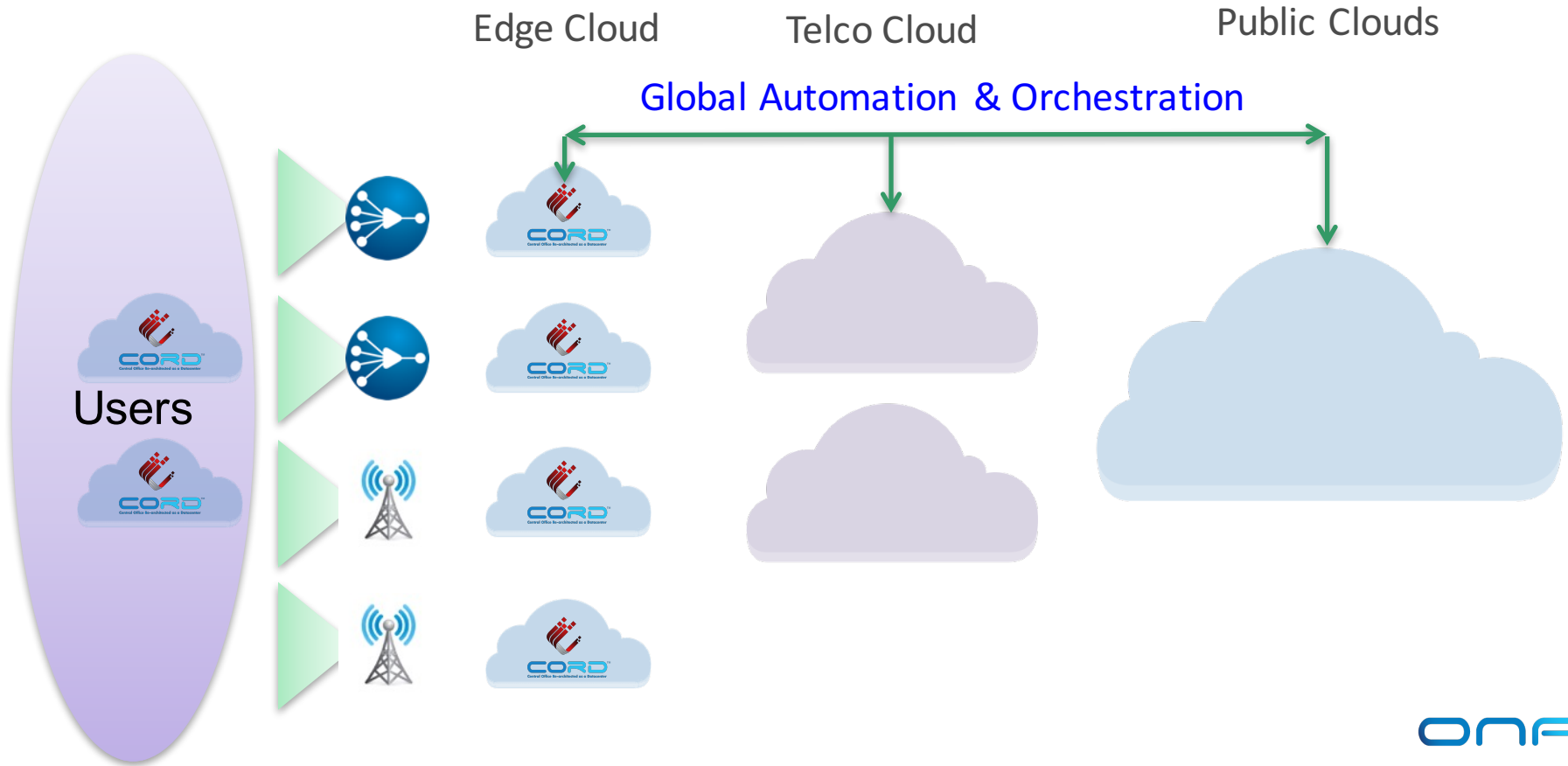
# Emerging Multi-Tier Cloud with New Network Edge



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



# Network Edge Extending into Enterprises

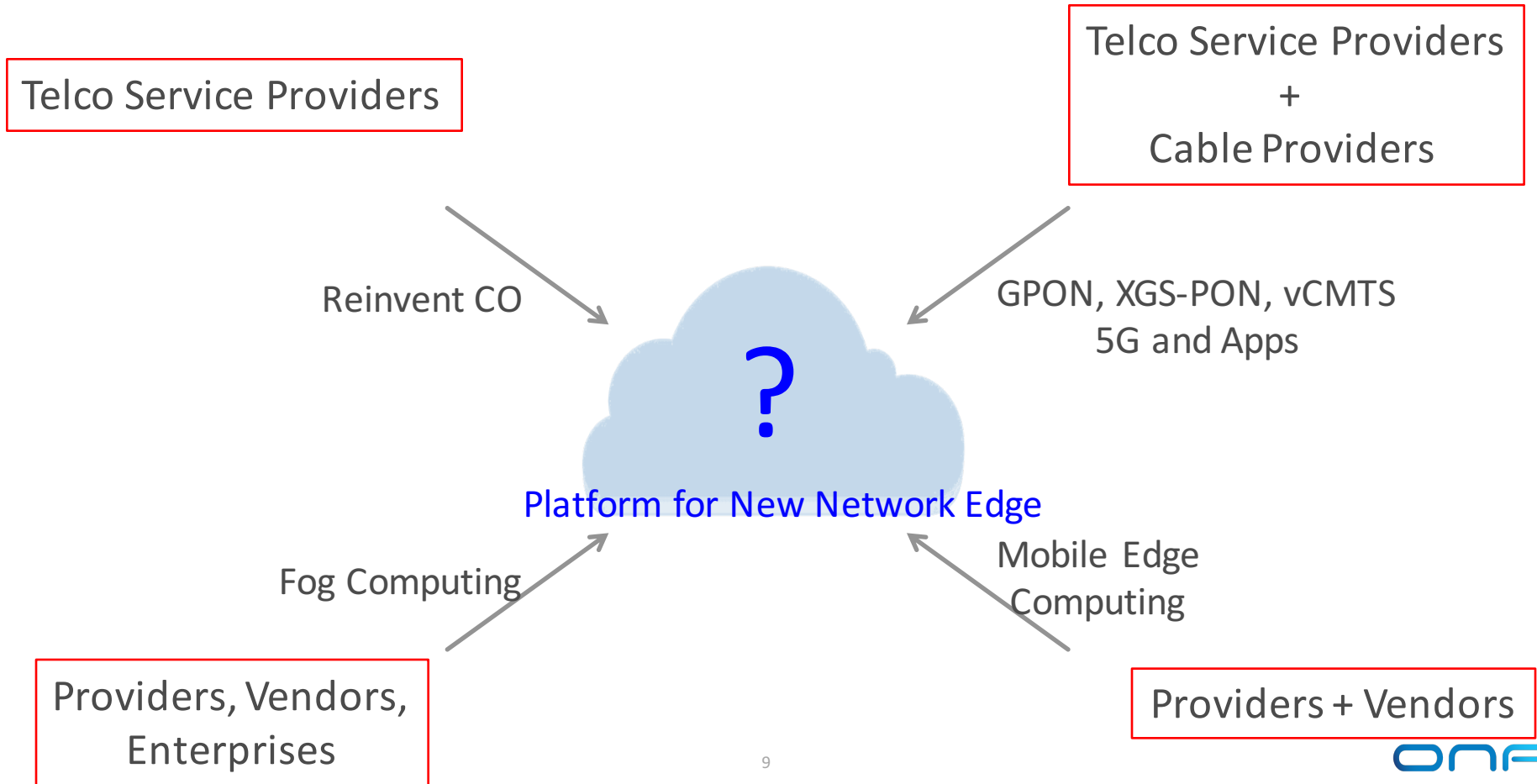




# CORD as a Platform for New Network Edge



# What does the New Network Edge require?



# What does the New Network Edge require?

## Functionality

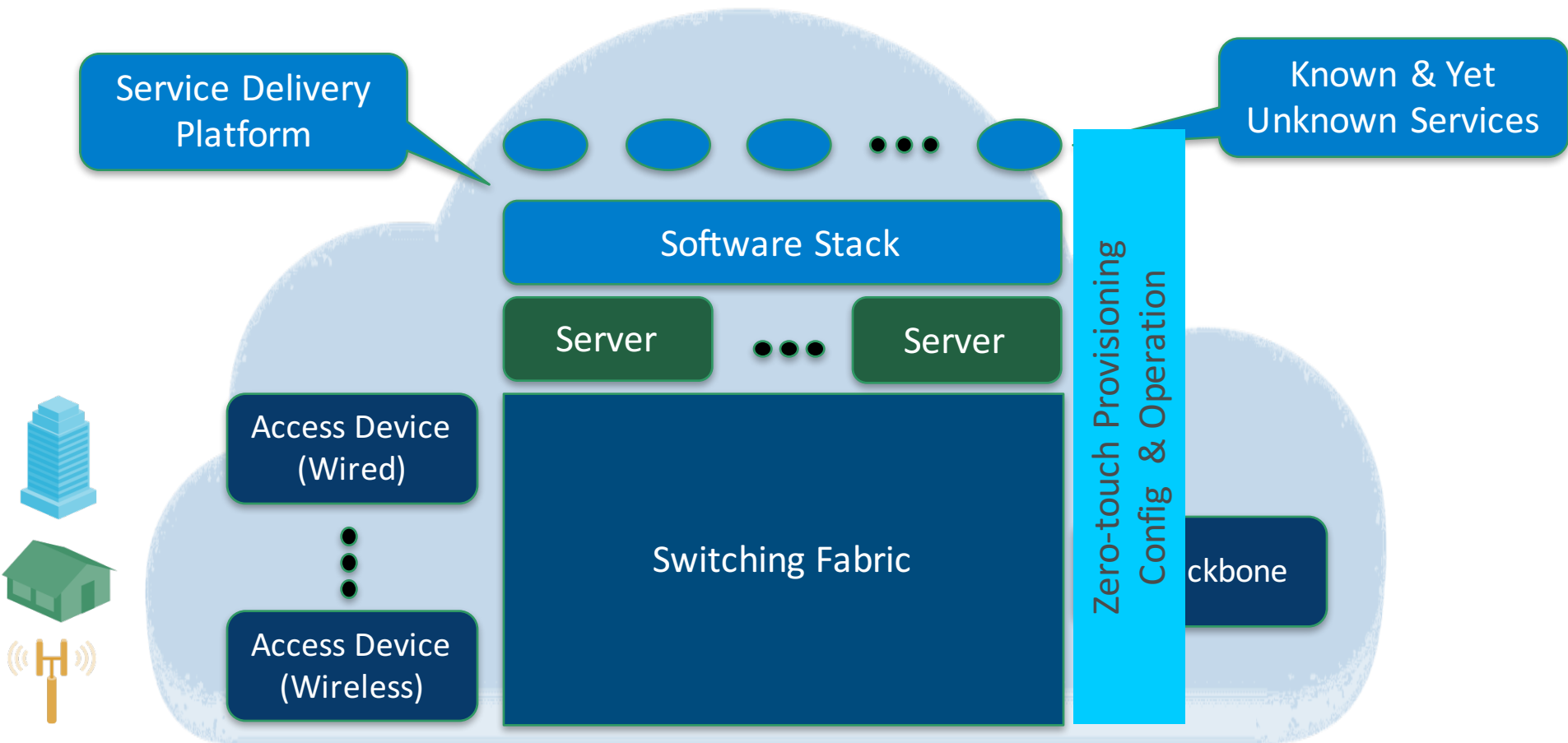
- A service delivery platform
  - For known & yet unknown services
- Many different configurations
  - Small to large
- Ability to plug-in different access devices/technologies
- Programmable control & monitoring
  - Millisecond control loops
- Economics of a datacenter
  - Space and power efficient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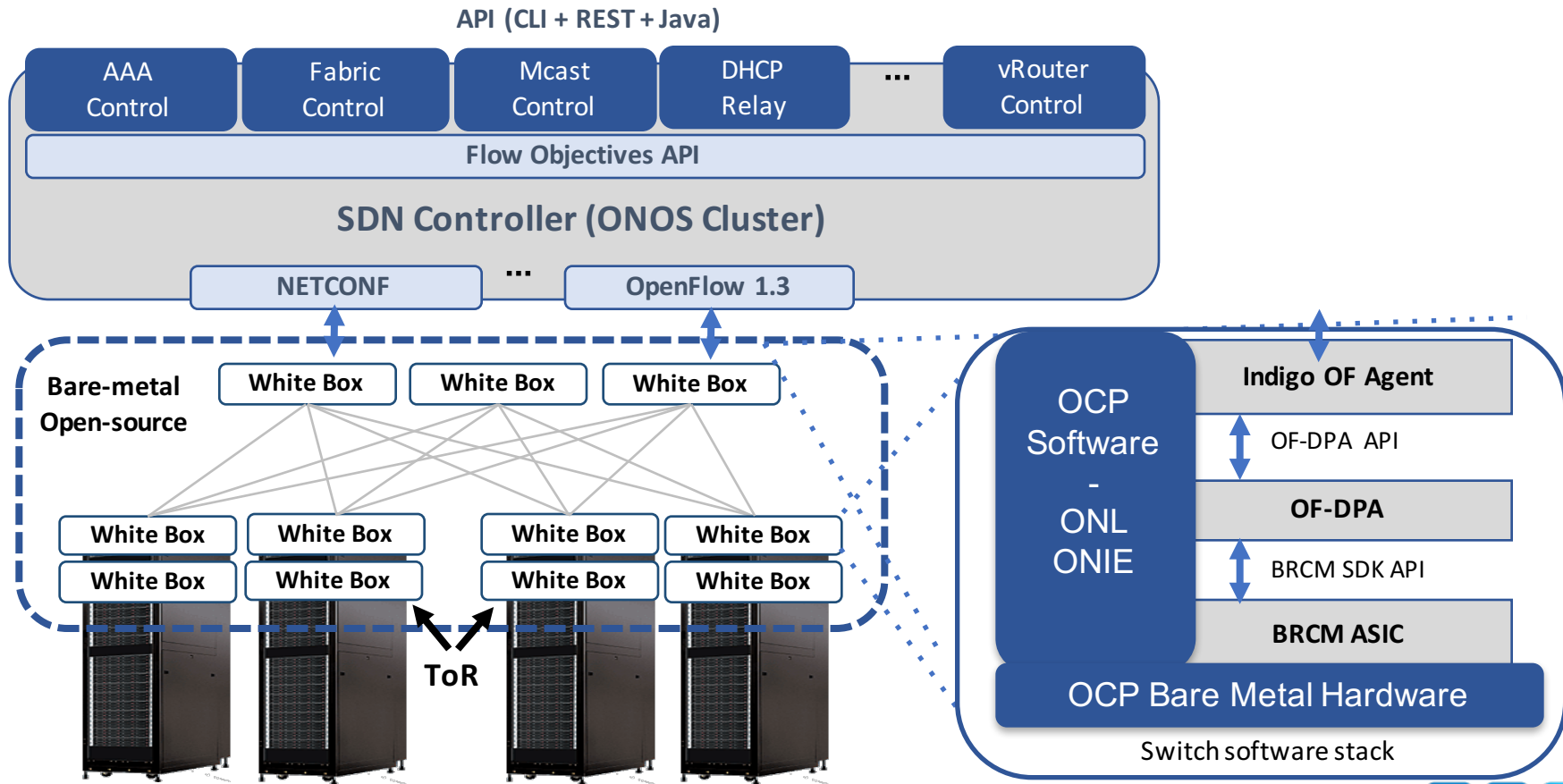
Server

ROADM

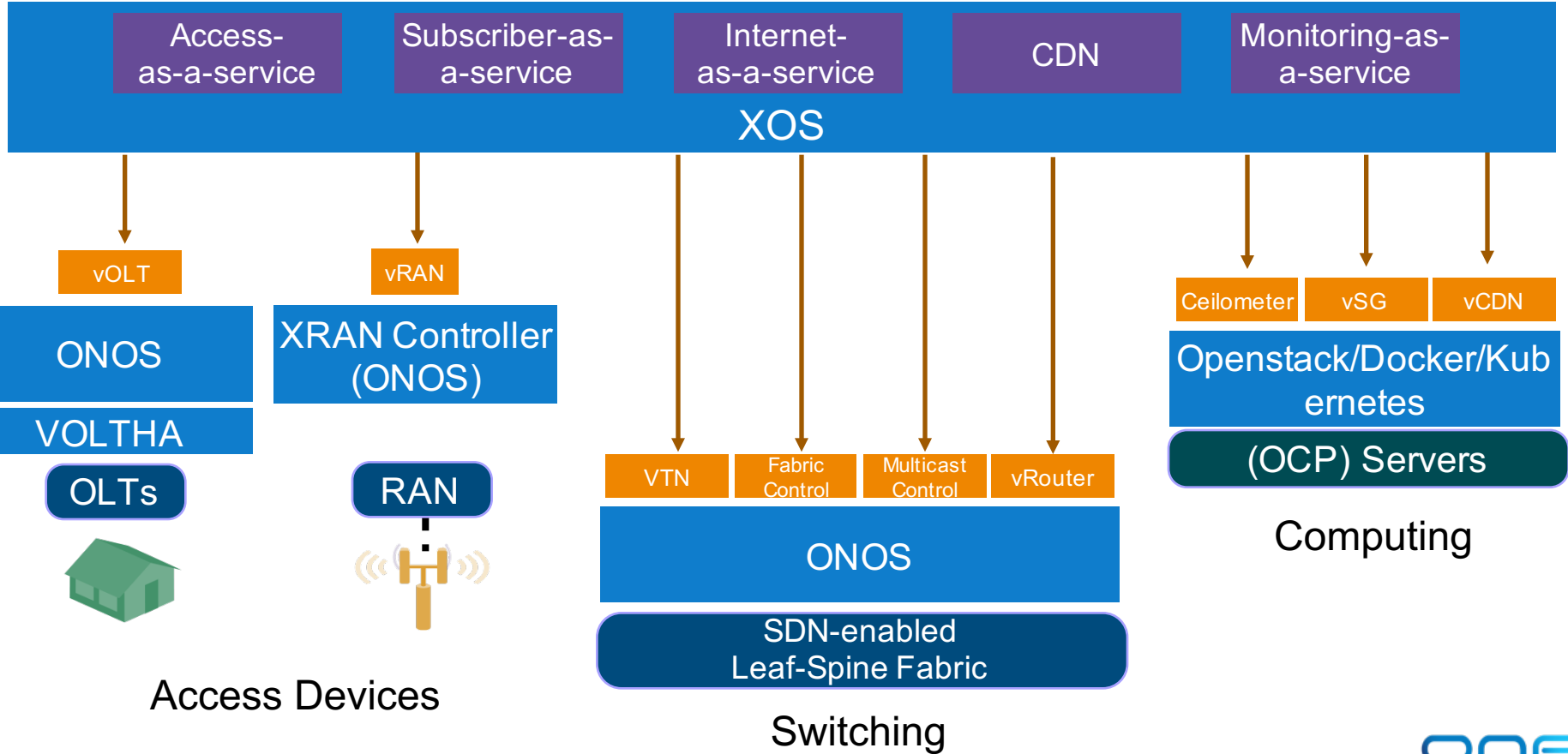
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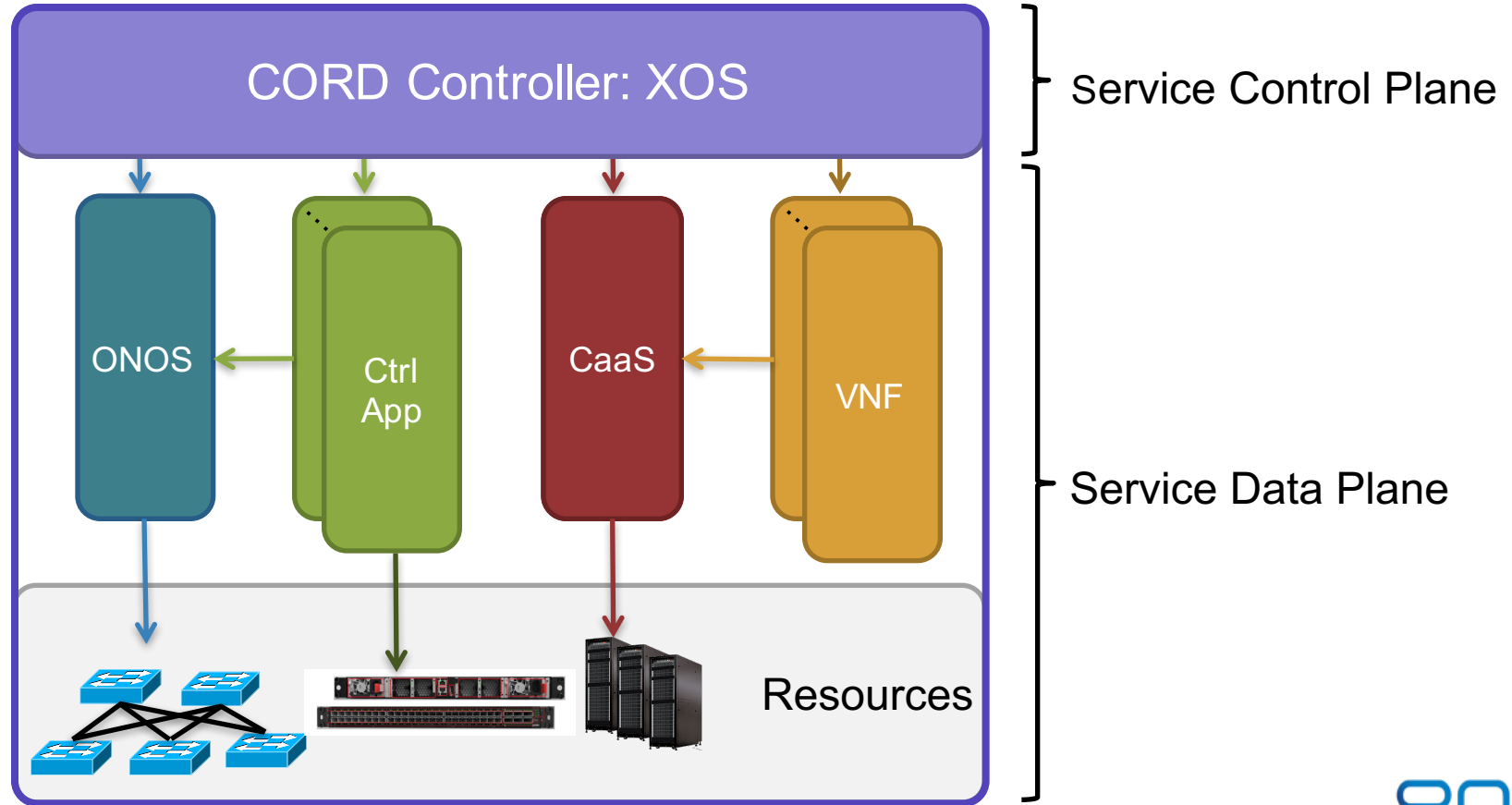
# Trellis Fabric – Bare-metal + Open-Source + SDN



# CORD Software Stack: Everything as a Service

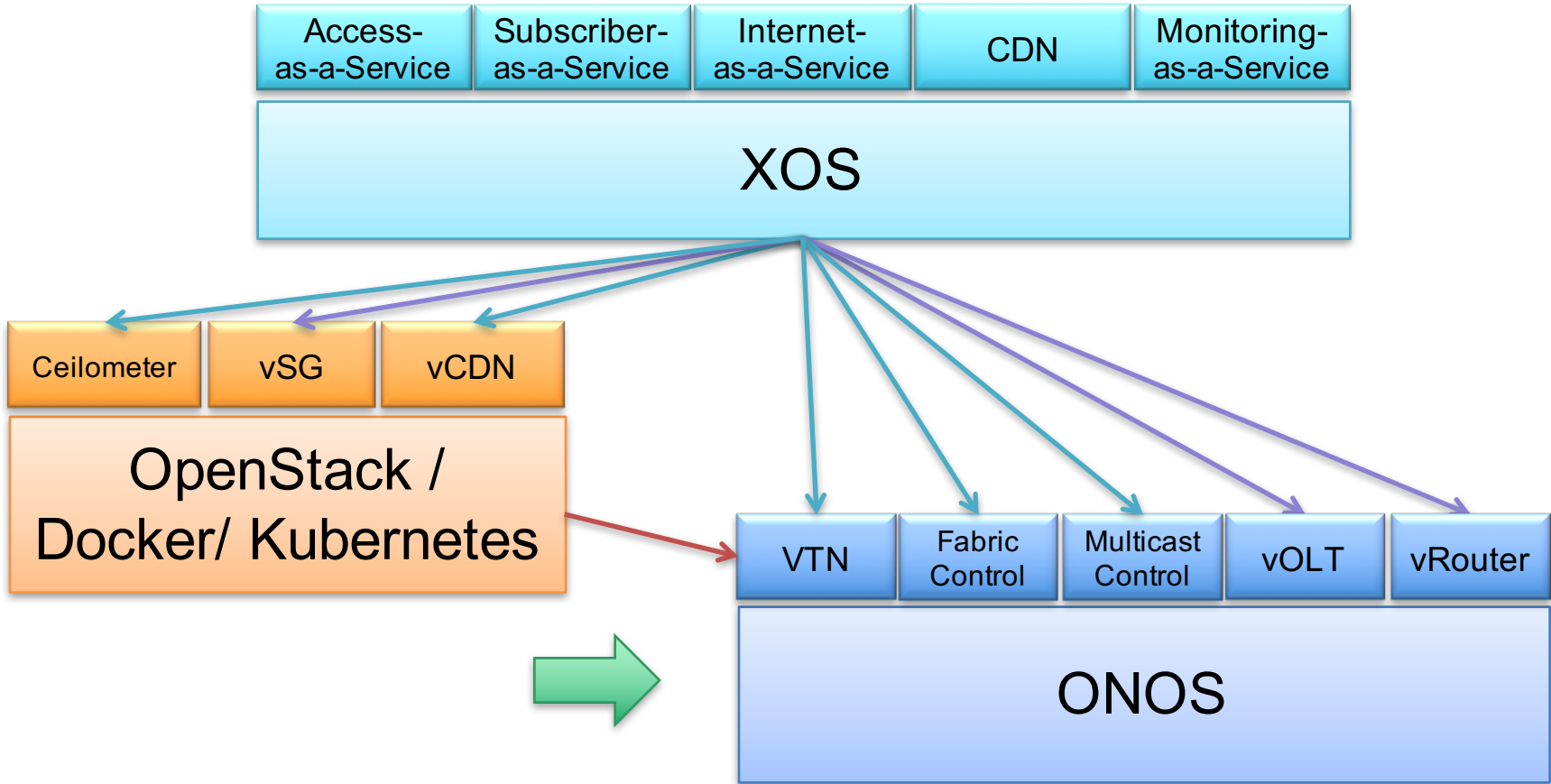


# CORD Software Architecture: Everything as a Service



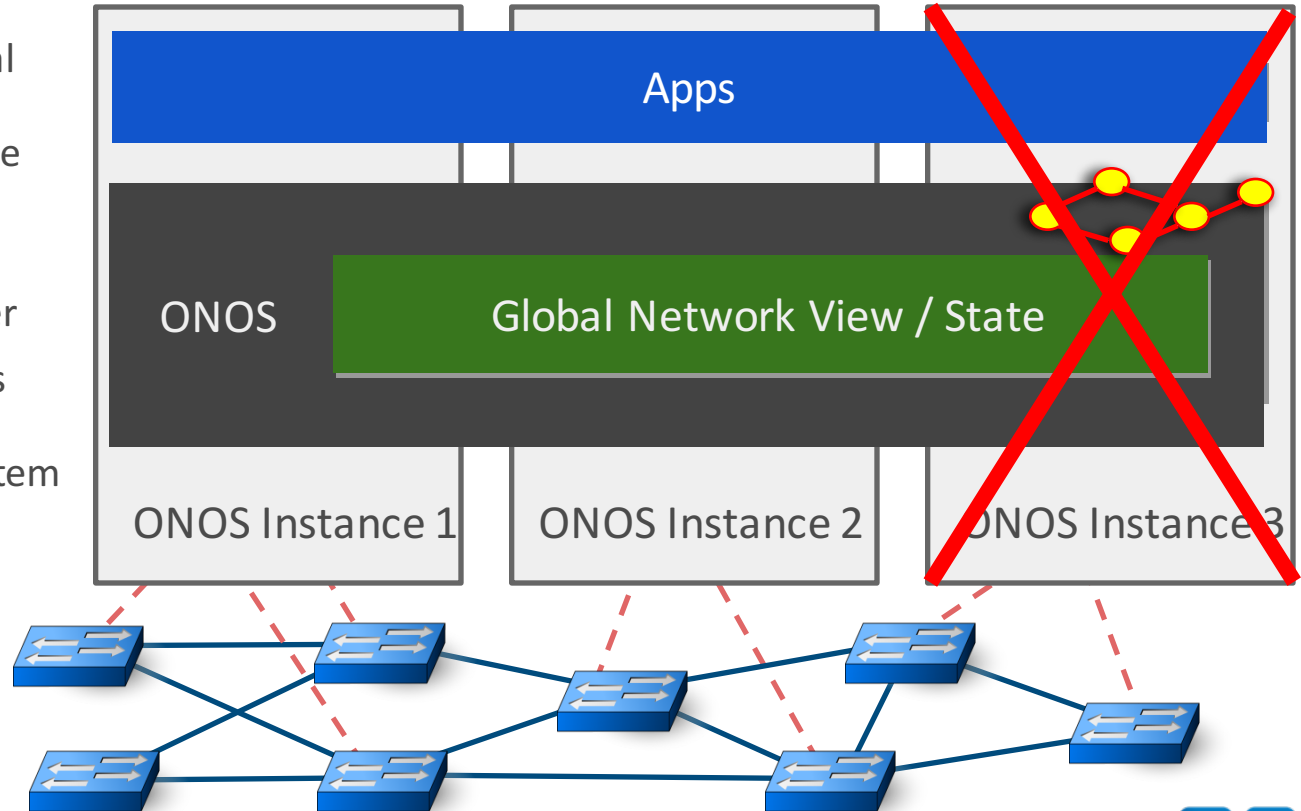


# XOS: Service OS or CORD Controller



# 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

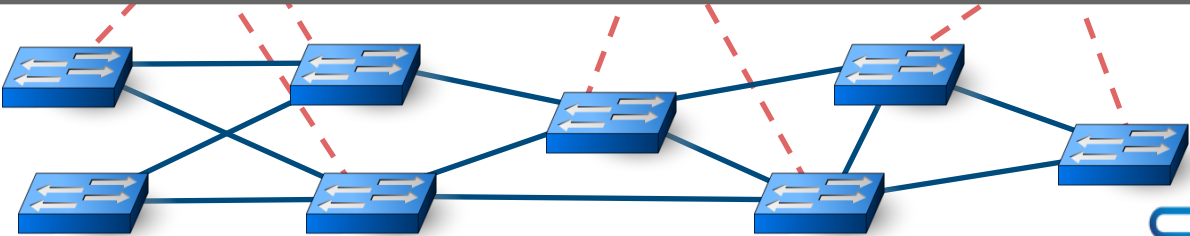
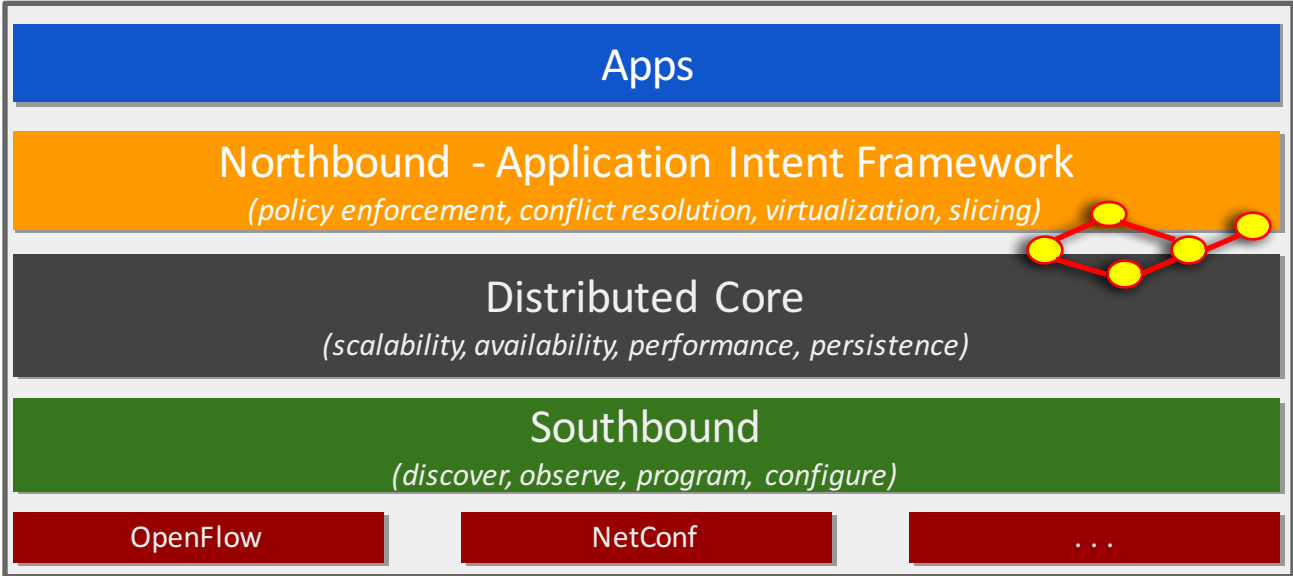
## Core:

- 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

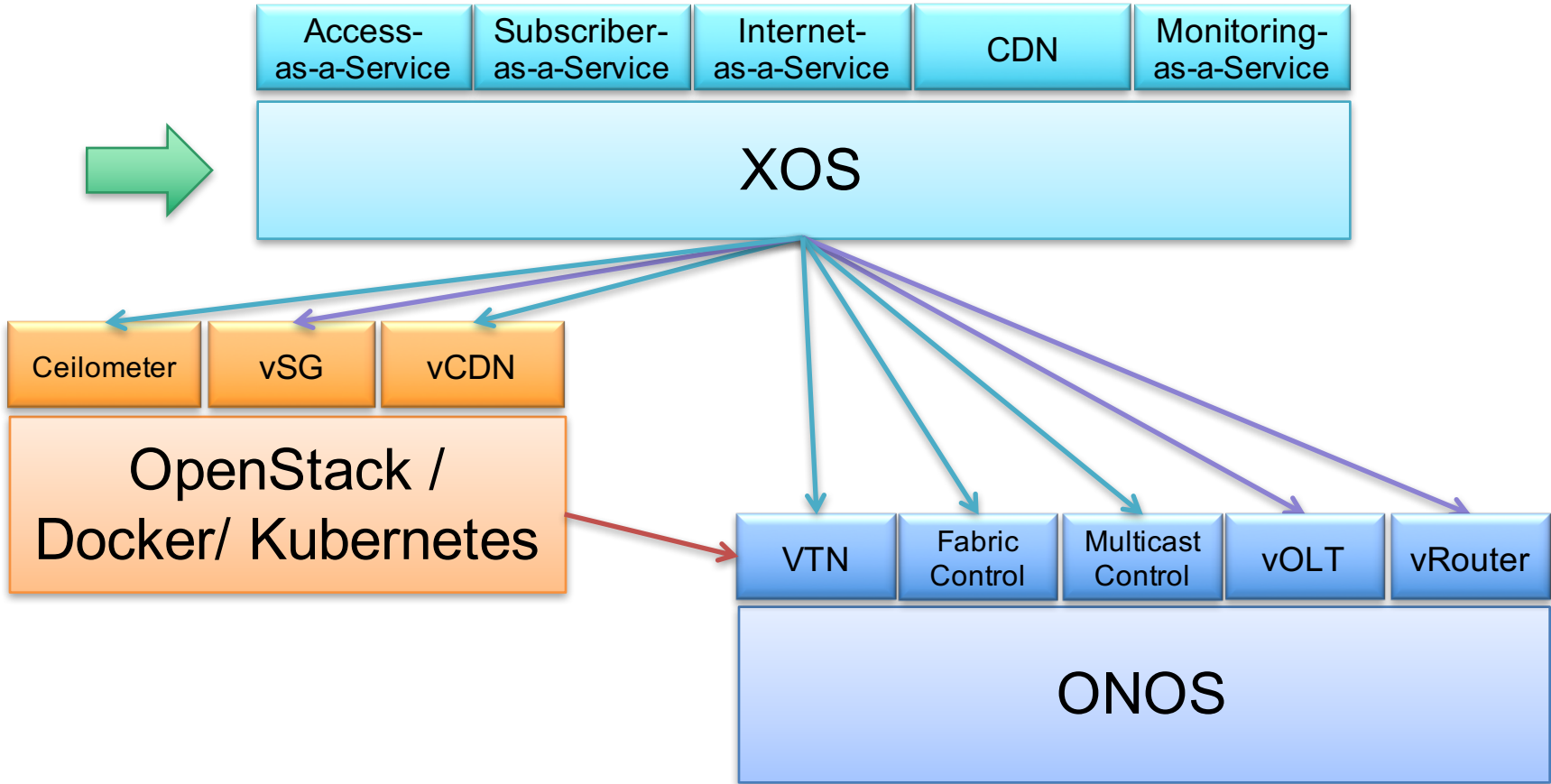
- **ONOS first few releases**
  - Focus on OpenFlow
- **ONOS subsequent releases**
  - Focus (led by vendors) on legacy protocols – most legacy protocols supported
- **ONOS recent and future releases** – “back to the future”
  - Focus is on device disaggregation: packet switches (P4), OLT (VOLTHA), eNB/RAN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

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

# State of ONOS: Applications

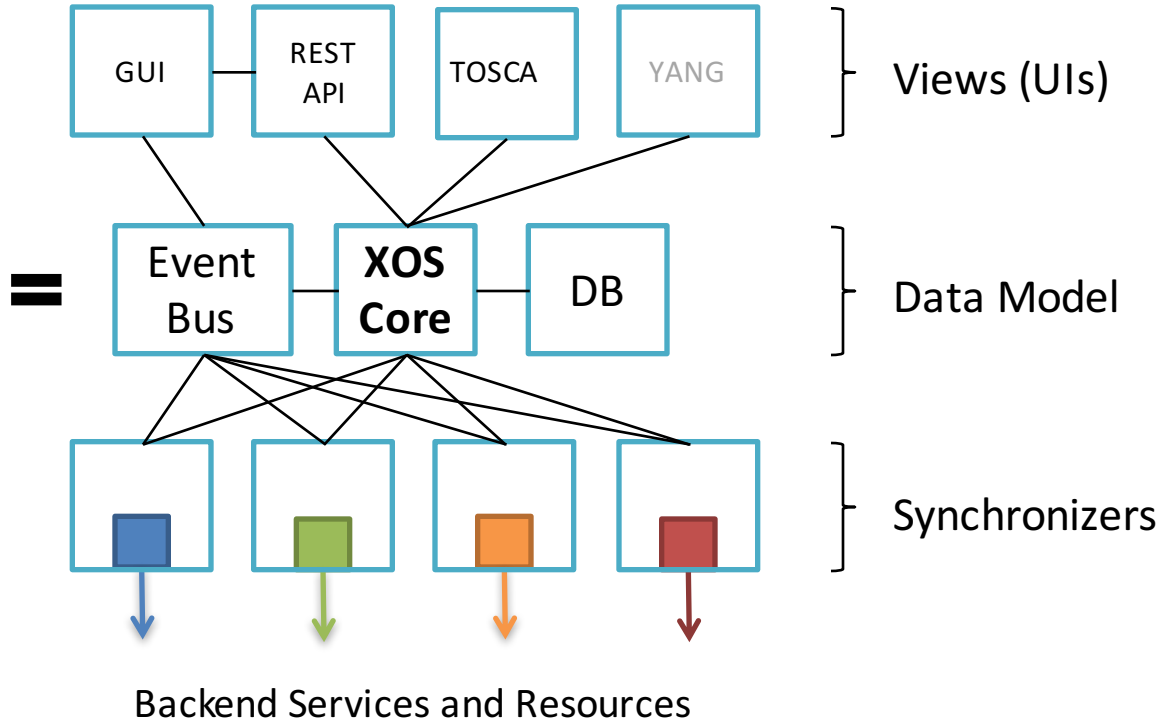
- ONOS platform now supports 125 applications
  - Small platform extensions & larger user apps
  - Contributed by ONF as well as many community members
- ONOS build will allow a user/vendor to build ONOS with specified services for a given use case or a solution
- Categories of apps include
  - Device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

# XOS: Service OS or CORD Controller



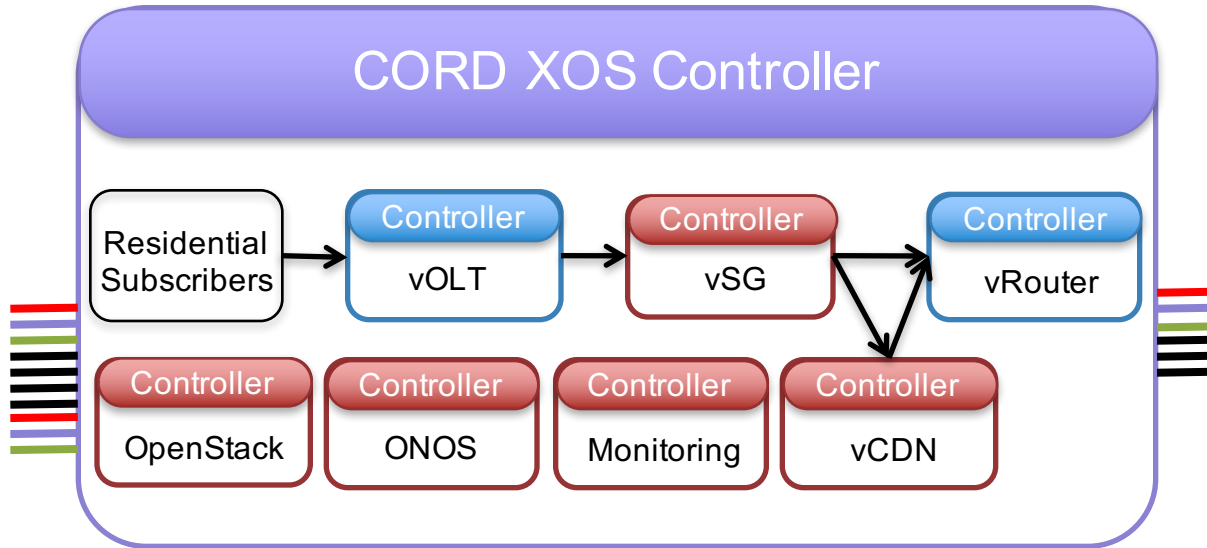
# XOS Constructed from Micro-Services

CORD Controller (XOS)





# CORD: Everything as a Service and Service Graphs



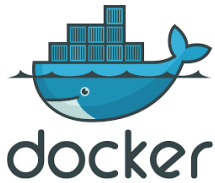
# CORD: Automated Provisioning, Config, & Operation



- 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

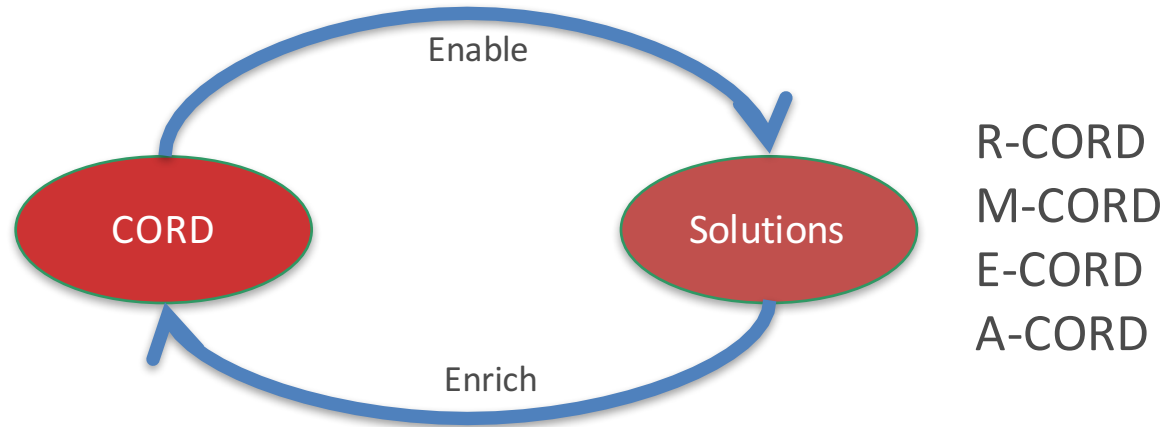
- All Nightly Jenkins Jobs: <https://jenkins.opencord.org/>
- Cord-in-a-Box (CiaB) Virtual Builds:
  - Cord 3.0: <http://tinyurl.com/nightly-ciab-3-0>
  - Cord 4.0: <http://tinyurl.com/nightly-ciab-4-0>
- Physical Pod Builds (Calix, Flex, QCT):
  - Cord 3.0: <http://tinyurl.com/nightly-3-0>
  - Cord 4.0: <http://tinyurl.com/nightly-4-0>
  - Cord 4.1: <http://tinyurl.com/nightly-4-1>

Jenkins > CORD 4.1 builds > automated-nightly-build-flex1-cord-4.1

Stage View

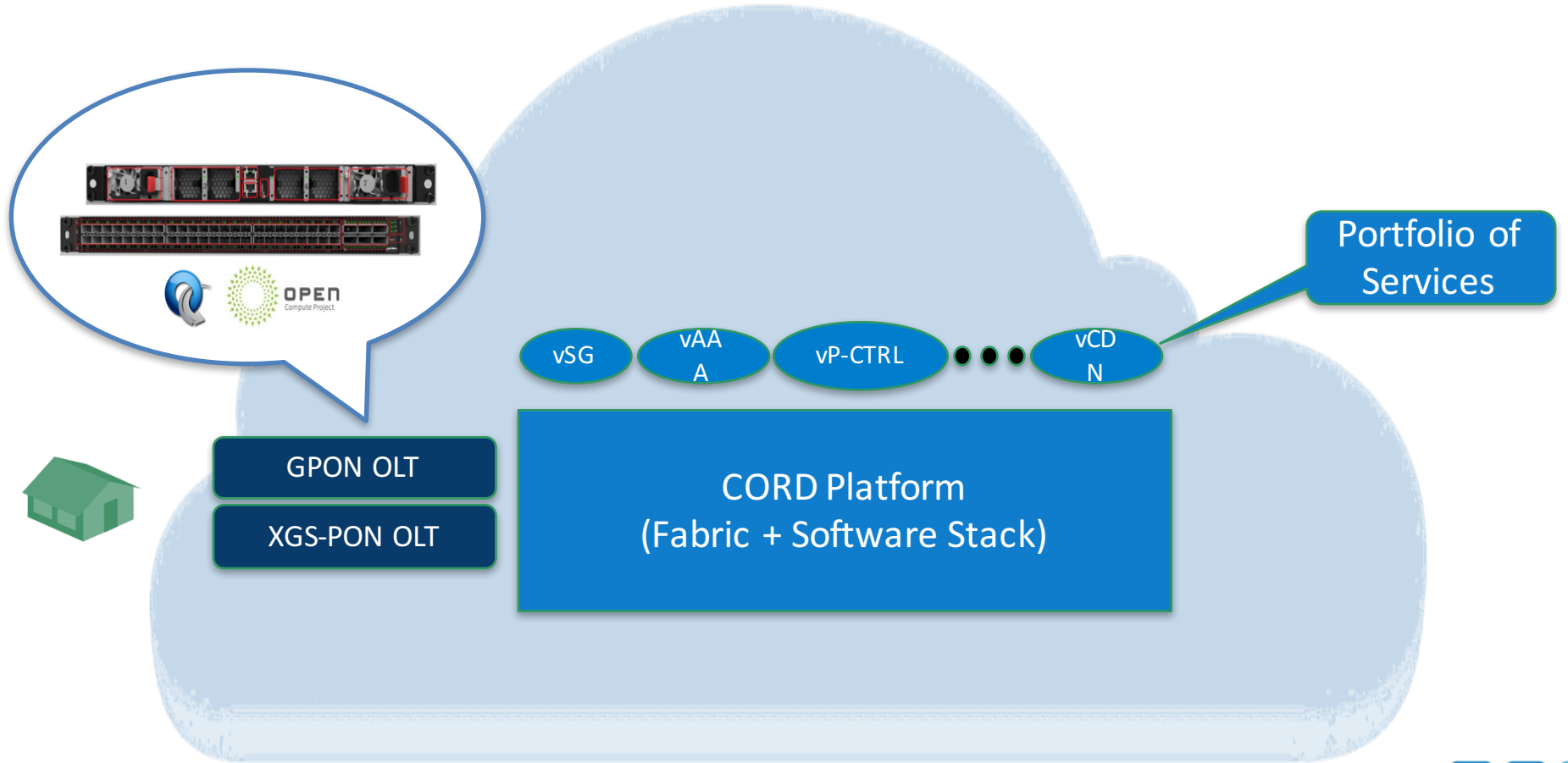
	Generate and Copy Manifest file	Parse deployment configuration file	Remove old head node from known hosts	Checkout cord repo	Re-deploy head node	Download CORD POD configuration	Generate CORD configuration	Reserve IPs for fabric switches	Deploy	Power cycle compute nodes	Wait for compute nodes to get deployed	Wait for compute nodes to be provisioned	Wait for fabric switches to get deployed	Wait for fabric switches to be provisioned	Contr fabric switch an cons node ONT
Average stage times: (Average full run time: ~2h 16min)	526ms	784ms	2s	10s	6min 24s	2s	4s	4s	1h 7min	4s	20min 30s	34min 53s	31s	9min 16s	1min
7/1 Oct 30 23:18	525ms	779ms	4s	7s	6min 14s	588ms	3s	2s	1h 4min	8s	16min 28s	33min 27s	31s	9min 27s	50s
7/1 Oct 30 16:38	526ms	778ms	5s	7s	6min 52s	1s	4s	6s	1h 11min	10s	16min 48s	34min 27s	30s	9min 8s	5min
7/1 Oct 19 16:19	526ms	803ms	5s	10s	6min 19s	877ms	4s	2s	1h 7min	1s	16min 34s	36min 47s	30s	9min 37s	1min
7/1 Oct 12 23:38	526ms	785ms	718ms	6s	6min 11s	680ms	4s	2s	1h 0min	2s	16min 13s	31min 43s	31s	8min 39s	5s
7/1 Oct 12 21:17	526ms	785ms	751ms	23s	6min 34s	6s	4s	2s	1h 5min	2s	16min 26s	33min 0s	31s	10min 18s	1min
7/1 Oct 12 16:13	528ms	779ms	778ms	10s	6min 30s	7s	3s	5s	1h 16min	2s	45min 4s				

# CORD Journey: 2015-Now



The Virtuous Cycle

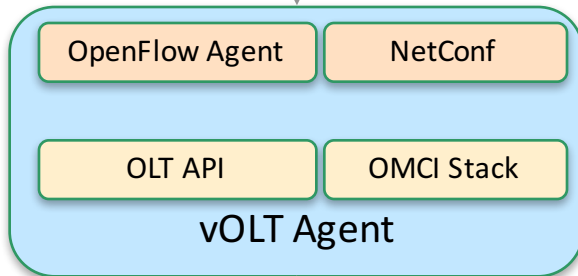
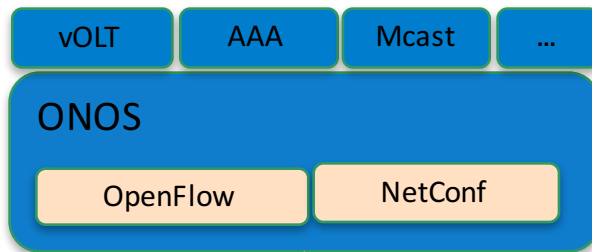
# R-CORD: GPON and XGS-PON for Residential Customers



# Approach to Access Devices: OLT Disaggregation



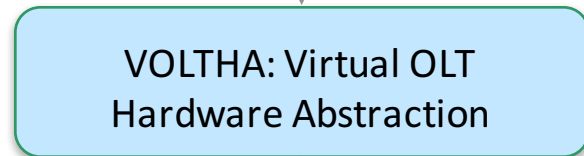
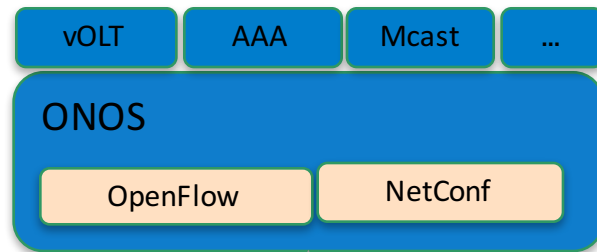
GPON OLT



L2/OMCI



GPON OLT Pizza Box



L2/OMCI



GPON and XGS-PON OLT Devices

# M-CORD: Enabling 5G

Disaggregated & Virtualized RAN  
With RAN Slicing

Disaggregated & Virtualized EPC  
EPC Slicing  
MEC

vMME

vHHS

vEPC

vCD  
N

vSGW-c

vSGW-u

vPGW-c

vPGW-u

vSG

vBBU

vRAN  
Slicing

RAN

eNB w/ xRAN

CBRS

CORD Platform  
(Fabric + Software Stack)



# M-CORD Capabilities Demonstrated at MWC San Francisco

xRAN  
INTEGRATION

OPEN SOURCE  
EPC

HYBRID CORD  
(MULTIACCESS  
CORD)

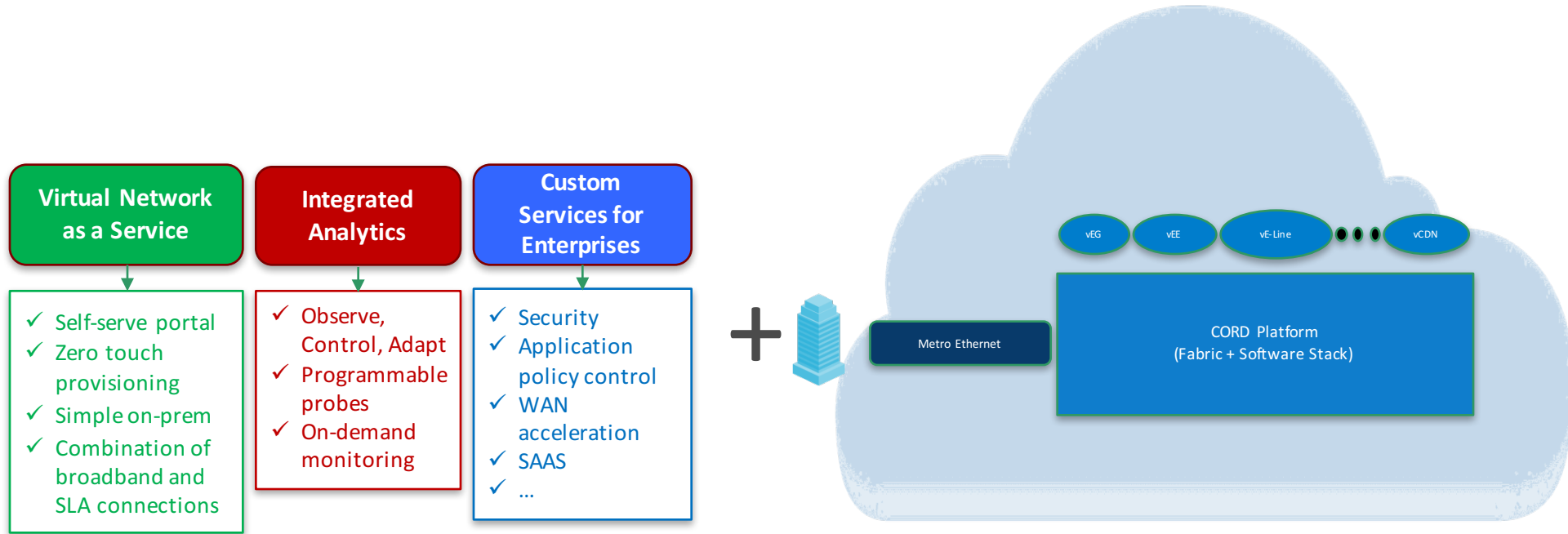
ARM + XPLIANT  
BASED M-CORD

CBRS &  
PRIVATE LTE

E2E SLICING &  
LINK AGGREGATION



# 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

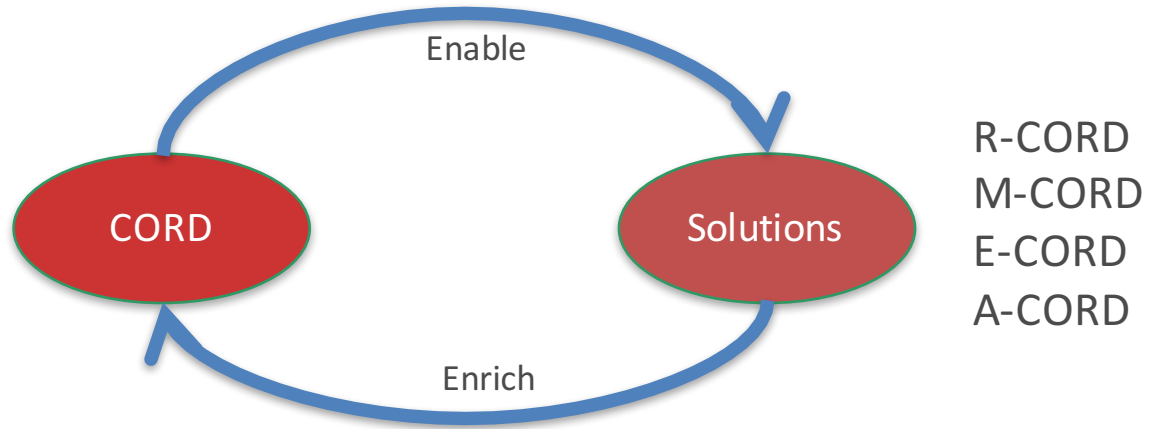
Bring your favorite (even proprietary) VNF!  
Love to demonstrate on CORD!

- 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

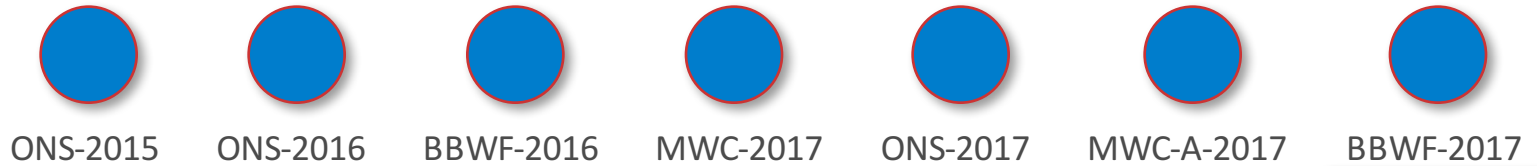
- CDN, Parental-control

# CORD Journey: 2015-Now



The Virtuous Cycle

POCs/Demos



CORD Releases



# 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!

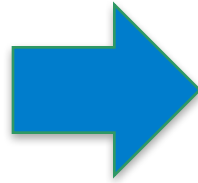


CORD is Taking Off!

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)



ONF

Open Networking Foundation



# The ONF Ecosystem

## Operator Led Consortium

### Partner

Operators (8)



Vendors (10)



### ONF Board

ONF (& Stanford)	Guru Parulkar
<u>Network Operators</u>	
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
<u>Research &amp; Vendor Community</u>	
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

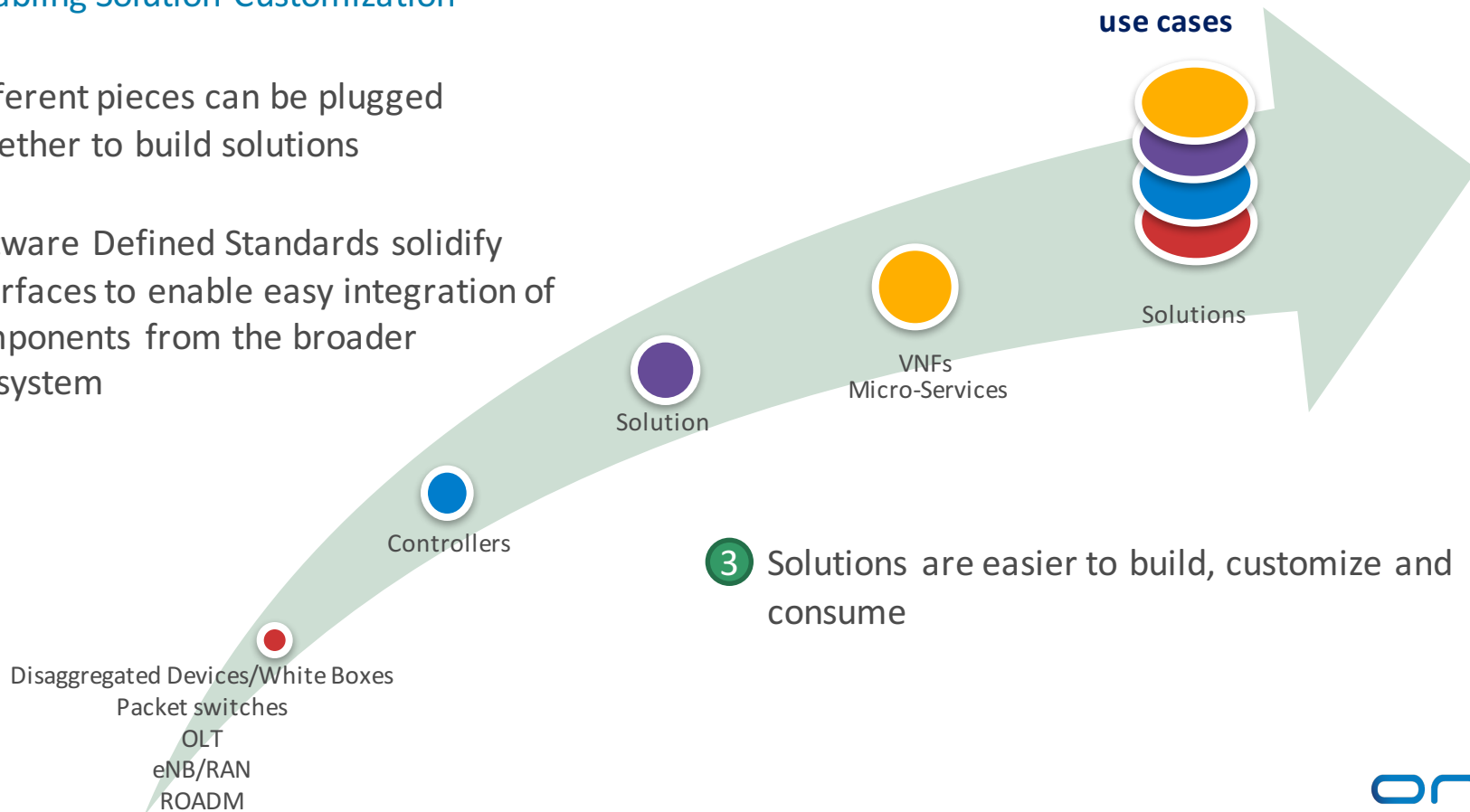
Catalyze our industry to accomplish this transformation

# ONF Open Innovation Pipeline

## Enabling Solution Customization

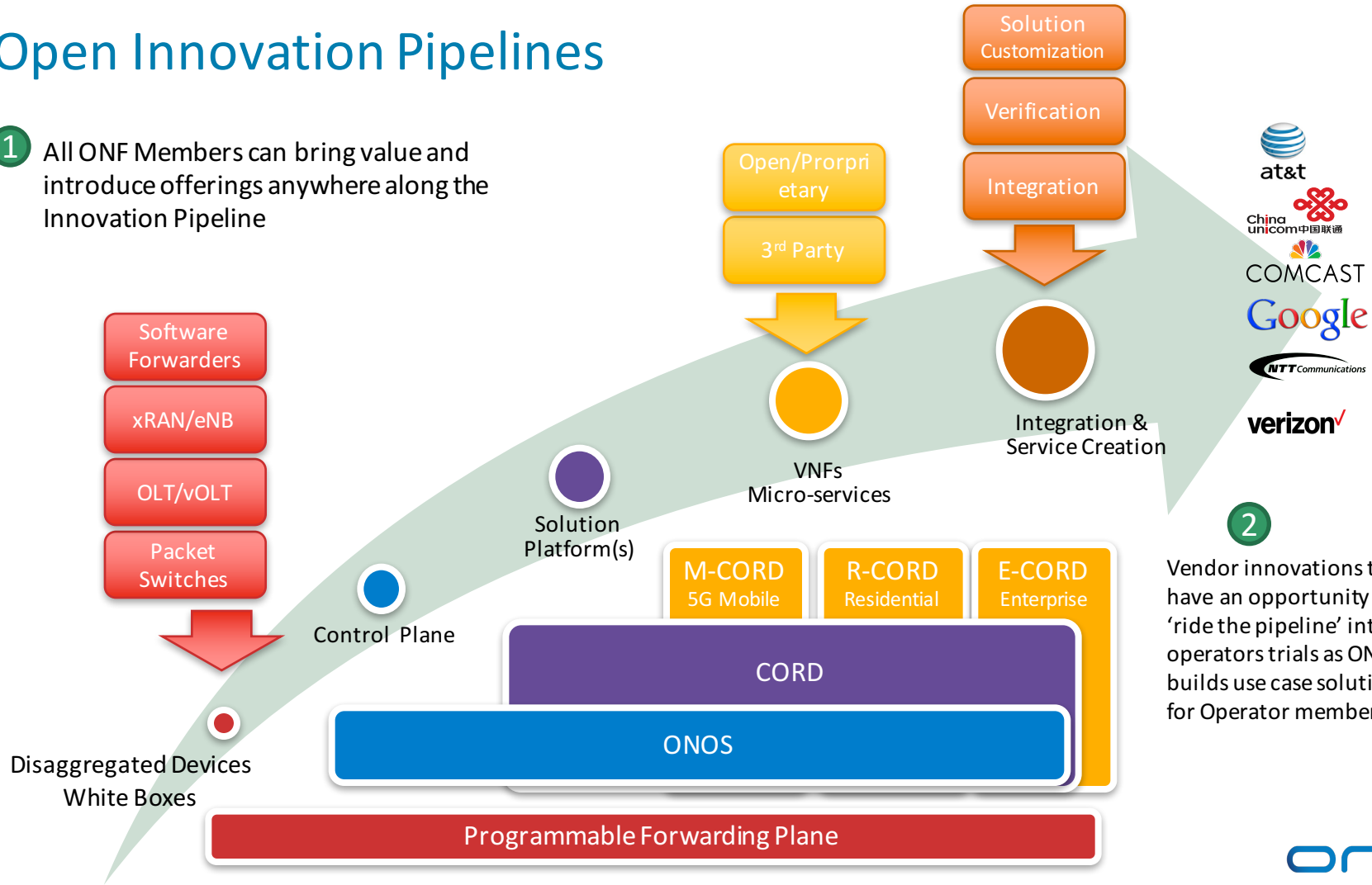
- 1 Different pieces can be plugged together to build solutions
- 2 Software Defined Standards solidify interfaces to enable easy integration of components from the broader ecosystem

## Building solutions for different use cases



# Open Innovation Pipelines

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



2 Vendor innovations then have an opportunity to 'ride the pipeline' into operators trials as ONF builds use case solutions for Operator members

# 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

