Reliability, Availability & Serviceability
@ Cloud Scale

Ian Hood, P. Eng.
Chief Architect – Global Telco
June 2016
The forces of change
Adapting to the networks of the future
The Business is Moving Fast - Downtime is Costly
Goal of Zero Service Downtime >>> Different Approaches

Laser Focus
- Deploy In Minutes
- Hot Deployments (DevOps)
- Optimize Resources / Costs
- Analytics / Self Healing

Stone Age Tools
- Deploy in Months / Years
- Complex Costly Service Environments
- Mandate 99.999% Availability
- Limited Service Visibility
Imagine if Your Network Was Completely Elastic

And Completely Automated!
We Have Done it Again..

Architecture is More Complex!

Implementations are More Complicated..
What Are Telco’s Looking For?

- Reliability
- Availability
- Serviceability

“Automation is a key business imperative”
Telco NFV Service Delivery Framework

MULTI-VENDOR

COMMUNITY COLLABORATION

OPEN INTEROPERABLE APIs

AUTOMATE EVERYTHING
Modernizing Network Functions

VIRTUAL MACHINE WITH APPLICATION

VIRTUAL MACHINE WITH APPLICATION

VIRTUAL MACHINE WITH APPLICATION

VIRTUAL MACHINE WITH APPLICATION

APPLICATION ORCHESTRATION

VIRTUAL INFRASTRUCTURE MANAGER (VIM)

PHYSICAL DATACENTER
Flexible Redundancy / Availability Zones

**MANAGEMENT PLANE**
Active: Standby / 1:N / Geo-Redundant

**CONTROL PLANE**
Hierarchical / N + 1 / 1:N / Active / Active

**DATA PLANE**
Diversity / 1+1 / 1: N
Serviceability / Manageability
Service Delivery at the Speed of Software

Automate -- Automate -- Automate (AAA)

• MANO - Performance, availability, and Life-Cycle Management

• Service Level Monitoring / Assurance Including Service Level OAM Telemetry

• Open Interoperable APIs and Data Models (Everywhere)

• Accelerate speed to Create / Modify / Delete Services -- Self-Service Portal

• Reduce Fault/Service Recovery Times – Automated Tools / Analytics
# Aligning with Key Telco Priorities

<table>
<thead>
<tr>
<th></th>
<th>Telco Priorities</th>
<th>Red Hat Open Telco</th>
<th>Key Telco Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Real-Time Low Latency Service Handling</td>
<td>Real-Time KVM DPDK Acceleration</td>
<td>Improve Ability to Deliver Per-Service SLAs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Improve End Customer Experience</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Enhanced Service Throughput, Latency, Jitter</td>
</tr>
<tr>
<td>2</td>
<td>Cost Effective Infrastructure Scale</td>
<td>Hyperconverged Infrastructure (HCI)</td>
<td>Cost-Effective Scale</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Improve Customer Experience</td>
</tr>
<tr>
<td>3</td>
<td>Open Interoperable MANO Elements</td>
<td>Open Source Automation</td>
<td>Open Interoperable APIs in Multi-Vendor Environment</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Automate Network/Service Deployments</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Migrate workloads across physical / virtual environments</td>
</tr>
<tr>
<td>4</td>
<td>Security and Policy Management</td>
<td>RBAC with Audit SELinux + sVirt Validated Encryption</td>
<td>Role-Based Audit of Application / Access Controls</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Multi-Tenancy /Application Isolation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Strong Intrusion Protection</td>
</tr>
<tr>
<td>5</td>
<td>In-Service Upgrades</td>
<td>High Availability OSP Reference Architecture</td>
<td>OSP Lifecycle Management</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Minimize Service Outages During Upgrades</td>
</tr>
</tbody>
</table>

Copyright 2016 Red Hat
WHAT IS NEEDED?

Resilient Services + Applications
Open Automation Software
Cost-Effective Robust Hardware

It’s About Delivering Trusted Reliable Services … Anywhere
COLLABORATION IN A COMMON SPACE TO SHARE INNOVATIONS AND SPEED SOLUTIONS.
LEARN. NETWORK. EXPERIENCE OPEN SOURCE.
Story of an agile frog in a large company

RedHat Summit, telco breakout session
June 29, 2016
Cyrille Puget – PaaS Product Manager
Innovation, Marketing and Technology division
Orange at a glance

- #53 in 2016 global brand ranking
- 263 millions customers worldwide
- 1.8 million Fibre customers (and 1 million in France)
- 450 000 kms of undersea cables (enough to go around the earth 10 times!)
- 16 millions Orange Money customers in 14 countries
- 263 millions customers worldwide
- 726 millions euros invested in research and innovation
- 6 930 patents in our R&D portfolio
- 4G in 13 countries
- +1 million visits on Orange.com each month
- +10 million fans on Facebook
- +130 000 followers on @orange on Twitter
- +130 000 followers on @orange on Twitter
- +130 000 followers on @orange on Twitter
Group strategic ambition is focused on Customer Experience and based on 5 levers.

Orange aims to provide everyone with a unique customer experience every day, by designing digital services that help them make the most of what is essential to them – with complete peace of mind.

A digital, efficient and responsible company
Innovation, Marketing and Technology division

Our role is to design digital services that are simple, reliable and secured for all Orange countries we serve and their respective customers.

Communication services, IoT, SIM, API, TV, Cloud, Mobile Banking, Big Data, Enterprise services

7,900 employees worldwide
5,000 in innovation
€726 M invested
Situation a few years back

« Legacy » organization, infrastructures, tools and processes
From traditional infrastructure to virtualization and cloud:
- Mainly VMWare based but new cloud infrastructure with OpenStack
- Pure telco services still using traditional infrastructure

Tools and processes:
- Some old tools, manual processes
- Distributed teams, many actors

Impacts:
- Time to market
- Hard to achieve reliability, availability, and serviceability at cloud scale
How are we evolving

Group evolution on:
- Service oriented architecture
- Project organization
- Skills and tools
- Cloud and platform infrastructure
- DevOps transformation
IaaS is not enough, let’s build a PaaS

Although improvements were realized, we believed we could do much more:
- We could go faster, no time to loose
- Provide modern cloud/platform solutions for projects
- Simplify projects’ everyday life (for developers, testers, ops)
- Support the whole DevOps cycle: build, deploy & operate applications

Indeed, for many projects, IaaS is not enough or doesn’t fit:
- It requires IT specialists/time that many project don’t have
- Projects need more than just IaaS (e.g CI/CD, test, scaling, monitoring…)

We should have a PaaS, quickly, but how?
PaaS is the solution? Prove it... in less than 6 months

Mission: demonstrate that PaaS is a good solution for our needs

Plan:
- Find a cute project name: Kermit
- Be agile, focus on serviceability, go fast
- Choose a hosting infrastructure
- Choose a PaaS solution
- Deploy a beta platform
- Get some users, support them
- Iterate
- Move to production
OpenShift adoption

2014
Deploy OpenShift
First developers

Evaluate and choose a PaaS

2015
Kermit beta self-service
Kermit production platform
500 users
778 applications
387 active
12 in production

2016
OpenShift 3 beta
860 users
1300 applications
550 active
52 in production
First applications in production
500 users
778 applications
387 active
12 in production
Examples of applications running on OpenShift

- Web application used in Orange shops
- Rich Communication Framework: infrastructure and client framework to ease development of communication and real-time services
- Backend of TV remote control mobile application providing an enriched experience by delivering information of on-going programs
- IoT data aggregation services targeting end users and service providers
- Ticketing tool used by some operations team
- Many backends for mobile applications
Outcomes

OpenShift platform:
- Easy to deploy and manage: only 2 persons doing ops/support
- Incredibly stable: >99.95% platform availability
- Valuable RedHat support

Users and projects:
- Strong adoption, numbers are speaking
- Enthusiast feedbacks, huge benefits
- 3 months saving on a 6 months project

Limitations:
- web app (http), scaling databases, resiliency
- Bronze SLA
What’s next?

Support larger scope of applications:
- Complex application architecture (micro-services)
- Telco services, not just web apps

Provide higher service availability:
- Large scale, multi-DC deployment
- Improved resiliency at platform and application level

Hopefully, OpenShift 3 / Kubernetes is designed for this.
Thanks!
VIRTUALIZED SP NETWORKING

!= Enterprise Switching

Dave Ward
dward@cisco.com
Target Assumption:
Simple to deploy Apps and Services and Stack Does the Right thing To manage itself

Workflow and Intent

Applications & Paas

Network Intelligence, Guidance

Services Orchestration

Analytics

Infrastructure Software
Management Orchestration
Analytics, Controllers

Programmability

Virtualized & Embedded SW
Route, Switch, Appliance
IOS, XR, NXOS

Statistics, States, Objects and Events

Network
Incorporating policy driven orchestration capabilities of complete services life-cycle manager that can implement Service Workflow topologies that span the network and data centers.
Business Impact

What business impact would you experience if you:
- Could repurpose your infrastructure in minutes by just moving software?
- Didn’t have to physically rewire or reconfigure hardware?
- Could create broadcast pop-up channels in minutes instead of months?
- Had an infrastructure which automatically flexed to the different demands of your workloads?
Whole Stack Can’t fit in a Everyone’s Head?

Policy View

Service View

Virtual Topology

Physical Topology

Resource View

Everything below This Line should be a NO-STACK WORLD

Where’s BW?
“Below the line”
Service WorkFlow orchestration: Just Make it happen

- Service Life Cycle Manager
  - Network Services Orchestrator

- Virtual Machine Life Cycle Manager
  - Elastic Services Controller

- VM Policy
  - Network Policy
  - Service Provisioning
  - Service Configuration
  - Service Chaining
  - Service Monitoring
  - Auto Recovery
  - Elastic Scaling
  - Workload Placement
  - Service Assurance

- OPEN DAYLIGHT [fd.io]
  - Fast data forwarder

- Compute
- Network
- Storage

Service Provisioning
- Workload Placement
- Service Configuration

VM Policy
- Service Monitoring
- Auto Healing
- Elastic Scaling

Network Controller
- Group Policy Service
- Chaining Physical and Virtual Network Control

Hypervisor

© 2016 Cisco and/or its affiliates. All rights reserved. Cisco Confidential
Containerized Virtualized Service Pipelines

Stand-alone Containerized Media Service with a REST Interface

Cloud Native Service

REST endpoint (control)

Packet Services

VPN endpoints

VPN In

VPN Out

Running services listed (+ health checks)

Services always ready & allocated to pipeline by media load balancer

Services deployed & maintained by Mesos/Marathon

Containerized Virtualized Service Pipelines

© 2016 Cisco and/or its affiliates. All rights reserved. Cisco Confidential
Network: IP Fabric for NFV
Creating the scalable foundation for virtualized services.
IPv4  Operational complexity: Underlays, Overlays, VLANs, NATs, ALGs,…

IPv6  IPv6-Centric Networking: Scale, Simplification and Services
SP Media DC != Enterprise switching

- Live production media is well groomed: Load Engineering
- Learning Media flows and flow bandwidths
- End to End bandwidth reservation/Admission Control
- Quality of Service
- Flow security
Multivendor Network Topologies

Highlights

- SMPTE 2022-6 Interop with 3 Vendors
- Non blocking 40G IP Fabric
- legacy control Panels to manage Video flows
- Mix of IGMP and SDN solutions
Service Brokered Networking: Guaranteeing WorkFlow Resources

- Rapid and transparent workload migration for VMs, containers, and content
- Dynamic, scalable, in-network workload discovery
- Data path, compute and storage management with integrated media load balancing
- Workflow service pipeline integrated with application engineered data paths
- Guaranteed high network throughput between workers
# Uncompressed video data rates

<table>
<thead>
<tr>
<th>Format</th>
<th>pixels/second</th>
<th>Pixel format</th>
<th>raw bitrate (Gbps)</th>
<th>+ audio &amp; ancilliary data (Gbps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>480i60 (SD)</td>
<td>10 368 000</td>
<td>YUV 4:2:2 10 bit</td>
<td>0.21</td>
<td>0.27</td>
</tr>
<tr>
<td>1080p30</td>
<td>62 208 000</td>
<td>YUV 4:2:2 10 bit</td>
<td>1.24</td>
<td>1.49</td>
</tr>
<tr>
<td>1080p60 (HD)</td>
<td>12 4416 000</td>
<td>YUV 4:2:2 10 bit</td>
<td>2.49</td>
<td>2.97</td>
</tr>
<tr>
<td>4Kp60</td>
<td>497 664 000</td>
<td>YUV 4:2:2 10 bit</td>
<td>9.95</td>
<td>11.88</td>
</tr>
<tr>
<td>4Kp120</td>
<td>995 328 000</td>
<td>YUV 4:4:4 16 bit</td>
<td>47.78</td>
<td></td>
</tr>
<tr>
<td>8Kp60</td>
<td>1 990 656 000</td>
<td>YUV 4:2:2 10 bit</td>
<td>39.81</td>
<td>47.52</td>
</tr>
<tr>
<td>8Kp120</td>
<td>3 981 312 000</td>
<td>YUV 4:4:4 16 bit</td>
<td>191.10</td>
<td></td>
</tr>
</tbody>
</table>

Greater bit depth for HDR

IO can keep up

SDI Bitrates
IP Fabric for Media: Getting into Production

- Flexible Workflow
- Deterministic Low Latency and Jitter
- Deterministic Quality of Service
- Zero Packet Loss
  - Reservation of network resources across redundant paths for zero congestion loss
- Video/Audio End Point Sync and Lock with Micro-sec Accuracy
  - Precision Timing and Synchronization
- Fast and Clean Switching
  - Switching streams with minimal delay and on frame boundary
- System Availability
  - Same or better than SDI-based system
- Network Security
  - Protect network operations from any malicious attacks

© 2016 Cisco and/or its affiliates. All rights reserved. Cisco Confidential
VPP in the Overall Stack

- Application Layer/App Server
- VM/VIM Management Systems
- Orchestration
- Network Controller
- Operating Systems
- Data Plane Service
  - Packet Processing
  - Network IO
- Hardware
VPP TECHNOLOGY IN A NUTSHELL

- Throughput NDR = “No Drop Rate”
- “No Drop Rate” = Read zero frame loss
  - And not “ITU 10^-7 packet loss ratio”
- Simply put NDR here is better than "ITU NDR"

NDR rates for 2p10GE, 1 core, L2 NIC-to-NIC

NDR rates for 2p10GE, 1 core, L2 NIC-to-VM/VM-to-VM

- Virtual network infrastructure – benchmarking the efficiency
- All tests with minimal connections only, single CPU core
- Higher performance with more connections, more CPU cores
- Latest SW at the time: OVSDPDK 2.4.0, VPP 09/2015
VNET-SLA BENCHMARKING AT SCALE: IPV6, V4, MAC

VPP-based vSwitch

Zero-packet-loss Throughput for 12 port 40GE, 24 cores, IPv6

- FD.io VPP data plane throughput not impacted by large size of IPv6 FIB
- VPP tested on UCS 4-CPU-socket server with 4 of Intel “Haswell” x86-64 processors E7-8890v3 18C 2.5GHz
- 24 Cores used – Another 48 cores can be used for other network services!

VPP vSwitch IPv6 routed forwarding FIB with 2 milion IPv6 entries 12x40GE (480GE) 64B frames

200Mpps zero frame loss
NIC and PCIe is the limit not VPP

VPP vSwitch IPv6 routed forwarding FIB with 2 milion IPv6 entries 12x40GE (480GE) IMIX frames

480Gbps zero frame loss
“Sky” is the limit not VPP
VNET-SLA BENCHMARKING AT SCALE: IPV4 + SECURITY
VPP-based vSwitch

Zero-packet-loss Throughput for 18 port 40GE, 36 cores, IPv4

That Is Right – No Impact on IMIX Performance

- FD.io VPP data plane throughput not impacted by large IPv4 FIB size, and stateless security input access lists and white-lists & black-lists*
- VPP tested on UCS 4-CPU-socket server with 4 of Intel "Haswell" x86-64 processors E7-8890v3 18C 2.5GHz
- 36 Cores used – Another 36 cores can be used for other network services!

VPP Cores Not Completely Busy
VPP Vectors Have Space For More Services and More Packets!!
PCIe 3.0 and NICs Are The Limit

VPP vSwitch IPv4 routed forwarding FIB with 2M IPv4 entries, 2k white-list* 18x40GE IMIX frame sequence
342Gbps zero frame loss
Sky* is the limit not VPP

VPP vSwitch IPv4 routed forwarding FIB with 2M IPv4 entries, 2k white-list* 18x40GE 1518B frames
462Gbps zero frame loss
PCIe 3.0 is the limit not VPP

* Test results extrapolated from 120GE 2-Socket machine. See next slides for why.
# VPP Features

## IPv4/IPv6
- 14+ MPPS, single core
- Multimillion entry FIBs
- Source RPF
- Thousands of VRFs
- Controlled cross-VRF lookups
- Multipath – ECMP and Unequal Cost
- Multiple million Classifiers – Arbitrary N-tuple
- VLAN Support – Single/Double tag

## Counters for Everything
- Mandatory Input Checks:
  - TTL expiration
  - header checksum
  - L2 length < IP length
  - ARP resolution/snooping
  - ARP proxy

## IPv4
- GRE, MPLS-GRE, NSH-GRE, VXLAN
- IPSEC
- DHCP client/proxy
- CG NAT

## IPv6
- Neighbor discovery
- Router Advertisement
- DHCPv6 Proxy
- L2TPv3
- Segment Routing
- MAP/LW46 – IPv4aas
- iOAM

## L2
- VLAN Support
- Single/Double tag
- L2 forwarding with EFP/Bridge Domain concepts
- VTR – push/pop/Translate (1:1,1:2, 2:1,2:2)
- Mac Learning – default limit of 50k addresses
- Bridging – Split-horizon group support/EFP
- Filtering
- Proxy Arp
- Arp termination
- IRB – BVI Support with Router Mac assignment
- Flooding
- Input ACLs
- Interface cross-connect

## MPLS
- MPLS-o-Ethernet – Deep label stacks supported
The Fast Data Project (FD.io)
Relentlessly focused on data IO speed and efficiency for more flexible and scalable networks and storage.
Incident Impact Analysis, Workflow Analytics, Application Engineered.
WorkFlow ANALYTICS IS A CF

- Analytics Today addressed by performing a query function against the entire data set = PROBLEM
  - Fault management = \( f(\text{event data}) \)
  - Performance management = \( f(\text{metric data}) \)
  - Service mediation = \( f(\text{event data, metric data}) \)
  - Capacity management = \( f(\text{metric data}) \)
  - Security analytics = \( f(\text{metric data, route data}) \)
Platform For Data Analytics

Principles

- Decouple data aggregation (publishers) from data analysis (consumers) – allow any OSS app the potential to access any data source
  - Simple, scalable, open data distribution platform
    - Scale-out architecture with support for horizontal scale in all core components
    - Very highly available core platform
    - Low and predictable latency
- Immutable Dataset
  - All data stored raw
  - Minimal filtering/processing on ingress
- Minimal filtering/processing on ingress
- Analytics based approach to analysis functions
- Support for streaming apps, real-time queries and batch processing

Data Sources
Publishers: Data Aggregation

Data Distribution
Data Store & Processing

Data Platform

Live Stream
Stream Processing
Real Time Data Store
Real Time Query

Fault Analysis
Perf Analysis
Log Search
Security and Threat Analysis
Capacity Analytics
Inventory
Billing (Mediation)
Business Intelligence

Deep Historical Query
Batch Processing

Netflow
Network Telemetry

Logs
Log Aggregation

SNMP
Monit, Collectd, Logstash, Ceilometer

Metric Aggregation
Event Aggregation

High performance pub/sub bus
Platform For Data Analytics
WorkFlow Service Impact Analysis

- Data analytics Platform
- Full-stack data instrumentation: BGP routing, telemetry, syslog, Netflow, Workflow
- Syslog analysis based on host | event frequency | event repetition
- Correlate data sources to identify root cause of service-impacting events
- Use this insight for platform service assurance e.g. optimal codec bitrate for max QoS and resource engineering
- Enable “Reactivity”
Putting the Pieces together

Applications/ Business Outcomes

Model Driven Orchestration

Cloud Platform

Compute, Network, Storage Infrastructure

Virtual Managed Services

Operator Portal

Service Life Cycle Manager
Network Services Orchestrator

Virtual Machine Life Cycle Manager
Elastic Services Controller

Platform For Network Data Analytics

Consuming Analytics Apps

Plugin Data Producers

Fast Data forwarder

OPEN DAYLIGHT

Plugin Data Producers

OPEN DAYLIGHT

Plugin Data Producers

OPEN DAYLIGHT

Plugin Data Producers

OPEN DAYLIGHT
NETWORKING FOCUSED ON LIMITED DEV COMMUNITY AND APPLICABILITY
NEW COMMUNITY = NOSTACKDEVELOPER

| Turning data into information to drive intent

Business Solutions
Platform

APPLICATIONS & PaaS

SERVICES ORCHESTRATION

ANALYTICS

NETWORK
WORKFLOW -> REACTIVE SERVICE BROKER
Enabling the SP Media Service Broker

- Workflow Creation
- Model Driven Orchestration
- Media Optimized Platform
- Compute, Network, Storage Infrastructure

PRODUCTION
- 3rd party Workflow Management
- 3rd party applications

DISTRIBUTION
- Cisco V2P-C
- V2P Applications (Cisco & 3rd Party)

- Applications & Pass
- Network Intelligence, Guidance
- Platform for Network Analytics
- Plugin Data Brokers
- Statistics, States, Objects and Events

Platform for Network Analytics
- OpenDaylight
- [k.d.io] Fast Data Forwarder

Workload Orchestration
- Service Life Cycle Manager
- Network Services Orchestration
- Virtual Machine Life Cycle Manager
- Elastic Services Controller
- Service Life Cycle Manager
- Elastic Services Controller

Programmability
- Network Intelligence, Guidance
- Statistics, States, Objects and Events

Model Driven Orchestration
- Workflow and Intent
- Model Driven Orchestration
- Workflow and Intent
Networking Open Source Project Participation ~ 2 years
Measuring Success

Committer/Contributor Diversity

- Single committer, little pull/patch activity
- Committed diversity, active developer engagement

Production Deployment

- Not in production, snowflake implementation
- In production broadly, cookie cutter implementation

Community & Ecosystem

- Dominated by single org, no commercial ecosystem
- Diverse community, commercial offers
Massive Growth in Project Engagement

In a Nutshell, FD.io...

... has had 679 commits made by 60 contributors representing 246,524 lines of code

... is mostly written in C with an average number of source code comments

... has a codebase with a very short history maintained by a very large development team with stable Y-O-Y commits

... took an estimated 65 years of effort (COCOMO model) starting with its first commit in November, 2015 ending with its most recent commit 3 days ago

In a Nutshell, OpenStack...

... has had 171,602 commits made by 4,009 contributors representing 1,751,287 lines of code

... is mostly written in Python with an average number of source code comments

... has a well established, mature codebase maintained by a very large development team with stable Y-O-Y commits

... took an estimated 499 years of effort (COCOMO model) starting with its first commit in December, 2006 ending with its most recent commit 5 days ago
Early 2015: Open Source Umbrella Architecture

- OpenShift
- MANO (Cloud Orchestration)
  - Neutron
  - OpenStack
  - OpenDaylight
- OVS
- DPDK
- Linux
- OpenCompute

OPNFV
2015-2016: Open Source Umbrella Architecture
~ 8 New Open Source Projects Under the Linux Foundation

- CloudFoundry
- OpenShift
- Neutron
- OpenDaylight/ONOS
- MANO (Cloud Orchestration)
- Cloud Native Computing Foundation
- OVS
- OpenStack
- DPDK
- IO Visor
- OCI
- Fd.io (Virtual Packet Processing)
- Linux
- OpenCompute

*New to LF in 2015/2016

- IoTivity
- Kinetic Open Storage
- Hyperledger
- OPNFV
2016++: Open Source Umbrella Architecture

- Cloud Foundry
- OpenShift
- MANO (Cloud Orchestration)
- OpenStack
- Neutron
- OpenDaylight/ONOS
- Fd.io (Virtual Packet Processing)
- DPDK
- CNI
- Linux
- OpenCompute
- Armory (Virtual Network Functions)
- OVS
- IO Visor
- OCI
- Cloud Native Computing Foundation
- OPNFV
- IoTivity
- Kinetic Open Storage
- Hyperledger
- PNDA
- Hadopp
- Storm
- Spark
- Kafka

*New to LF in 2015/early 2016
*Coming in 2016
Open Networking Architecture

- Application Layer / App Server
- VM/VIM Management Systems
- Orchestration
- Network Controller
- Operating Systems
- IO Abstraction & Feature Path (Performance & Functionality)
- Hardware
Enter The #NoStackDeveloper: “Dear Infra, Do what I need”

• Assume stable stack infra
  • Controllers, analytics, orchestration, service chaining
  • HV, Container management and lifecycle maintenance

• Simplify communication of intent w/ resources

• Visualize how Workflow actually performed and how it can work better

• Want to express Needs/Wants to layers down w/o every changing “Whole Stack” awareness/change in project