

#### Software Defined Networking

- · Routers & switches are proprietary hardware
- Evolve slowly (usually designed with custom ASICs)
- Need to be configured individually making changes in a large organization is a pain
- · But the computers connected to the network
- Can change spontaneously thanks to VMs

It can take minutes (or seconds) to bring up or reconfigure a node ... but days to reconfigure a network!

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## Software Defined Networking (SDN)

- "Standard" software-based approach to managing network hardware
- Decouples the network control & forwarding functions
- OpenFlow™ dominant SDN protocol, defined by the Open Networking Foundation (ONF)
- Features
  - Directly programmable: decoupled from forwarding engine
- Dynamic: easy for administrators to make spontaneous changes
- Centrally-managed via SDN controllers: global view of an organization's network – which appears as a single switch
- Programmatic configuration: open APIs

SDNs allow you to mix and match network vendors

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#### **Network Virtualization**

- · Virtualization & Cloud computing
- Let someone else manage resources for you
- Access computing, storage, & networking resources without worrying about where they are or how they are implemented

#### $\mbox{ Virtual machines} \rightarrow \mbox{ software defined data center}$

- Create logical networks that are decoupled from the underlying hardware
  - Software-based view of networking HW (switches, routers, firewalls, load balancers, VPNs)
- Physical hardware is responsible for forwarding packets

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#### **Network Virtualization**

- · Virtual Machines (VMs) send standard layer 2 (ethernet) frames
- Hypervisor encapsulates the frame in a UDP datagram
  - VXLAN: Virtual Extensible LAN Layer 2 over Layer 3 encapsulation

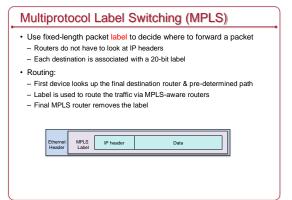


- Datagrams are forwarded to the destination
- Destination decapsulates headers & sends original frame to the VM
- · Create overlay virtual network topologies on a common network
- Central management (via APIs)
- Virtual switches (vSwitch) or virtual routers at each device route traffic

See Open vSwite

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#### Multiprotocol Label Switching (MPLS)

- · Original reason for MPLS
- Improves performance: simple lookup, no IP header modification
- No need to do longest prefix matching
- But ASICs can handle tens of millions of IP lookups per second
- · Although they can be expensive
- · Why is MPLS still used?
- Protocol independent
- No dependence on data link layer (2) or network layer (3)
- · Support routing of IP traffic as well as other data services
- Supports traffic engineering
- E.g., distribute traffic among several links not just shortest path
  Choose uncongested path with higher latency than a "better" congested path
- Routing is transparent to the IP layer · Bandwidth reservation with RSVP-TE
- Enables resilient networks (Fast Reroute)

# Wide Area Ethernet (WAE)

- · Virtual Private LAN Services (VPLS)
- · Provide the simplicity of a "flat" Ethernet
- · Makes multiple sites look like they are on one logical Ethernet
- · Common deployments
  - Ethernet (in building) MPLS (wide area) Ethernet (in building)
- Carrier-Ethernet Transport

### Internet of Things

- · In-home
- Connectivity
- Ad-hoc mesh networks (ZigBee): each node participates in routing route discovery
- Wi-Fi
- Bluetooth
- Lights, thermostats, switches, appliances
- · Wide area
- Cellular connectivity (usually)
- Microcontrollers (usually)
- Sensors
- Internet access
- Back-end acquisition & analytics
- Loose connectivity
- Domains: smart grid, smart cars, smart homes/cities, shipping containers

The end

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