Nested Virtualization Friendly KVM

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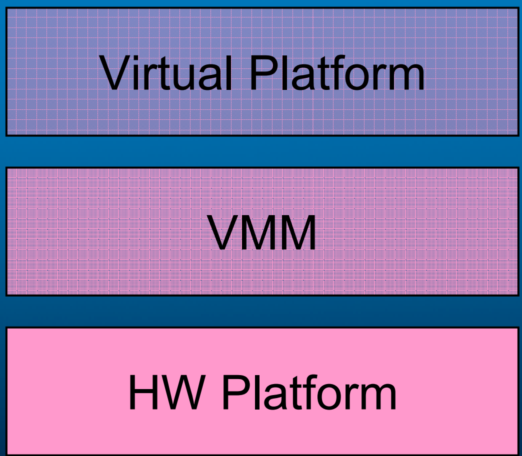
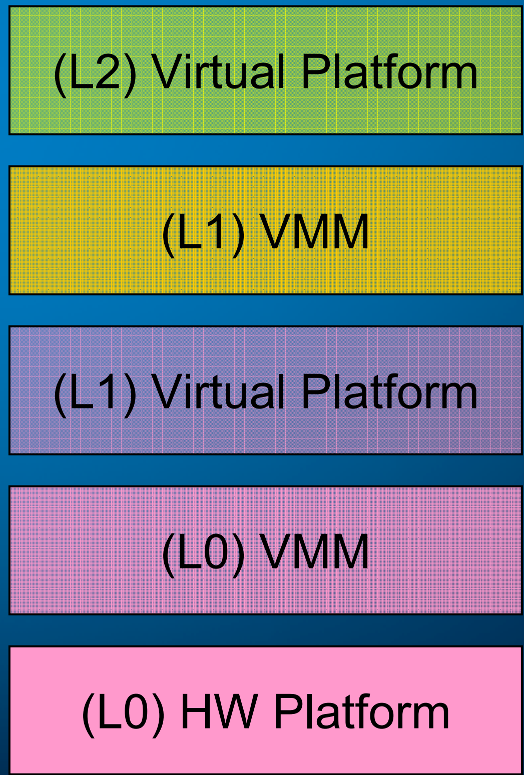
Virtualization vs. Nested Virtualization

- Single-Layer Virtualization



- Multi-Layer (Nested) Virtualization

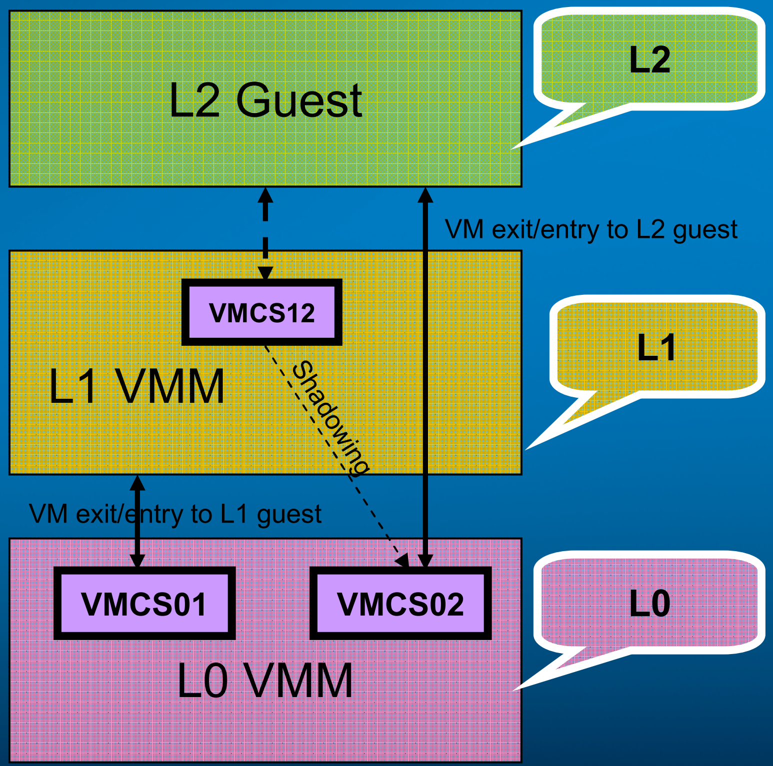


Challenge of Nested Virtualization

- Ideal virtualization model:
  - The Virtual Platform is exactly the same as the real hardware platform, except for timing/performance.
  - However, commercial VMM typically presents only a subset of hardware features in the virtual platform
    - Enough to accommodate commercial OS
    - But can't run the VMM inside → No nested virtualization
      - KVM/Xen/Vmware/Hyper-V are all examples
- Challenges of nested virtualization:
  - Present full underlying hardware features to the virtual platform efficiently, such as VMX, EPT.

Nested Virtualization: Virtual VMX

- Virtual VMX

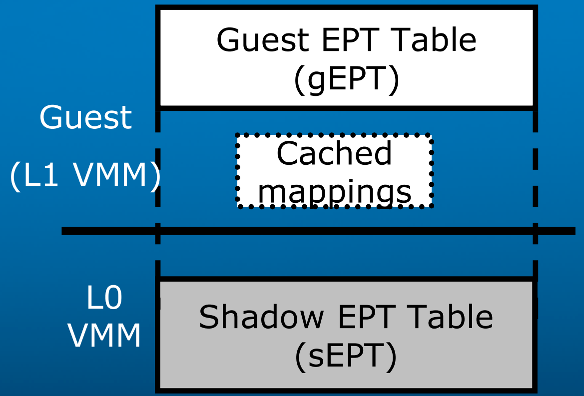


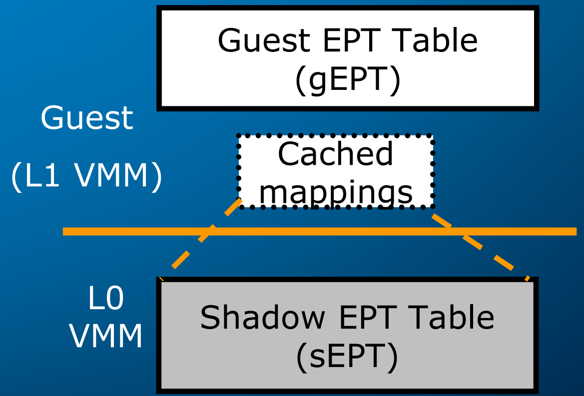
- Significant virtualization overhead was observed due to shadow page fault in L1 VMM
  - Kernel build in L2 guest is only 1/3 of L1 guest

Nested Virtualization: Virtual EPT

- Shadow-like virtual EPT
  - Write-protection guest EPT table
    - Update sEPT when gEPT changes
  - Directly invept of guest
  - May suffer from global lock

- VTLB-like virtual EPT
  - No write-protection to gEPT
  - Trap-and-emulate guest INVEPT
    - Updating sEPT when cached mappings may (?) be changed
  - Better SMP scalability (Preferred)





Prefer VTLB-like virtual EPT for better scalability!

Performance Challenges

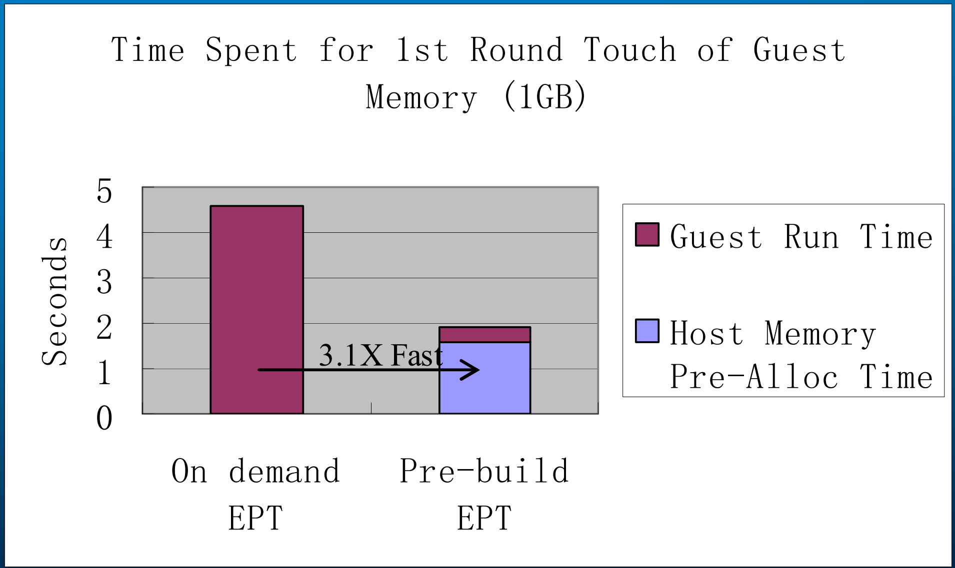
- L1 VMM VMCS register access is trapped-and-emulated by L0 VMM
  - An L1 VM exit may trigger tens of VMCS access, which is trapped-and-emulated by L0 VMM
  - Emulation of INVEPT is extremely expensive
    - The entire sEPT has to be re-generated ☺
- Reducing the frequency of L1 VM exit is key
  - Virtual EPT significantly improves performance
  - Virtual VT-d etc.
  - Nested virtualization friendly guest

Optimizations

- Minimize the frequency of L1 VM exit
  - Build as possible as static guest EPT table
  - Mitigate the host swap activity in L1 VMM
  - Cross-layer I/O para-virtualization
- Accelerate handling of virtual VM exit
  - Minimize privilege resource access per virtual VM exit
    - Such as VMCS access
  - Avoid unnecessary INVEPT
  - Choose efficient operands

Pre-build vs. On-demand EPT

- On-demand build of EPT hurts nested virtualization
  - KVM sets up EPT table on demand so far
  - Page age checking of LRU zaps EPT entry



A command line option for static EPT ?

Mitigate the Host Swap Activity

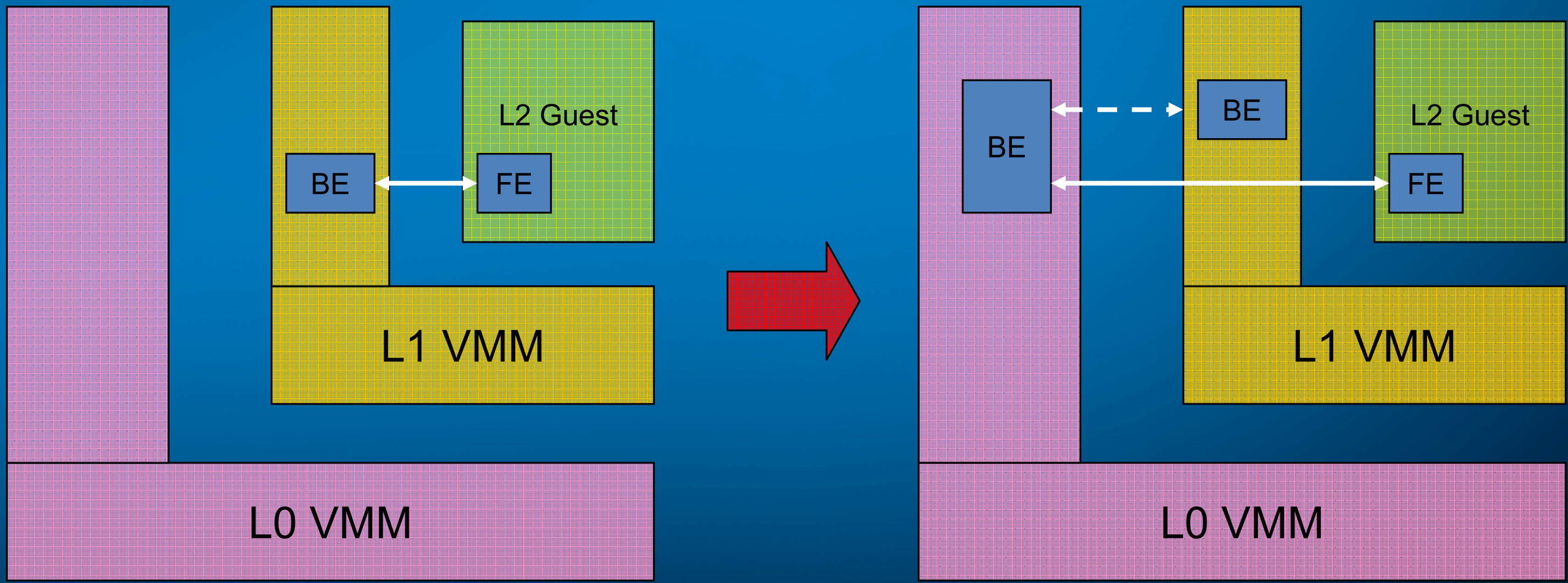
- Virtual host swap is expensive in L1 VMM
  - It may generate up to ~4K/s EPT table modification
  - Emulation of INVEPT has to zap and rebuilt the entire shadow EPT table in vTLB-like virtual EPT
    - L0 VMM may defer part of the shadow EPT rebuilt effort

Retain host swap in L0 VMM rather than L1 VMM by presenting enough pseudo memory to L1 guest

Cross-Layer I/O Paravirualization

- Backend service from L1 may trigger tremendous VM exit to L0

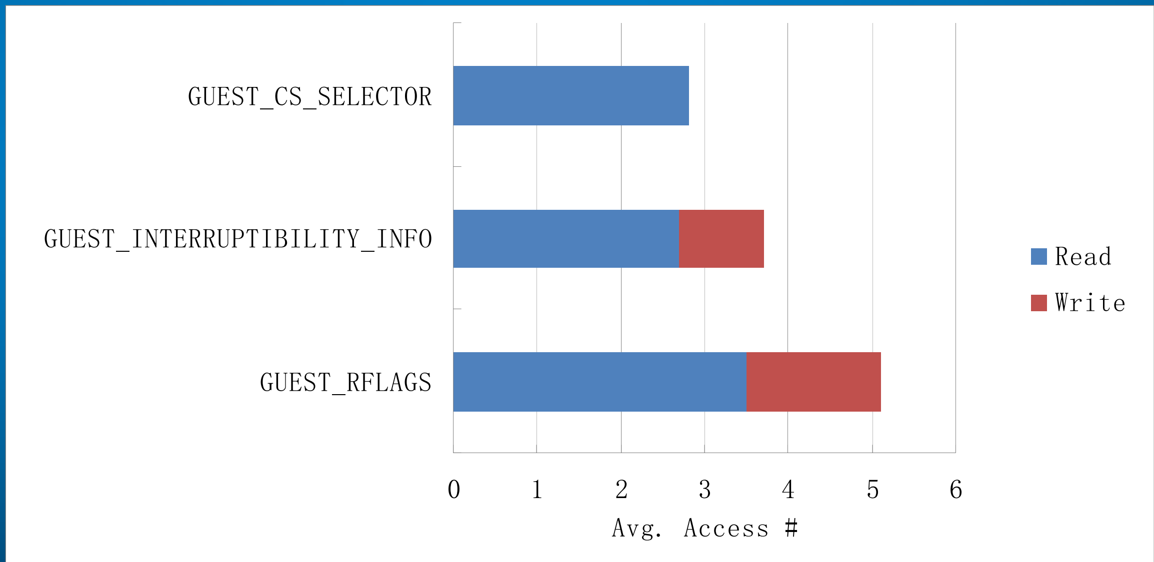
- Can L0 directly service L2 I/O ?
  - Network is stateless
  - Cooperation between L1/L2 BE



Give some data here: How L1 BE overhead is?

Accelerate Handling of Virtual VM exit

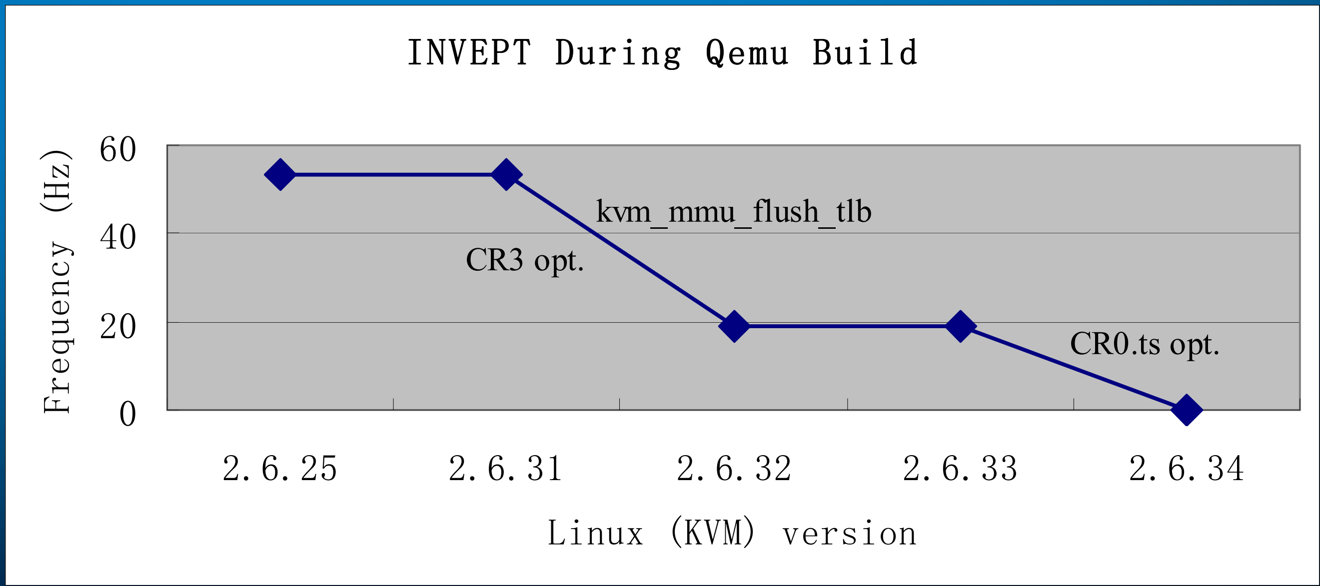
- # of privilege resource (VMCS) access in virtual VM exit handler (top 3)



Extending cache_reg to efficiently reduce average VMCS access # !

Avoid Unnecessary INVEPT

- Emulation of INVEPT in vTLB-like virtual EPT implementation has to remove the entire sEPT table
  - Extreme heavy cost ☺



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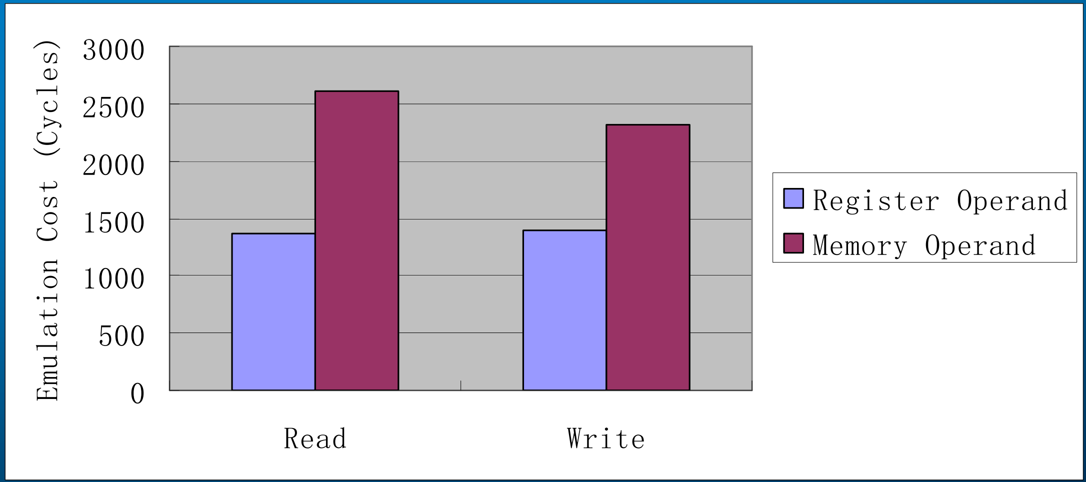
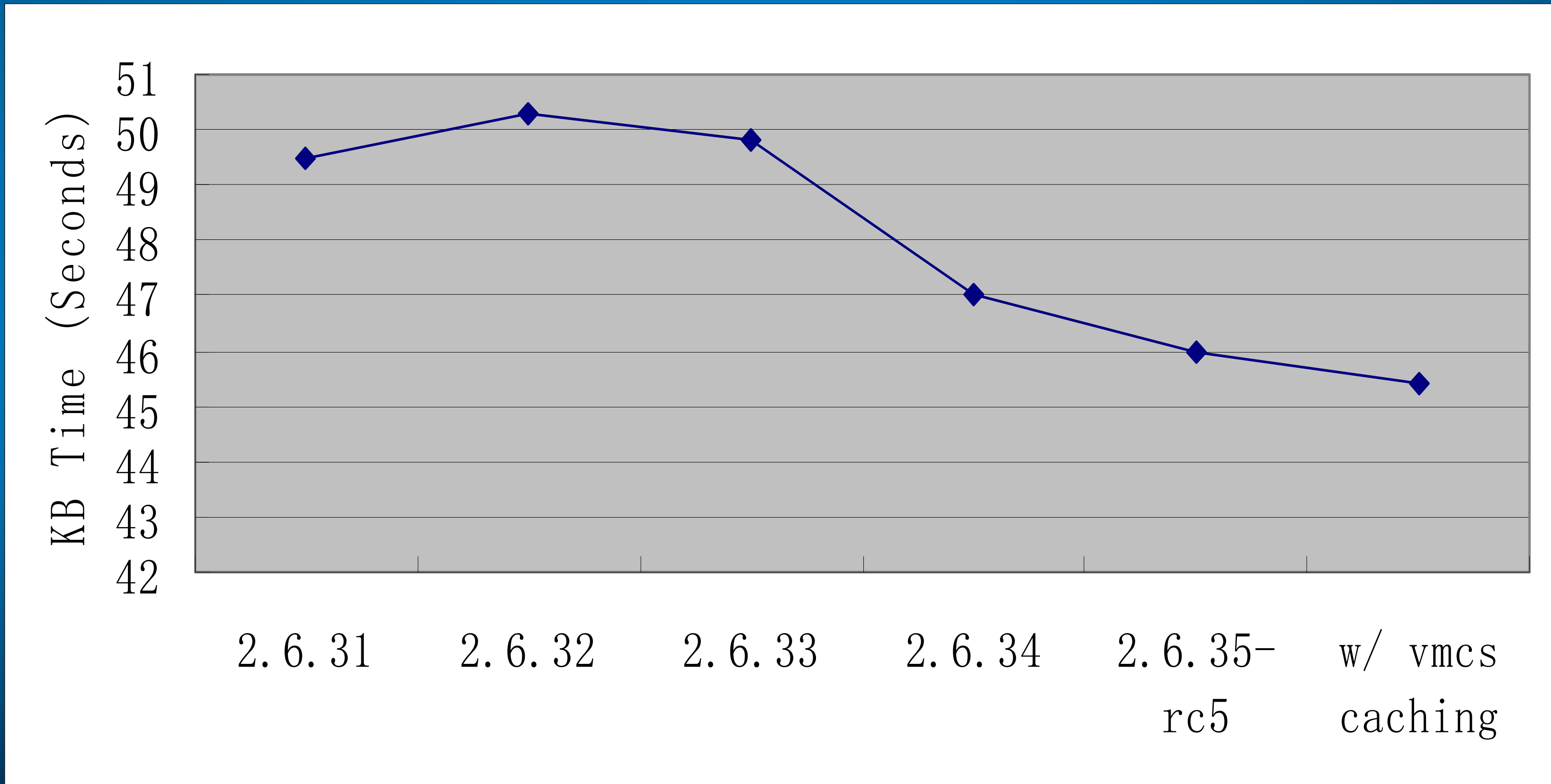
Efficient Operands in VMCS Access

- Register operands can be easily emulated by L0 VMM, while memory operand is expansive
  – Access of L1 memory needs additional map and un-map in L0 VMM



So far KVM uses register operand for VMCS read/write, keep the good behavior ☺

Performance Status



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