BROCADE

Software Defined Networking

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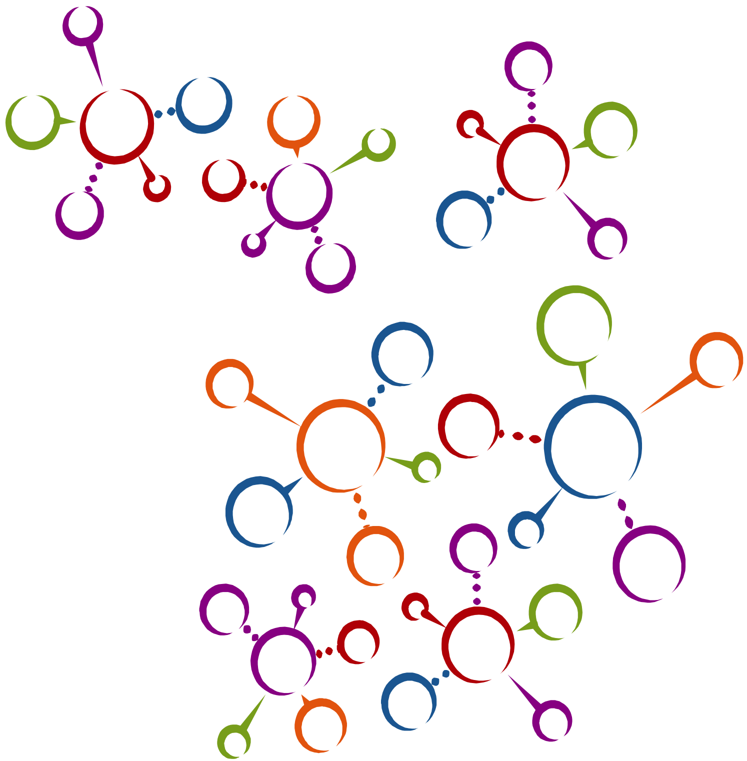
Agenda

- Business Consideration
- A Customer Journey
- Quick Overview of SDN and NFV
- Software Networking Solutions
  - SDN Controller
  - vRouter
  - Virtual Application Delivery Controller (vADC)
- Network Complexity , Why the Need for SDN
- SDN A New Solution
- OpenFlow Basics
- SDN Solution Demo



Business Considerations

Profit, Revenue

Time to Market

Business Growth

Handle Spikes in Customer Requests

CAPEX/OPEX

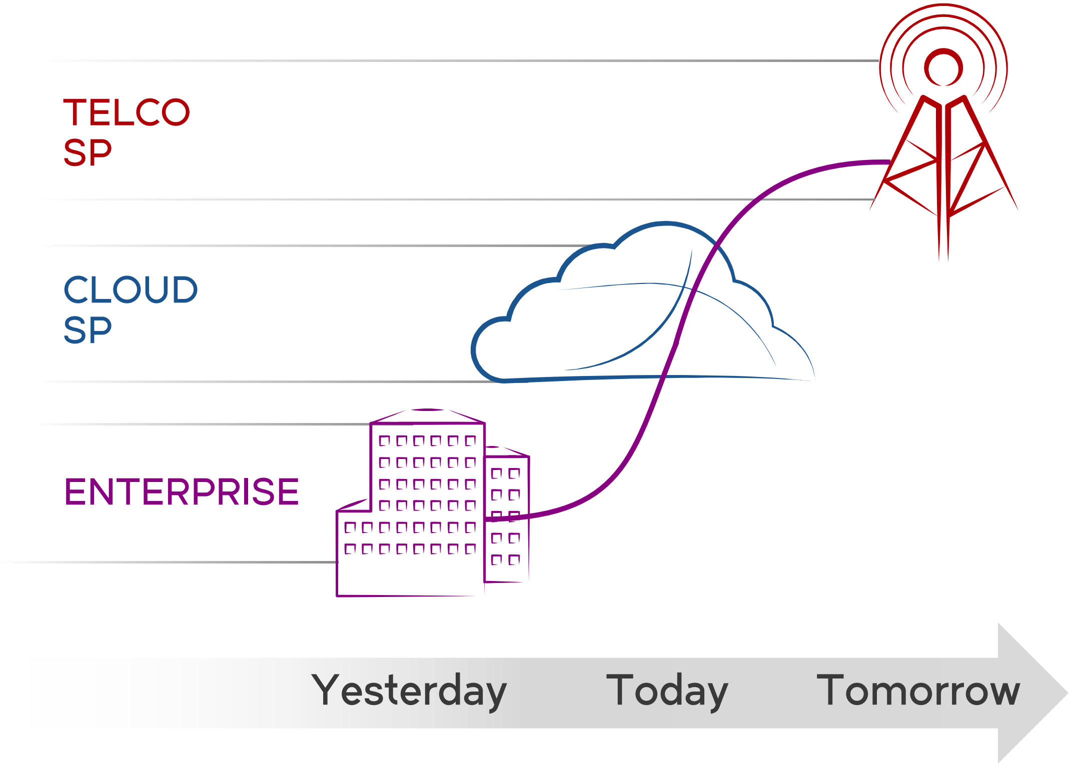
Customer SLAs

Executive Management

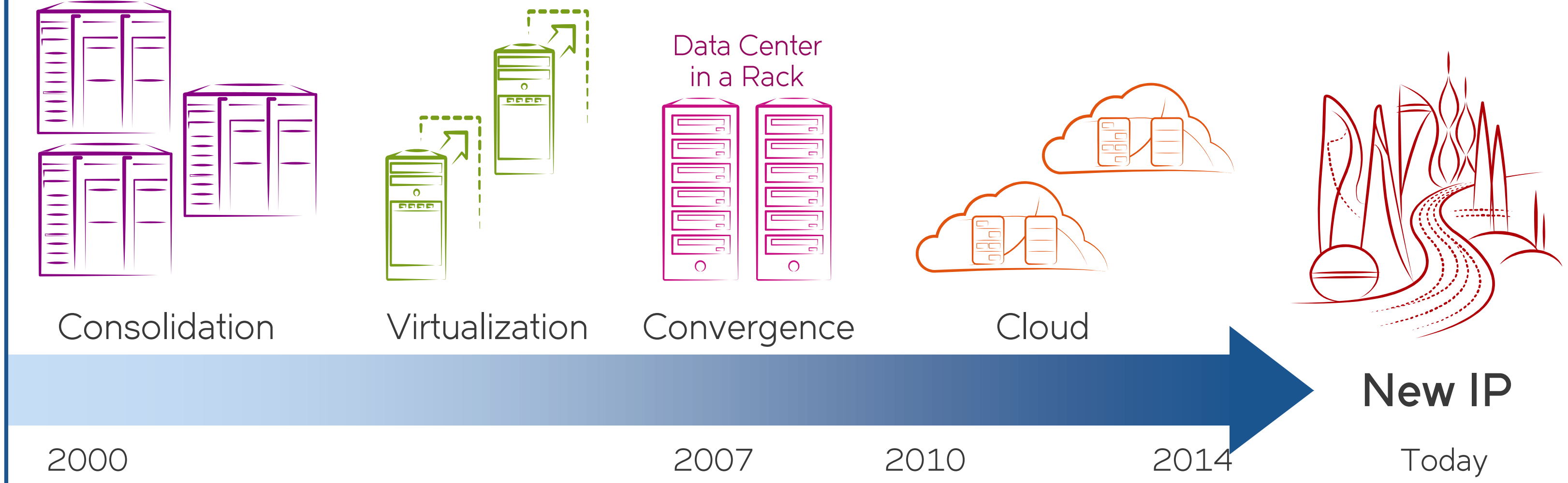
Industry Shifts

How do I achieve…

- Rapid Deployment of New Services
- Economies of Scale
- Better ROI

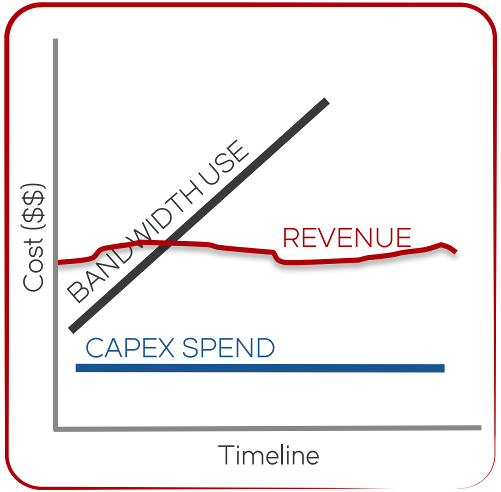


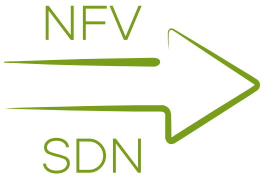
Data Center Journey over the Past Decade!



Business Dynamics Act as a Catalyst for Network Change

Customers Journey Towards Success

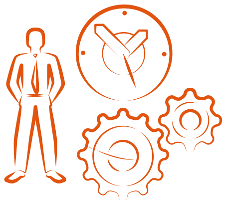




High Performance

Rapid Setup / Speed
Delivered new services to 100 markets in under 6 months

Executive Management



Save Time and Resources
95% provisioning time eliminated

Save Costs / Decreased CapEx and OpEx

BEFORE

AFTER

Overview
Software-Defined Networking (SDN)
Network Function Virtualization (NFV)

Components of a Data Center

Application and Services

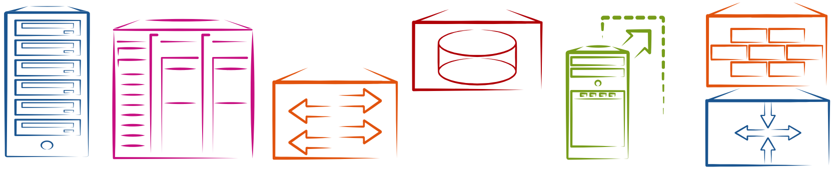
OSS/BSS, ERP, Databases, Enterprise Apps, Consulting, Professional Services, Systems Integrations

Management (Infrastructure, Enterprise)

Infrastructure (Configuration, HA, DR, Workload)

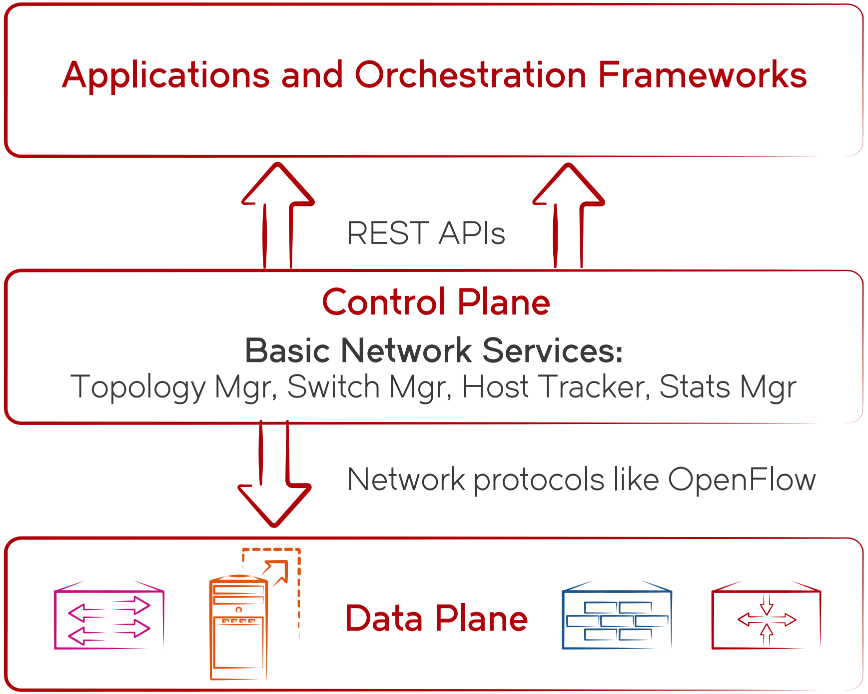
Enterprise (Monitoring, Analytics, Chargeback)

Physical and Virtual Infrastructure



Software Defined Networking (SDN)

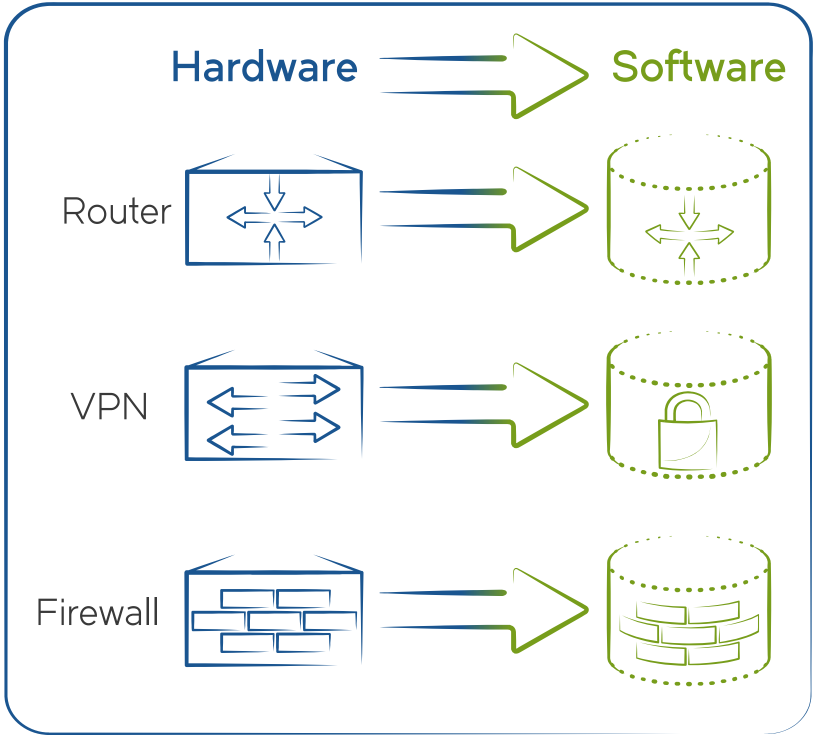
A Programmable Network—Design, Build, Manage



Advantages

- Logically centralized view of the overall network
- Improved interoperability and manageability
- Enable users to develop and deploy unique capabilities for their network needs

Network Functions Virtualization (NFV)



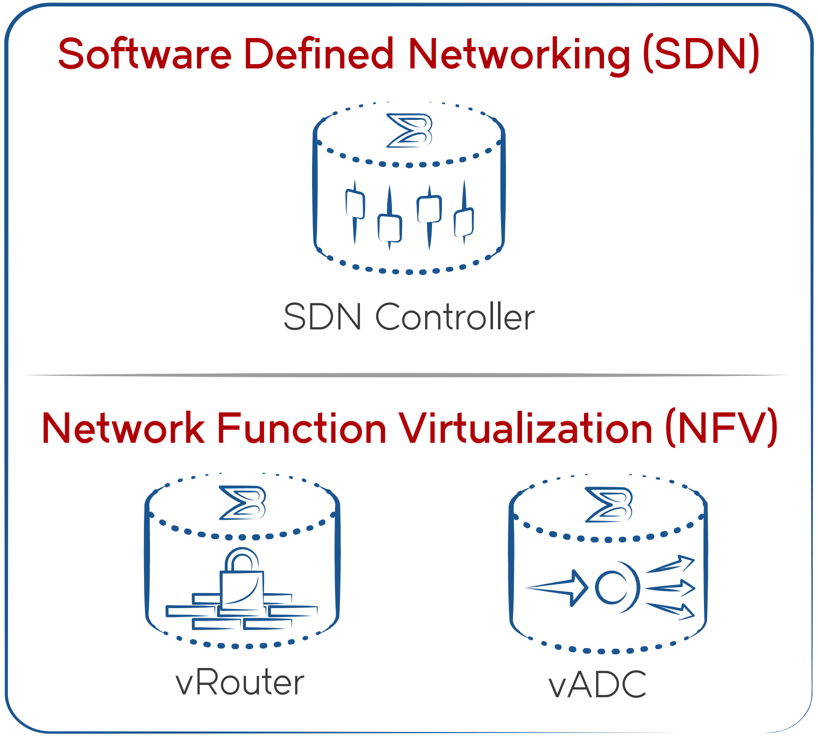
Advantages

- Virtualize the network devices to create multiple virtual functions for various network appliances
- Enable service innovations and meet service SLAs
- Reduce CAPEX/OPEX

Software Networking Solutions

Software Networking Solutions

Stepping stones to Next Gen Connectivity



Greater Agility

- Deliver industry leading performance for any given resource assignment
- On-demand licensing and flexible utility-based pricing brings agility to capacity acquisition
- Streamline network processes

Open with a Purpose

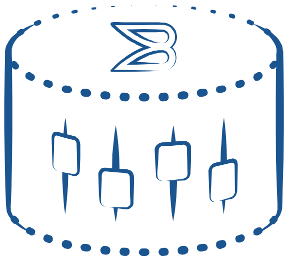
- Delivers an open modular architecture that enables customers to program and control their network of choice
- Strong investments in NFV management and orchestration through open source frameworks like OpenStack
- First pure OpenDaylight SDN Controller distribution

Improved Economics

- Economies of scale
- Investment protection for heterogeneous infrastructure
- Lower CAPEX/OPEX

SDN Controller

Open source SDN Controller



Open-source SDN Controller
built directly from OpenDayLight.

Rapid Service Delivery

Designed for an open, multivendor world

- Each layer can be selected independently
- No platform or northbound dependencies

Simple on-ramp to SDN

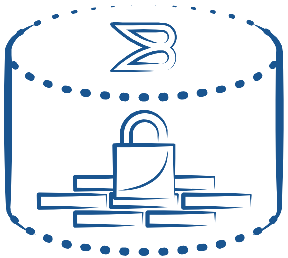
- Low-risk investment protection
- Smooth installation and maintenance

Collaborative innovation

- Joint and custom app development
- Bridge to OpenDayLight community

vRouter

Increase networking agility and connectivity with improved ROI



vRouter is the first virtual router capable of providing advanced networking and security in software with scale, reliability, and performance.

Proven High Density with Breakthrough Performance

High ROI and efficiency

- Proven high VNF density of vRouters in single server
- Low CPU consumption provides headroom for other VNFs

Delivers breakthrough performance

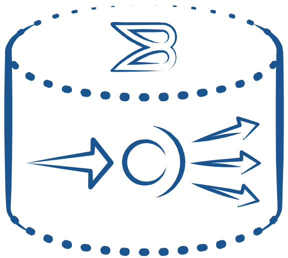
- 80Gbps line rate on single vRouter
- Advanced enhancements with Intel DPDK

High versatility

- Single product, multiple functions for Cloud & SP
- Cloud network segmentation, Secure gateway services and Workload and Subscriber firewall

Virtual Application Delivery Controller (vADC)

Fast, secure, available applications



Virtual Application Delivery Controller (vADC) solutions help ensure predictable high-performance for applications whenever and wherever they are deployed.

Purpose-built for the Cloud

- Deploy in any Hybrid Cloud architectures
- On-demand application delivery—ADCaaS
- Established CSP partnerships—Azure, AWS, Rackspace, Joyent, etc.

Process automation

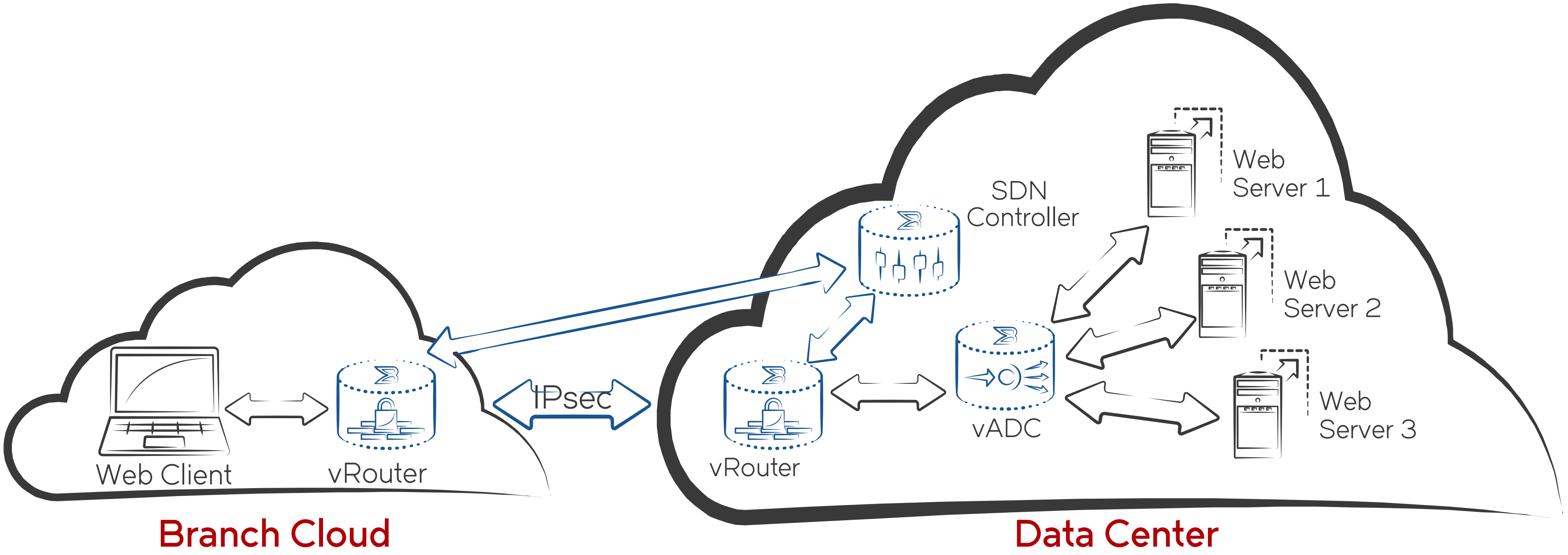
- Easy, consistent deployment of Service templates (LBaaS) and service isolation with centralized mgmt.
- Usage visibility—metering and billing capabilities for chargeback
- Integration with key orchestration tools—OpenStack, VMware NSX and Brocade SDN Controller

Hyperscale and Performance on Demand

- Highest Layer 7 throughput for software (50GB/node)
- Unique web application security solution

Software Networking Solutions

Agile, Open, Economics



Network Complexity and Why the need SDN

Network adaption to demands

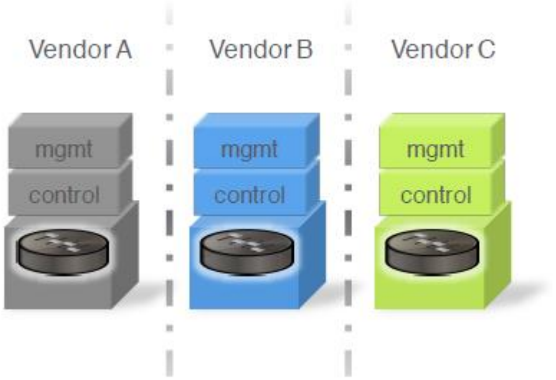
- Last 20 years > radically shifting network demands
  - Massive increase in scale (end points, switches, bytes, flows etc.)
  - Static endpoints (weeks-months) > dynamic endpoints (hours-days)
  - Mostly north-south traffic > mostly east-west traffic
- By contrast, network haven't changed much
  - Link speeds have gone up, but...
  - Still largely managed networks devices-by-device via CLI
  - If you're lucky, orchestration at the granularity of a few device

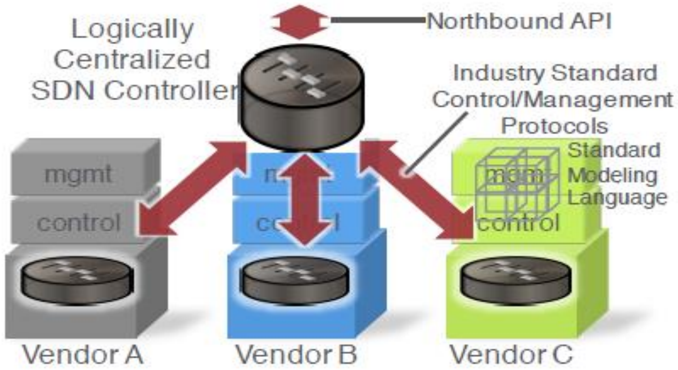
Things are changing

- Device-to-device > Network wide
- Open Standards > Open Standards + Open Source
- Proprietary Software > Open Source
- Networking, Storage, Compute > Converge IT
- Hardware > Software (Virtualized)

- To large extend, moving towards open source networking

Solution: disaggregation and open software





- Device-by-device operations
- Proprietary, vendor-specific verticals stacks for control, management and orchestration
  - Limited innovation in individual silos

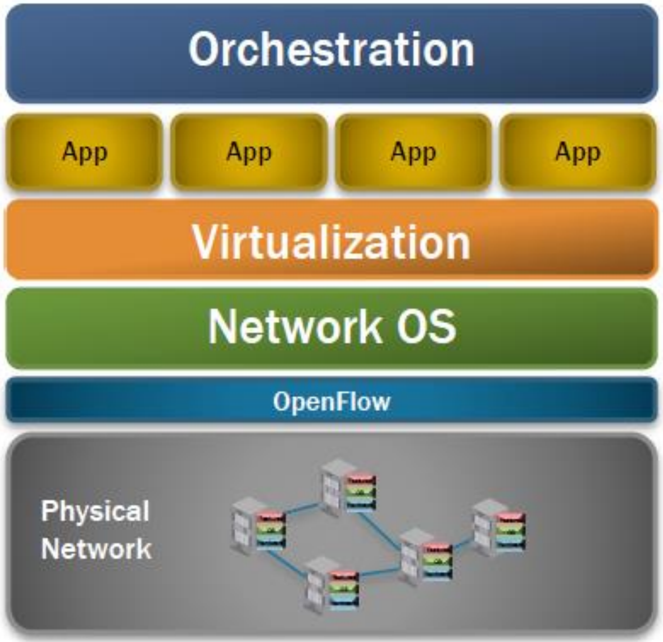
- Network-wide operation
- Open control, management and orchestration using open control protocols/modeling language
  - Independent innovation at each layer of the stack

SDN A New Solution

Who is behind Software Defined networking?

Open Networking Foundation (ONF)

- ONF launched publicly in March 2011
- Support from more than 70 major companies
- The ONF define OpenFlow and API specifications
- Founding member of ONF
  - Deutsche Telecom
  - Microsoft
  - Facebook
  - Verizon Wireless
  - Google
  - Yahoo



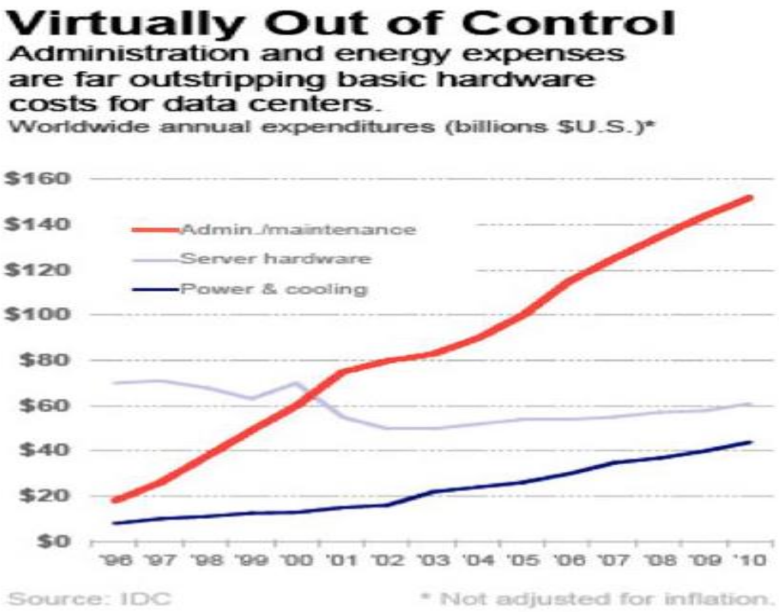
ONF SDN Model
(simplified)

So, SDN is all about...

- Network Programmability
  - API interaction with network elements
- Separation of Control Plane and Forwarding Plane
  - Forwarding Plane can be software or hardware
  - Control Plane – agnostic to the underlying hardware
- Integration with higher-order Orchestration platforms
  - OpenStack, CloudStack, vCloud Director
- Network topology and orchestration derived from the application tenant. This is how SDN is different from switched networks.
- Vendor independence – open source

What is Driving SDN?

- SDNn is not about Agility
- It is about new services
- It is about the economics of networking
  - Capital Costs an the 'Tax"
  - Energy costs
  - Real-Estate
  - Operating Costs



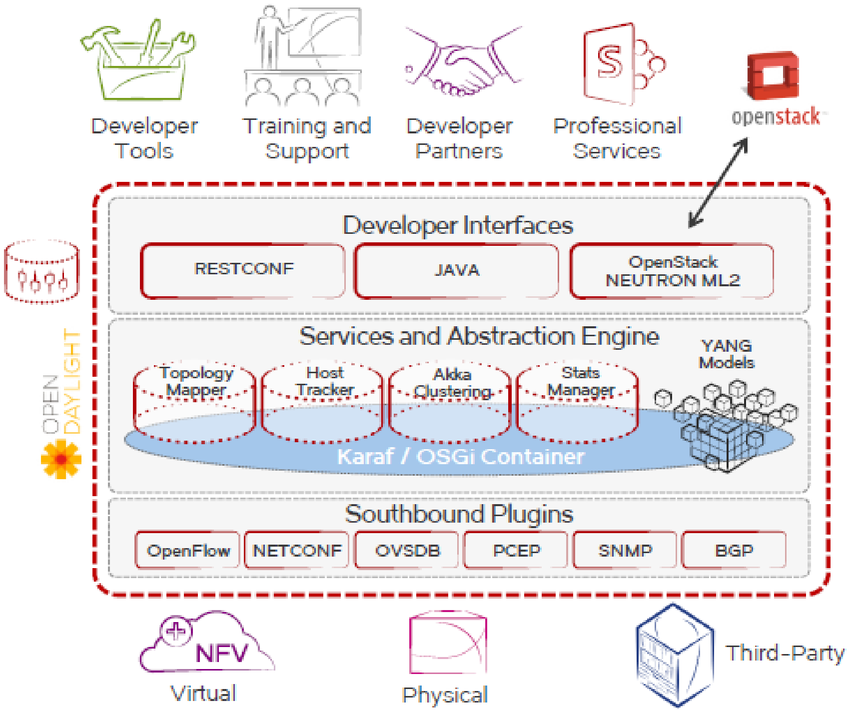
SDN Use Cases

- Custom Analytics and Compliance
- Big Data
- Security
- QoS and Traffic Management
- Network Virtualization
- Service Configuration Policy
- Research and New Protocols
- Fault and Disaster Recovery
- WAN Optimization

SDN Controller

Open, Modular

- Designed for open, multivendor world
  - Each layer can be selected independently
  - No platform or northbound dependencies
- Simple on-ramp to SDN
  - Low risk investment protection
  - Smooth installation and maintenance
- Collaborative Innovation
  - Joint and custom app development
  - Bridge to OpenDayLight community



Yang

- Data modelling language for the NETCONF network configuration protocol. Specifically designed to support service activation and provisioning.
- Is a modular language representing data structures in an XML tree format. XML content transported over SSH+TCP.
- XML Namespaces make it possible to add e.g. new RPC types or new table columns without breaking existing applications.
- Configuration changes happen all-or-nothing and all-at-once which simplifies network management applications.
- Can address multiple network elements in parallel to implement network-wide transactions.

YANG Header

Yang Models

Network Topology
List of Nodes
List of Links
Links and Nodes can be "augmented" later

Can have multiple topologies
Overlay/underlay
Disjoint
Peered

```
container network-topology {
        ...

        list node {
              description "...";
              key "node-id";
              uses node-attributes;
        }

        list link {
              description "...";
              key "link-id";
              uses link-attributes;
        }
}
```

YANG Submodules

Each submodules belongs to one specific main module

```
module acme-module {
  namespace "…";
  prefix acme;

  import "ietf-yang-types" {
    prefix yang;
  }
  include "acme-system";

  organization "ACME Inc.";
  contact joe@acme.example.com;
  description "Module describing the
  ACME products";
  revision 2007-06-09 {
    description "Initial revision.";
  }
```

```
submodule acme-system {
  belongs-to acme-module {
    prefix acme;
  }

  import "ietf-yang-types" {
    prefix yang;
  }

  container system {
    …
  }
}
```

Postman to test API interaction

- Is a language for developers to communicate and test APIs. This led to the build, test, and document APIs faster.
- Postman features include:
  - History of sent requests
  - Create requests quickly
  - Replay and organize
  - Switch context quickly
  - Built-in authentication helpers
  - Customize with scripts
  - Automate collections

RESTCONF – Northbound API

- RESTCONF describes how to map a YANG specification to a REST interface.
- RESTCONF provides a simplified interface that follows REST-like principles and is compatible with a resource-oriented device abstraction.
- SDN Controller implements a memory data store to store data that is related to the YANG models. Using the RESTCONF protocol, you can perform a CRUD (create, read, update or delete) operation on the data that is stored in the memory data store.

NETCONF

- Network management protocol specifically designed to manipulate configuration, support service activation and provisioning.
  - XML content transported over SSH+TCP.
  - XML Namespaces make it possible to add e.g. new RPC types or new table columns without breaking existing applications.
  - Can address multiple network elements in parallel to implement network-wide transactions.

Comparison between SNMP and NETCONF

	SNMP	NETCONF
Data models	MIB	YANG
Data Modeling Language	SMI	YANG
Management Operations	SNMP	NETCONF
Transport Protocol	UDP	SSH

SDN Controller using NETCONF

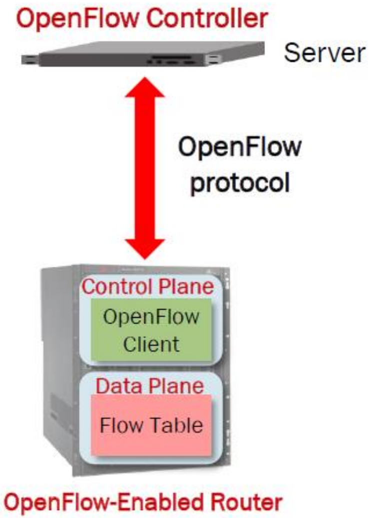
Feature Supported

- NETCONF Protocol Version 1.1, RFC 6241
  - Read-config(get/get-config)
  - Edit-config
  - Copy-config
  - Delete-config
- Notifications Lock/unlock
  - Lock the candidate configuration, which prevents other users or applications from changing it until the application releases the lock

OpenFlow Basics

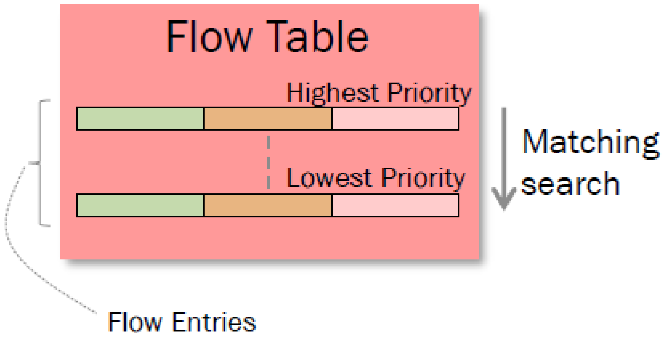
OpenFlow Introduction

- Consists of a controller, an OpenFlow-enabled switch, and the OpenFlow communications protocol.
- The switch and the controller communicate by exchanging OpenFlow protocol messages, which the controller uses to add, modify, and delete flows in the switch.
- Control various aspects of the network, such as traffic forwarding, topology discovery, Quality of Service.
- OpenFlow-enabled router supports an OpenFlow Client (control plane software)
- OpenFlow Client communicates with an OpenFlow Controller using the OpenFlow protocol
  - OpenFlow Controller runs on a server
- OpenFlow-enabled routers support the abstraction of a Flow Table, which is manipulated by the OpenFlow Controller



OpenFlow-Enabled Router Operation

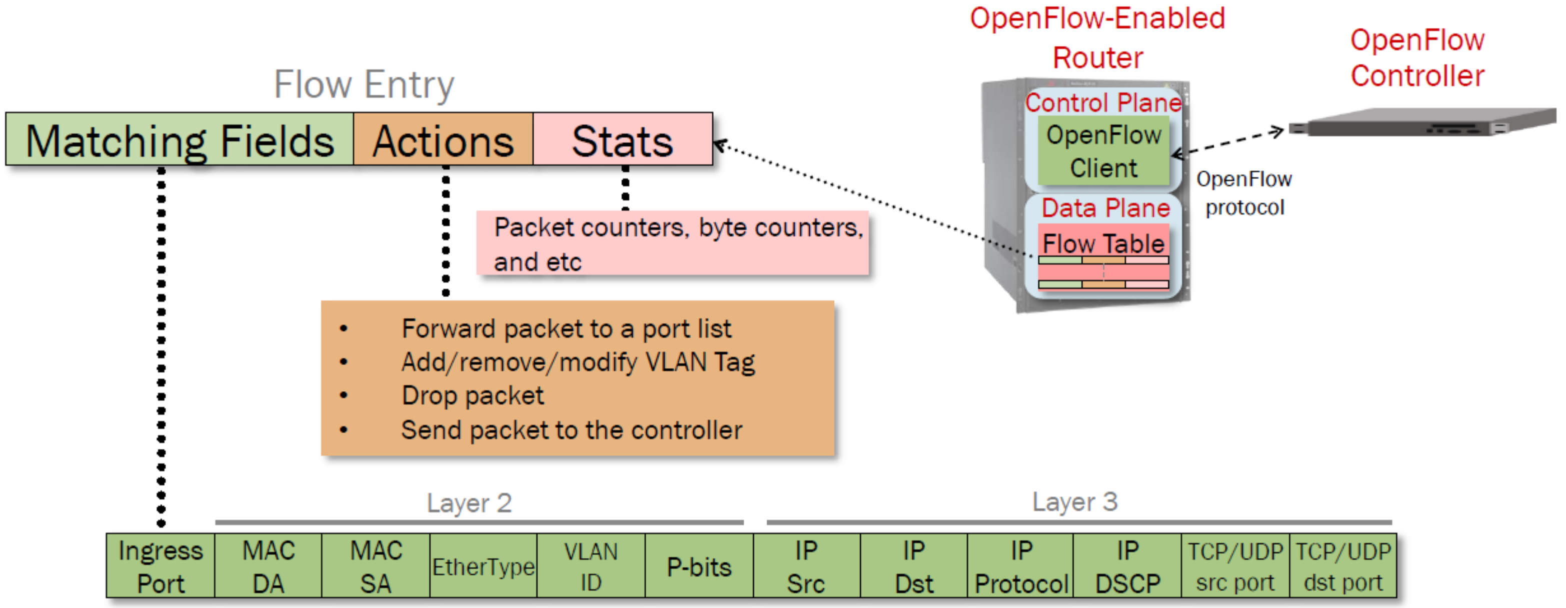
- Flow Table contains Flow Entries
  - Each Flow Entry represents a Flow, e.g., packets with a given destination IP address
- The flow table is sorted by flow priority, which is defined by the controller
  - Highest priority flows are at the top of the Flow Table
- Incoming packets are matched against the flow entries (in order)
  - Matching means: Does the packet belong to this Flow?
- If there is match, flow matching stops, and the set of actionsfor that flow entry are performed
  - Packets that don't match any flow entry are typically dropped



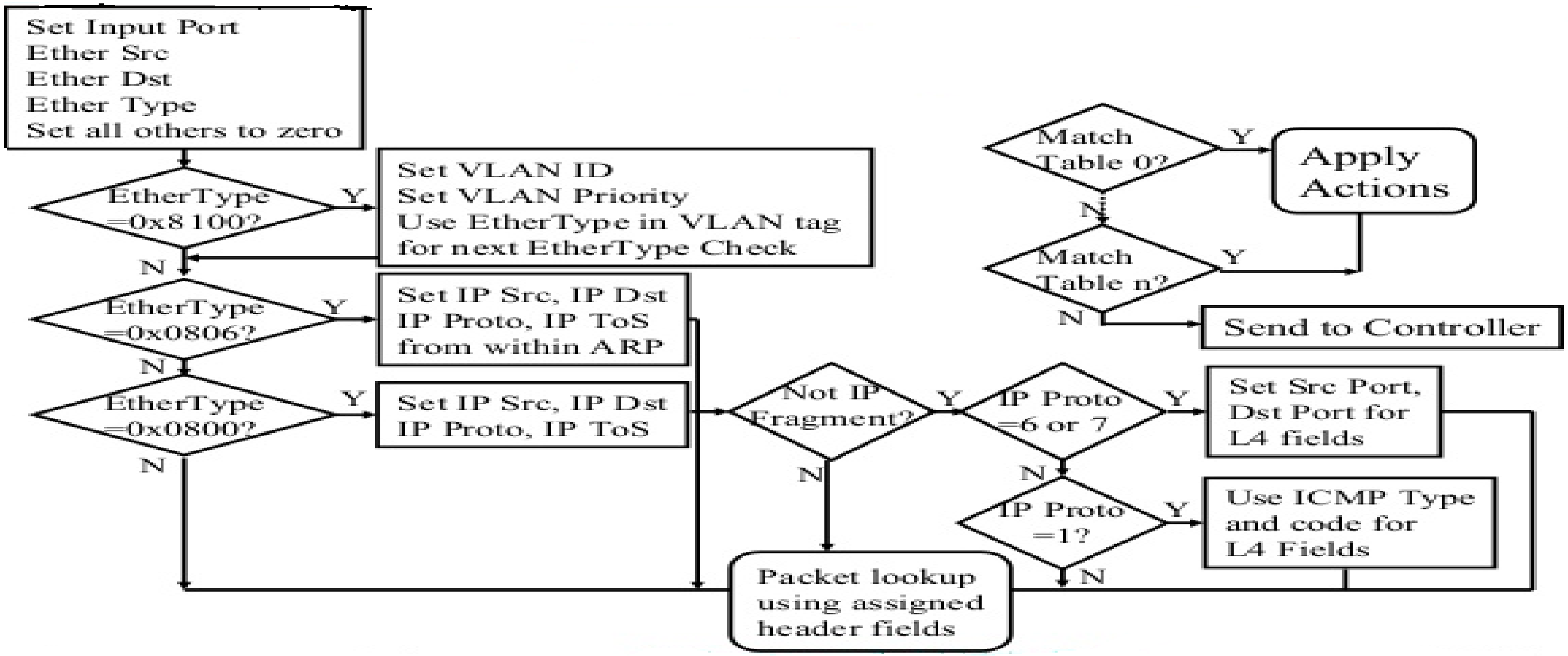
Flow Table Entry

Open Flow 1.0

Each flow table entry contains a set of rules to match (e.g., IP src) and an action list to be executed in case of a match (e.g., forward to port list)



OpenFlow Matching Operation



OpenFlow Counter

Per Table	Per Flow	Per Port	Per Queue
Active Entries	Received Packets	Received Packets	Transmit Packets
Packet Lookups	Received Bytes	Transmitted Packets	Transmit Bytes
Packet Matches	Duration (Secs)	Received Bytes	Transmit overrun errors
	Duration (nanosecs)	Transmitted Bytes	
		Receive Drops	
		Transmit Drops	
		Receive Errors	
		Transmit Errors	
		Receive Frame Alignment Errors	
		Receive Overrun erorrs	
		Receive CRC Errors	
		Collisions	

OpenFlow Timer

- Idle timeout
  - Remove entry if no packets received from this time
- Hard timeout
  - Remove entry after this time
- If both are set, the entry is removed if either one expires

OpenFlow Action

- Forward to physical port I or to Virtual Port
  - All: to all interfaces except incoming interface
  - Controller: encapsulate and send to controller
  - Local: Send to its local forwarding table
  - Table: Perform action in the flow table
  - In_port: Send back to input port
  - Normal: Forward using traditional Ethernet
  - Flood: Send along minimum spanning tree except the incoming interface
- En queue: To a particular queue in the port => QoS
- Drop
- Modify field: E.g., add/remove VLAN tags, ToSbits, Change TTL

Open vSwitch Features

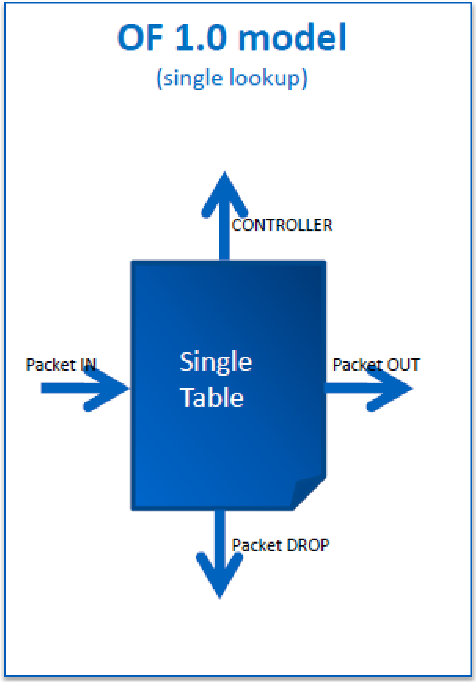
Inter-VM communication monitoring via:

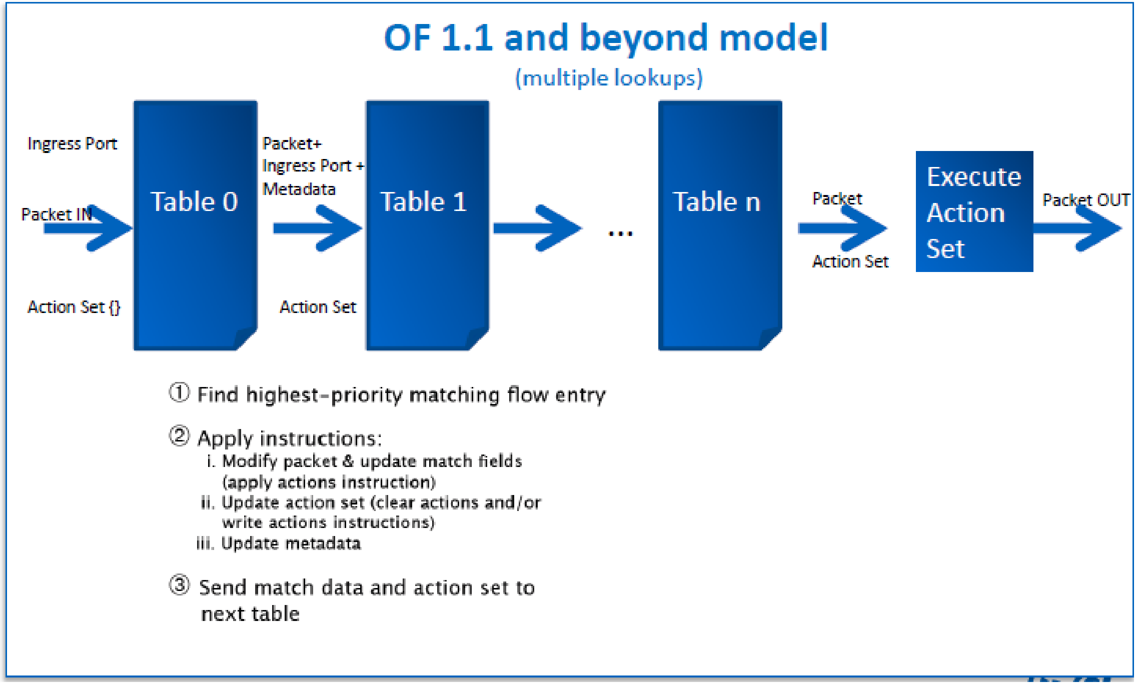
- NetFlow: protocol for sampling and collecting traffic statistics (RFC 3954)
- sFlow: Similar to NetFlowby sflow.org (RFC 3176)
- Jflow: Juniper's version of NetFlow
- NetStream: Huawei's version of NetFlow
- IPFIX: IP Flow Information Export Protocol (RFC 7011) IETF standard for NetFlow
- SPAN, RSPAN: Remote Switch Port Analyzer–port mirroring by sending a copy of all packets to a monitor port
- GRE-tunnelled mirrors: Monitoring device is remotely connected to the switch via a GRE tunnel

OpenFlow Version Development

- Version 1.1
  - Perform action on a match. Ethernet/IP only. multipath (a flow can be sent over one of several path), MPLS, Q-in-Q and tunnel
- Version 1.2
  - IPv6 Support: Matching fields include IPv6 source address, destination address, protocol number, traffic class. ICMPv6 type, ICMPv6 code, IPv6 neighbor discovery header fields, and IPv6 flow labels
- Version 1.3
  - IPv6 extension headers: Can check if Hop-by-hop, Router, Fragmentation, Destination options, Authentication, Encrypted Security Payload (ESP), unknown extension headers are present MPLS Bottom-of-Stack bit matching MAC-in-MAC encapsulation Tunnel ID meta data: Support for tunnels (VxLAN, …)
  - Meter Band: If the packet/byte rate exceeds a pre-defined Band 's threshold , the meter has triggered the band. Action can be set to remark DSCP or drop

Key Difference Between OpenFlow 1.0 and Beyond





Required matched Field and Action

Field
OXM_OF_IN_PORT
OXM_OF_ETH_DST
OXM_OF_ETH_SRC
OXM_OF_ETH_TYPE
OXM_OF_IP_PROTO
OXM_OF_IPV4_SRC
OXM_OF_IPV4_DST
OXM_OF_IPV6_SRC
OXM_OF_IPV6_DST
OXM_OF_TCP_SRC
OXM_OF_TCP_DST
OXM_OF_UDP_SRC
OXM_OF_UDP_DST

- Output
- *Set-queue
- Drop
- Group
- *Push-Tag/Pop-Tag
- *Set-Field (example: VLAN)
- *Change-TTL
- * Optional fields

Metering

- Per-flow metering measures and controls the rate of packets for each flow entry.
- Per-flow meters enable OpenFlow to implement simple QoS operations, such as rate-limiting, and can be combined with per-port queues to implement complex QoS frameworks, such as DiffServ.
- Meters are attached directly to flow entries. Each meter can have one or more meter bands. Each meter band specifies the rate of the band applies and the way packets are processed (DROP or DIFFSERV). OpenFlow metering operation is similar to ingress rate limiting in a QoS operation.

OpenFlow Applications

What can we do with OpenFlow

- OpenFlow itself does not define or mandate any specific application
- OpenFlow enables a large set of applications due to its flexibility
- Supported applications should increase over time as new functionality is added to the OpenFlow specification
  - E.g., flow policing/rate limiting
- Ideal for automating common operations
  - E.g. security via ACLs, isolation via VLANs or VRFs etc.

OpenFlow Applications (cont..)

What can we do with OpenFlow

- Hyper-scale Data Centers
  - Address the Virtual Machine (VM) scale challenge with OpenFlow and facilitating VM mobility
  - Facilitating multi-tenancy
- Network Virtualization
  - Simplifying multi-tenancy (also part of any hyper-scale DC solution)
- Flow Management in metro/WAN
  - Traffic engineering, load balancing, security management, and etc
- Enterprise/campus data center applications
  - Reduce operational complexity and facilitating deployment of new features

Hybrid Switch versus Hybrid Port Modes

- Hybrid Switch Mode
  - OpenFlow is enabled on a per-port basis
  - OpenFlow ports do not run existing features
  - Non-OpenFlow-enabled ports run existing features, e.g., MPLS/IP routing

- Hybrid Port Mode
  - OpenFlow is enabled on a per-port basis
  - OpenFlow-enabled ports can run existing features, i.e., MPLS/IP routing, concurrently with OpenFlow on the same port
  - Supports "protected" VLANs (next slide)

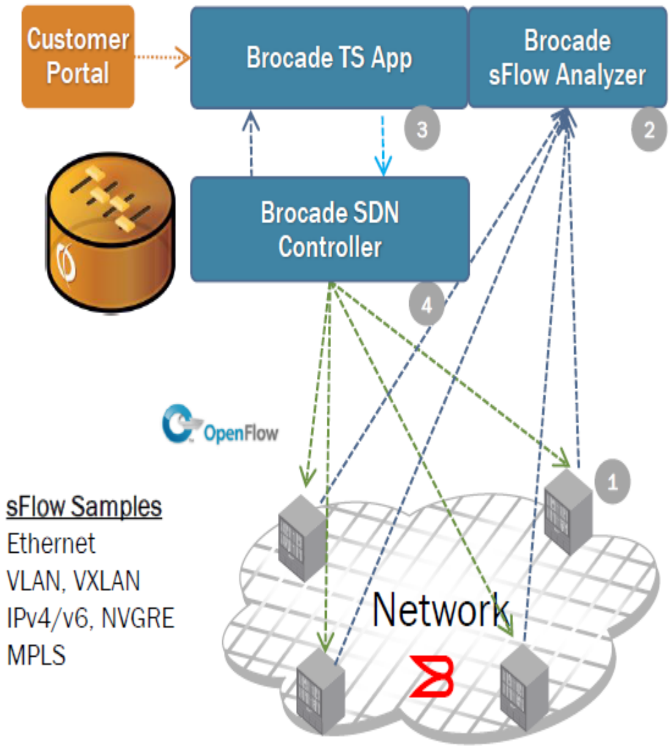
Hybrid Port Mode with Protected VLANs

- Protected VLANs
- A set of VLANs can be defined as protected
- OpenFlow rules cannot affect the traffic of protected VLANs
- Ingress frames on protected VLANs are not subject to OpenFlow rules
- Protection is supported in hardware
- Other VLANs (i.e., unprotected VLANs) are subject to OpenFlow rules

Volumetric Attack Mitigation

Out of the box solution

1. Data Center Devices
   - Send sFlow samples to the collector
2. sFlowAnalyzer
   - Analyze and report volumetric flow trigger
3. Traffic steering application with policy-based UI and REST APIs
   - Instruct controller to redirect volumetric flows
4. Brocade SDN Controller
   - Program OpenFlow1.3 rules in Brocade MLX and Brocade ICX



SDN Solutions Demo

How to install and configure a virtual router

- Configure the following:
  - Router interfaces
  - Redundancy
    - VRRP
  - Routing Protocol
    - OSPF, BGP
  - Firewall Configuration

How to install and configure a SDN Controller

- Configure the following:
  - Install SDN Controller and GUI interface
  - Verify Configuration
    - Connect to RESTCONF
    - Access API Docs
  - Install Controller Apps
    - Flow Manager

OpenFlow Demo

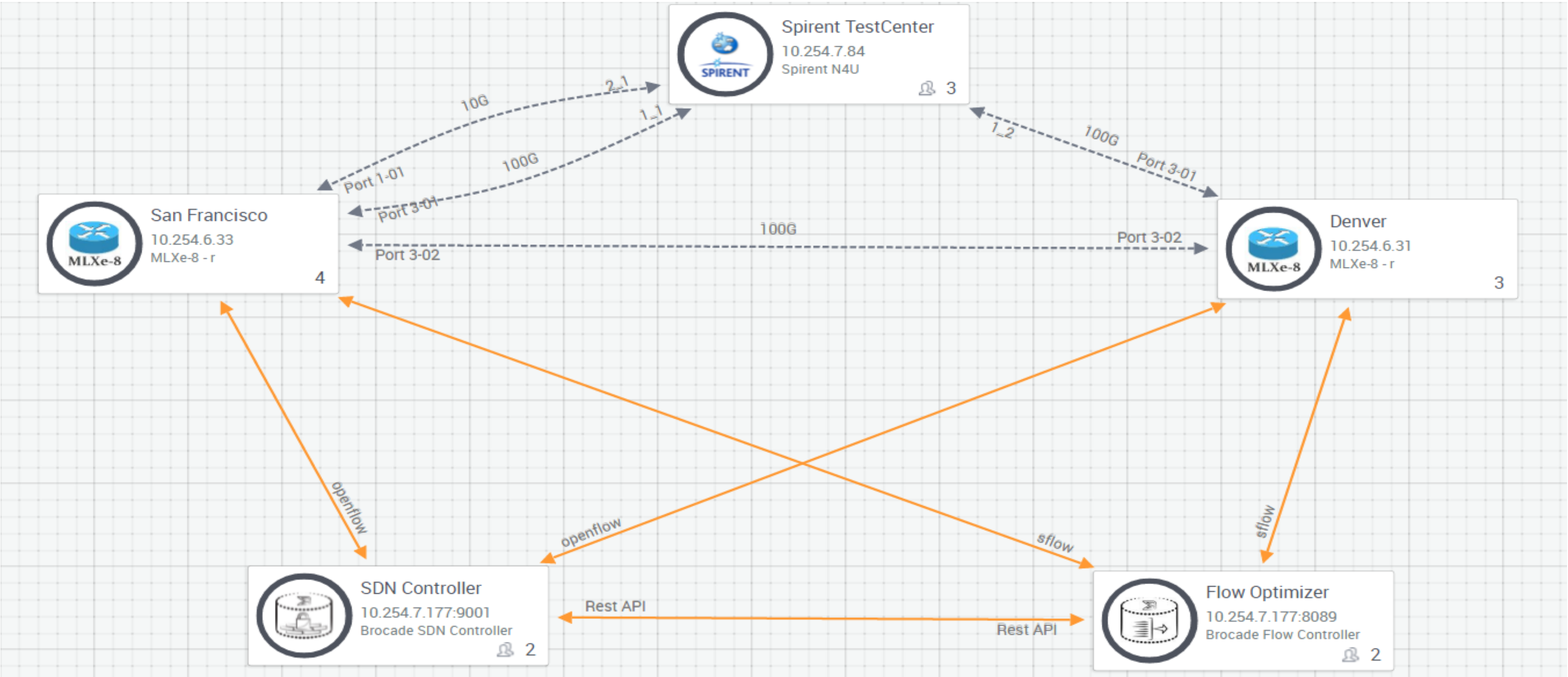
- Deploying the Controller in an OpenFlow Scenario
- Testing Host Tracker Function
  - Tracking Mode
  - Flood Mode
  - No Food Mode
  - Viewing Hosts and Topology
- How to create path between two hosts

RESTCONF Tools

- Retrieving the installed flow
- Deleting installed flow
- Getting the inventory using Postman
- Getting Operational Flow

SDN with Flow Optimizer Application

DDOS, redirect and mirror



Sample Python script interaction with SDN

- Add add view virtual router configuration
- Create and Remove Firewall
- Display Firewall Configuration
- Applying Firewall Rules
- Deleting virtual router from Controller

Thank you