Introduction to Software-Defined Networking (SDN) and Network Programmability

Jason Davis, Distinguished Engineer (Services)
BRKRST-1014
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Abstract

SDN is an exciting new approach to network IT Service Management. You may have questions about SDN, Controllers, APIs, Overlays, OpenFlow and ACI. You may also be wondering what products and services are SDN-enabled and how you can solve your unique business challenges and enhance your differentiated services by leveraging network programmability.

In this introductory session we will cover the genesis of SDN, what it is, what it is not, and Cisco’s involvement in this space. Cisco’s SDN-enabled Products and Services will be explained enabling you to consider your own implementations. Since SDN extends network flexibility and functionality which impacts Network Engineering and Operations teams, we’ll also cover the IT Service Management impact.

Network engineers, network operation staff, IT Service Managers, IT personnel managers, and application/compute SMEs will benefit from this session.
Agenda

• What is SDN & Network Programmability
• What are the Use Cases and Problems Solved with SDN?
• What Are Cisco's solutions?
• An Overview of Network Controllers
• An Overview of ACI

• The Impact to IT Service Management
• How to Get Ready
What is Software-Defined Networking (SDN)?

- An approach and architecture in networking where control and data planes are decoupled and intelligence and state are logically centralized.
- An enabling technology where underlying network infrastructure is abstracted from the applications [network virtualization].
- A concept that leverages programmatic interfaces to enable external systems to influence network provisioning, control and operations.
SDN is...

...an approach to *network transformation*

...empowering *external, non-traditional entities to influence network* design and operations

...impacting the networking industry - *challenging the way we* think about engineering, implementing and managing networks

...providing new methods to interact with equipment/services via *controllers, APIs*

...normalizing the interface with equipment/services

...enabling high-scale, rapid network and service provisioning/management

...providing a catalyst for traditional Route/Switch engineers to branch-out

* [...]not the first attempt!*
SDN is **not**

...an easy button... [but is intending to make things easier for all!]

...a panacea or end-state

...narrowly defined

...meaning the death of network engineers

...a mandate for all network engineers to become C and Java programmers*

...a new ISDN service from Apple called iSDN 😊

...a new attempt at network evolution...

* [...]but...how do you distinguish yourself and your career?]
Have We Seen This Before?

Control Plane / Data Plane Separation – Centralized Control

- SS7
- ATM LANE
- Wireless LAN Controller
- GMPLS

Overlays / Encapsulations

- MPLS
- VPLS
- VPN
- GRE Tunnels
- LISP

Management and Programmatic Interfaces

- SNMP
- NETCONF
- EEM
Where Did SDN Come From?

Have you tried rebooting the Internet yet?

http://cleanslate.stanford.edu/
The Traditional Network…

Control and Data Plane resides within Physical Device

Control plane learns/computes forwarding decisions
Data plane acts on the forwarding decisions
The Network As It Could Be…to an SDN ‘Purist’

Control plane becomes centralized
Physical device retains Data plane functions only
The Network As It Could Be…In a ‘Hybrid SDN’

A Controller is centralized and separated from the Physical Device, but devices still retain a localized Control plane intelligence.
What are the Use Cases and Problems Solved with SDN?
Use Cases: Network Programmability

- **Research/Academia**: Experimental OpenFlow/SDN components for production networks.
- **Massively Scalable Data Center**: Customize with Programmatic APIs to provide deep insight into network traffic.
- **Cloud**: Automated provisioning and programmable overlay.
- **Service Providers**: Policy-based control and analytics to optimize and monetize service delivery.
- **Enterprise**: Virtual workloads, VDI, Orchestration of security profiles.

**Diverse Requirements Across Segments (Automation & Programmability)**
SDN Addresses Needs for…

- Centralized configuration, management/control, monitoring of network devices (physical or virtual)
- Ability to override traditional forwarding algorithms to suite unique business or technical needs
- Allowing external applications or systems to influence network provisioning and operation
- Rapid and scalable deployment of network services with life-cycle management
Why Change?

• Familiar Manual, CLI-driven, device-by-device approach is inefficient

• Increased need for programmatic interfaces which allow faster and automated execution of processes and workflows with reduced errors

• Need for a ‘central source of truth’ and touch-point
Weather-Based Routing
Business Metrics Influencing Routing

- Class Schedule
- Staff Directory
- Main Campus
- Remote Classroom

Controller

API

GUI

WAN1 (MPLS)
WAN2 (EPL)
WAN3 (Internet)
Hey Team, Chuck went into the DC with a laptop and console adapter, FYI.

NSO bot (@sparkbot.io)  5/4/17, 10:53 AM
CPO Integration with NSO PROVISIONED the Service named “Jason Test 1” for Job 93 at 5/4/2017 10:53:14 AM with results “Created / 201” in 28.2 seconds
CPO Integration with NSO TESTED the Device "CSS-38" with result
   SIGNALING-ENB: Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/4 ms

You  5/4/17, 10:54 AM
Hey Team, Chuck went into the DC with a laptop and console adapter, FYI

NSO bot (@sparkbot.io)  5/4/17, 10:58 AM
Alert! User nso1 made an unauthorized configuration change to device CSS-38 at May 4 20:28:10.970 IST Review

NSO bot (@sparkbot.io)  5/4/17, 10:59 AM
Network Administrator “admin” approved the unauthorized config change to device CSS-38. NSO has merged it with the latest archive.
An Overview of OpenFlow
What is OpenFlow?

...a Layer 2 communications protocol that gives access to the forwarding plane of a network device,...

...a specification for building switches conforming to the protocol
What Makes OpenFlow Different?

Actions

1. Forward out all ports except input port
2. Redirect to OpenFlow Controller
3. Forward to local Forwarding Stack (CPU)
4. Perform action in flow table
5. Forward to input port
6. Forward to destination port
7. Drop Packet

OF v1.0 Example

<table>
<thead>
<tr>
<th>Required Actions</th>
<th>Action Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Forward out all ports except input port</td>
</tr>
<tr>
<td>2</td>
<td>Redirect to OpenFlow Controller</td>
</tr>
<tr>
<td>3</td>
<td>Forward to local Forwarding Stack (CPU)</td>
</tr>
<tr>
<td>4</td>
<td>Perform action in flow table</td>
</tr>
<tr>
<td>5</td>
<td>Forward to input port</td>
</tr>
<tr>
<td>6</td>
<td>Forward to destination port</td>
</tr>
<tr>
<td>7</td>
<td>Drop Packet</td>
</tr>
</tbody>
</table>
# What Makes OpenFlow Different?

## Flow Table

<table>
<thead>
<tr>
<th>Ingress Port</th>
<th>Source MAC</th>
<th>Dest MAC</th>
<th>Ether Type</th>
<th>VLAN ID</th>
<th>VLAN Priority</th>
<th>IP SRC</th>
<th>IP DEST</th>
<th>IP Protocol</th>
<th>IP TOS</th>
<th>TCP/UDP SRC</th>
<th>TCP/UDP DEST</th>
<th>Action</th>
<th>Priority</th>
<th>Counter</th>
</tr>
</thead>
<tbody>
<tr>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>Fwd Port 10</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>00:01:E7:*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>Fwd Port 14...24</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>Firewall/Security</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>Inspection</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>00:01:E7:*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>Vlan10</td>
<td>80</td>
<td>200</td>
</tr>
<tr>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>192.168.1.*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>Multi-action ; NAT</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

*Local handling*
<table>
<thead>
<tr>
<th>OpenFlow Version</th>
<th>Introduced</th>
<th>Notable Features</th>
<th>Flow-spec Tuple</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>2009-12</td>
<td>Initial Specification</td>
<td>12</td>
</tr>
<tr>
<td>1.1</td>
<td>2011-02</td>
<td>Support for multiple flow tables; Added support for MPLS Defined two operating modes – Hybrid</td>
<td>Pure OpenFlow</td>
</tr>
<tr>
<td>1.2</td>
<td>2011-12</td>
<td>Support for IPv6 Multiple Controller support</td>
<td>34</td>
</tr>
<tr>
<td>1.3</td>
<td>2012-06</td>
<td>Support for Rate Limiting; IPv6 Extensions, GRE Version increasingly used by customers/manufacturers</td>
<td>38</td>
</tr>
<tr>
<td>1.3.1</td>
<td>2012-09</td>
<td>Support for Negotiation TLVs</td>
<td>38</td>
</tr>
<tr>
<td>1.3.2</td>
<td>2013-04</td>
<td>Support for controller-initiated connections</td>
<td>38</td>
</tr>
<tr>
<td>1.4</td>
<td>2013-10</td>
<td>Support for Rule change ‘transactions’</td>
<td>40</td>
</tr>
<tr>
<td>1.3.3</td>
<td>2013-12</td>
<td>Update with IANA registered TCP port : 6653 Clarify multipart segmentation rules, clarify use of empty multipart messages Specify the normal fragment handling is mandatory, drop/reasm optional</td>
<td>40</td>
</tr>
<tr>
<td>1.3.4</td>
<td>2014-03</td>
<td>Clarify table feature wildcard list should not include fields that are mandatory in some context only Add section about control channel maintenance Push MPLS should add a MPLS header before the IP header and before MPLS tags, not before VLAN which is not valid</td>
<td>40</td>
</tr>
<tr>
<td>1.5</td>
<td>2014-12</td>
<td>Egress Tables; Packet aware pipeline (IP, PPP); flexible encoding - OpenFlow eXtensible Statistics (OXS); set-field action wildcard; Controller connection status</td>
<td>44</td>
</tr>
<tr>
<td>1.5.1</td>
<td>2015-03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input Switch Port</td>
<td>Switch Physical Input Port</td>
<td>Intra-Table Metadata</td>
<td>Ethernet Dest Addr</td>
</tr>
<tr>
<td>-------------------</td>
<td>-----------------------------</td>
<td>----------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>TCP Source Port</td>
<td>TCP Dest Port</td>
<td>UDP Source Port</td>
<td>UDP Dest Port</td>
</tr>
<tr>
<td>IPv6 Flow Label</td>
<td>ICMP v6 type</td>
<td>ICMP v6 code</td>
<td>Target Addr for ND</td>
</tr>
</tbody>
</table>

**RFC 7443**
What Is OpenDaylight?

• …an **open source project** formed under the Linux Foundation to further the adoption and innovation of Software Defined Networking (SDN) through the creation of a common vendor supported framework.

• Focus: Customers with some programming resources that desire a free, community-supported SDN controller, especially if focus is on OpenFlow
OpenDaylight Contributions

Source: [http://spectrometer.opendaylight.org/?metric=loc](http://spectrometer.opendaylight.org/?metric=loc)
**OpenDaylight Architectural Model**

**Hydrogen**
- Released February 2014
- 1.87M+ lines of code
- 28 Projects
- 256 Contributors

**Helium**
- Released October 2014
- 1.87M+ lines of code
- 28 Projects
- 256 Contributors

**Lithium**
- June 2015

**Beryllium**
- Feb 2016

**Boron**
- November 2016
OpenFlow-enabled devices that are configured to this controller automatically show up in the topology.
Other Aspects of SDN
SDN Protocols in Networking
Industry Communities, Projects and Standards Bodies

Technical Advisory Board seat

Technical Advisory Group Chair, Working Groups:
- Config, Hybrid, Extensibility, Futures/FPMOD/OF2.0

Puppet Agent Modules
- Puppet Labs investor

Contributor - Technical Committee Management Area Projects

Cisco Innovations:
- FEX Architecture
- 802.1 Overlay Networking Project

Open Network Research Center at Stanford University

Initiatives:
- Neutron API
- Donabé
- Cisco Innovations: OpenStack API for Nexus OpenStack Extensions

Founding Platinum member
- Catalyzed initial Open Source offering

Open Source Cloud Computing project

Cisco Innovations:
- Open Daylight

Overay Working Groups:
- NVO3, L2VPN, TRILL, L3VPN, LISP, PWE3

Working Groups:
- NETCONF, ALTO, CDNI, XMPP, SDNP, I2AEX
- PCE, FORCES
- I2RS – Interface to Routing System

Technical Advisory Board seat

IETF

Contributor - Technical Committee Management Area Projects

CloudStack

MEF

Open Networking Foundation

ONRC Research

IETF

Chef
Software-Defined Wide Area Network (SD-WAN)

• Design and implementation of WANs using principles of SDN to selectively route traffic (TE)

• Shift Traffic monitoring, service assurance and management from physical devices to (virtualized) applications

• Intelligence abstracted to virtual overlay -- enables private and public connections, automation, centralized network control, and agile, real-time traffic management over multiple links securely

• Enables administration via a central controller, reduces provisioning times and eliminates manual configuration of branch routers

• Enables network programmability through broad availability of APIs
I WAN Enabling SD-WAN

Transport-independent design
Intelligent path control
Application optimization
Secure connectivity

Dual MPLS
- Oracle
- Internet
- Public
- Branch
- MPLS

Hybrid
- Enterprise
- VMware
- Citrix
- SAP
- SharePoint
- Webex
- Public
- Branch
- MPLS and Internet

Dual Internet
- Enterprise
- VMware
- Citrix
- SAP
- SharePoint
- Webex
- Public
- Branch
- Internet

✔ Highest SLA guarantees
- Tightly coupled to SP
- Expensive

✔ More bandwidth for key applications
✔ Balanced SLA guarantees
- Moderately priced

✔ Best price/performance
✔ Most SP flexibility
- Enterprise responsible for SLAs
Network Function Virtualization (NFV)

Network infrastructure Services to run on Virtualized compute platforms

Key Enabler: using cloud technology to support network functions
- Hypervisor and cloud computing technology
  - X86 compute hardware
- Network automation / orchestration

Benefits:
- Reduction in CAPEX and OPEX
- Faster service provisioning
- Service agility

SDN is complementary, but not mandatory – APIs, Controllers
Network Function Virtualization (NFV)

Service provisioning from days to minutes

From Cabling to Service Chaining

Simple Logistics & Common Sparring

Dynamic & Elastic Scale

Seamless Integration with IP NGN
Virtualizing Network Functions

x86 vs. Custom Network Processing Unit (NPU)

Network Forwarding (L0-3)
- e.g. IPv6/v4, MPLS, VPNs, Optical
- High throughput / BW
- Stateless functions
- Mostly predictable traffic
- Many flows needing isolation, significant traffic management needed
- Interface-specific functions (2-stage forwarding)

Network Services (L4+)
- e.g. DPI, FW, CGN, BNG, Mobility S/Pgw, AAA, DNS, DDOS
- Low to Med Throughput
- Stateful functions
- Unpredictable traffic
- # of flows (traffic management) – varies
- No interface-specific functions

Better fit for NPU
- Better fit for x86 (Virtualization)
NFV – #1 Use-case
Virtual Route Reflector

IPv4
IPv6
VPNv4
VPLS

Wide Area Network

8 RR chassis

Primary RR
Secondary RR

Primary Server
Secondary Server

IPv4
IPv6
VPNv4
IPv4
IPv6
VPNv4

Better fit for x86

Compute
Bandwidth

2 Server Chassis
1 RR per VM
Overlays

Overlay / Virtual Network
- Mobile
- Scalable
- Supports Segmentation / multi-tenancy
- Programmable & Manageable

Underlay / Fabric
- High Capacity
- Resilient
- Intelligent Traffic Handling
- Programmable & Manageable

Cisco live!
Layer-2 Overlays

- Emulate L2 LAN Segment
- Transport Ethernet Frames (IP and non-IP)
- Can emulate physical topologies
  - Single Subnet Mobility (L2 domain)
  - Exposure to L2 Flooding
Layer-3 Overlays

+ Abstract IP-based connectivity
+ Transport IP Packets
+ Can emulate physical topologies
+ Full Mobility regardless of subnet
+ Contain Network Failures/Flooding
+ Useful in abstracting connectivity and policy
The Edges of Overlays

Network Overlays
- Physical
- Router/Switch end-points
- Protocols for Resiliency & Loops
- Traditional VPNs
- OTV, VXLAN, VPLS, LISP

Host Overlays
- Virtual
- Virtual end-points only
- Single administrative domain
- VXLAN, NVGRE, STT

Integrated Overlays
- Virtual
- Physical and virtual end-points
- Resiliency & Scale; Cross-org & Federation
- Open Standards
- ACI
Network Overlay/SDN Humor

This is totally the future. All you folks with drivers licenses – sorry - your jobs are at risk.

Aaaah!! Why can’t I go any faster? I thought I had control?!?

I see smoke but there’s no warning lights on my dashboard! WTH?!!

Credit to Sean McGee
What Are Cisco's SDN solutions?
Cisco SDN: Providing Choice in Automation and Programmability

Application Centric Infrastructure

- Turnkey integrated solution with security, centralized management, compliance and scale
- Automated application centric-policy model with embedded security
- Broad and deep ecosystem

Programmable Fabric

- VxLAN-BGP EVPN standard-based
- 3rd party controller support
- VTS for software overlay provisioning and management across N2K-N9K

Programmable Network

- Modern NX-OS with enhanced NX-APIs
- Automation Ecosystem (Puppet, Chef, Ansible etc.)
- Common NX-API across N2K-N9K

Mass Market (commercial, enterprises, public sector)

Service Providers

Mega Scale Datacenters
SDN / SD-WAN / NFV Solutions

• Hardware
  – Cisco 4000 Series Integrated Services Router (ISR) with UCS E-series server module
  – Cisco 5000 Enterprise Network Compute System (ENCS)
  – Cisco ASR 1000 Series Router
  – Nexus 9000 (ACI)
### SDN / SD-WAN / NFV Solutions

- **Software**

<table>
<thead>
<tr>
<th>Product Description</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cisco Integrated Services Virtual Router (ISRv), ASAv, vWLC, vWAAS</td>
<td>Virtual Network Functions</td>
</tr>
<tr>
<td>Enterprise Service Automation (ESA)</td>
<td>a module to APIC-EM that automates Virtual Network Functions (VNFs) across multiple sites</td>
</tr>
<tr>
<td>Cisco Enterprise Network Functions Virtualization Infrastructure Software (NFVIS)</td>
<td>provides the Linux-based virtualization layer allowing addition of VNFs to the network with an integrated hypervisor and graphical user interface</td>
</tr>
<tr>
<td>Cisco Virtual Managed Services (VMS)</td>
<td>Service Provider focused</td>
</tr>
<tr>
<td>APIC-EM</td>
<td>Enterprised-focused controller for IWAN, Plug and Play, Easy QoS</td>
</tr>
<tr>
<td>Virtual Topology System (VTS)</td>
<td>Nexus Data Center focused – software-overlay management and provisioning system</td>
</tr>
<tr>
<td>WAN Automation Engine (WAE)</td>
<td>Planning and Automation for application engineered routing and analysis</td>
</tr>
<tr>
<td>Viptela</td>
<td>(Pending Acquisition)</td>
</tr>
</tbody>
</table>
WAE

Provides a cross-sectional view of traffic, topology, and equipment status.

Provides a predictive model that performs "what if" analyses of failure impacts.

WAE Planning evolved from the Cisco MATE software suite -- used in Service Provider networks for more than 10 years.
Cisco WAE Automation combines smart data collection, modeling, and predictive analytics into an extensible API-based configuration platform.

Demand-Admission Requests
Coordinated Maintenance
Load-Balancing Label-Switched Paths
Application Engineered Routing
Cisco Virtual Topology System (VTS)

- Datacenter Overlay Provisioning and Management System
- Automates Overlay provisioning across Cisco Datacenter Top of Rack Nexus switches (Nexus 2K-9K), Virtual Switches & DCI routers
- Automates fabric provisioning for physical, bare metal, virtual machine and container workloads
- For container networking VTS integrates with Cisco Container Networking (CCN) based on Contiv/VPP
- Programmable using North Bound REST APIs
- Tighter Integration with Orchestration systems such as Openstack, vCenter and Cisco NSO

Simplified Management for Ease of Operations

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## Unified Open NX-OS Release for Nexus Platforms

**Delivering Operational Flexibility and Lower OPEX**

<table>
<thead>
<tr>
<th>Programmable Open APIs</th>
<th>3rd Party DevOps Automation Tools</th>
<th>Custom Application Development</th>
<th>Managing Switch with Linux Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open, Modular Operating System</td>
<td>Toolset Integration in Open NX-OS</td>
<td>Extensible Open NX-OS</td>
<td>Leverage Linux Toolchain for Switch Management</td>
</tr>
<tr>
<td>Enhancements to existing NX-API to support object-based, model driven APIs (RESTful XML/JSON)</td>
<td>Pre-developed RPMs from Cisco and Partners Leverage same software tools and expertise across different IT departments</td>
<td>New SDK enables custom application development with option for secure lxc containers CPU, memory, priority controls</td>
<td>Leverage tcpdump, ifconfig ethtool, iproute, BASH shell commands for config and troubleshooting</td>
</tr>
</tbody>
</table>

---

**Programmable Open APIs**

- Enhancements to existing NX-API to support object-based, model driven APIs (RESTful XML/JSON)

**3rd Party DevOps Automation Tools**

- Toolset Integration in Open NX-OS
  - Pre-developed RPMs from Cisco and Partners Leverage same software tools and expertise across different IT departments

**Custom Application Development**

- Extensible Open NX-OS
  - New SDK enables custom application development with option for secure lxc containers
  - CPU, memory, priority controls

**Managing Switch with Linux Tools**

- Leverage Linux Toolchain for Switch Management
  - Leverage tcpdump, ifconfig ethtool, iproute, BASH shell commands for config and troubleshooting
• Application Policy Infrastructure Controller – Enterprise Module
  A purpose-built, easy to use SDN controller
• Does NOT require programming experience [but does have REST NBI]
• Does NOT require HW/SW upgrades to take advantage of controller model
• Has specific applications built-in to address common network needs: Enterprise Service Automation (ESA), Intelligent WAN (IWAN)*, Plug-and-play (PnP), Path Trace, Easy QoS
• Foundation Software Available to SmartNet customers without charge

• Focus: Enterprise Customers with Few to No Programming Resources that desires a Commercially-supported solution that preserves existing investment and doesn’t require HW/SW upgrades
APIC-EM Architecture

A New Software-Driven Platform for Solutions Development
## Network Information Base Provides “One Source of Truth”

### Filters

<table>
<thead>
<tr>
<th>Device Name</th>
<th>MAC Address</th>
<th>IP Address</th>
<th>IOS/Firmware</th>
<th>Platform</th>
<th>Serial Number</th>
<th>Config</th>
<th>Device Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDN-BRANCH-2960S</td>
<td>5C:50:15:BF:6D:C0</td>
<td>40.0.5.4</td>
<td>15.2(1)E2</td>
<td>WS-C2960S-24TS-L</td>
<td>FOC1612W3Z2</td>
<td>View</td>
<td>Access</td>
</tr>
<tr>
<td>SDN-BRANCH-2960S-STACK</td>
<td>00:26:52:7D:2C:C0</td>
<td>40.0.7.5</td>
<td>15.2(1)E2</td>
<td>WS-C2960S-48FPD-L</td>
<td>FOC14122K</td>
<td>View</td>
<td>Access</td>
</tr>
<tr>
<td>SDN-BRANCH-3560C</td>
<td>1C:AA:07:63:8B:40</td>
<td>40.0.5.7</td>
<td>12.2(55)E2</td>
<td>WS-C3560CG-8PC-S</td>
<td>FOC1516W4X</td>
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<tr>
<td>SDN-BRANCH-3560X</td>
<td>60:73:5C:EF:13:40</td>
<td>40.0.5.9</td>
<td>15.2(1)E2</td>
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<td>Access</td>
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<td>SDN-BRANCH-3650</td>
<td>F8:72:EA:0D:67:47</td>
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<td>03.03.06SE</td>
<td>WS-C3650-24PD</td>
<td>FDO1733OQ2X</td>
<td>View</td>
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<tr>
<td>SDN-BRANCH-3750X</td>
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<td>40.0.7.4</td>
<td>15.2(1)E1</td>
<td>WS-C3750X-48P</td>
<td>FDO1612P1X</td>
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<td>Access</td>
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<tr>
<td>SDN-BRANCH-AP1252-1</td>
<td>00:26:CB:7E:D2:DC</td>
<td>40.0.5.39</td>
<td>15.2(20130113:221158)</td>
<td>AIR-LAP1252AG-A-K</td>
<td>FTX13590NE</td>
<td>View</td>
<td>Access</td>
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<tr>
<td>SDN-BRANCH-ASR1002</td>
<td>78:DA:6E:13:5E:00</td>
<td>40.0.3.6</td>
<td>15.2(4)S3</td>
<td>ASR1002</td>
<td>FOX1737GJ</td>
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<td>Border Router</td>
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<td>SDN-BRANCH-C2960S-L</td>
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<td>15.2(1)E2</td>
<td>WS-C2960S-48TS-S</td>
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<td>Access</td>
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<tr>
<td>SDN-BRANCH-C4K</td>
<td>A8:0C:0D:98:CA:7F</td>
<td>40.0.5.2</td>
<td>03.03.00XO</td>
<td>WS-C4510R+E</td>
<td>FXS1749Q1LC</td>
<td>View</td>
<td>Distribution</td>
</tr>
</tbody>
</table>
QoS Classification Management

[Diagram of QoS Classification Management interface with various categories and settings, including current map, bandwidth distribution, priority classes, and applications.]
Policy Analysis (ACL Trace Example)
Plug-and-Play

Site Workflow

- Serial # and PID based device matching on server
- Operational Config and/or IOS image for each device
- Bootstrap config optional
- Import/Export to use table driven data entry

→ Or use REST for import!
IWAN

- Cisco's APIC-EM focuses on policy-based management using business language in a simple GUI.
- Plug and Play
- Centralized policy automation
- Public-key-infrastructure certificate
- QoS/DMVPN deployment and change management
- Network wide visibility and segmentation with AVC
Enterprise Service Automation (ESA)
NFV for the Enterprise - Network services in minutes, on any platform

ESA with APIC-EM

Virtual Router (ISRv)
Virtual Firewall (ASAv)
Virtual WAN Optimization (vWAAS)
Virtual Wireless LAN Controller (vWLC)
3rd Party VNFs

Network Functions Virtualization Infrastructure Software (NFVIS)

ISR 4000 & UCS E-Series
UCS C-Series
COTS
Create New Custom Profile

Matching Templates
6 templates found

- vBranch-ISRv-FW
- Virtual-ISRv-ASAv
- Virtual-ISRv-Only
- Hybrid-Small-VirtualBranch
- Virtual-SmallBranch
- Secured-Virtual-Branch

Enterprise NFV
• Network services in minutes, on any platform
Device Configuration
Enter configuration for each device

vWAAS       FW       vWLC
service-net mgmt-net lan-net
enp2   enp6s0f0   enp6s0f1 enp6s0f2 enp6s0f3

Medium Branch
Select device for ASAv
- Please Select a Group -

vCPU Count
1 CPU

Memory Size in MB
256 MB

Image location
file:///data/qcow2/images/asav951-201.qcow2
Cisco SD-WAN Options
Choose Based on Budget, Expertise, Business Priorities

On Premises DIY
- Purchase, deploy, manage yourself with Cisco® APIC-EM and IWAN App/Prime™
- Maximum control over your network using a single tenant IWAN platform
- Utilize Cisco ONE™ Software for license portability running on Cisco IWAN products

Meraki
- Cloud-based network mgmt with Cisco Meraki® for Enterprises or Service Providers
- Real-time feature and security updates pushed from the cloud
- Subscription-based, using Meraki on-premises switching and security products

Cloud Managed
- Deliver Cloud Managed IWAN from your Service Provider using VMS
- Secure multi-tenant platform, simplified NSO orchestration and tenant self-service
- Reduced CapEx, pay-as-you-grow OpEx, using Cisco IWAN and security products (physical and virtual)

Virtual Managed Services (VMS)
Key Capabilities of Cisco’s **VMS Cloud Managed SD-WAN**

Optimized for **Ease of Management**

- Automated end-to-end SD-WAN Services managed from the Service Provider Cloud
- Secure multi-tenant Cloud Managed platform, simplified orchestration and tenant self-service
- SD-WAN created with Zero Touch Provisioning (PnP) and validated IWAN Service Packs (NSO)
- Rapidly create new monetized services, modify existing services instantly from Cloud
- Perfect for distributed customers looking for lower cost and self-managed SD-WAN options
Key Technologies in Cisco’s **VMS Cloud Managed SD-WAN**

Optimized for **Flexibility and Control**

- Add lower cost Internet and LTE branch links using simple, secure, active-active links
- Integrated compute, storage, voice, caching for branch consolidation and virtualization (x86)
- Scalable, 1000+ sites per IWAN tenant, each tenant can customize their IWAN service
- Customizable Intelligent path control based on PfRv3 for granular path selection
- Application classification using NBARv2, automated link monitoring (jitter, loss, latency)
Viptela
Overview of Application Centric Infrastructure (ACI)
What Is APIC?

• The Data Center-centric SDN controller which is the unifying point of automation and management for the Application Centric Infrastructure (ACI) fabric.

• Offers services for managing System, Tenant(s), Fabric, VM(s), L4-7 Services in the Nexus 9K datacenter fabric

• NBI: REST, Python

• SBI: OpFlex ACI, REST, L4-7 Scripting API/VTY

• Focus: Data Center Customers that desire a Commercially-supported solution that leverages a centralized controller for the Nexus 9k product family
Centralized Automation and Fabric Management

- Unified point of data center network automation and management:
  - Application-centric network policies
  - Data model-based declarative provisioning
  - Application, topology monitoring, and troubleshooting
  - Third-party integration (Layer 4-7 services, storage, compute, WAN, etc.)
  - Image management (spine and leaf)
  - Fabric inventory

- Single Cisco® APIC cluster supports one million+ endpoints, 200,000+ ports, and 64,000+ tenants

- Centralized access to all fabric information - GUI, CLI, and RESTful APIs

- Extensible to computing and storage management
Architecture

Network Applications
- Cisco Sourced
- Customers
- 3rd Parties

Cisco APIC-DC Controller

Controller Applications/Feature
- System Manager
- Tenant Manager
- Fabric Manager
- VM Manager
- L4-7 Services Manager

Northbound APIs
- Python
- RESTful

Southbound APIs
- REST
- L4-7 Scripting API / VTY

OpFlex
Cisco’s proposal to IETF to standardize a SBI for policy management

Advanced GUI with Extended Features

OpFlex/ACI Agent

NETWORK DEVICES
- Cisco Nexus 9k Family
- f5
- Citrix Sourcefire
Unified API

Unified Information Model

RESTful over HTTP(s)

Object Oriented

- Comprehensive access to underlying information model
- Consistent object naming directly mapped to URL
- Supports object, sub-tree and class-level queries

- JSON + XML
- **Unified**: automatically delegates request to corresponding components
- **Transactional**
- Single Management Entity yet fully independent components

Cisco Live!
APIC
APIC GUI – Fabric Topology
APIC – Topology/Connectivity
Management Access

Any APIC

REST

GUI
CLI
Web
Object Browser
Python SDK
API Tools

https://apic.local/api/mo/uni/tn-common.xml
API Inspector in GUI
Impact to ITSM & How to Get Ready
SDN/Network Programmability Impact to ITSM

• **External** Programs (and App Developers) have access to traditional network devices – *You Good with that!?*

• **Change Control** – Must Be More Real-Time – Programs/Apps are participating

• You MUST have *Focused, Intentional* monitoring of the controllers – they are the brains!

• You MUST have a *Robust backup/redundancy plan* for controllers

• You MUST implement Good RBAC, *security* and accounting – lock-down the controllers and APIs!

• The Uncle Ben Principle - “With Great Power Comes Great Responsibility”
Management Tools, Cisco Prime and SDN/NP

Management and Orchestration Layer
- CPO
- UCSD
- PRIME INFRASTRUCTURE & NAM
- 3rd Party Apps
- Catalog/Provisioning
- Fault/Events
- User/Data Management
- Performance Monitoring
- Reporting/Analytics

Control Layer
- APIC Controller
- Data Center Module
- Enterprise Module
- REST API
- CLI, OpenFlow, OpFlex API

Device Layer
- Cisco Devices
  - Data Center, Enterprise Networks

Operational Intelligence
- Automated Service Provisioning
- Dynamic Service Assurance
- Visualization and Analytics

Network Intelligence
- Device Layer Abstraction
- Network Control
- Policy Enforcement and Network Change
So…Are All Network Engineers Becoming Programmers?

```javascript
var myQuestion = { "question":"All Engineers Becoming Programmers?", "answer":[true,false] };```

Remember This Inflection Point?

Telephony in 1998

• IP Telephony struggled until we got ‘hybrid engineers’ to translate between the Circuit Switch ‘Tip & Ring’ and Packet Switch ‘Bits & Bytes’ camps

• Likewise, now, we need the next generation of ‘hybrid engineers’ to translate between traditional network domain engineers and software/application developers
What Skills Are Helpful to a Network Engineer Branching Out?

- Basic Programming constructs (conditionals, loops, data structures)
- Basic Python / Perl
- REST / Web Services
- Regular Expression
- Data encoding - XML / XSLT; JSON
- Basic SQL
- Basic shell scripting - grep
- #1 - Communicating **Effectively** with Programmers
Job Roles: Cisco Network Programmability Evolution

Business Application Developer

- System Engineer/Network Designer
- Network Engineer
- Support Engineer
- Traditional Networking Infrastructure

Development Curriculum

Business Application Developer — Network Programmability Aware

- Network Programmability Developer
- Network Programmability Designer
- Network Programmability Engineer

Open Infrastructure

http://www.cisco.com/web/learning/certifications/specialist
# Network Programmability Cisco Education Offerings

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Questions? Visit the Learning@Cisco Booth
Cisco Services

Cisco Data Center Services for Operations Enablement

Cisco Readiness Planning

Cisco Business Strategy

Cisco Data Center Optimization Service

Cisco Quick Start Service for Nexus 9000

Cisco Accelerated Deployment Services for Nexus 9000

Product Support, SMARTNet, Smart Net Total Care

Services from Cisco Together with Cisco Certified Partners
Driving Catalyst 6500 Migration To Nexus 9000

Catalyst Environments

Migration Tools

- Automate Nexus 9000 deployment and configuration
- Migrate any Cat6500 topology to any Nexus 9000 topology
- Advanced Services best practices
- Catalyst IOS to NX-OS config conversion

Nexus 9000 Deployment
Cisco Quick Start Service For Nexus 9000

Overview

• Technical advice and guidance for smooth integration of Nexus 9000
• Technical consultant 3-day on-site
• High-level use case/design discussion

Deliverables

• N/A

Outcomes

• Share best practices and knowledge
• Increase competency and speed to optimize ACI in your environment
• Gain valuable expertise by having direct access to Cisco consultants
Cisco Accelerated Deployment Services
For Nexus 9000

Overview

• Define business and technical objectives, use case alignment, current and future state
• Assess data center ecosystem (server, network, storage, and virtualization)
• Functional specs, design, test plan, acceptance criteria
• Support customer team during validation
• Knowledge transfer

Deliverables

• Design document
• Configuration migration
• Operations guideline
• Custom script development
• Knowledge transfer

Outcomes

• Blueprint for ACI
• Accelerate time-to-value attainment and production
Technical Assistance From Cisco TAC
Resolve Issues Quickly

Direct Access to Cisco Technical Experts

- Highly trained network and application software engineers worldwide
- Expertise and best practices across data center technologies
- Computer science/electrical engineering degrees
- Engineering staff averages 5 years' industry experience
- CCIE professionals
- 24x7 global access by phone, web, or email
Did you know?
ciscolvie! is also a software developer event

Visit the DevNet Zone at Cisco Live

June 7-11, 2016 | San Diego, CA

Join DevNet

Sandbox  IoT  Cloud  Networking  Data Center  Collaboration  Security  Services

Community  View All  >

Cisco has joined with F5 in this Developer Event!

Cisco Live

https://developer.cisco.com
Cisco SDN: Providing Choice in Automation and Programmability

**Application Centric Infrastructure**

Turnkey integrated solution with security, centralized management, compliance and scale

Automated application centric-policy model with embedded security

Broad and deep ecosystem

**Programmable Fabric**

VxLAN-BGP EVPN standard-based

3rd party controller support

VTS for software overlay provisioning and management across N2K-N9K

**Programmable Network**

Modern NX-OS with enhanced NX-APIs

Automation Ecosystem (Puppet, Chef, Ansible etc.)

Common NX-API across N2K-N9K

---

Mass Market (commercial, enterprises, public sector)  

Service Providers  

Mega Scale Datacenters
Complete Your Online Session Evaluation

• Give us your feedback to be entered into a Daily Survey Drawing. A daily winner will receive a $750 gift card.

• Complete your session surveys through the Cisco Live mobile app or on www.CiscoLive.com/us.

Don’t forget: Cisco Live sessions will be available for viewing on demand after the event at www.CiscoLive.com/Online.
Continue Your Education

• Demos in the Cisco campus
• Walk-in Self-Paced Labs
• Lunch & Learn
• Meet the Engineer 1:1 meetings
• Related sessions
Thank you
You’re it
## Data Center / Virtualization Cisco Education Offerings

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<tr>
<td>Introducing Cisco Data Center Networking (DCICN); Introducing Cisco Data Center Technologies (DCICT)</td>
<td>Get job-ready foundational-level certification and skills in installing, configuring, and maintaining next generation data centers.</td>
<td>CCNA® Data Center</td>
</tr>
<tr>
<td>Implementing Cisco Data Center Unified Computing v6.0 (DCUCI)</td>
<td>Obtain professional level skills to design, configure, implement, troubleshoot next generation data center infrastructure.</td>
<td>CCNP® Data Center</td>
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<tr>
<td>Implementing Cisco Data Center Infrastructure v6.0 (DCII)</td>
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<tr>
<td>Implementing Cisco Data Center Virtualization and Automation v6.0</td>
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<td>Troubleshooting Cisco Data Center Infrastructure v6.0 (DCIT)</td>
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<tr>
<td>Product Training Portfolio:DCAC9K, DCINX9K, DCMDS, DCUCS, DCNX1K, DCNX5K, DCNX7K, HFLEX200 UCSDF, UCSDACI, DCUCCEN</td>
<td>Gain hands-on skills using Cisco solutions to configure, deploy, manage and troubleshoot unified computing, policy-driven and virtualized data center infrastructure.</td>
<td></td>
</tr>
<tr>
<td>Designing the FlexPod® Solution (FPDESIGN); Implementing and Administering the FlexPod® Solution (FPIMPADM)</td>
<td>Learn how to design, implement and administer FlexPod® solutions</td>
<td>Cisco and NetApp Certified FlexPod® Specialist</td>
</tr>
<tr>
<td>Designing the VersaStack Solution (VSDESIGN); Implementing and Administering the VersaStack Solution (VSIMP)</td>
<td>Learn how to design, implement and administer VersaStack solutions</td>
<td></td>
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Questions? Visit the Learning@Cisco Booth
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# Cloud Cisco Education Offerings

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<td>Understanding Cloud Fundamentals (CLDFND)</td>
<td>Learn how to perform foundational tasks related to Cloud computing, and the essentials of Cloud infrastructure, administration and operations</td>
<td>CCNA Cloud</td>
</tr>
<tr>
<td>Introducing Cloud Administration (CLDADM)</td>
<td></td>
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<tr>
<td>Implementing and Troubleshooting the Cisco Cloud Infrastructure (CLDINF); Designing the Cisco Cloud (CLDDES); Automating the Cisco Enterprise Cloud (CLDAUT); Building the Cisco Cloud with Application Centric Infrastructure (CLDACI)</td>
<td>Obtain professional level skills to design, automate, secure, provision and manage private and hybrid Clouds</td>
<td>CCNP Cloud</td>
</tr>
<tr>
<td>Product Training Portfolio: UCS Director: UCSDF, UCSDACI</td>
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<tr>
<td>Prime Service Catalog: PSCF, PSCI, PSCD</td>
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<tr>
<td>MetaPod: MPODF20</td>
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Questions? Visit the Learning@Cisco Booth
# Digital Business Transformation

## Cisco Education Offerings

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<td>Building Business Specialist Skills</td>
<td>• Builds non-technical skills key to ensure business impact and influence. Topics include: business analysis, finance, technology adoption and effective communications. • Bridges IT and business impacts of mature and emerging solutions including cloud plus Internet of Everything</td>
<td>Cisco Enterprise IT Business Specialist</td>
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<tr>
<td><strong>For Technology Sellers:</strong></td>
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<tr>
<td>Applying Cisco Specialized Business Value Analysis Skills</td>
<td>Builds skills to discover and address technology needs using a business-focused, consultative sales approach</td>
<td>Cisco Business Value Specialist</td>
</tr>
<tr>
<td>Executing Advanced Cisco Business Value Analysis and Design Techniques</td>
<td>Enables customer transformation through business architecture and solution selling expertise</td>
<td>Cisco Certified Business Value Practitioner</td>
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<tr>
<td>Performing Cisco Business-Focused Transformative ArchitectureEngagements</td>
<td>Provides skills and an approach to build a strategic roadmap of IT initiatives, aligned to business priorities</td>
<td>Cisco Transformative Architecture Specialist</td>
</tr>
<tr>
<td>Cisco Customer Success Manager Specialist</td>
<td>Prepares for the crucial role that drives adoption and enablement, ensuring that customers achieve their expected business outcomes, and reduces churn/increases renewal for services and subscription based products.</td>
<td>Cisco Certified Customer Success Manager</td>
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Questions? Visit the Learning@Cisco Booth
Acronym Decoder Ring [Aka Glossary]

- SDN -- Software Defined Networking
- BGP-LS – Border Gateway Protocol – Link State
- onePK – one Platform Kit
- NFV – Network Functions Virtualization
- SS7 – Signaling System No. 7
- ATM LANE – Asynchronous Transfer Mode LAN Emulation
- GMPLS – Generalized Multi-Protocol Label Switching
- VPLS – Virtual Private LAN Service
- VPN – Virtual Private Network
- GRE – Generic Routing Encapsulation
- LISP – Locator/ID Separation Protocol
- SNMP – Simple Network Management Protocol
- NETCONF – Network Configuration Protocol [IETF Standard]
- EEM – Embedded Event Manager
Acronym Decoder Ring [Aka Glossary]

- CP – Control Plane
- DP – Data Plane
- CLI – Command-Line Interface
- API – Application Programmatic Interface
- GUI – Graphical User Interface
- OF – OpenFlow
- NAT – Network Address Translation
- TLV – Type-Length-Value
- PCEP – Path Computation Element (PCE) Communication Protocol
- I2RS – Interface To Routing System
- OTV – Overlay Transport Virtualization
- VXLAN – Virtual Extensible LAN
- REST – Representational State Transfer
- IDE – Integrated Development Environment
Acronym Decoder Ring [Aka Glossary]

- CA – Controlled Availability
- GA – General Availability
- EFT – Early Field Trial
- NVGRE – Network Virtualization using Generic Routing Encapsulation
- STT – Stateless Transport Tunneling
- ODL – OpenDaylight
- OSGi – Open Service Gateway Initiative
- NBI – North-Bound Interface
- SBI – South-Bound Interface
- iWAN – Intelligent Wide Area Network