Cloud Networking (VITMMA02)
Server Virtualization
Data Center Gear

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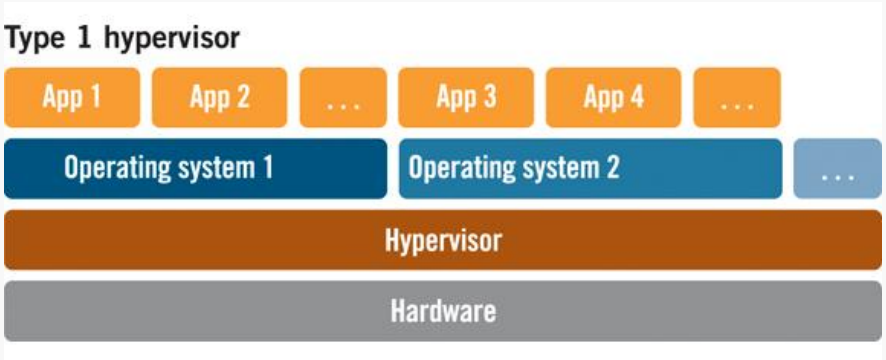
SERVER VIRTUALIZATION

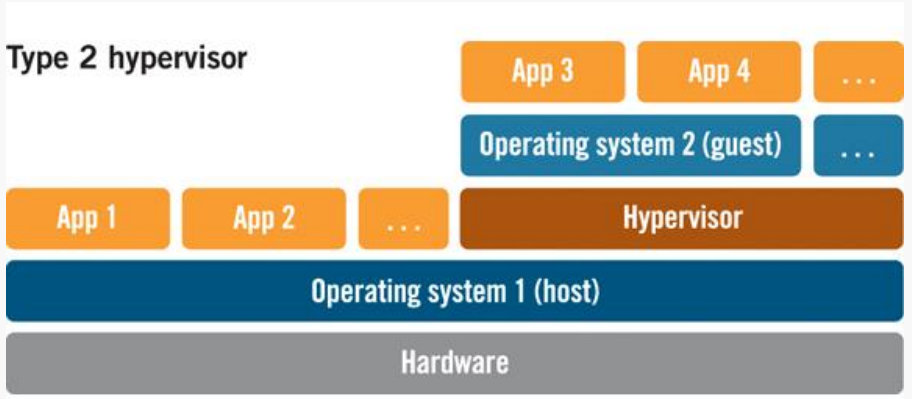
Server Virtualization

- Low server utilization ⇨ virtualization
  - PCs, servers: 10%
  - storage: 50%
- Server CPU and network bandwidth utilization is growing
  - Started from: 2-4(-10) VM / physical server (Virtual/Physical Machine)
  - today: ~16 VM/PM
  - for processes with low resource requirements even 100 VM/PM
- Hypervisor
  - virtual machine monitor/manager (VMM)
  - terminology
    - hardware: host
    - VM: guest
  - running VMs on the host
    - separated memory and disk management, CPU scheduling

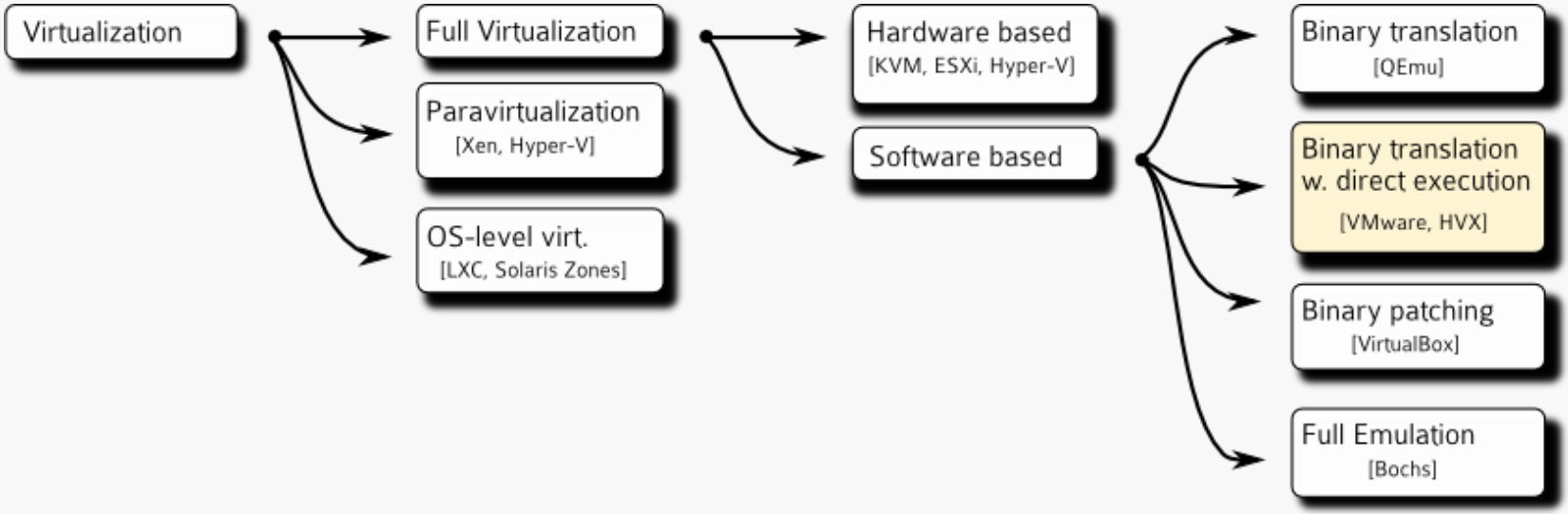
Server Virtualization

- Hypervisor
  - types, taxonomy: Gerald J. Popek and Robert P. Goldberg, „Formal Requirements for Virtualizable Third Generation Architectures”, 1974
    - Type 1: native (bare metal)
      - hypervisor is running directly on the hardware
      - e.g. Citrix XenServer, VMware ESX/ESXi, Microsoft Hyper-V
    - Type 2: hosted
      - hypervisor is running on the host OS (VM: guest)
      - e.g. VMware Workstation/Player, VirtualBox
    - other: Linux Kernel-based VM (KVM)
      - running as a kernel module, host OS is converted to Type 1
      - usually classified as Type 2





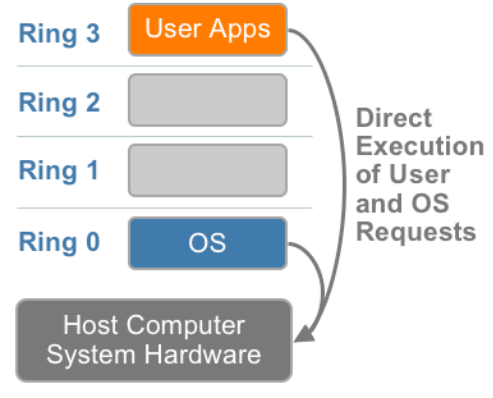
Types of Virtualization

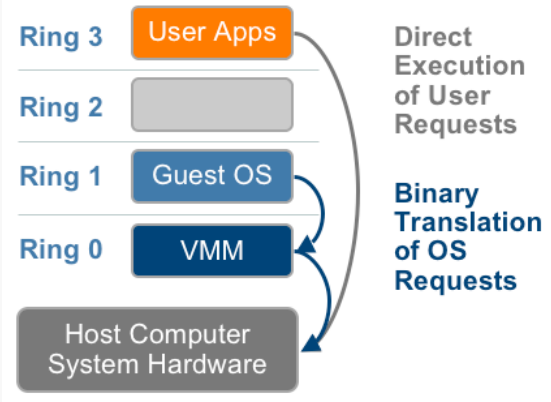


CPU Virtualization

- 2005-2006 hardware support for CPU virtualization: Intel VT-x and AMD-V
- Spread of virtualization software
- x86 CPU virtualization

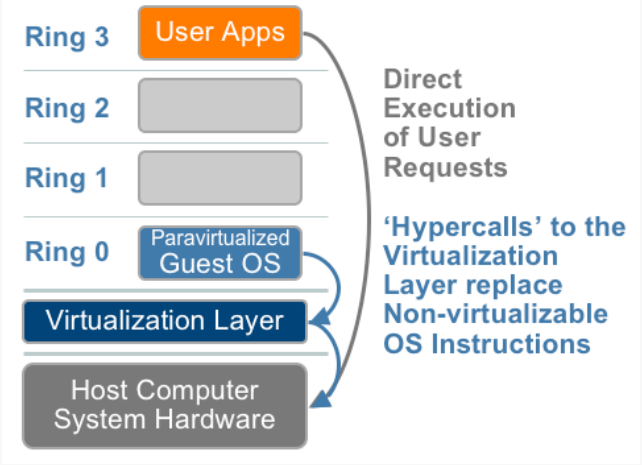
Privilege levels without virtualization

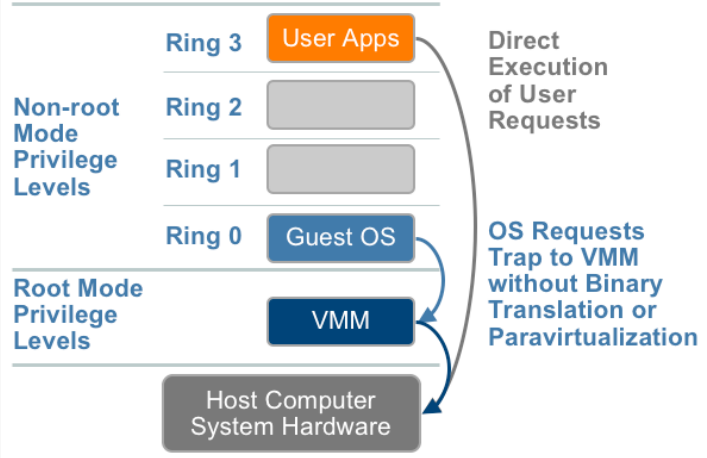




Full virtualization with dynamic binary instruction set translation

Paravirtualization (static translation)



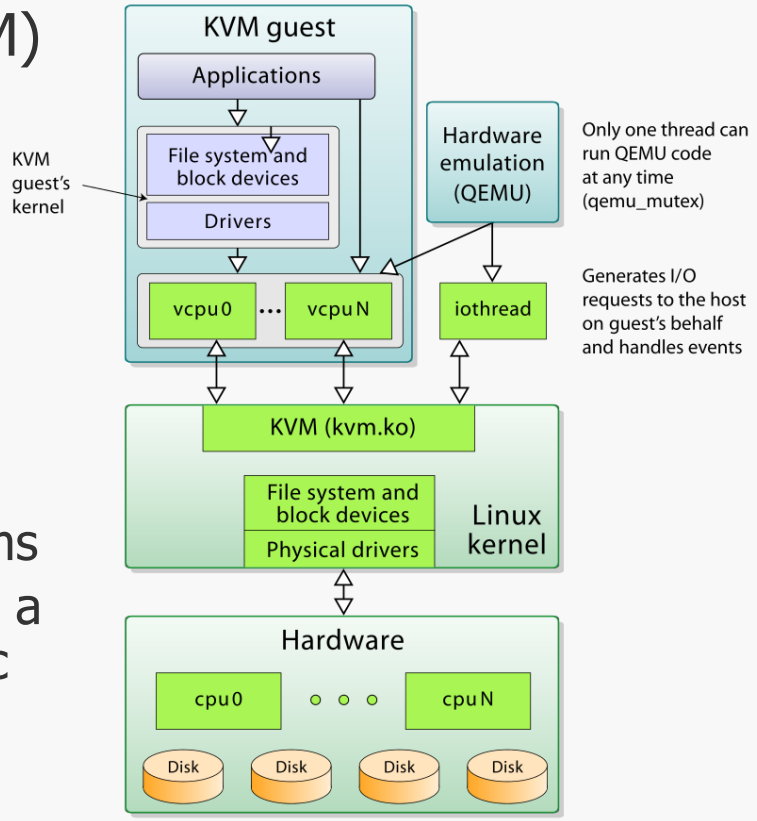


Hardware - assised virtualization

Source of figures: Vmware, Understanding Full Virtualization, Paravirtualization, and Hardware Assist, White Paper, 2007

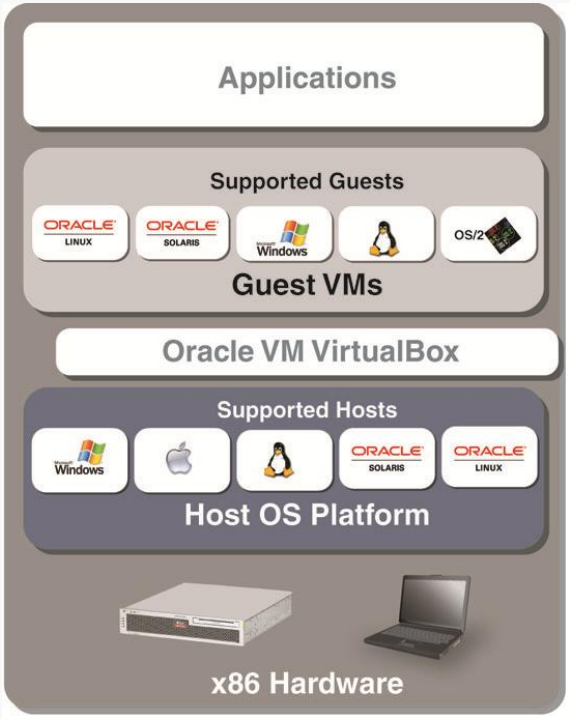
Platform Virtualization Software

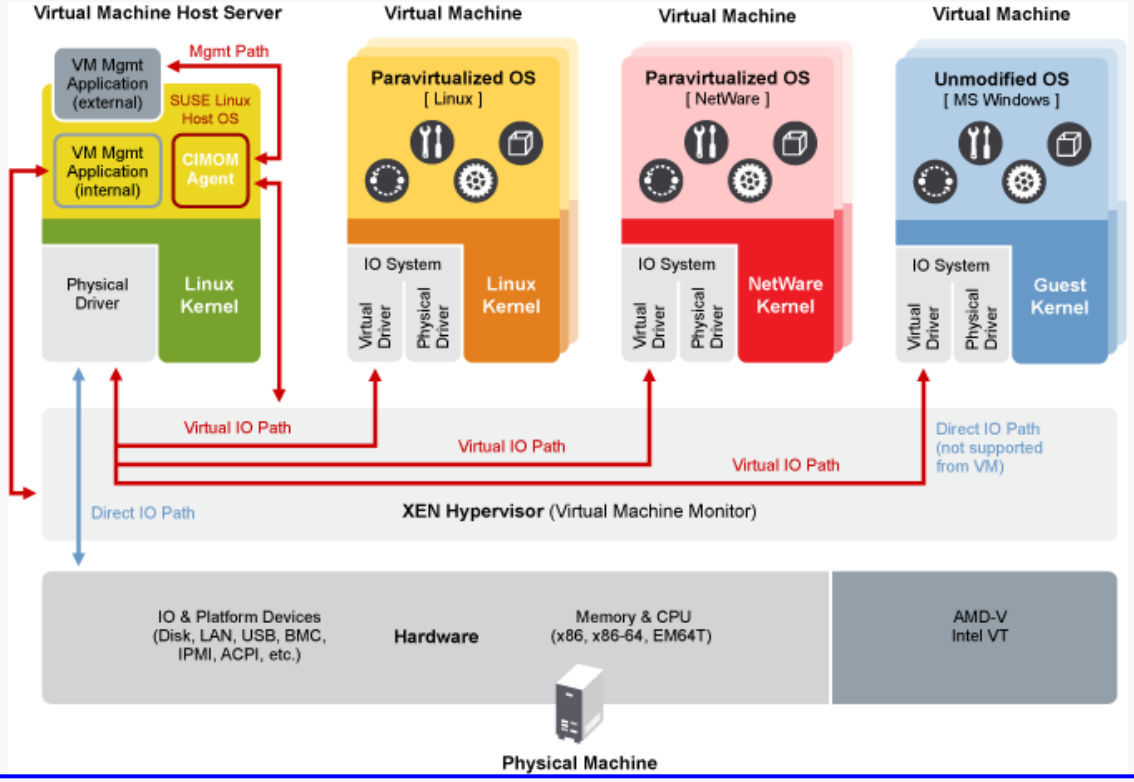
- Free and Open Source Software
  - Kernel-based Virtual Machine (KVM)
    - Type 2
    - part of Linux kernel
    - requirement: hardware-assisted virtualization
  - QEMU
    - generic and open source machine emulator and virtualizer
    - emulation: can run OSes or programs
    - programs made for one machine on a different machine, by using dynamic translation
    - virtualization: Xen or KVM
      - if host and guest is the same arch.
      - otherwise only software virtualization



Platform Virtualization Software

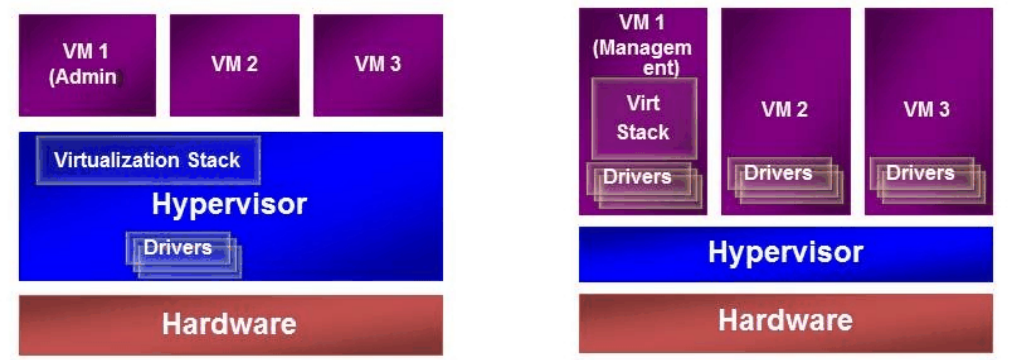
- Free and Open Source Software
  - Oracle VirtualBox
    - Type 2
    - software- or hardware-assisted virtualization
  - Xen
    - Type 1
    - paravirtualization or hardware-assisted virtualization





Platform Virtualization Software

- Closed Source / Commercial Products
  - VMware ESXi
    - Type 1
    - paravirtualization or hardware-assisted virtualization
    - small size: approx. 200 MB
    - monolithic VMkernel
      - hypervisor contains and manages all kind of device drivers
  - Microsoft Hyper-V
    - Type 1
    - partitions
      - parent partition (Admin, Management) : x86-64 Windows Server
      - child partitions : VMs
    - paravirtualization or hardware-assisted virtualization
    - larger size: approx. 5GB core, or 10GB full
    - mikorkernel
      - device drivers at VM level



NETWORKING IN DATA CENTERS: NETWORK DEVICES

Data Center Network

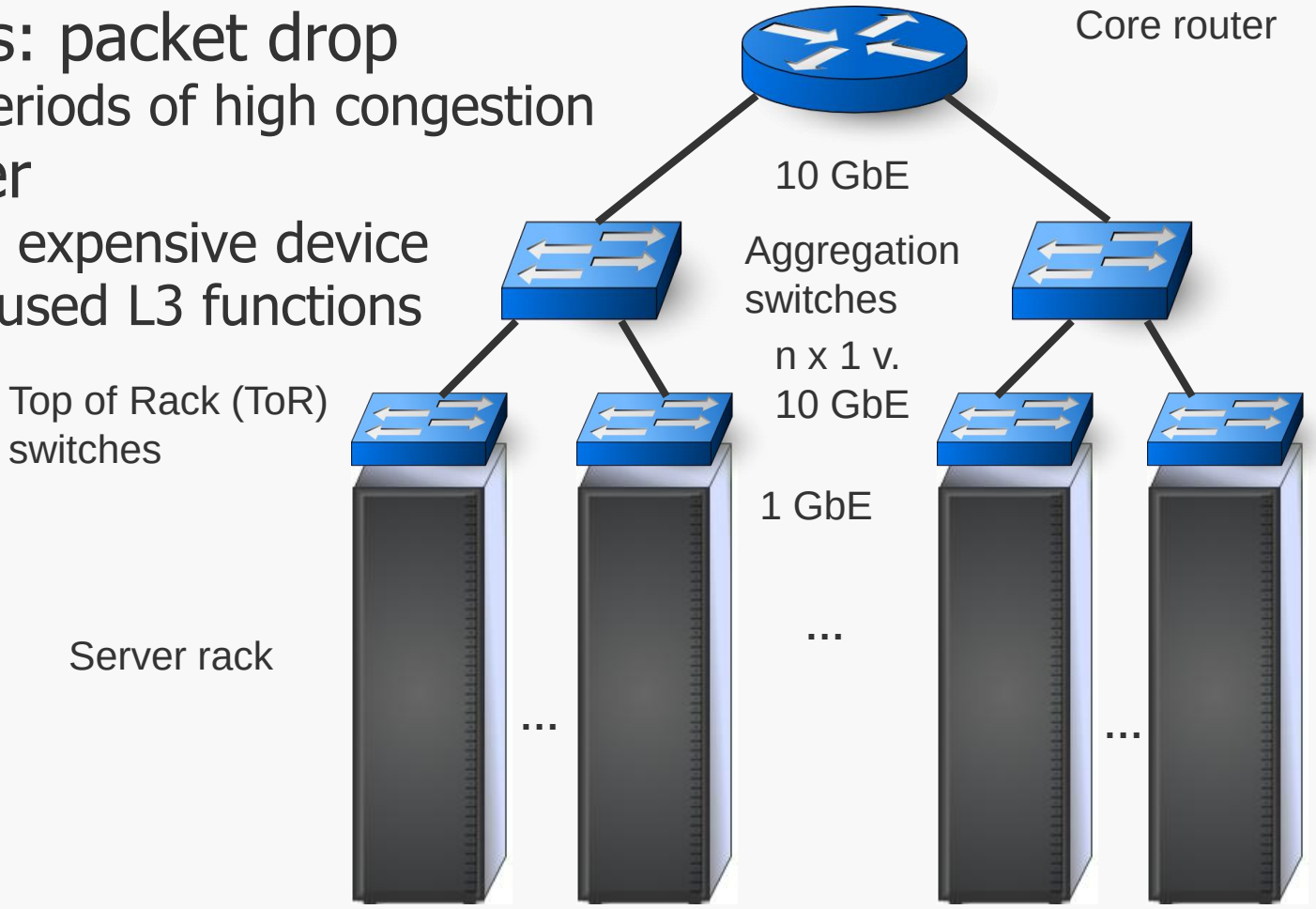
- Servers arranged in racks
  - several 10 or 100 thousand servers
- Reducing Capital and Operating Expenses (CapEx, OpEx)
- Network devices
  - Network Interface Card – NIC
  - switch, bridge
  - router
  - cabling (copper or fiber optic)
  - new trend
    - build network hardware according to custom specification and add own software (e.g. Google) ⇨ Software Defined Networking (SDN)

Data Center Network

- Why Ethernet?
  - high performance-to-cost ratio
  - ease of configuration
  - high speed: 1, 10, 40 (, 100) GbE
  - 10 GbE
    - since 2006 devices appear on the marker
    - since 2012 wide spread use
  - storage network traffic
    - Fibre Channel over Ethernet (FCoE)
- Challenges
  - different requirements compared to the LAN: scalability, reliability, bisection bandwidth, automated address allocation
- Convergence
  - not only data communication, but also storage network traffic is on the same network
    - data loss not tolerated
    - minimum bandwidth guarantees

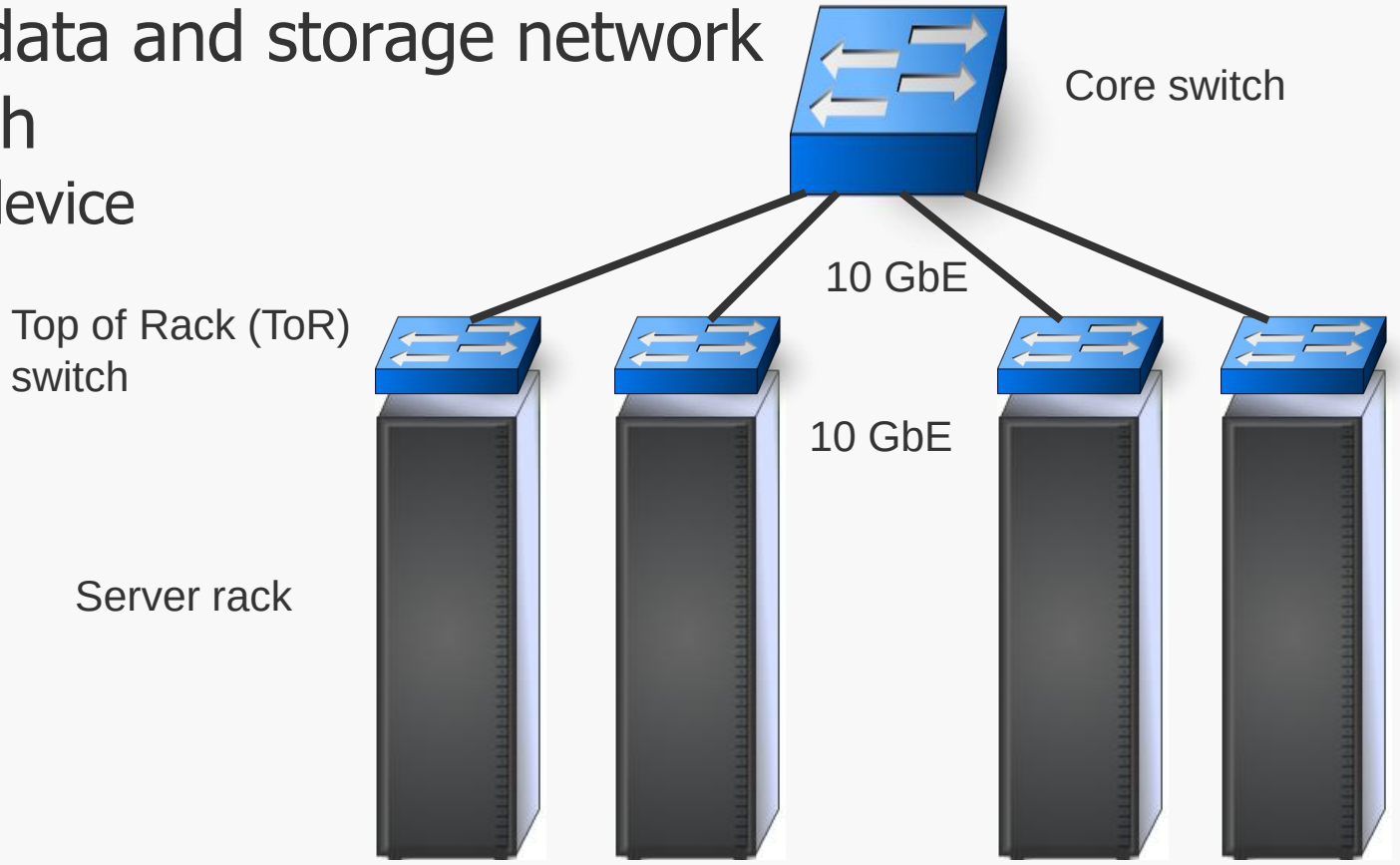
Enterprise Data Center

- Traffic between servers over multiple devices (hops)
  - latency, latency variation
- Traffic loss: packet drop
  - during periods of high congestion
- Core router
  - complex, expensive device
  - many unused L3 functions



Cloud Data Center

- Traffic between servers over few hops
  - flat(ter) network topology
  - lower latency and latency variation
- Common data and storage network
- Core switch
  - simpler device

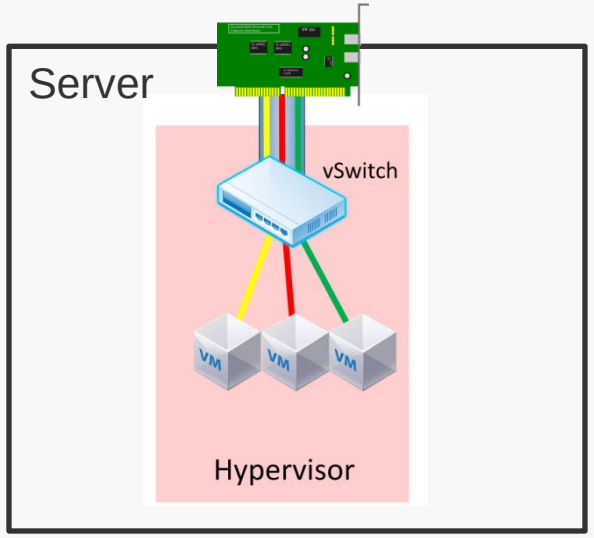


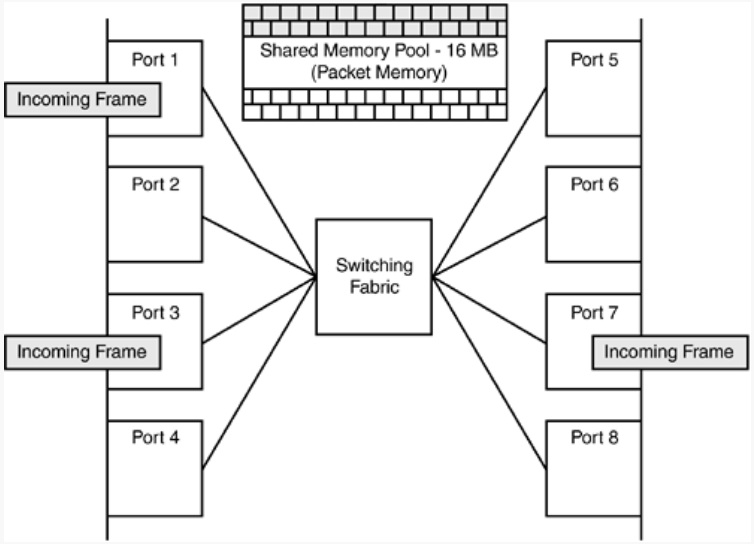
Data Center Switch Types

- Virtual Switch, vSwitch
  - between VMs on the same physical server
- Top of Rack (ToR) switch
- End of Row (EoR) switch
- Aggregation switch
- Core switch/router

Virtual Switch

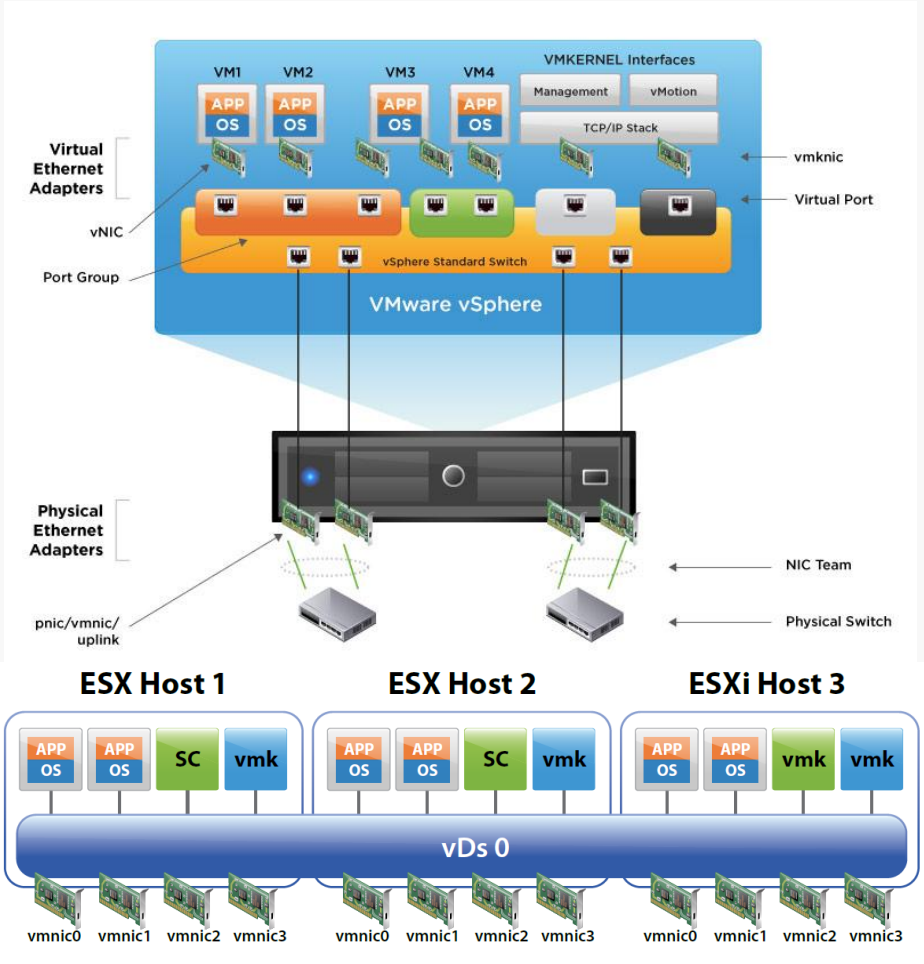
- Hypervisor
  - configuration of VMs and virtual switches
- vSwitch
  - attached to physical NIC, typically all VMs are connected to the same vSwitch
    - limiting the bandwidth of the VMs input/output traffic
  - server CPU is used for switching
  - in practice the vSwitch is implemented with shared memory
    - data (frames, packets) is stored in memory of the servera
    - VMs exchange pointers to this data
    - high bitrate!
  - also part of the network
    - uniform configuration and management would be ideal with the physical switches





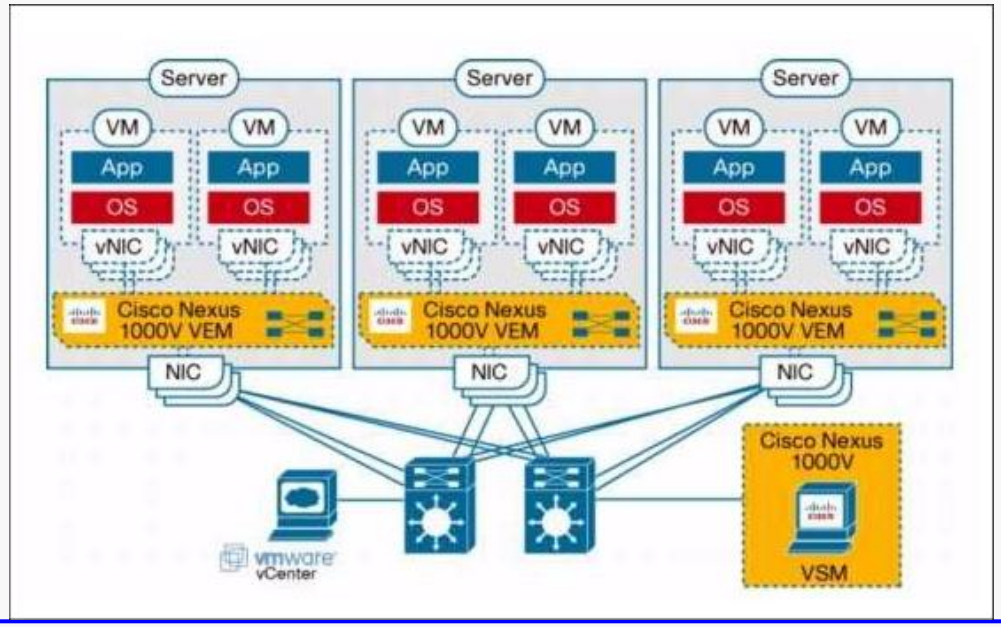
Virtual Switching: VMware vSwitch

- multiple VM – one (or multiple) NIC
- software vSwitch – hypervisor
  - VMware vSphere (ESXi)
    - vNetwork Standard Switch (VSS)
    - abstract, distributed switch: vSphere Distributed Switch (VDS)
      - unifying multiple physical servers
    - New features (with significant CPU usage)
      - traffic monitoring
      - VLAN isolation
      - traffic shaping (max. bandwidth)
      - vMotion support



Virtual Switching: VMware vSwitch

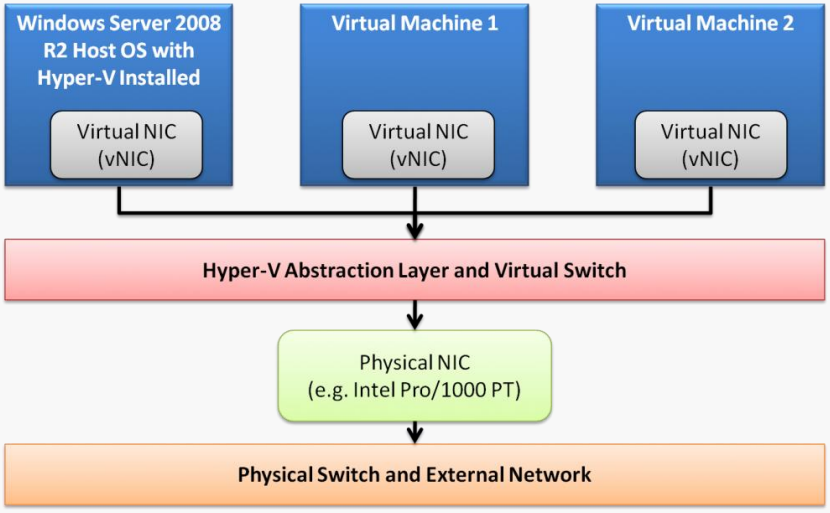
- VMware vSphere (ESXi)
  - Cisco Nexus 1000V
    - Cisco/VMware collaboration
    - feature set is close to a physical switch, but with limitations
    - components
      - Virtual Ethernet Module: runs inside the hypervisor
      - Virtual Supervisor Module: manages VEMs
    - integrated Cisco Command Line Interface (CLI) and VDS API
    - VXLAN support

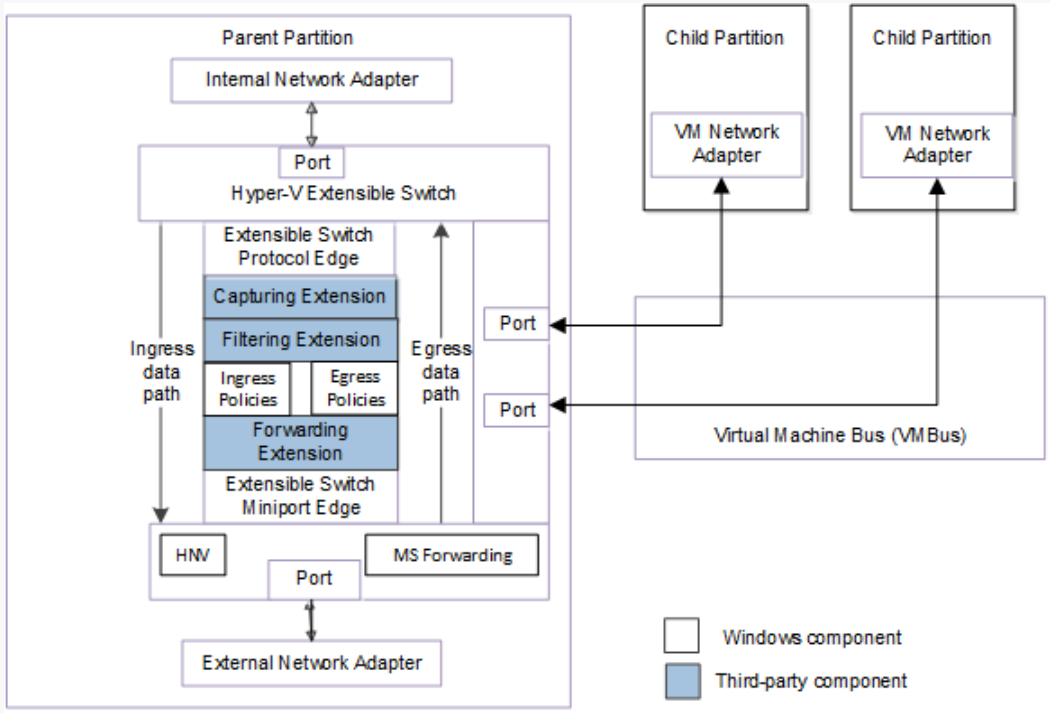


Virtual Switching: Microsoft Hyper-V

- Private/Internal/External modes
- Hyper-V 3.0: Windows Server 2012
  - Hyper-V Extensible Switch
  - traffic classification, filtering and monitoring
  - guarantee a minimum and/or limit the outbound speed
  - congestion control
  - VM queues
  - live migration
  - extensibility
  - Cisco Nexus 1000V can be integrated

Hyper-V Networking Basic Diagram

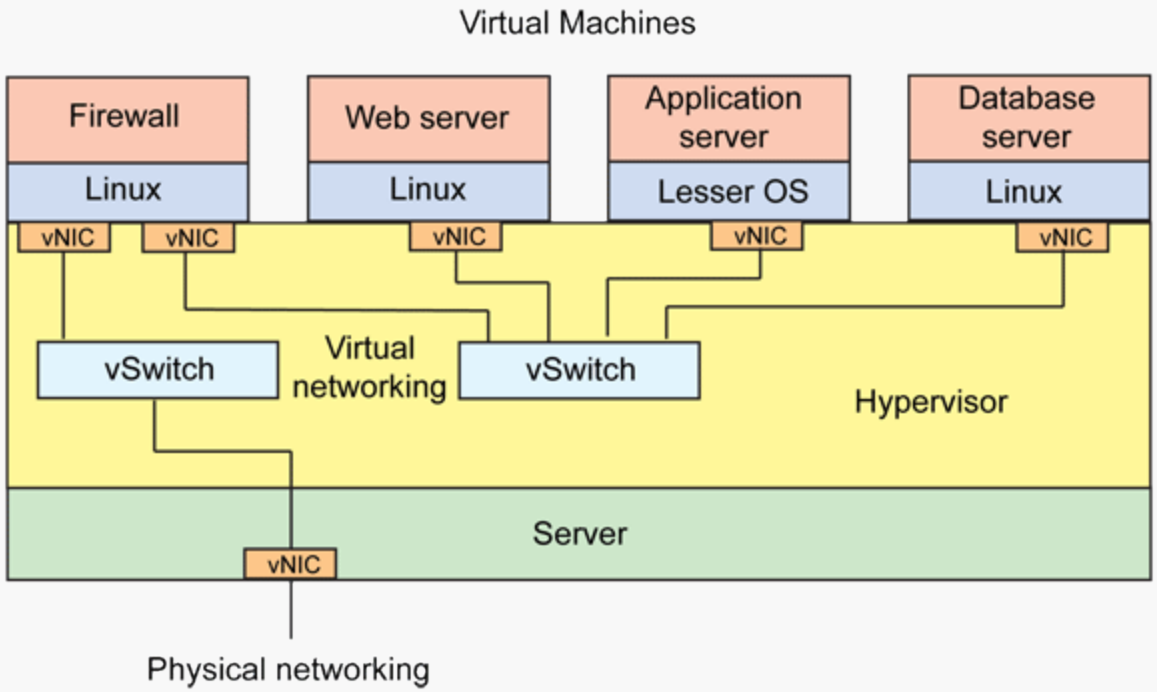




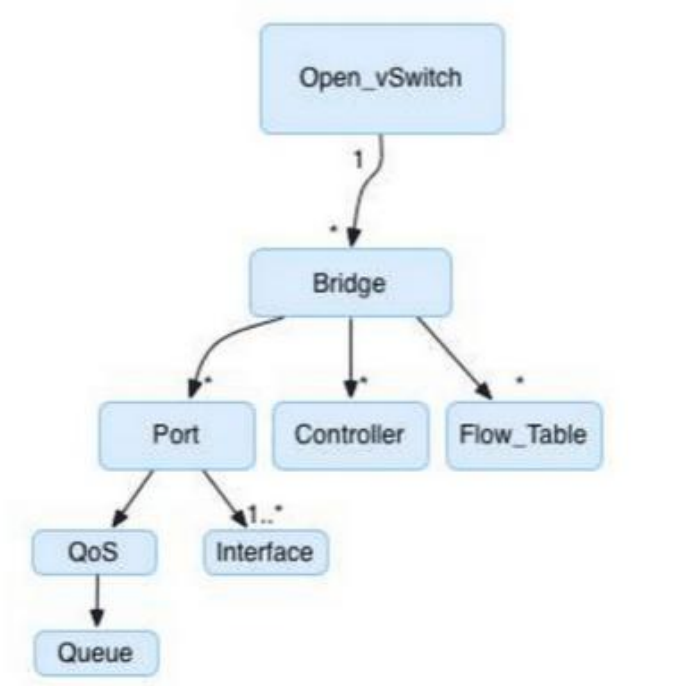
Virtual Switching: Open vSwitch

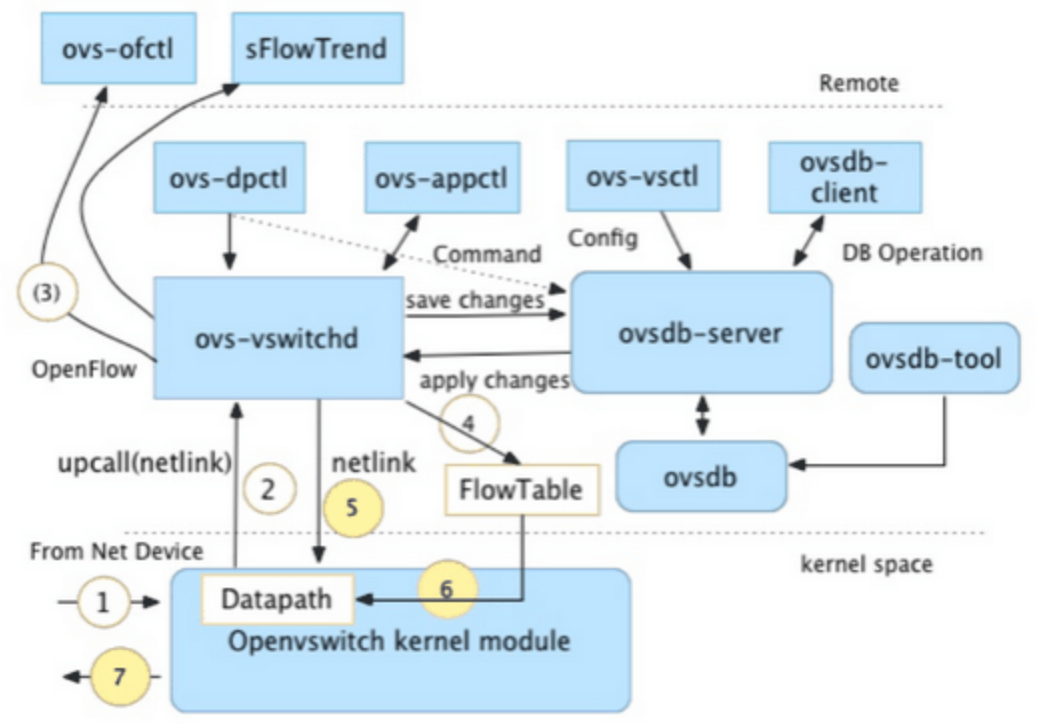
- open source implementation
- standard management protocols
- Features
  - Visibility into inter-VM communication via e.g. NetFlow
  - 802.1Q VLAN
  - STP (IEEE 802.1D-1998)
  - QoS control
  - Per VM interface traffic policing
  - NIC bonding
  - OpenFlow protocol support (including many extensions for virtualization)
  - IPv6 support
  - Multiple tunneling protocols (GRE, VXLAN, STT, and Geneve, with IPsec support)
  - Kernel and user-space forwarding engine options
  - user-space control
- Characteristics
  - Mobility of state: all network state (e.g. an entry in an L2 learning table, ACLs, QoS policy, etc.) associated with a network entity (say a virtual machine) should be easily identifiable and migratable between different hosts
  - Responding to network dynamics: VM startup, shutdown, migration
  - Maintenance of logical tags: tunneling, VM identification
  - Hardware integration: can be the control plane of a hardware switch
  - distributed vSwitch: with OpenFlow
- Platforms
  - XenServer, Xen, KVM, VirtualBox, OpenStack, OpenNebula, Linux (kernel), FreeBSD

Virtual Switching: Open vSwitch



Open vSwitch data structures and architecture



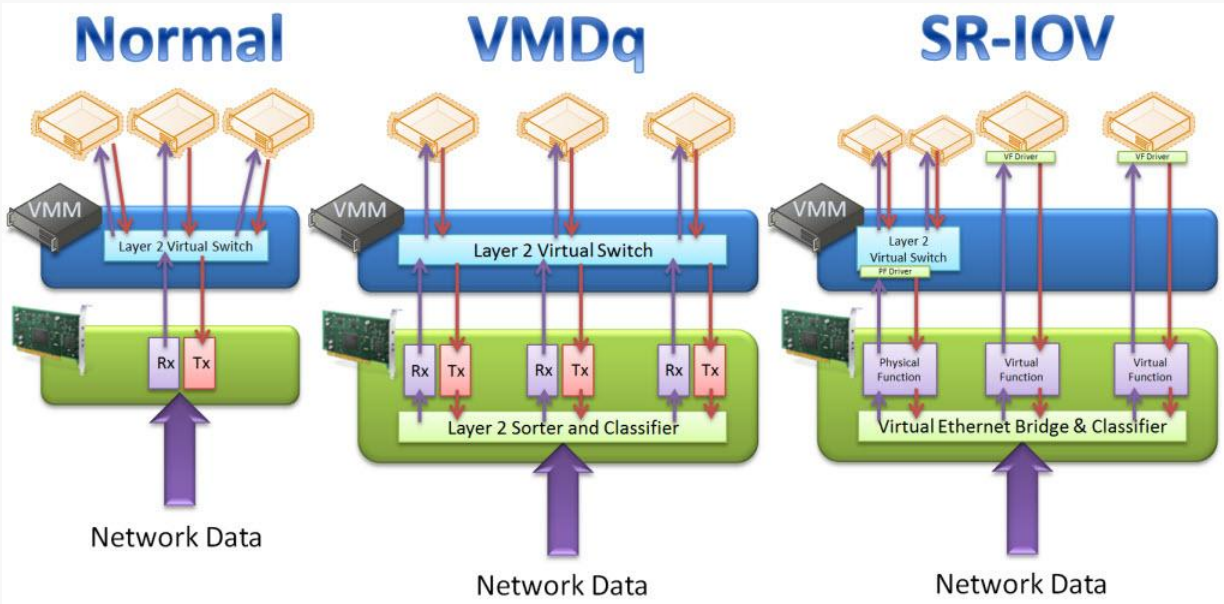


Linux Bridge

- alternative switch technology
- simpler than OVS
  - simple model, not flow-based
  - forwarding layer in the Linux kernel
  - less code-base
  - easier to troubleshoot
  - set-up: brctl, ip route
- Tunneling
  - supported GRE Tunnels
  - VXLAN support: from Linux kernel 3.7 (2012)

Enhancing VM Network Performance

- Virtual machine device queues (VMDq) – Intel
  - intensive CPU usage by vSwitch affects performance of the VMs
  - VMDq implemented on NIC
  - separate receive and transmit queues for VMs
    - based on MAC address and VLAN tag information
  - advantages
    - parallelization
    - filtering and sorting of packets is done by hardware
- PCIe single-root IO virtualization (SRIOV)
  - moves the vNIC functionality into the NIC
  - one physical function (PF) with multiple virtual functions (VFs)
  - vSwitch is by-passed, therefore it is used only in special applications
  - DMA between VF and VM
  - requires support from
    - VM network driver
    - hypervisor
  - approx. 10-15% CPU load reduction

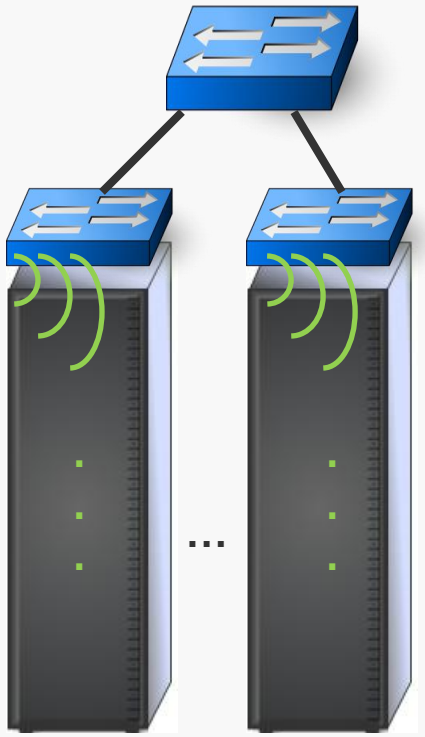


ToR Switch

- Typical configuration
  - servers connected using star topology
  - 48 x 10 GbE port towards servers
  - 4 x 40 GbE towards aggregation switche(s)
  - 480 Gbps ⇔ 160 Gbps
    - 3:1 oversubscription
      - typical values: 2,5:1 – 8:1
  - 1 rack – 1 switch
    - rack level redundancy
- ToR switch
  - low latency
  - large address space tables
  - also for storage traffic
- Possible extra functions
  - tunneling
  - filtering
  - metering
  - load balancing

Advantages:
- shorter and simpler cabling
- rack level management/redundancy

Disadvantages:
- more switches has to be managed
- scalability limits (STP, ports)
- control plane for each switch

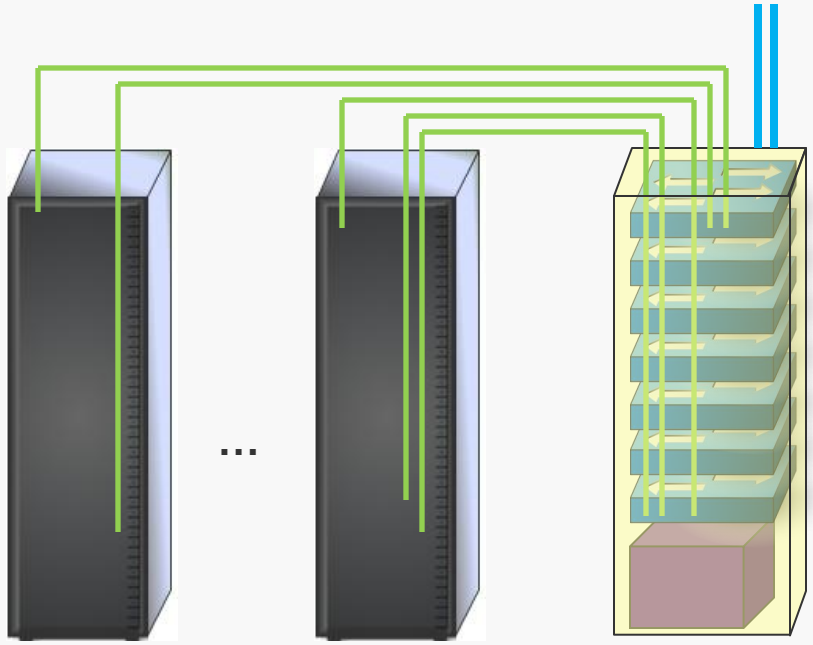


EoR Switch

- Cost reduction
  - large number of switch components together connecting servers and core switch
  - like switch cards plugged into a modular chassis
  - sharing common power, cooling and mgmnt. infrastructure
- Cabling
  - max. 100 m towards servers
  - cable distance ⇨ cost

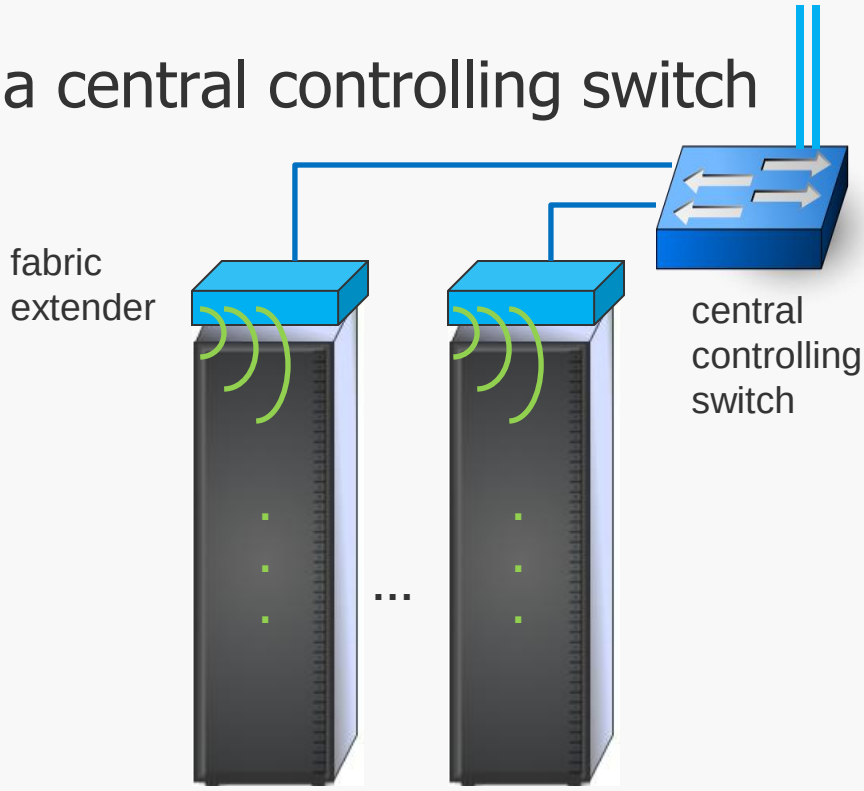
Advantages:
- central management processor
- less aggregation ports
- less STP instance
- one control plane

Disadvantages:
- expensive, inflexible cabling
- longer and hard to handle cables
- row level management/redundancy



Fabric Extenders (FEX)

- ToR / EoR hybrid solution
  - like a logically a distributed EoR switch
  - fabric extender on ToR: physical switch of limited functionality
  - controlled and monitored by a central controlling switch
  - cabling, like ToR switches



Advantages:
- central management processor
- less aggregation ports
- less STP instance
- one control plane
- cost effective cabling
- rack level management/redundancy

Disadvantages:
- not commonly used

Aggregation and Core Switches

- Aggregation: connecting ToR switches and Core switch
- Core Switch
  - connection to the outside network
  - high-bandwidth links and high port counts
  - modular design: cards attached to a common backplane
    - line cards (first stage)
    - switch cards (second stage)
    - processing cards (CPU, memory) – e.g. firewall, load balancer
    - management cards
  - complexity can be reduced by simple packet forwarding rules using various types of forwarding tags