CORD: A Platform for “The New Network Edge”
“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

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

Michael Howard
IHS Markit
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)
- **Telefónica**: 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?

Telco Service Providers

Telecom Providers + Cable Providers

Reinvent CO

XGS-PON, vCMTS
5G and Apps

Providers, Vendors, Enterprises

Fog Computing

Mobile Edge Computing

Platform for New Network Edge

Providers + Vendors
Emerging Multi-Tier Cloud with New Network Edge

Edge Processing is Vital

- Subscriber experience dictated from here
  - Human Reaction time: 210ms
  - Latency to Centralized Cloud: 100 – 400ms
- Emerging Applications Require Edge Processing
  - AR visual overlays
  - Autonomous Vehicle Coordination
  - IoT Battery Life (50-75% improvement with edge processing)
Multi-Tier Cloud Needs: CORD for the Edge & Global Automation and Orchestration
CORD as a Platform for New Network Edge
What does the New Network Edge require?

- Telco Service Providers
- Reinvent CO
- Fog Computing
- GPON, XGS-PON, vCMTS
- Mobile Edge Computing
- Providers, Vendors, Enterprises
- Providers + Vendors
- 5G and Apps

Platform for New Network Edge
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

Service Delivery Platform

Software Stack

Server

Switching Fabric

Access Device (Wired)

Access Device (Wireless)

Known & Yet Unknown Services

Zero-touch Provisioning Config & Operation

Backbone

OpenCORD
CORD as the New Network Edge Platform: Specifics

~25 services residential, mobile, & enterprise use cases

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

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

OCP Server

Metro-Ethernet
GPON OLT
XGS-PON OLT
RAN
eNB w/ xRAN

ROADM
Disaggregated ROADM

Zero-touch Provisioning Config. & Operation With MAAS, Ansible, Docker, Kubernetes, XOS
CORD as the New Network Edge Platform: Specifics

Software Stack:
- OpenStack/Docker/Kubernetes
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Built with:
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- White Boxes
- Open source
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Server

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ROADM
Disaggregated ROADM

~25 services residential, mobile, & enterprise use cases

Zero-touch Provisioning Config & Operation
With MAAS, Ansible, Docker, Kubernetes, XOS
Trellis Fabric – Bare-metal + Open-Source + SDN

API (CLI + REST + Java)

AAA Control
Fabric Control
Mcast Control
DHCP Relay
... vRouter Control

Flow Objectives API

SDN Controller (ONOS Cluster)

NETCONF
...
OpenFlow 1.3

Bare-metal Open-source

White Box
White Box
White Box

White Box
White Box
White Box

White Box
White Box
White Box

White Box
White Box
White Box

BRCM ASIC
OF-DPA

OF-DPA API

Indigo OF Agent

OCP Bare Metal Hardware

Switch software stack

OCP Software
- ONL
ONIE
CORD Software Stack: Everything as a Service

Access-as-a-service
Subscriber-as-a-service
Internet-as-a-service
CDN
Monitoring-as-a-service

XOS

ONOS
VOLTHA
OLTs
XRAN Controller (ONOS)

vOLT
vRAN

RAN

Access Devices

ONOS

VTN Fabric Control Multicast Control vRouter

SDN-enabled Leaf-Spine Fabric

Switching

Computing

Openstack/Docker/Kubernetes (OCP) Servers

Ceilometer vSG vCDN

vRAN

vOLT

ONOS

VOLTHA
OLTs

XRAN Controller (ONOS)
CORD Software Architecture: Everything as a Service

CORD Controller: XOS

- ONOS
- Ctrl App
- CaaS
- VNF

Service Control Plane

Service Data Plane

Resources
XOS: Service OS or CORD Controller

Access-as-a-Service  Subscriber-as-a-Service  Internet-as-a-Service  CDN  Monitoring-as-a-Service

XOS

Ceilometer  vSG  vCDN

OpenStack / Docker/ Kubernetes

VTN  Fabric Control  Multicast Control  vOLT  vRouter

ONOS
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

Northbound - Application Intent Framework
(policy enforcement, conflict resolution, virtualization, slicing)

Distributed Core
(scaleability, availability, performance, persistence)

Southbound
(discover, observe, program, configure)

OpenFlow  NetConf  ...

Apps
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

Access-as-a-Service
Subscriber-as-a-Service
Internet-as-a-Service
CDN
Monitoring-as-a-Service

OpenStack / Docker/ Kubernetes

Ceilometer vSG vCDN

VTN Fabric Control Multicast Control vOLT vRouter

ONOS
XOS Constructed from Micro-Services

CORD Controller (XOS)

Event Bus

XOS Core

GUI

REST API

TOSCA

YANG

DB

Views (UIs)

Data Model

Synchronizers

Backend Services and Resources
CORD: Everything as a Service and Service Graphs

![Diagram showing CORD XOS Controller and various services connected to it.]

- Residential Subscribers
- vOLT Controller
- vSG Controller
- vRouter Controller
- OpenStack Controller
- ONOS Controller
- Monitoring Controller
- vCDN Controller
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/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/](https://jenkins.opencord.org/)
- Cord-in-a-Box (CiaB) Virtual Builds:
  - Cord 3.0: [http://tinyurl.com/nightly-ciab-3-0](http://tinyurl.com/nightly-ciab-3-0)
  - Cord 4.0: [http://tinyurl.com/nightly-ciab-4-0](http://tinyurl.com/nightly-ciab-4-0)
- Physical Pod Builds (Calix, Flex, QCT):
  - Cord 3.0: [http://tinyurl.com/nightly-3-0](http://tinyurl.com/nightly-3-0)
  - Cord 4.0: [http://tinyurl.com/nightly-4-0](http://tinyurl.com/nightly-4-0)
  - Cord 4.1: [http://tinyurl.com/nightly-4-1](http://tinyurl.com/nightly-4-1)
CORD Journey: 2015-Now

Enrich

Enable

CORD

Solutions

The Virtuous Cycle

R-CORD
M-CORD
E-CORD
A-CORD
R-CORD: GPON and XGS-PON for Residential Customers

CORD Platform
(Fabric + Software Stack)

GPON OLT
XGS-PON OLT

Portfolio of Services
Approach to Access Devices: OLT Disaggregation

- **vOLT Agent**
  - ONOS
    - OpenFlow
    - NetConf
  - OLT Agent
    - OpenFlow Agent
    - NetConf
    - OLT API
    - OMCI Stack
  - L2/OMCI

- **VOLTHA: Virtual OLT Hardware Abstraction**
  - ONOS
    - OpenFlow
    - NetConf
  - GPON OLT Pizza Box
  - GPON and XGS-PON OLT Devices
M-CORD: Enabling 5G

Disaggregated & Virtualized RAN With RAN Slicing

Disaggregated & Virtualized EPC EPC Slicing MEC

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

Virtual Network as a Service
- Self-serve portal
- Zero touch provisioning
- Simple on-prem
- Combination of broadband and SLA connections

Integrated Analytics
- Observe, Control, Adapt
- Programmable probes
- On-demand monitoring

Custom Services for Enterprises
- Security
- Application policy control
- WAN acceleration
- SAAS
- ...

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

Enable

CORD

Solutions

Enrich

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

R-CORD
M-CORD
E-CORD
A-CORD
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 Con tribute

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

ONF Board

Operators (8)

Vendors (10)

Innovator (110+)

Collaborator (70+)

Operators:
- China Mobile
- SK Telecom
- ECI Telecom
- Facebook
- Globe Telecom
- Goldman Sachs
- Microsoft

Vendors:
- Ciena
- Cisco
- Ericsson
- Fujitsu
- Huawei
- Intel
- NEC
- NOKIA
- radisys
- Samsung

Network Operators:
- AT&T
- China Unicom
- Comcast
- DT
- Google
- NTT
- Turk Telekom
- Verizon

Research & Vendor Community:
- Nick McKeown
- Fabian Schneider
- Stanford

Collaborator:
- Volunteers
- 100s

Including 13 Operators:
- China Mobile
- SK Telecom
- ECI Telecom
- Facebook
- Globe Telecom
- Goldman Sachs
- Microsoft

Volunteers:
- Goldman Sachs
- Swisscom
- Telefonica
- Telus
- Vodafone
- Yahoo

Partner:
- ONF
- Stanfords

Collaborator:
- 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

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.

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