"ENLIGHTENING" KVM

HYPER-V EMULATION

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DevConf 2019
Windows VM

Linux VM

Linux VM

kvm
DOES GUEST OS MAKE A DIFFERENCE?
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IN THEORY, IT DOESN'T

KVM + QEMU =
DOES GUEST OS MAKE A DIFFERENCE?

IN PRACTICE, IT DOES

# dmesg | grep -i kvm
[ 0.000000] DMI: Red Hat KVM, BIOS rel-1.11.1-0-g0551a4be2c-prebuilt.qemu-project.org 0
[ 0.000000] Hypervisor detected: KVM
[ 0.000000] kvm-clock: Using msrs 4b564d01 and 4b564d00
[ 0.000000] kvm-clock: cpu 0, msr 2768001, primary cpu clock
[ 0.000000] kvm-clock: using sched offset of 9962523967 cycles
[ 0.000003] clocksource: kvm-clock: mask: 0xffffffffffffffff max_cycles: 0x1cd42e4dffb,
[ 0.038540] Booting paravirtualized kernel on KVM
[ 0.147439] KVM setup async PF for cpu 0
[ 0.147444] kvm-stealtime: cpu 0, msr 13ba16140
[ 0.480396] KVM setup pv remote TLB flush
[ 0.584919] clocksource: Switched to clocksource kvm-clock
Emulating hardware Interfaces can be slow
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Invent virtualization-friendly (paravirtualized) interfaces!
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Add support to guest OSes
Emulating hardware Interfaces can be slow

Invent virtualization-friendly (paravirtualized) interfaces!

Add support to guest OSes

... but what about proprietary OSes?
We can try writing device drivers for such OSes
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... but some core features (interrupt handling, timekeeping,...) are not devices
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... but some core features (interrupt handling, timekeeping,...) are not devices

Emulate an already support (proprietary) hypervisor interfaces solving the exact same issues!
Hyper-V Emulation in KVM

Core enlightenments

Device drivers (VMBus)
Hyper-V Emulation in KVM

Core enlightenments

Device drivers (VMBus)
### hyperv

Enable various features improving behavior of guests running Microsoft Windows.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
<th>Value</th>
<th>Since</th>
</tr>
</thead>
<tbody>
<tr>
<td>relaxed</td>
<td>Relax constraints on timers</td>
<td>on, off</td>
<td>1.0.0 (QEMU 2.0)</td>
</tr>
<tr>
<td>vapic</td>
<td>Enable virtual APIC</td>
<td>on, off</td>
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<tr>
<td>spinlocks</td>
<td>Enable spinlock support</td>
<td>on, off; retries - at least 4095</td>
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<tr>
<td>vppindex</td>
<td>Virtual processor index</td>
<td>on, off</td>
<td>1.3.3 (QEMU 2.5)</td>
</tr>
<tr>
<td>runtime</td>
<td>Processor time spent on running guest code and on behalf of guest code</td>
<td>on, off</td>
<td>1.3.3 (QEMU 2.5)</td>
</tr>
<tr>
<td>sync</td>
<td>Enable Synthetic Interrupt Controller (SyNIC)</td>
<td>on, off</td>
<td>1.3.3 (QEMU 2.6)</td>
</tr>
<tr>
<td>stimer</td>
<td>Enable SyNIC timers</td>
<td>on, off</td>
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</tr>
<tr>
<td>reset</td>
<td>Enable hypervisor reset</td>
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</tr>
<tr>
<td>vendor_id</td>
<td>Set hypervisor vendor id</td>
<td>on, off; value - string, up to 12 characters</td>
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</tr>
<tr>
<td>frequencies</td>
<td>Expose frequency MSRs</td>
<td>on, off</td>
<td>4.7.0 (QEMU 2.12)</td>
</tr>
<tr>
<td>reenlightenment</td>
<td>Enable re- enlightenment notification on migration</td>
<td>on, off</td>
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<tr>
<td>tlbflush</td>
<td>Enable PV TLB flush support</td>
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<tr>
<td>ipl</td>
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<td>4.10.0 (QEMU 3.1)</td>
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<td>Enable Enlightened VMCS</td>
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Existing documentation

- [https://libvirt.org/formatdomain.html](https://libvirt.org/formatdomain.html)


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EXISTING HYPER-V ENLIGHTENMENTS
RELAXED TIMING

QEMU syntax:
- cpu ....,hv-relaxed

libvirt syntax:
<features>
  <hyperv>
    ...
    <relaxed state='on' />
  </hyperv>
</features>

- Tells guest OS to disable watchdog timeouts
- Some Windows versions do this regardless of the setting when running on Hyper-V
PARAVIRTUALIZED APIC

QEMU syntax:
- cpu ....,hv-vapic

libvirt syntax:
<features>
  <hyperv>
    ...
    <vapic state='on' />
  </hyperv>
</features>

- Provides "VP assist page" MSR for Paravirtualized EOI signalling (exit-less).
- Pre-requisite for Enlightened VMCS feature
- Some features are not yet implemented in KVM.
PARAVIRTUALIZED SPINLOCKS

QEMU syntax:
- cpu ...., hv-spinlocks=4096

libvirt syntax:
<features>
  <hyperv>
    ...
    <spinlocks state='on' retries='4096'/>
  </hyperv>
</features>

- Spinlock retry attempts [0xfff .. 0xffffffff]
  - 0xffffffff means 'never retry' (default)
- Allows **other** guests to run when vCPU is blocked on a spinlock
**VP INDEX**

QEMU syntax:
- cpu ....,hv-vpindex

libvirt syntax:
```xml
<features>
  <hyperv>
    <vpindex state='on'/>
  </hyperv>
</features>
```

- "The partition has access to the synthetic MSR that returns the virtual processor index"
- Required for **hv-tlblush**, **hv-ipi** enlightenments
RUN TIME INFORMATION

QEMU syntax:
- cpu ....,hv-runtime

libvirt syntax:
<features>
  <hyperv>
    ...
    <runtime state='on' />
  </hyperv>
</features>

- Provides virtual MSR with time spent in the guest/hypervisor information.
- Windows may use the info for better scheduling.
CRASH INFORMATION

QEMU syntax:
- cpu ....,hv-crash

libvirt syntax:
<devices>
  ...
  <panic model='hyperv'/>
</devices>

- Provides additional crash information when Windows crashes
  - available in libvirt domain log
  - useful for analyzing crashes at scale
HYPER-V CLOCKSOURCE

QEMU syntax:
- cpu ....,hv-time

libvirt syntax:
<clock offset='localtime'>
  ...
  <timer name='hypervclock' present='yes'/>
</clock>

- Significantly speeds up time related operations
- Libvirt's syntax is quite different from other Hyper-V enlightenments
- Requires stable TSC on the host! (check that you have 'tsc' in
  /sys/devices/system/clocksource/clocksource0/current_clocksource!)
SYNTHETIC INTERRUPT CONTROLLER

QEMU syntax:
- cpu ....,hv-synic

libvirt syntax:
<features>
  <hyperv>
    <synic state='on'/>
  </hyperv>
</features>

- Enables synthetic interrupt controller implementation
  - Post messages, Signal events
- Required for VMBus emulation (not yet in qemu)
- Required for hv-stimer enlightenment
SYNTHETIC TIMERS

QEMU syntax:
- cpu ...., hv-time, hv-synic, hv-stimer

libvirt syntax:
<features>
  <hyperv>
    <synic state='on'/>
    <stimer state='on'/>
  </hyperv>
</features>
<clock offset='localtime'>
  ...
  <timer name='hypervclock' present='yes'/>
</clock>

- Requires **hv-synic** and **hv-time** enlightenments
- Provide 4 synthetic timers per vCPU
- Significantly reduces CPU load for Win10+
PARAVIRTUALIZED TLB SHUTDOWN

QEMU syntax:
- cpu ....,hv-vpindex,hv-tlbflush

libvirt syntax:
<features>
  <hyperv>
    <vpindex state='on'/>
    <tlbflush state='on'/>
  </hyperv>
</features>

- Requires **hv-vpindex**
- Significantly improves performance in overcommited environments
PARAVIRTUALIZED IPI

QEMU syntax:
  - cpu ...., hv-vpindex, hv-mpi

libvirt syntax:
  <features>
    <hyperv>
      <vpindex state='on'/>  
      <mpi  state='on'/>   
    </hyperv>
  </features>

- Requires **hv-vpindex**
- Similar to PV tlb flush, significantly improves performance of overcommitted environments
VENDOR ID

QEMU syntax:
- cpu ....,hv-vendor-id='KVM Hv'

libvirt syntax:
<features>
  <hyperv>
    ...
    <vendor_id state='on' value='KVM Hv'/>
  </hyperv>
</features>

- Defaults to "Microsoft Hv"
  - Windows doesn't care about the value
- Does NOT enable Hyper-V identification in QEMU
  - Some other hv_* feature needs to be enabled
RESET

QEMU syntax:
  - cpu ... , hv-reset

libvirt syntax:
<features>
  <hyperv>
    ...
    <reset state='on' />
  </hyperv>
</features>

- Just another fancy way to reset your guest
- Even genuine Hyper-V doesn't suggest using it
NESTED RELATED ENLIGHTENMENTS
STABLE CLOCKSOURCE FOR L2

QEMU syntax:
- cpu ....,hv-frequencies,hv-reenlightenment

libvirt syntax:
<features>
  <hyperv>
    <frequencies state='on'/>
    <reenlightenment state='on'/>
  </hyperv>
</features>

- Enables synthetic MSR with APIC/TSC frequencies and notifications on TSC frequency change (migration)
- Essential for Hyper-V to pass stable clocksource to L2
- Not yet fully supported by KVM
ENLIGHTENED VMCS

QEMU syntax:
- cpu ....,hv-vapic,hv-evmcs

Libvirt syntax:
<features>
  <hyperv>
    <vapic state='on'/>
    <evmcs state='on'/>
  </hyperv>
</features>

- Requires **hv-vapic**
- Speeds up L2 vmexits (10%)
- But disables certain virtualization features (posted interrupts)
DIRECT MODE STIMERS (WIP)

QEMU syntax (proposed):
- `cpu ....,hv-stimer-direct`

libvirt syntax (proposed):
```xml
<features>
  <hyperv>
    <stimer_direct state='on'/>
  </hyperv>
</features>
```

- Same as stimer but uses real interrupts instead of VMBus messages
- Used by Hyper-V when running nested
SOME BENCHMARKS
before = rdtsc();

for (i = 0; i < COUNT; i++)
    clock_gettime(CLOCK_REALTIME, &tp);

after = rdtsc();

printf("%d\n", (after - before)/COUNT);

<table>
<thead>
<tr>
<th>Without hv-time</th>
<th>With hv-time</th>
</tr>
</thead>
<tbody>
<tr>
<td>17600</td>
<td>430</td>
</tr>
</tbody>
</table>
before = rdtsc();

for (i = 0; i < COUNT; i++)
    cpuid(0x1);

after = rdtsc();

printf("%d\n", (after - before)/COUNT);

<table>
<thead>
<tr>
<th>Without hv-evmcs</th>
<th>With hv-evmcs</th>
</tr>
</thead>
<tbody>
<tr>
<td>20850</td>
<td>19400</td>
</tr>
</tbody>
</table>
PARAVIRTUALIZED TLB SHOOTDOWN

Physical host: 12 CPUs
Test: 64 pthreads doing (simplified)

```c
for (j = 0; j < nrounds; j++) {
    for (i = 0; i < nchunks; i++)
        addr[i] = mmap(NULL, PAGE_SIZE * pagecount, PROT_READ, MAP_SHARED,
                        fd, i * PAGE_SIZE);
    for (i = 0; i < nchunks; i++)
        v += *addr[i];
    for (i = 0; i < nchunks; i++)
        munmap(addr[i], PAGE_SIZE * pagecount);
}
```

<table>
<thead>
<tr>
<th>No of vCPUs</th>
<th>Without hv-htlbflush (sec)</th>
<th>With hv-htlbflush (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>22.08</td>
<td>22.43</td>
</tr>
<tr>
<td>24</td>
<td>24.79</td>
<td>22.90</td>
</tr>
<tr>
<td>36</td>
<td>26.74</td>
<td>22.99</td>
</tr>
</tbody>
</table>
THANK YOU!