DPDK Summit 2014
DPDK in a Virtual World

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Agenda

- Data Plane Virtualization Trends
- DPDK Virtualization Support
- VMware ESXi : Key Features and Performance

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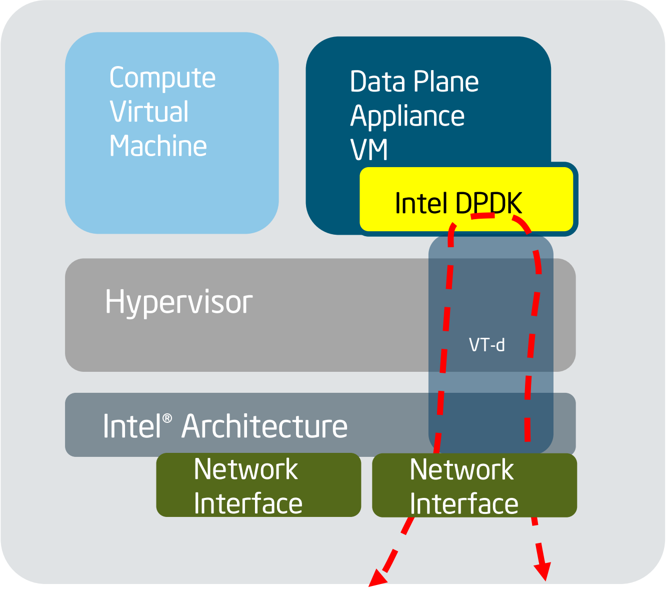
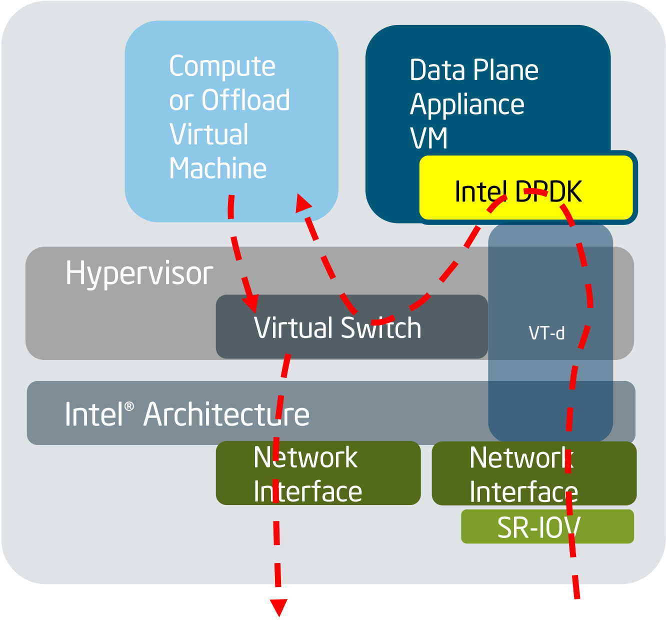
Data Plane Virtualization Trends

Virtualization for Directed I/O Packets are routed to Virtual Machine using DirectPath I/O. Limited flexibility but native performance



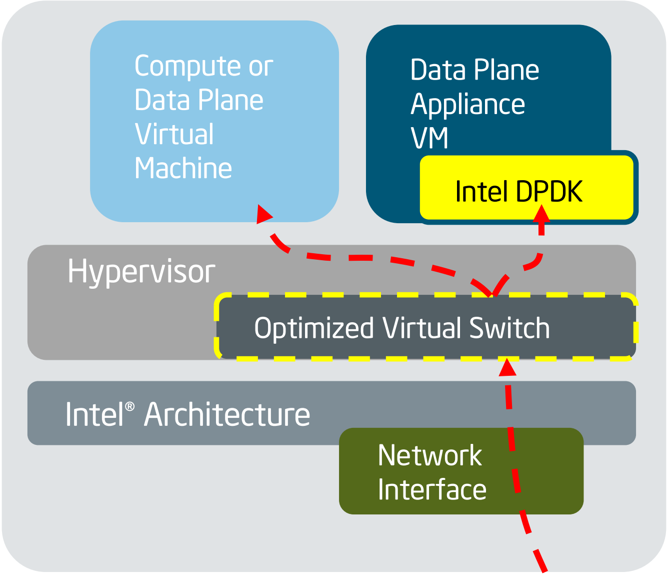
Standalone appliance integration, Firewall, WAN acceleration, Traffic Shaping

Hybrid Switching Solution, combining vSwitch support with direct assignment of SR-IOV Virtual Function



Service Chaining, Unified Threat Management, Intrusion Detection / Prevention

Optimized Virtual Switching solution, combining flexibility with performance. Support for live migration and data plane performance.



Increasing flexibility through high performance soft switching supporting both communications and compute workloads

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- DPDK Virtualization Support
- VMware ESXi : Key Feature and Performance

DPDK Virtualization Support

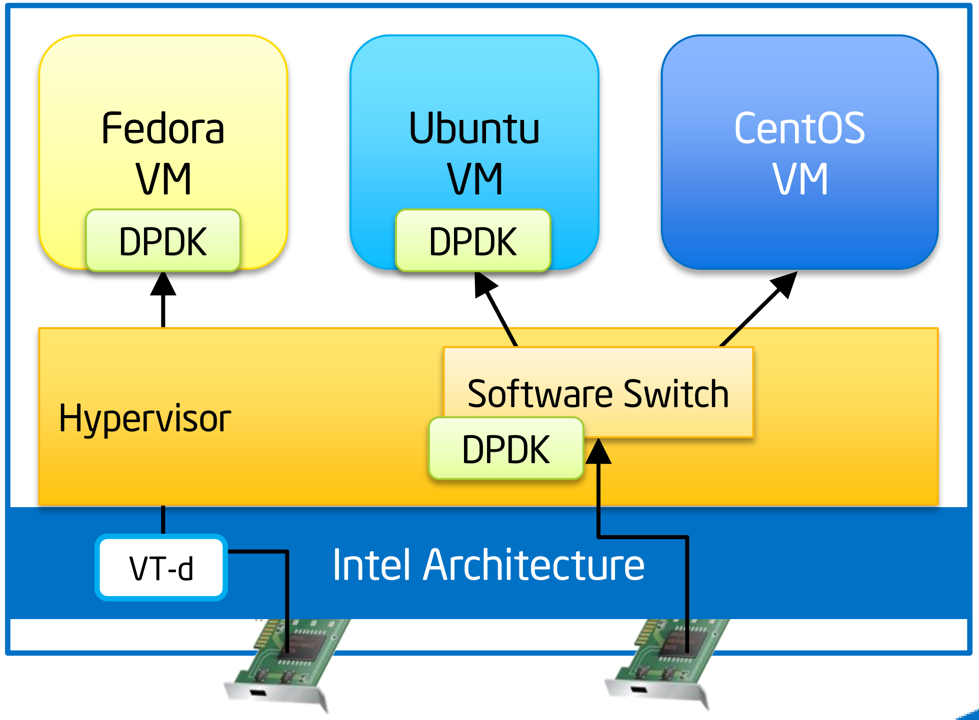
Virtual Machine

- Niantic 82599 Virtual Function PMD
- Fortville Virtual Function PMD
- E1000 Emulated Device (Intel® 82540 Ethernet Controller) PMD
- Virtio Para-virtual Device (Qumranet Device) PMD
- IVSHMEM Shared Memory Interface
- Virtqueue-GrantTable Interface in Xen DomU
- E1000 Emulated Device (Intel® 82545EM Ethernet Controller) PMD
- E1000E Emulated Device (Intel® 82574 Ethernet Controller) PMD
- Vmxnet3 Para-virtual Device PMD

VMware ESXi

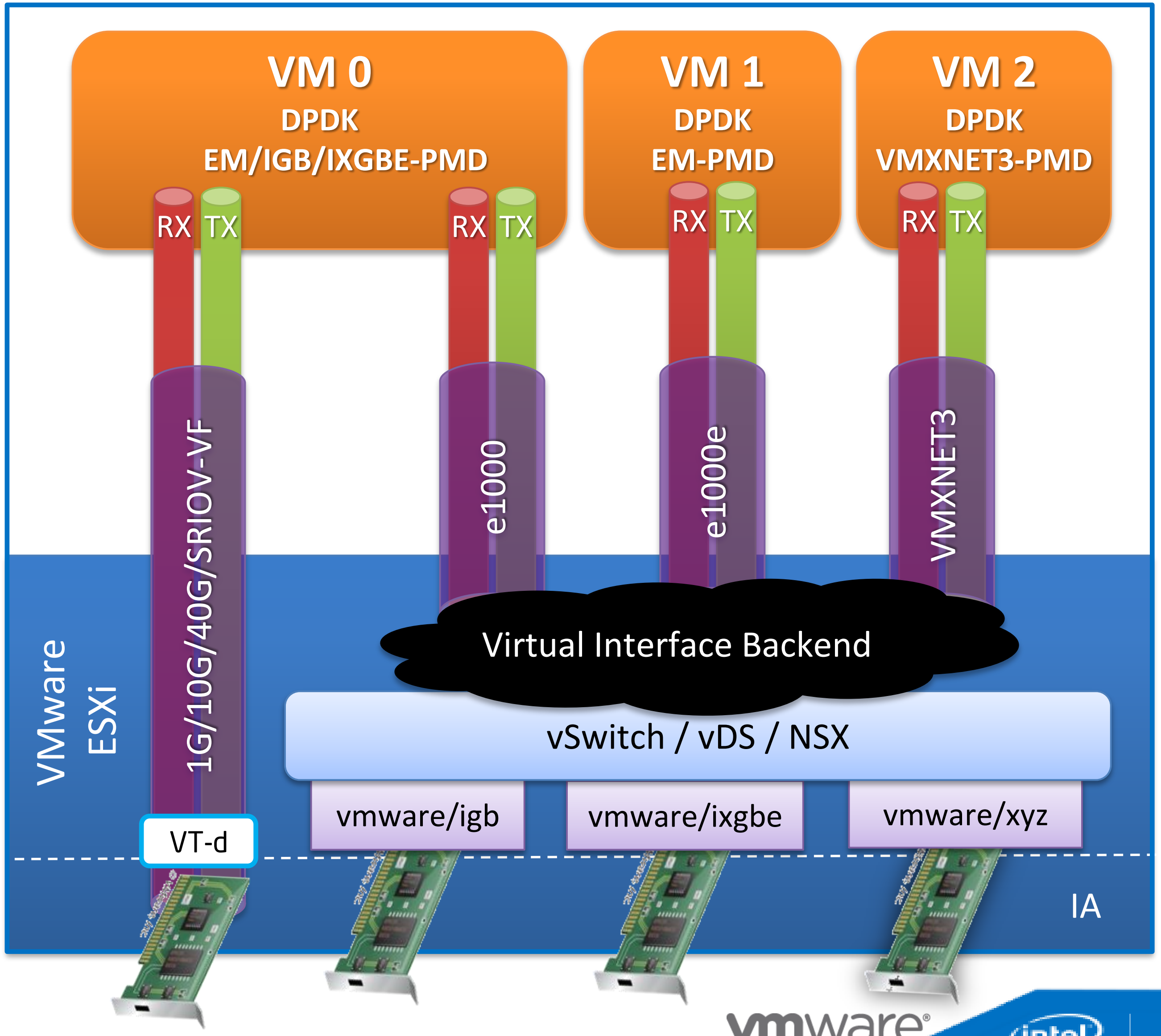
Hypervisor/Host

- Niantic 82599 Physical Function Driver
- Fortville Physical Function Driver
- Userspace-Vhost Backend support
- IVSHMEM Backend support

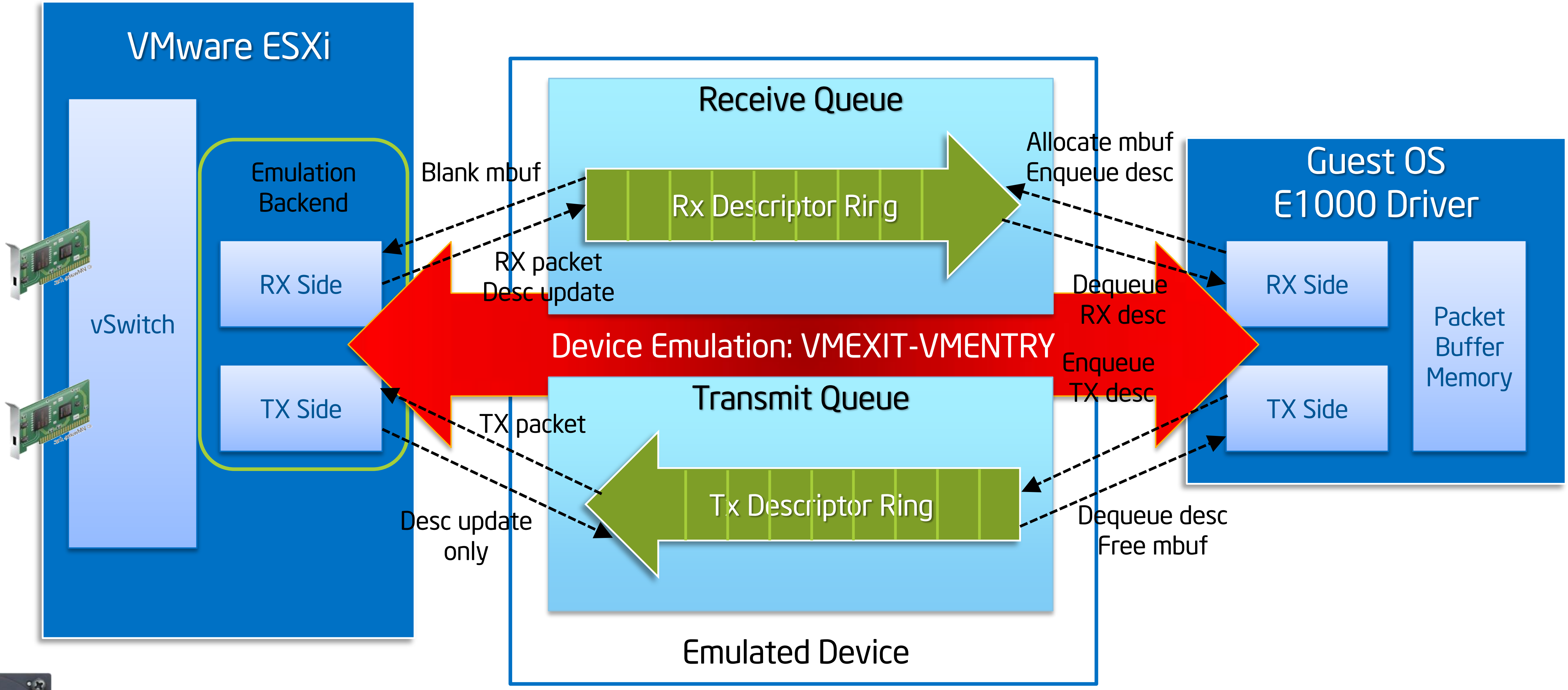


VMware ESXi Virtual Interfaces

- vSS/vDS/NSX – A software switch
  - Emulated devices
    - E1000 (Intel® 82545EM)
    - E1000E (Intel® 82574)
    - VLance (AMD PCnet32)
  - Para-virtual devices
    - VMXNET interface
    - VMXNET2 interface
    - VMXNET3 interface
- Direct assignment – vSwitch bypass
  - Intel® VT-d / IOMMU required
  - DirectPath I/O Full PCI function
  - SR-IOV PCI VF assignment
  - Incompatible with virtualization features: vMotion, HA, FT, snapshots, network virtualization overlays (VXLAN/STT/Geneve)

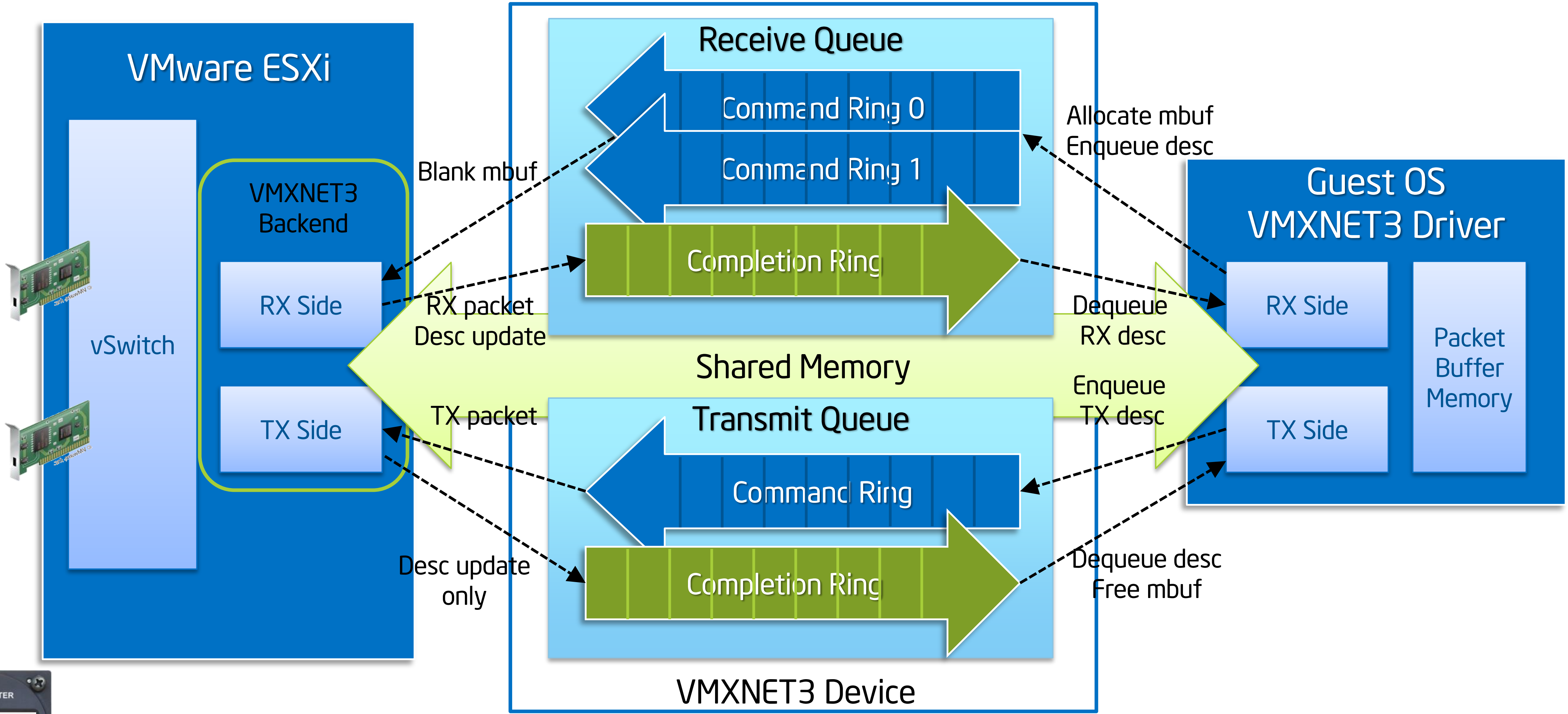


VMware ESXi Emulated Device (E1000)



Every emulated PCI MMIO access from a VM results in VM exit

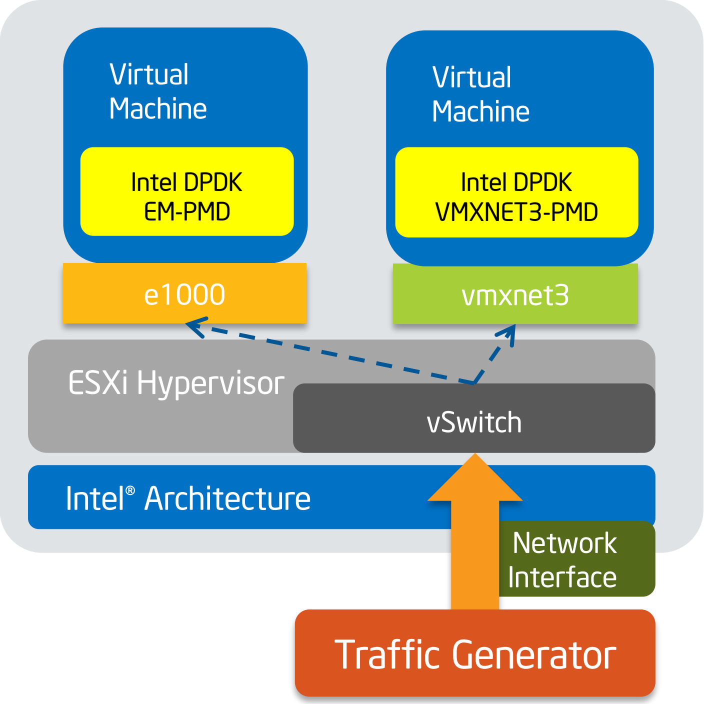
VMware ESXi Paravirtual Device (VMXNET3)



Reduced VM exits by moving Queue Control Registers in Shared Memory and passing hints from ESXi to Guest OS

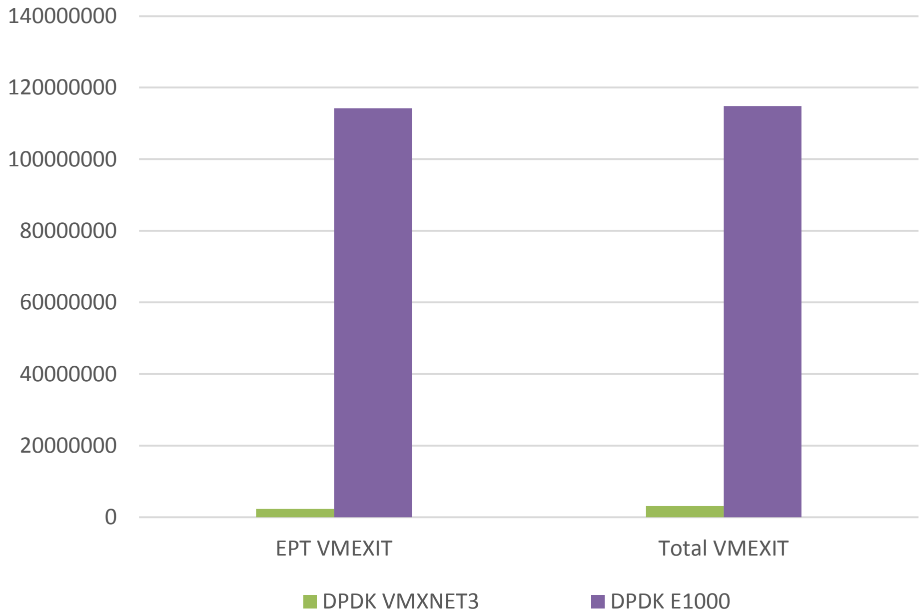
ESXi 5.5 - VMXNET3 vs E1000

- Optimized Rx/Tx queues handling in VMXNET3 controlled through shared memory region – reduced VM exits compared to E1000's inefficient MMIO emulation
- Multiqueue infrastructure of VMXNET3 with RSS capability enhance the performance with Multicores in a VM



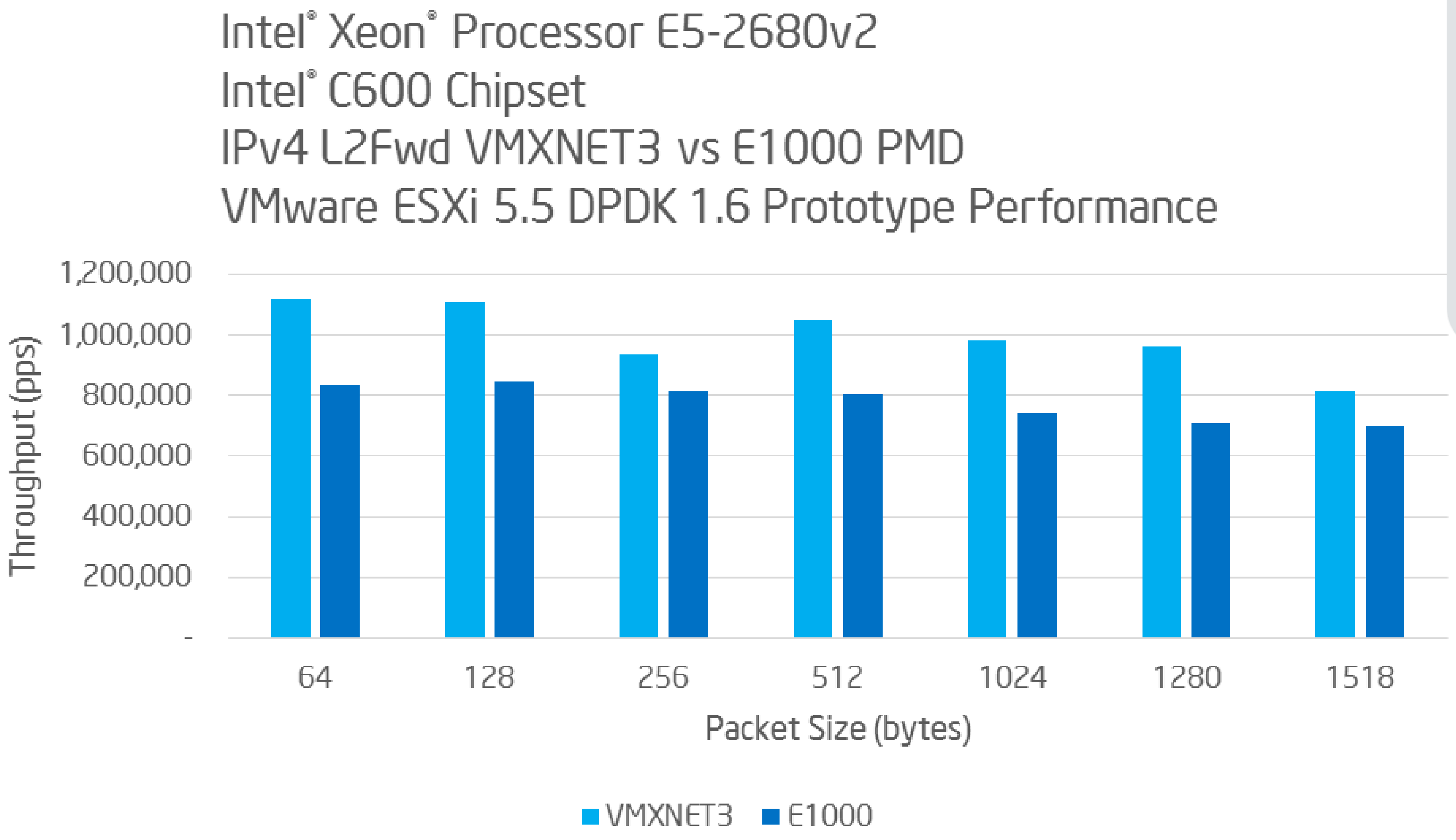
- Average cost for a VM exit/VM entry sequence includes ~600 cycles for VMCALL instruction. Average cost for EPT violation ~1000 cycles

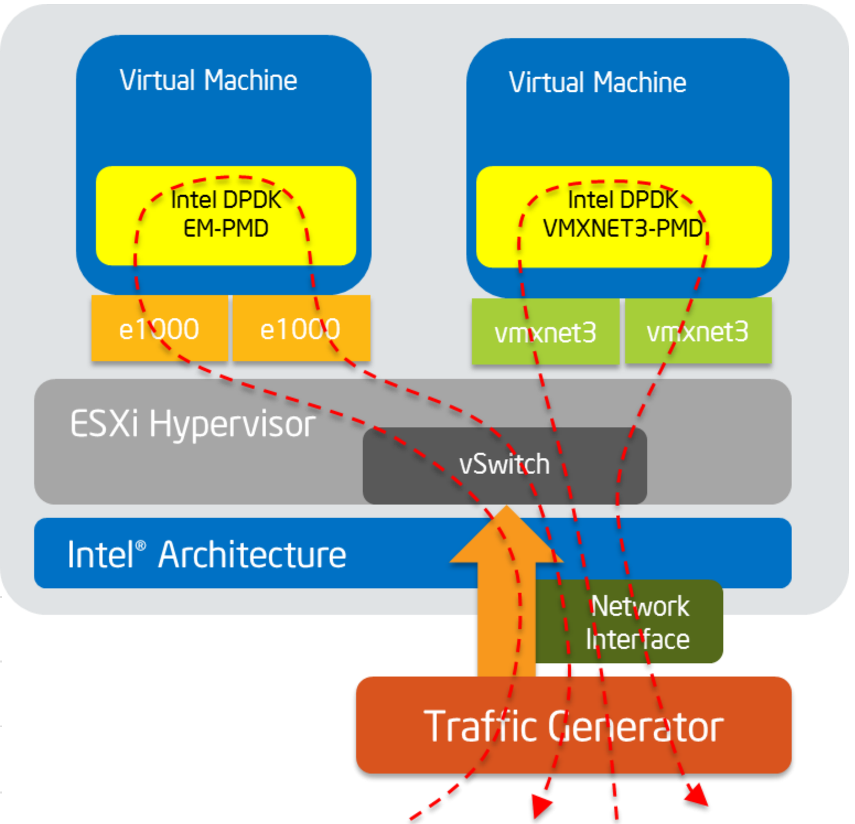
Intel® Xeon® Processor E5-4610 v2
(16M Cache, 2.30 GHz)
VM exit/ VM entry frequency



97% Reduction of VM exits associated with DPDK based Packet forwarding benchmark

Hypervisor Backend Impact





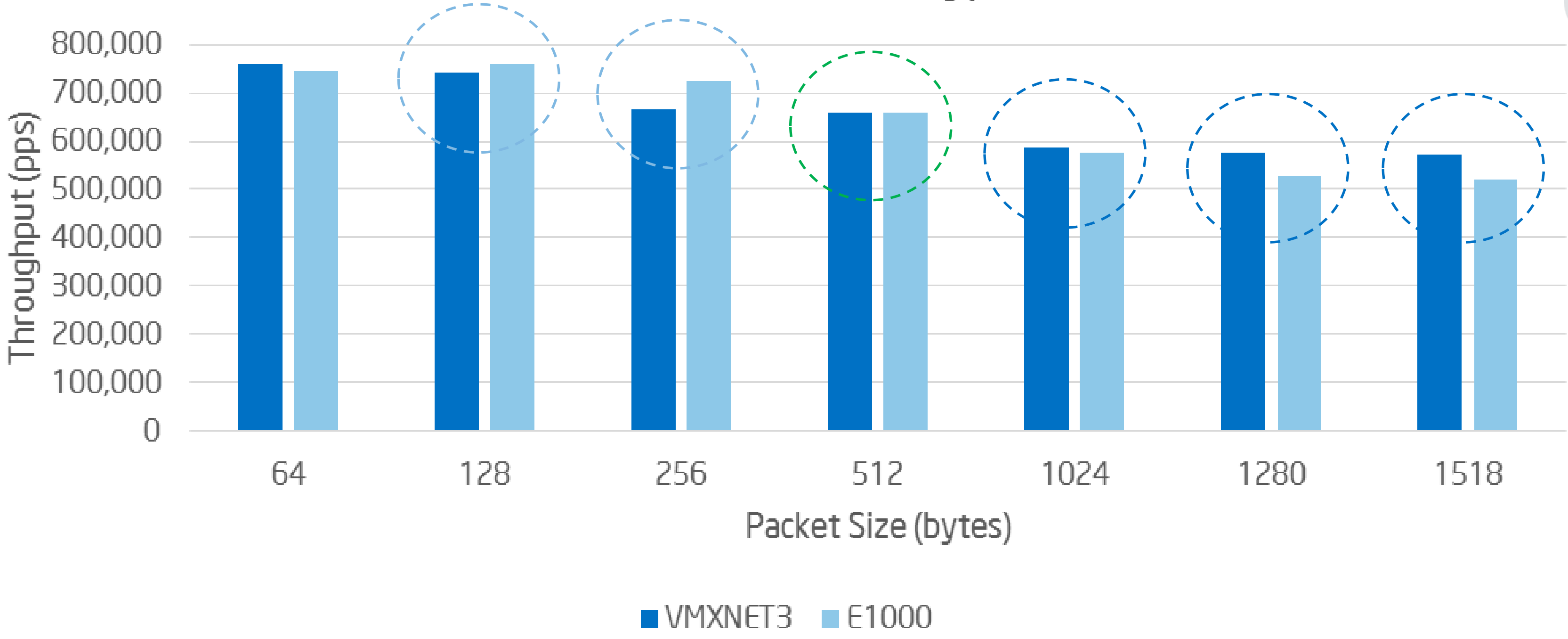
L2Fwd Loopback in VM

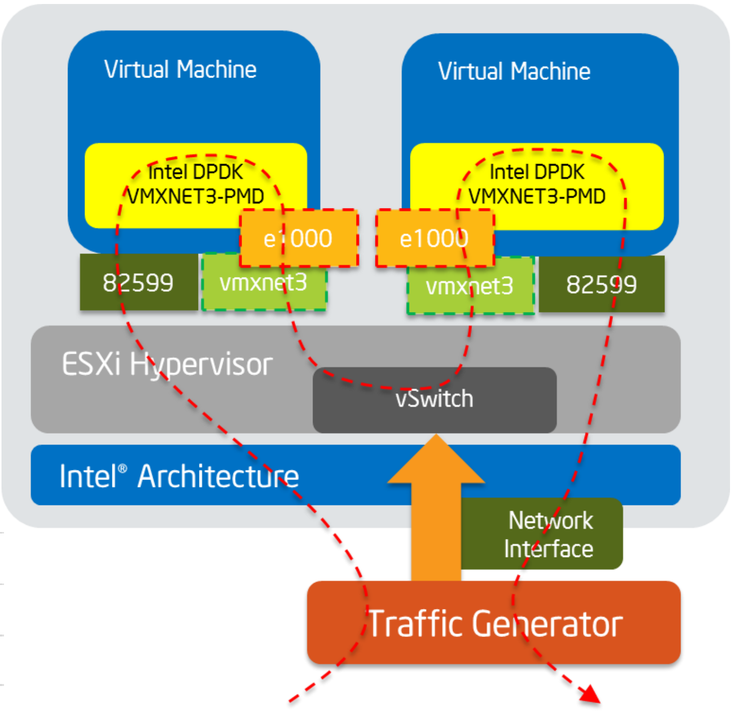
Traffic Flow:
Traffic Gen. -> vSwitch -> VMXNET3 (or E1000) -> VM (DPDK) -> VMXNET3 (or E1000) -> vSwitch -> Traffic Gen.

VM exit reduction doesn't translate to big difference in packet throughput; Hypervisor Backend and Native Networking stack needs optimizations

Device Model Research

Intel® Xeon® Processor E5-2680v2
Intel® C600 Chipset
IPv4 L2Fwd VMXNET3 vs e1000 (VM-to-VM)
VMware ESXi 5.5 DPDK 1.6 Prototype Performance





L2Fwd Chained VM-to-VM

Traffic Flow:
Traffic Gen. -> 10G (VT-d) -> VM1 (DPDK)
-> VMXNET3 (or E1000) -> vSwitch
-> VMXNET3 (or E1000) -> VM2 (DPDK)
-> 10G (VT-d) -> Traffic Gen.

Important to understand for designing changes in device model for future ESXi releases

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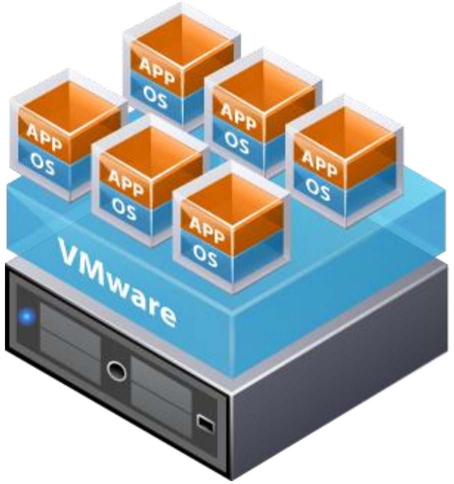
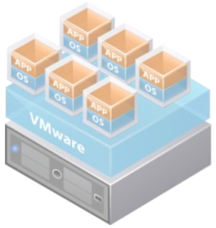
Key Properties of Virtual Machines



Partitioning

- Run multiple operating systems on one physical machine
- Divide system resources between virtual machines

Key Properties of Virtual Machines : Continued



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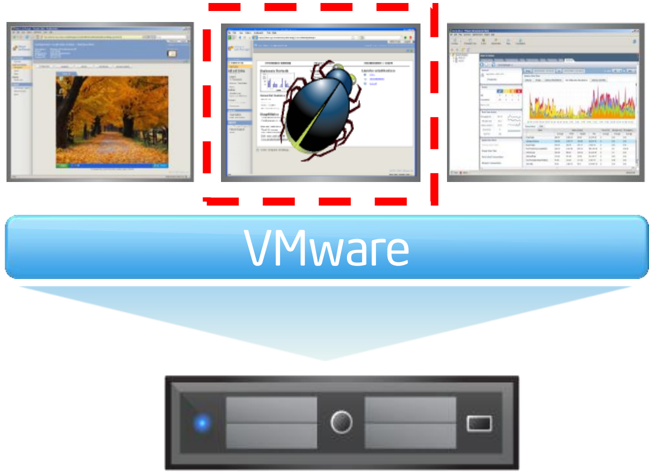
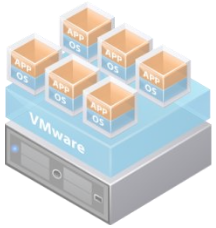


Isolation

- Fault and security isolation at the hardware level
- Advanced resource controls preserve performance

Key Properties of Virtual Machines : Continued



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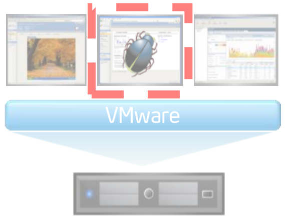

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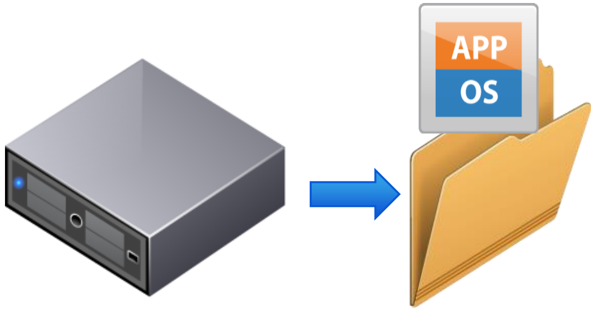
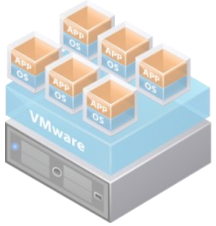
Encapsulation



- Entire state of the virtual machine can be saved to files
- Move and copy virtual machines as easily as moving and copying files

Key Properties of Virtual Machines : Continued



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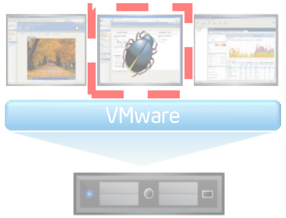

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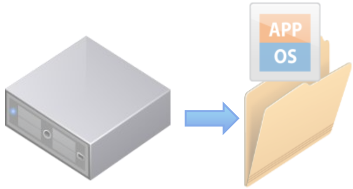

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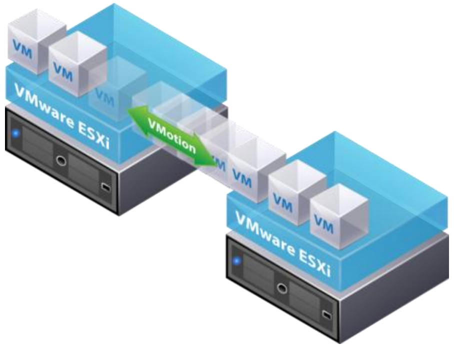
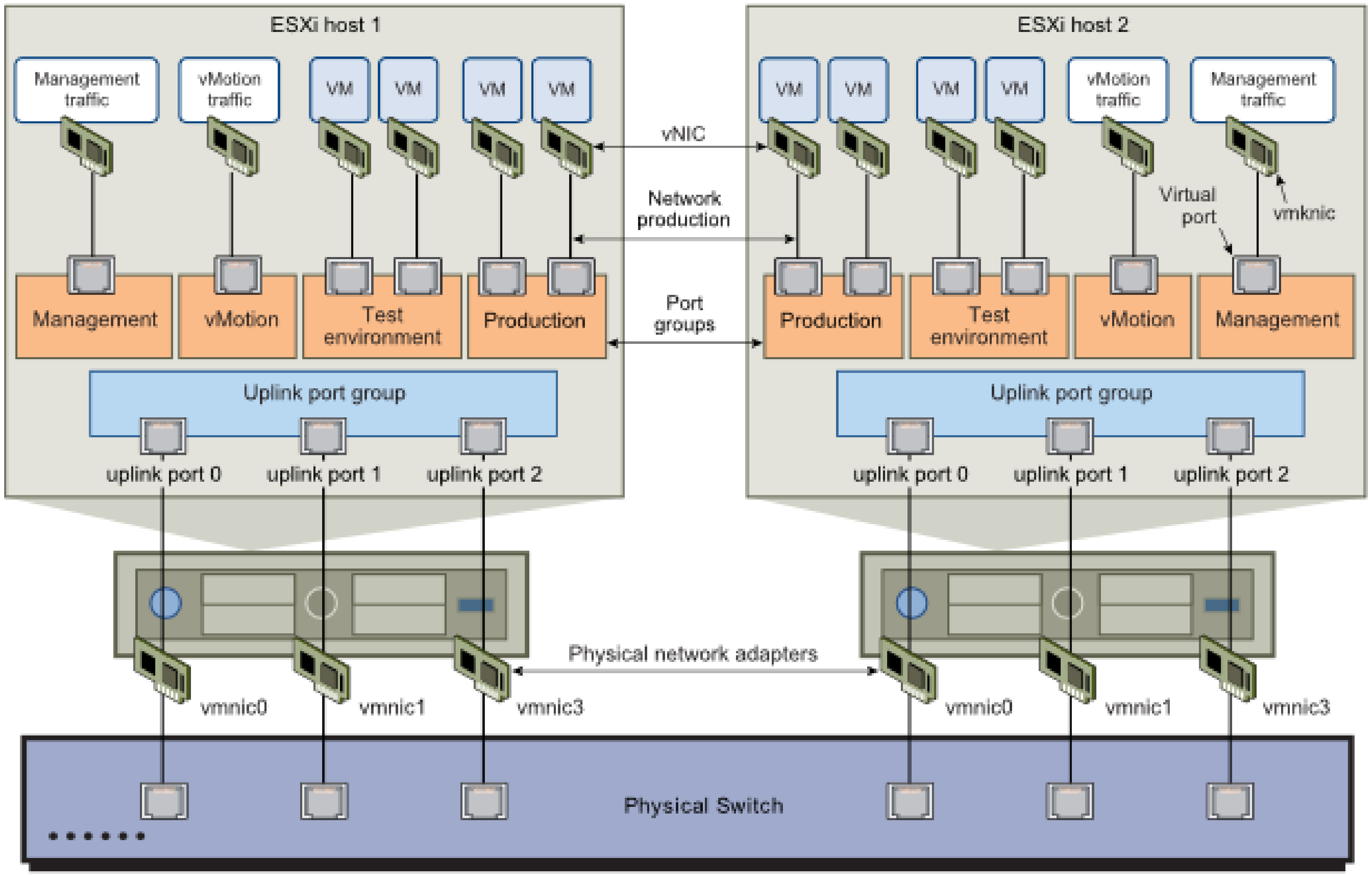


Hardware Independence

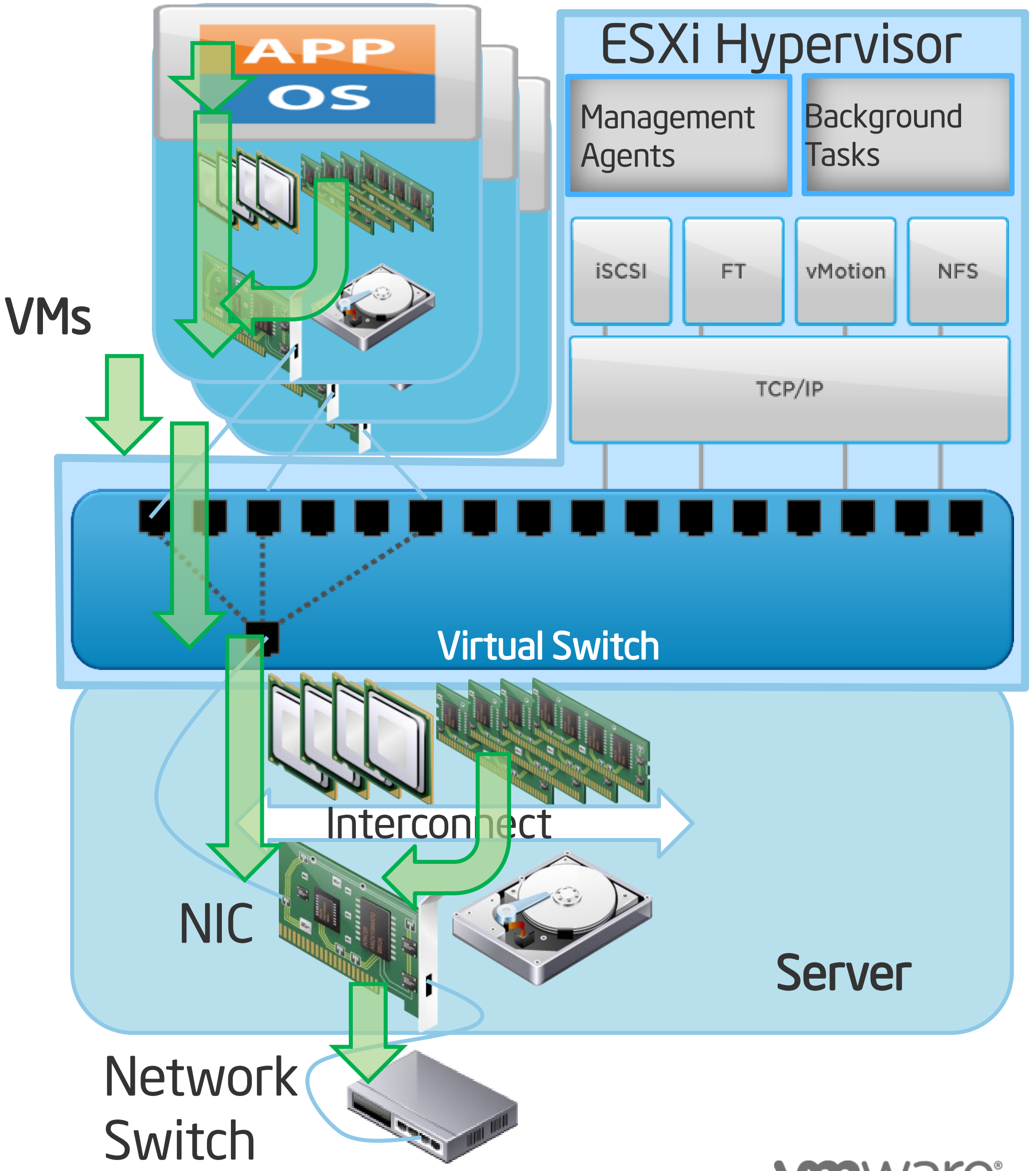
- Provision or migrate any virtual machine to any similar or different physical server

ESXi Networking Architecture Overview

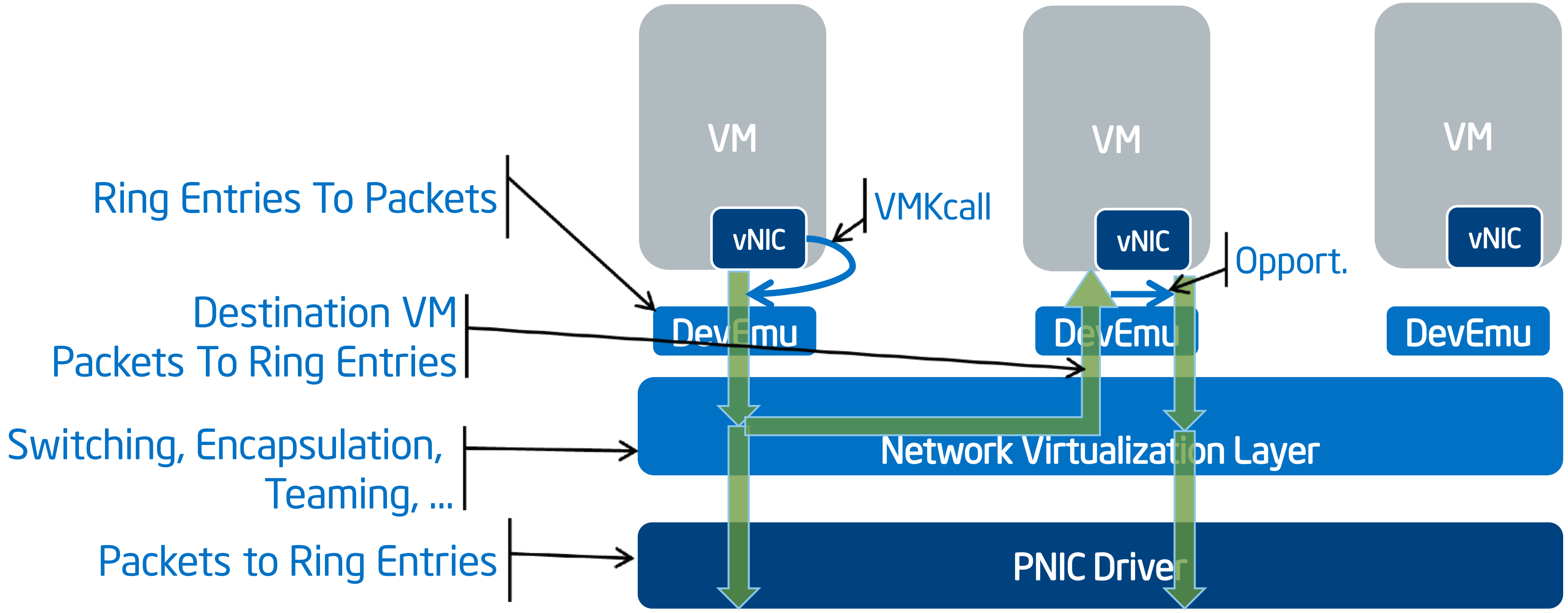


ESXi Networking Datapath Overview

- Message copy from application to GOS (kernel)
- GOS (network stack) + vNIC driver queues packet for vNIC
- VM exit to VMM/Hypervisor
- vNIC implementation emulates DMA from VM, sends to vSwitch
- vSwitch queues packet for pNIC
- pNIC DMAs packet and transmits on the wire

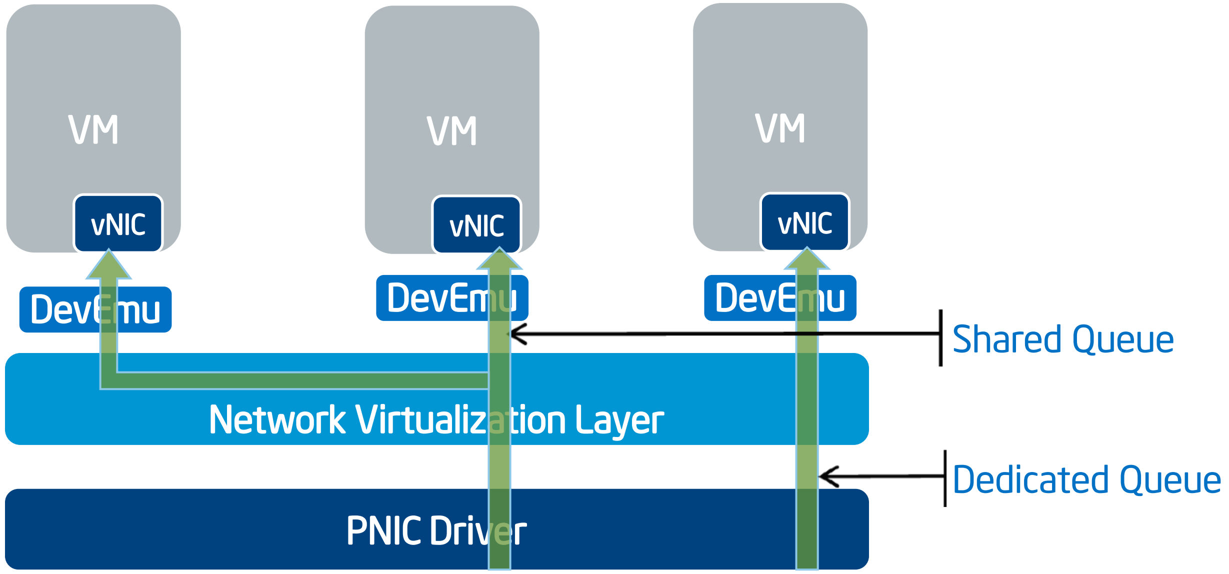


Transmit Processing for a VM



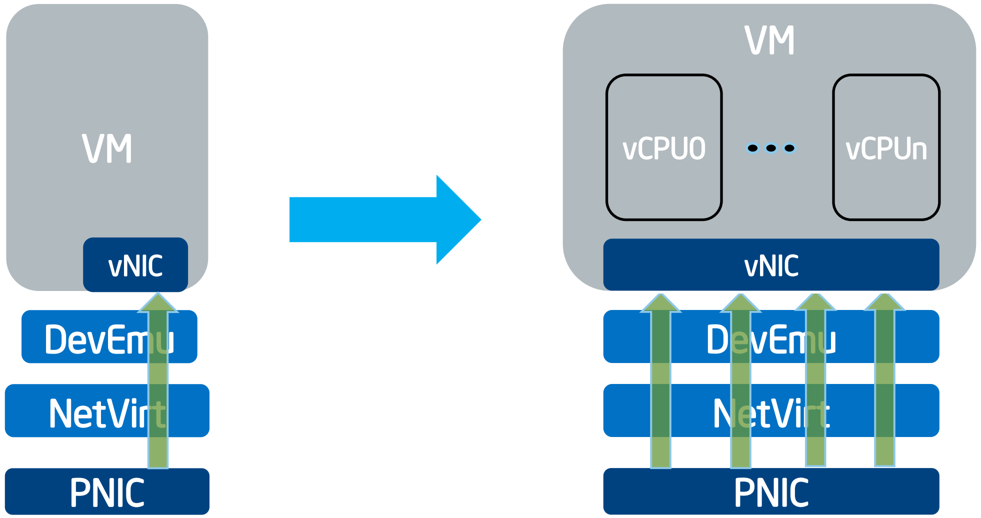
- One transmit thread per VM, executing all parts of the stack
  - Transmit thread can also execute receive path for destination VM
- Activation of transmit thread: Two mechanisms
  - Immediate, forcible activation by VM (low delay, expensive)
  - Opportunistic activation by other threads or when VM halts (potentially higher delay, cheap)

Receive Processing For a VM



- One thread per device
- NetQueue enabled devices: one thread per NetQueue
  - Each NetQueue processes traffic for one or more MAC addresses (vNICs)
  - NetQueue → vNIC mapping determined by ***unicast*** throughput and FCFS.
- vNICs can share queues
  - due to low throughput, too many vNICs or Queue type mismatch (LRO Queue vs. non-LRO VNIC)

Improve receive throughput to a single VM



Single thread for receives can become bottleneck at high packet rates (> 1 Million PPS or > 15Gbps)

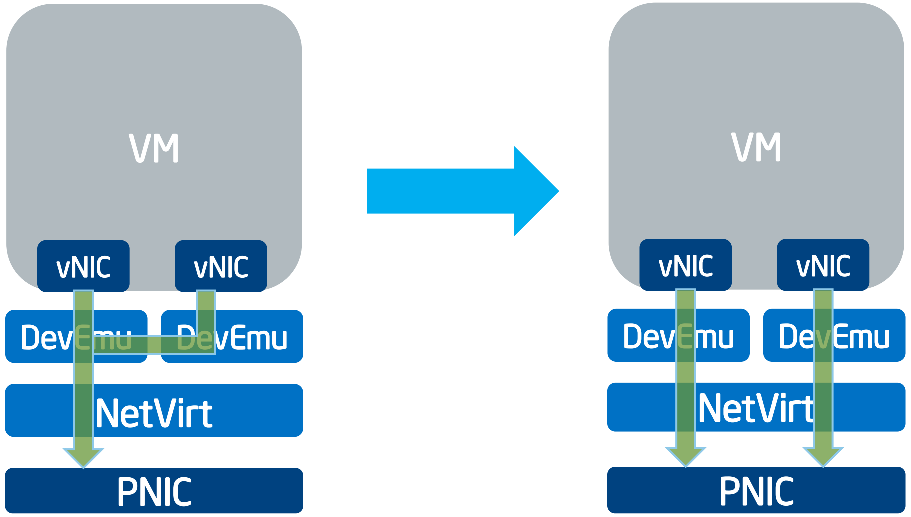
Use VMXNET3 virtual device, Enable RSS inside Guest

Enable RSS in Physical NICs (only available on some PNICs)

Add ethernetX.pnicFeatures = “4” to vmx file

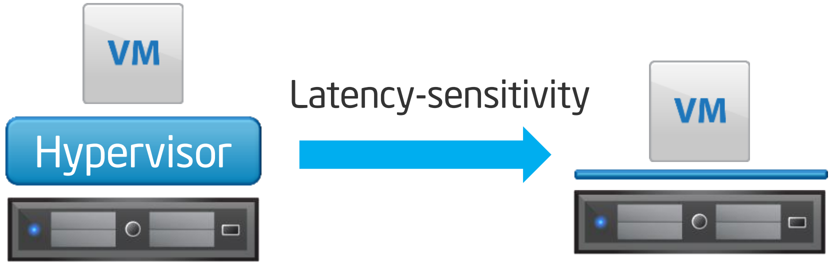
Side effects: Increased CPU Cycles/Byte

Improve transmit throughput with multiple vNICs



- Some applications use multiple vNICs for very high throughput
- Common transmit thread for all vNICs can become bottleneck
- Set ethernetX.ctxPerDev = 1 in vmx file
- Side effects: Increased CPU Cost/Byte

The Latency Sensitivity Feature in vSphere 5.5



Minimize virtualization overhead, near bare-metal performance

New virtual machine property: “Latency sensitivity”

- High => lowest latency
- Medium => low latency

Exclusively assign physical CPUs to virtual CPUs of “Latency Sensitivity = High” VMs

- Physical CPUs not used for scheduling other VMs or ESXi tasks

Idle in Virtual Machine monitor (VMM) when Guest OS is idle

- Lowers latency to wake up the idle Guest OS, compared to idling in ESXi vmkernel

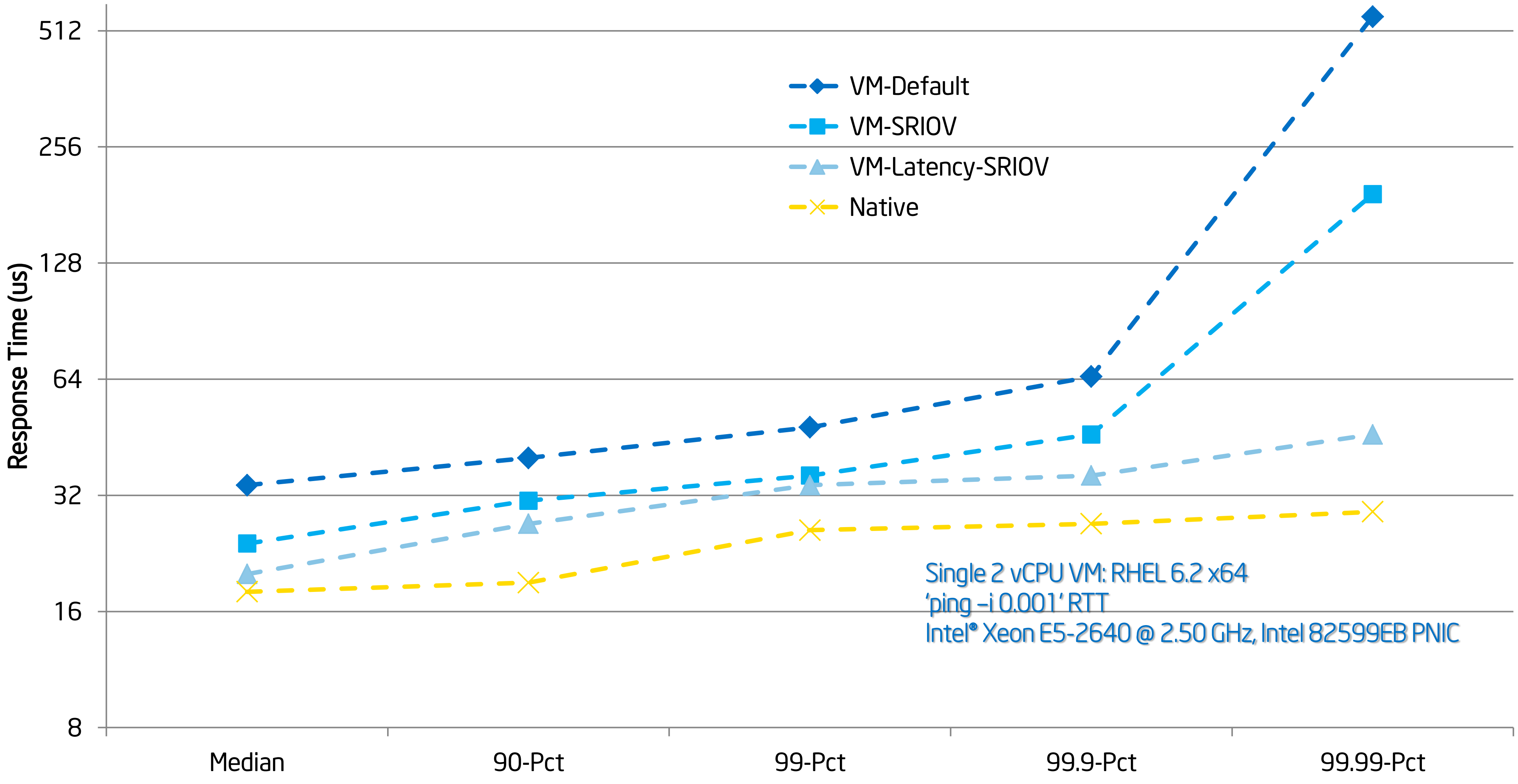
Disable vNIC interrupt coalescing

For DirectPath I/O, optimize interrupt delivery path for lowest latency

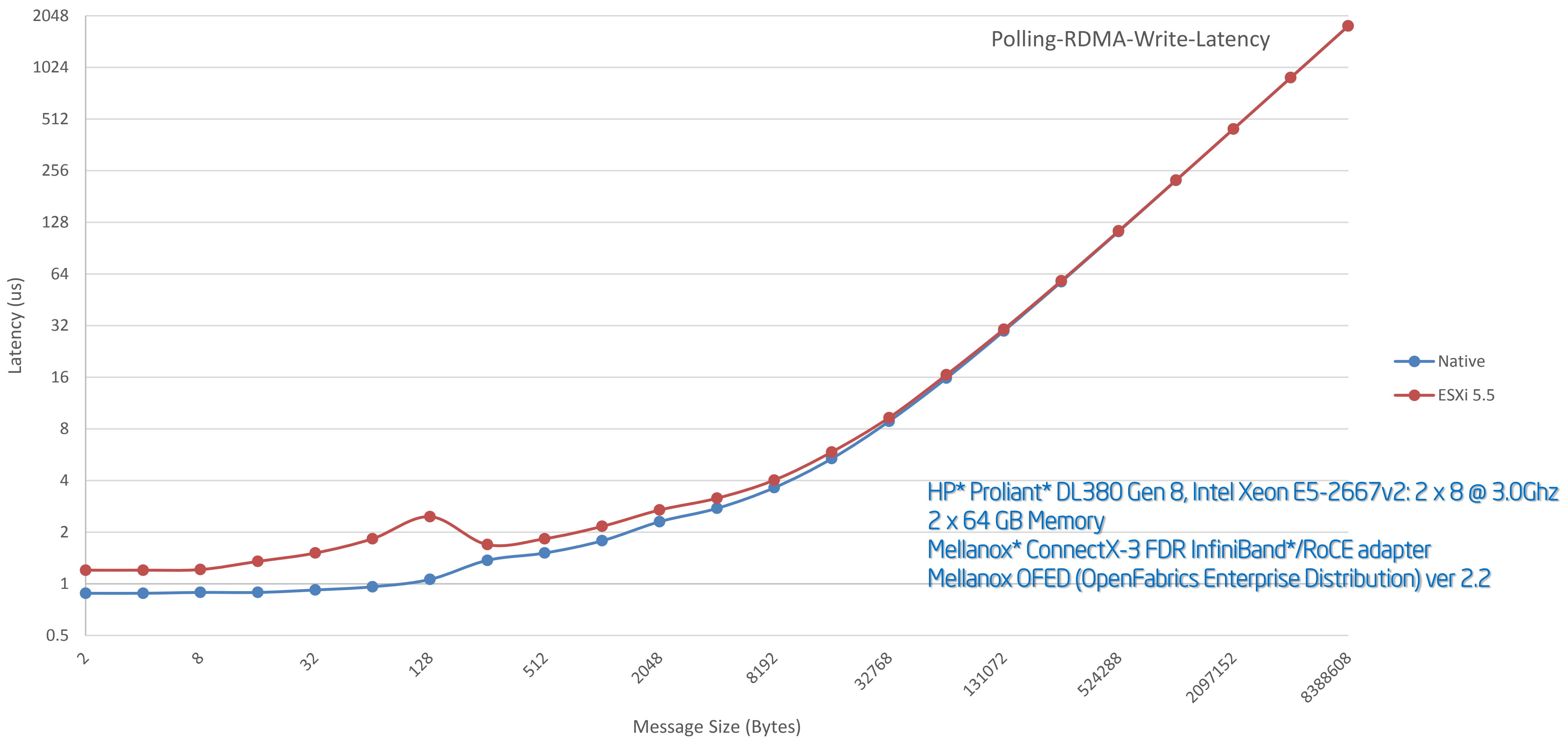
Make ESXi vmkernel more preemptible

- Reduces jitter due to long-running kernel code

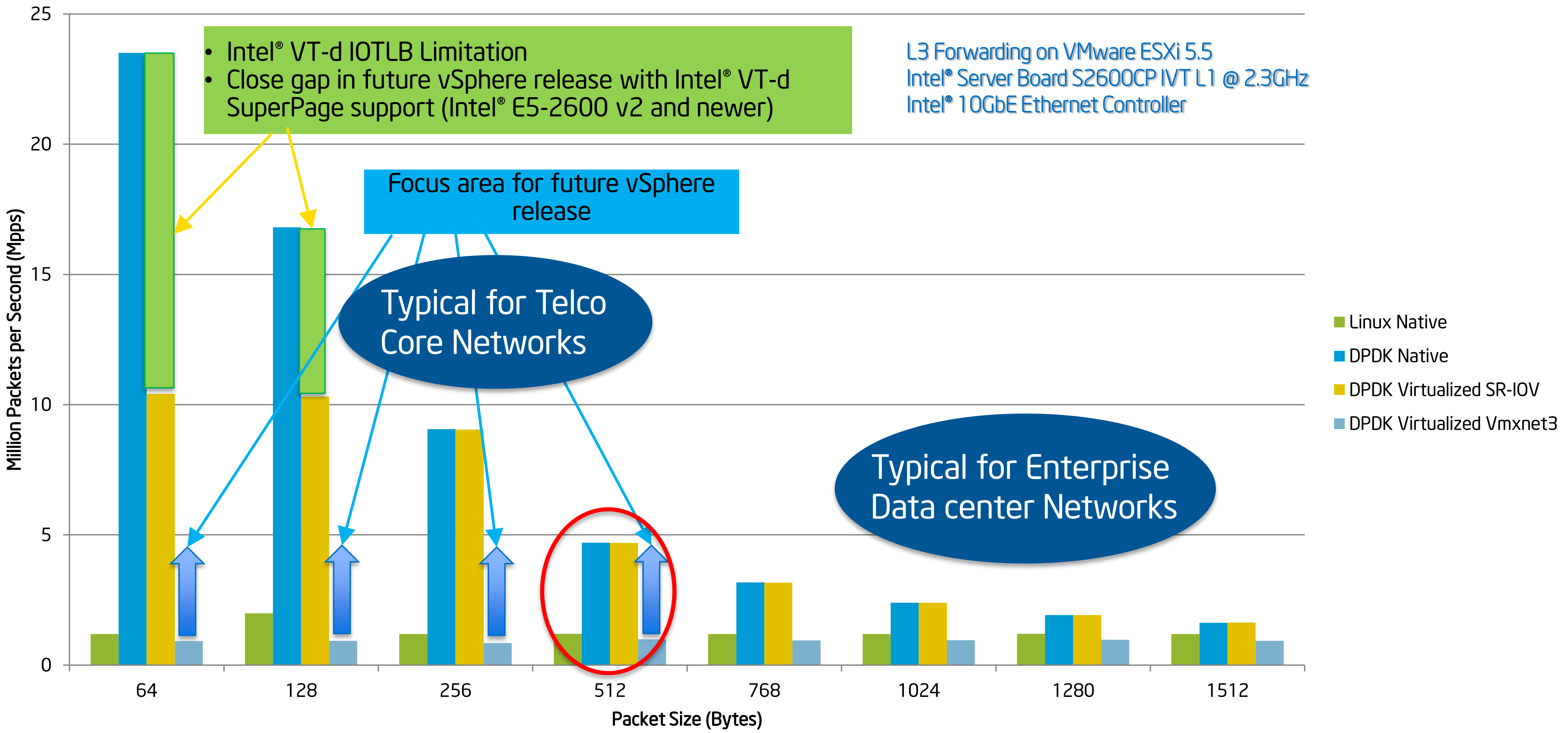
ESXi 5.5 Network Latencies and Jitter



ESXi 5.5 ultra-low latency w/ InfiniBand DirectPath I/O

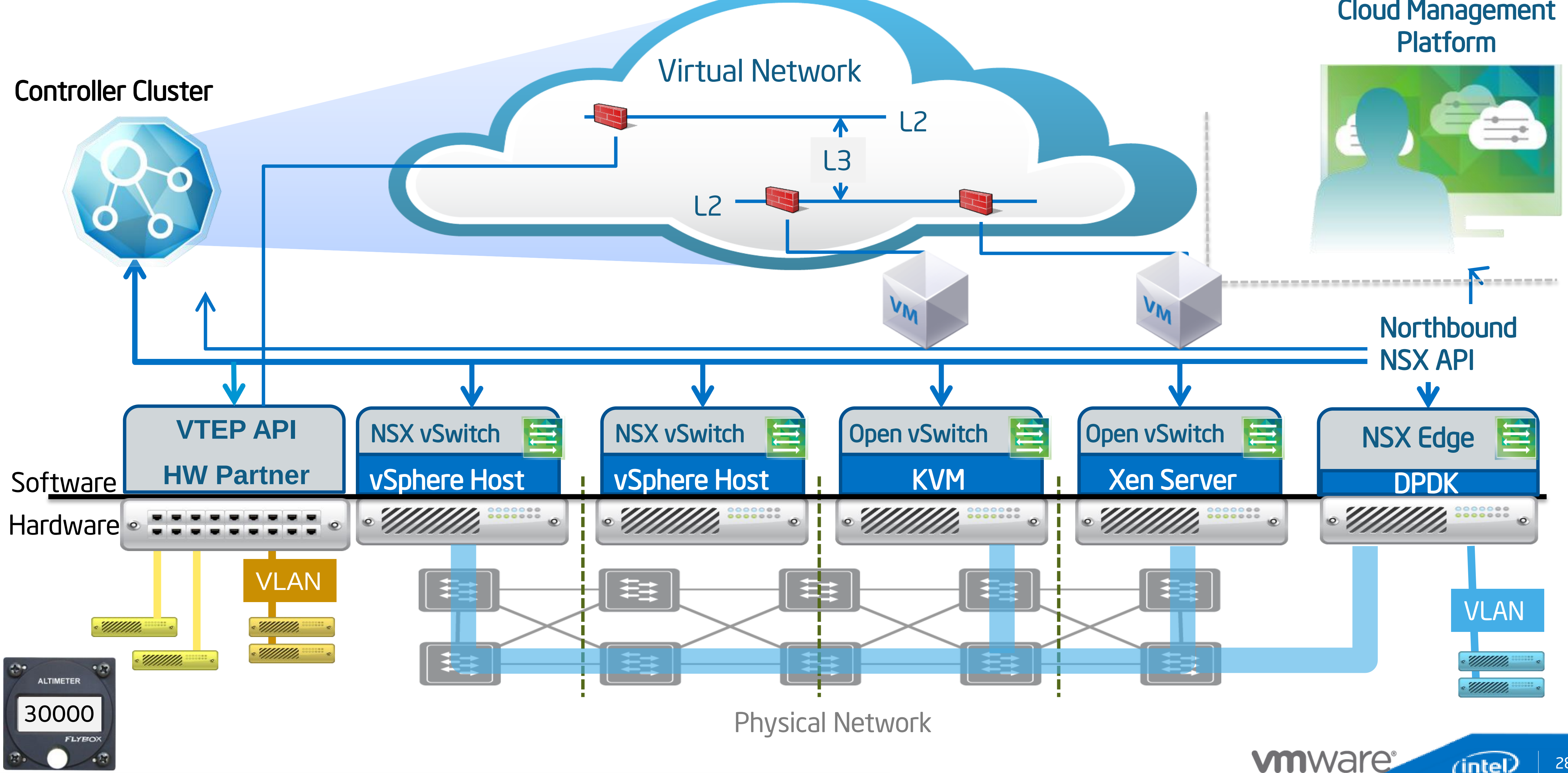


ESXi 5.5 packet rates with Intel® DPDK



Intel® Virtualization Technology (Intel® VT) for Directed I/O (Intel® VT-d)
Intel® Data Plane Development Kit (Intel® DPDK)

NSX – Network Virtualization Platform



Summary

- Virtual Appliances performing Network Functions needs high performance on commodity x86 based server platforms
- Virtualized interfaces supported in DPDK offer multiple options and flexibility for data plane application developers
- ESXi hypervisor supports multiple interfaces, including para-virtual and emulated interfaces while offering best in class virtualization features, as well as direct assigned interfaces via DirectPath I/O and SR-IOV

vSphere ESXi Performance Related References

Best Practices for Performance Tuning of Latency-Sensitive Workloads in vSphere VMs
http://www.vmware.com/files/pdf/techpaper/VMW-Tuning-Latency-Sensitive-Workloads.pdf

Intel® Data Plane Development Kit (Intel® DPDK) with VMware vSphere
http://www.vmware.com/files/pdf/techpaper/intel-dpdk-vsphere-solution-brief.pdf

Deploying Extremely Latency-Sensitive Applications in VMware vSphere 5.5
http://www.vmware.com/files/pdf/techpaper/latency-sensitive-perf-vsphere55.pdf

The CPU Scheduler in VMware vSphere 5.1
https://www.vmware.com/files/pdf/techpaper/VMware-vSphere-CPU-Sched-Perf.pdf

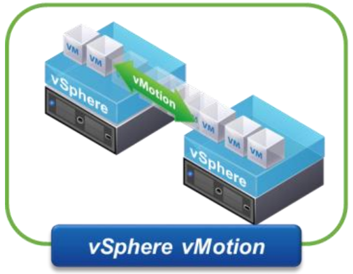
RDMA Performance in Virtual Machines using QDR InfiniBand on VMware vSphere 5
https://labs.vmware.com/academic/publications/ib-researchnote-apr2012

intel®

vmware®

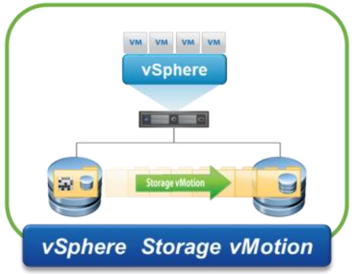
Backup

VMware vSphere Sample Features



vSphere vMotion

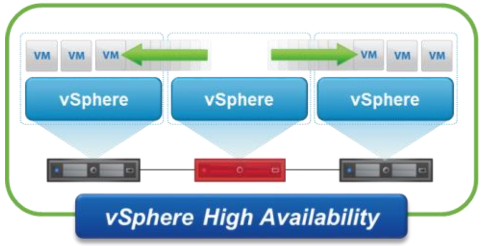
- Migrate VMs between vSphere hosts without application downtime
- Move VMs out of failing or underperforming servers without downtime
- Perform hardware maintenance without scheduling downtime or disrupting agency operations



vSphere Storage vMotion

- Perform live migration of VM disk file across heterogeneous storage array with complete transaction integrity and application availability
- Eliminate application downtime for storage maintenance
- Simplify array refresh/retirement, improve array performance and capacity balancing

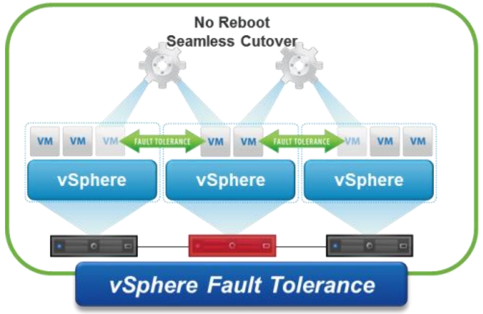
Protect Against Failures



vSphere High Availability (HA)

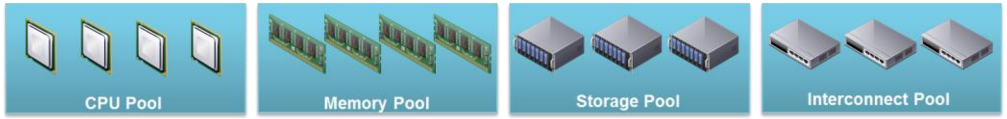
- Detect server failures and provide rapid recovery by automatically restarting VMs on available severs
- Protect applications from operating system failures by automatically restarting VMs when an operating system failure is detected.

Eliminate Planned Downtime



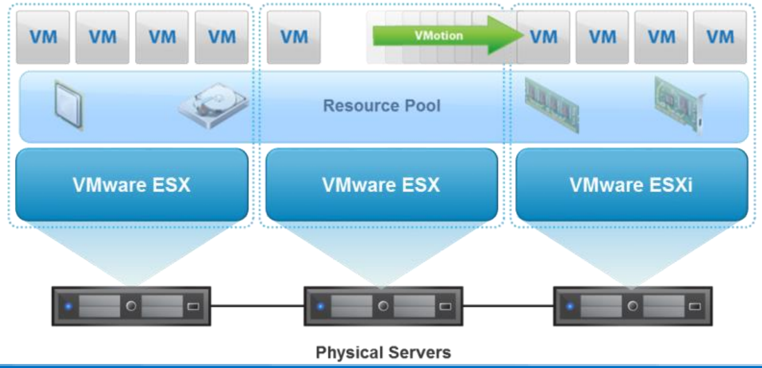
vSphere Fault Tolerance (FT)

- Single identical VMs running in lockstep on separate hosts
- Guarantee application availability and zero data loss even when a server fails
- No complex clustering or specialized hardware required



Pooled Resources Lead to Dynamic Resource Consumption via Distributed Resource Scheduler (DRS)

Distributed Resource Scheduler



Getting started: vSphere Hypervisor

Minimum Hardware Requirements:

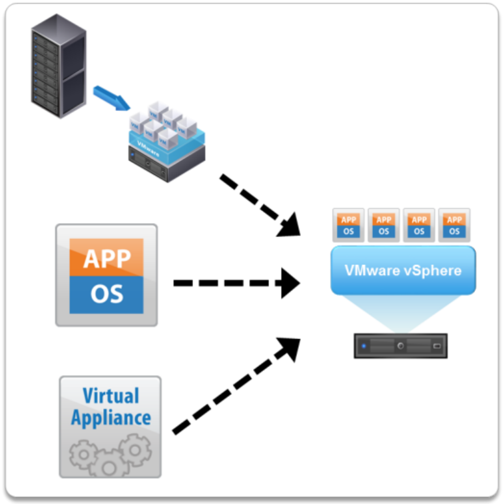
CPU Memory	▪ Single socket, dual core ▪ 4 GB
Network	▪ Two NICs (VM I/O, Management Interface)
Storage	**Local Storage (SATA/SAS):** ▪ ESXi Installable requires a 1 GB drive

Creating Virtual Machines:

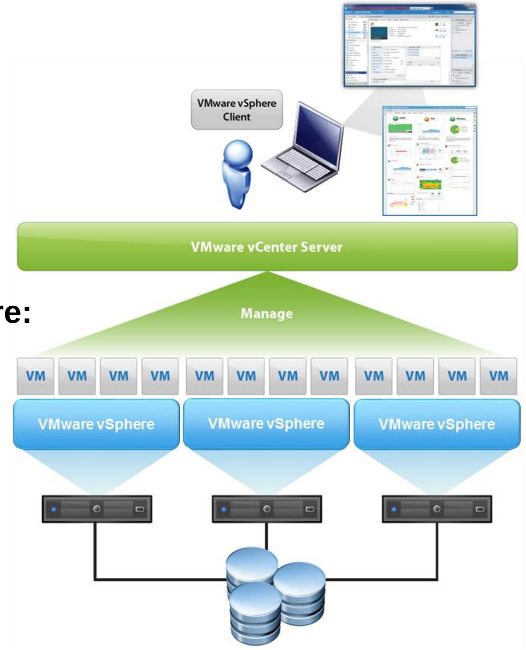
Use VMware Converter
- Transfer existing physical servers into virtual machines
- Import existing VMware and 3rd party virtual images

Create from Scratch
- Specify CPUs, Memory, Disks, Network interfaces
- Load OS from ISO image

Import a Virtual Appliance
- Hundreds to choose from on the Virtual Appliance Marketplace
- Download directly via vSphere Client and deploy on host

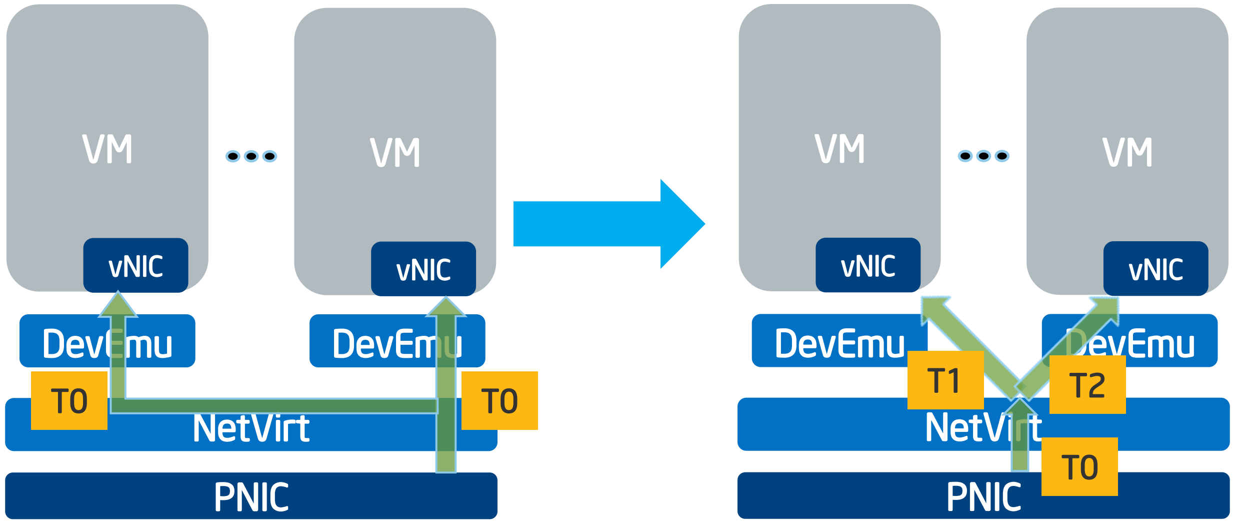


vSphere Deployment Architecture:



- Deploy vSphere on each host
- Add vCenter Server to centrally manage vSphere hosts
- Deploy vCenter Operations Management
- Upgrade license file to vSphere

Improve Multicast throughput to multiple VMs



Multicast receive traffic: single thread has to duplicate packets for ALL VMs

Set “ethernetX.emuRxMode = 1”

- Receive thread queues packets with the device emulation layer
- Per-VM thread picks up packets and carries out receive processing

Side effects: Increased receive throughput to single VM, Increased CPU Cycles/Byte