

# Reviewing Unused and New Features for Interrupt/APIC Virtualization

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# VMFUNC Instruction

- **Allows code in guest to invoke VM function**
  - Configured by software (such as hypervisor) in VMX root operation.
  - No VM exits (if successful)
- **VM function 0: EPTP switching VMFUNC**
  - Allows code in guest to load new value for EPT pointer (EPTP)
  - Loads EPTP from EPTP list (indexed by value of ECX)
  - Does not modify state of any registers; no flags are modified.

# VMFUNC Instruction: Example Usages

- **Allow HVM guests to share pages/info with hypervisor in secure fashion**
  1. Hypervisor sets up EPT page tables with additional mapping
  2. VCPU executes VMFUNC instruction in “special” thread
  3. Upon successful execution, it can access additional space that other VCPUs cannot access
  4. Hypervisor forces VCPU to use usual ETP page tables after job is done
- **Optimizations for grant page tables**
  1. Hypervisor sets up EPT page tables so that front-end and back-end can share pages (buffers)
  2. VCPU granted executes VMFUNC instruction to share buffers only for data transfer between front-end and back-end

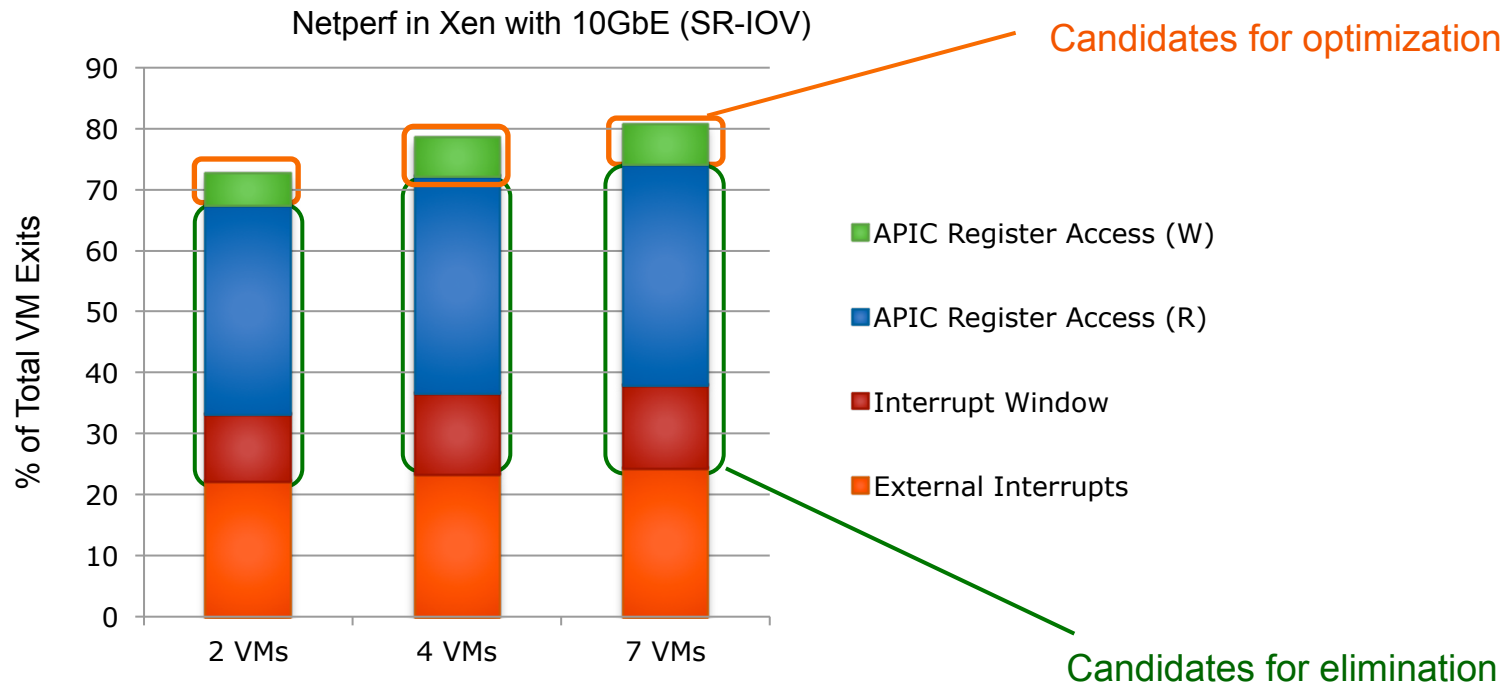
# Agenda

- Useful VMX Features and Example Usages for Xen
  - Descriptor-Table Exiting
  - Accessed and Dirty Flags for EPT
  - VMFUNC
- **New Features for Interrupt/APIC Virtualization**

# Interrupt/APIC Virtualization: Overview

- **VMM must virtualize guest's interrupts and interrupt controller (APIC)**
  - Models APIC control state on a “virtual-APIC page” in memory
- **VMM must emulate nearly all guest accesses to APIC control registers**
  - Requires “VM exits” – time-consuming transitions into VMM for emulation – and back
  - VMM must decode and emulate guest instructions that access APIC
  - Except for Intel® VT FlexPriority, which virtualizes access to one APIC control register
    - Task priority – TPR
    - No VM exits required in this case
- **VMM must virtualize all interrupts coming to guest**
  - Must determine when guest is ready to receive interrupts and deliver as needed
- **Virtualization of interrupts and APIC is a major source of overhead**
  - Illustration on next slide

# Interrupt/APIC Virtualization: Major Source of Overhead\*



- Performance cost of virtualization mostly due to VM exits
- Significant fraction of VM exits are for APIC & interrupt virtualization
- Opportunities:
  - Eliminate entirely VM exits for operations that can be performed by CPU
  - Optimize handling of remaining VM exits by simplifying task of emulation

# Motivations for Further Optimizations

- **Reduce unique overheads of virtualization**
  - Intel is fanatically committed
- **Virtualization has come to be default deployment platform for IT**
  - Any application, even most performance demanding, may run in virtualization
- **Virtualization is foundation of Cloud**
  - More I/O performance/scalability for Web apps, Database, Big Data, HPC, etc.



# New Features for Interrupt/APIC Virtualization

- **APIC-register virtualization:**

- Redirects most guest APIC reads/writes to virtual-APIC page
- Most reads will be allowed without VM exits
  - such as, interrupt command register - ICR\_Low
- VM exits occur **after** writes (no need for decode)
  - such as, ICR\_low, timer's initial-count register

- **Virtual-interrupt delivery:**

- Extend TPR virtualization to other APIC registers
- No need for VM exits for most frequent accesses (e.g., EOI – required for every interrupt)
- CPU delivers virtual interrupts to guest (including virtual IPIs)
- VMM needn't track guest readiness or deliver manually
  - Eliminates old “pending interrupt” VM exits

- **Net result\*: (Intel Netperf estimation)**

- Eliminate up to 50% of VM exits (most of those related to virtualization of interrupts/APIC)
- Optimize up to 10% of VM exits (emulation made easier for some APIC writes)

# Call To Action

- **Use existing VMX features to enhance Xen:**
  - Descriptor-Table Exiting
- **Get ready. Spec is already in Software Developer's Manual\*:**
  - Accessed and Dirty Flags for EPT
  - VMFUNC
- **Stay tuned:**
  - New Features for Interrupt/APIC Virtualization
  - Updated Spec is online now