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A SLIGHTLY DIFFERENT NESTING

KVM on Hyper-V

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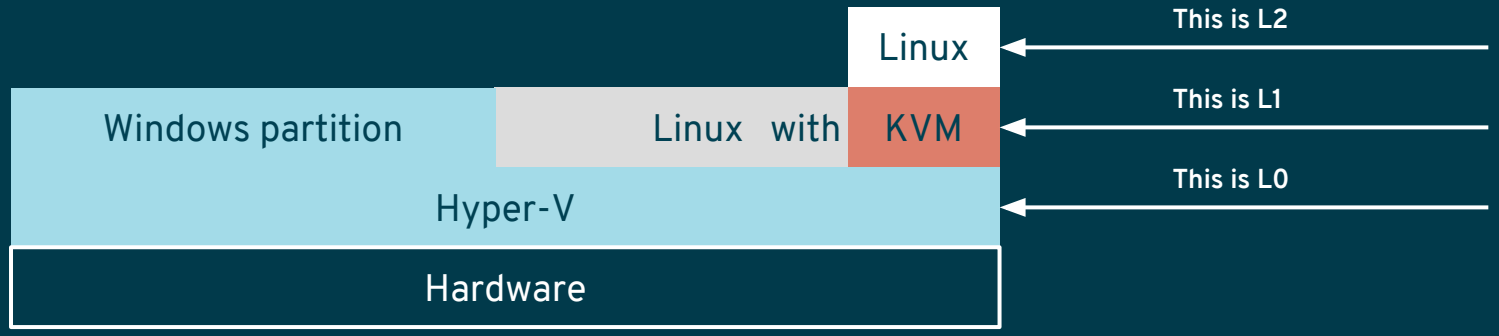
What is nested virtualization?

In this presentation:



Why does it matter?

- Private and public clouds (Azure) running Hyper-V
  - Partitioning ‘big’ instances for several users
  - ‘Secure containers’ (e.g. Intel Clear Containers)
  - Running virtualized workloads (OpenStack, oVirt, …)
  - Debugging and testing
  - …

Nesting in Hyper-V

- Introduced with Hyper-V 2016
- Main target: Hyper-V on Hyper-V
- Not enabled by default

```
Set-VMProcessor -VMName <VMName> -ExposeVirtualizationExtensions $true
```

MICRO-BENCHMARKS

Benchmark: tight CPUID loop

"Worst case for nested virtualization"

```
#define COUNT 10000000

before = rdtsc();

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

after = rdtsc();

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

Benchmark: tight CPUID loop

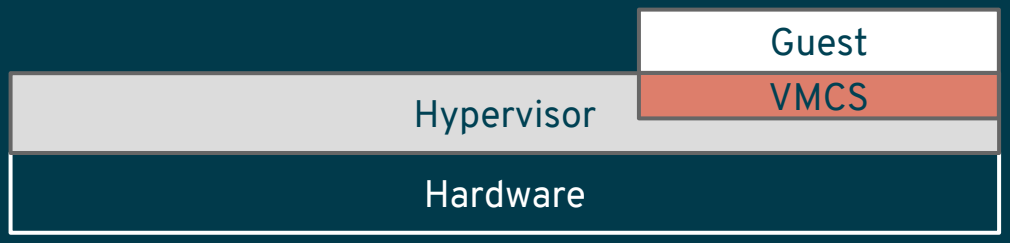
Results:

Bare metal	180 cycles
L1	1350 cycles
L2	**20700 cycles**

How virtualization works (on Intel)

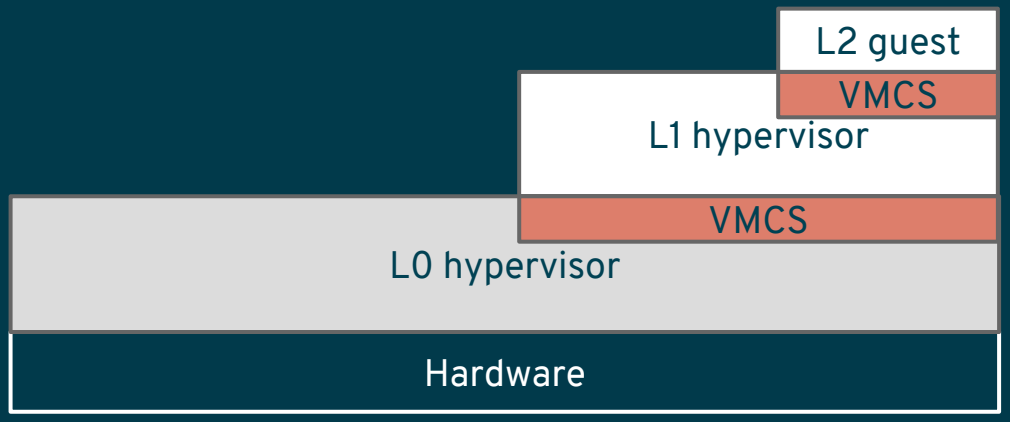
(simplified)

- Hypervisor prepares VMCS area (4k) representing guest state
- Hypervisor ‘runs’ the guest
- Guest runs on hardware until some ‘assistance’ is needed
- We ‘trap’ back into the hypervisor
- Hypervisor analyzes guest’s state in VMCS area and provides the required assistance
- Hypervisor modifies guest’s state in VMCS area
- Hypervisor ‘resumes’ the guest



How one may think nested virtualization works on Intel

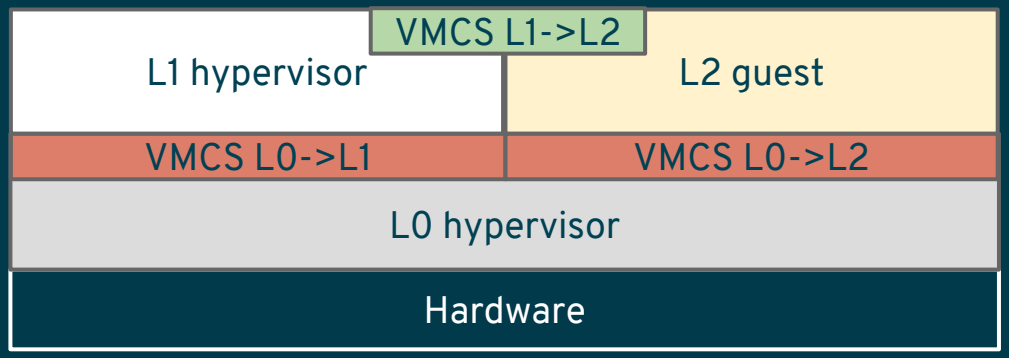
- L0 creates VMCS for L1, runs L1
- L1 creates VMCS for L2, runs L2
- L2 traps into L1 when needed, L1 resumes L2, ...



How nested virtualization really works on Intel

(simplified)

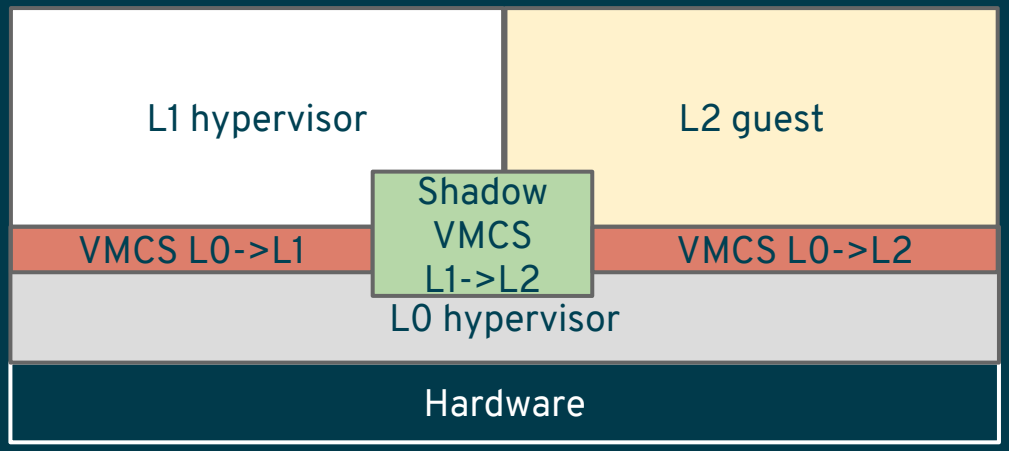
- L1 prepares his idea of VMCS for L2
- L1 'runs' L2 guest, this traps into L0
- L0 merges VMCS for L1 with L1's idea of VMCS for L2, creates 'real' VMCS for L2 and 'runs' L2
- When 'assistance' is needed L2 traps into ***L0***
- L0 analizes L2 state, makes changes and resumes L1
- L1 analizes L2 state, makes changes and resumes L2, this traps into L0
- L0 merges VMCS for L1 with L1's idea of VMCS for L2, creates 'real' VMCS for L2 and 'runs' L2



How nested virtualization really works on Intel

(continued)

- L0 may use “Shadow VMCS” hardware feature so each VMREAD/VMWRITE instruction in L1 doesn’t trap into L0 (extremely slow otherwise)
- When L1 is done, L0 will have to copy the whole Shadow VMCS to some internal representation and re-create regular VMCS for L2 ...
- ... so this is still not very fast



Benchmark: tight CPUID loop

Solution?

- Not really, L2 VMEXITs are always going to be significantly slower compared to L1 with current Intel architecture
- … but we can cut some corners, in particular:
  - L1 accessing and modifying L2's VMCS
  - The need to re-create VMCS L0->L2 upon entry
- Hyper-V provides "Enlightened VMCS"
  - Store VMCS L1->L2 in a defined structure in memory, access it with normal memory reads/writes
  - "CleanFields" mask signalling to L0 which parts of VMCS really changed
  - "[PATCH 0/5] Enlightened VMCS support for KVM on Hyper-V" on the mailing list

Benchmark: tight CPUID loop

Results:

Bare metal	180 cycles
L1	1350 cycles
L2	**8900 cycles**

Benchmark: clock_gettime()

"What time is it now"

```
#define COUNT 10000000

before = rdtsc();

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

after = rdtsc();

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

Benchmark: clock_gettime()

Results:

Bare metal	55 cycles
L1	70 cycles
L2	**1500 (post-Meltdown/Spectre)**

Benchmark: clock_gettime()

On L1:

```
# cat /sys/devices/system/clocksource/clocksource0/current_clocksource
hyperv_clocksource_tsc_page
```

On L2:

```
# cat /sys/devices/system/clocksource/clocksource0/current_clocksource
kvm-clock
```

Benchmark: clock_gettime()

Reason?

arch/x86/kvm/x86.c:

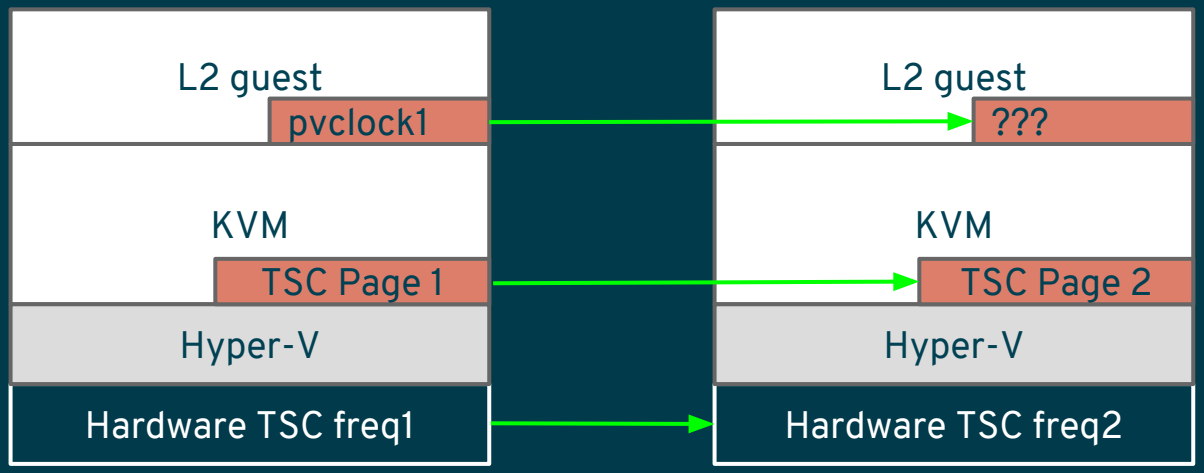
```
/*
 * If the host uses TSC clock, then passthrough TSC as stable
 * to the guest.
 */
host_tsc_clocksource = kvm_get_time_and_clockread(
                                &ka->master_kernel_ns,
                                &ka->master_cycle_now);

ka->use_master_clock = host_tsc_clocksource && vcpus_matched
                        && !ka->backwards_tsc_observed
                        && !ka->boot_vcpu_runs_old_kvmclock;
```

Benchmark: clock_gettime()

Solution?

- Tell KVM Hyper-V TSC page is a good clocksource!
- But what happens when L1 is migrated and TSC frequency changes?



- Need to make L1 aware of migration

Benchmark: clock_gettime()

Solution

- ‘Reenlightenment Notifications’ feature in Hyper-V:
  - L1 receives an interrupt when it is migrated
  - TSC accesses are emulated until we update all pvclock pages for L2 guests
- See “[PATCH v3 0/7] x86/kvm/hyperv: stable clocksource for L2 guests when running nested KVM on Hyper-V”

Benchmark: clock_gettime()

Results:

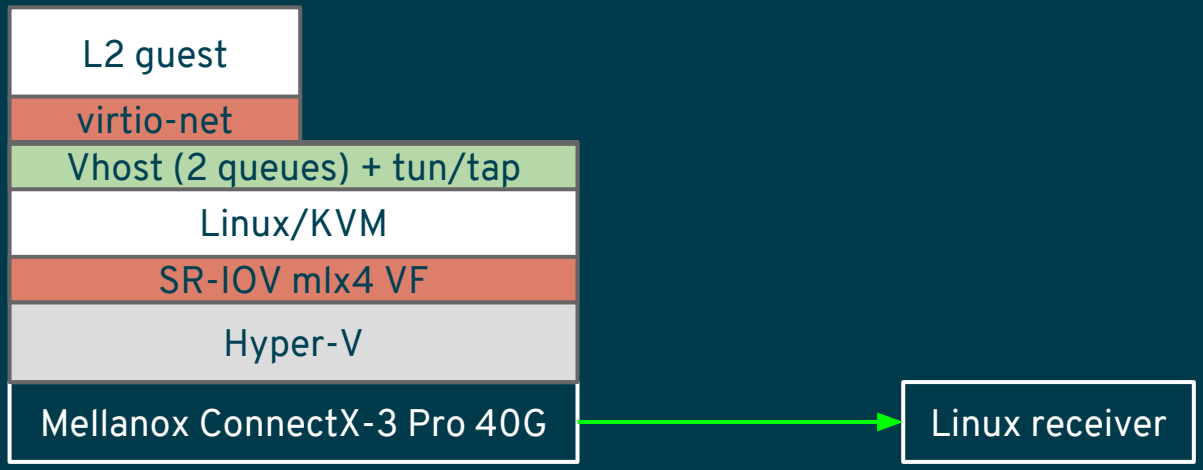
Bare metal	55 cycles
L1	70 cycles
L2	**80 cycles**

MACRO-BENCHMARKS

Benchmark: iperf with SR-IOV

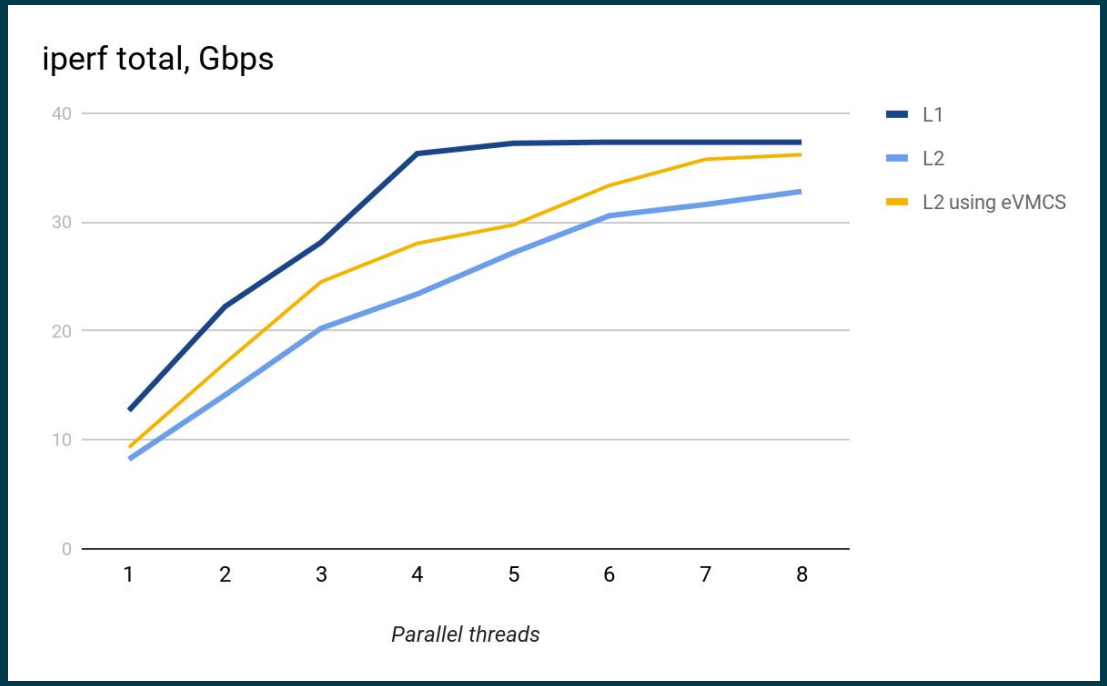
Setup

- L1: 16 cores, 2 NUMA nodes, mlx4 VF, 4.15.0-rc8+ eVMCS/clocksource patchsets
- L2: 8 cores, 1 NUMA node, virtio-net, 4.14.11-300.fc27



Benchmark: iperf with SR-IOV

Results



Benchmark: iperf with SR-IOV

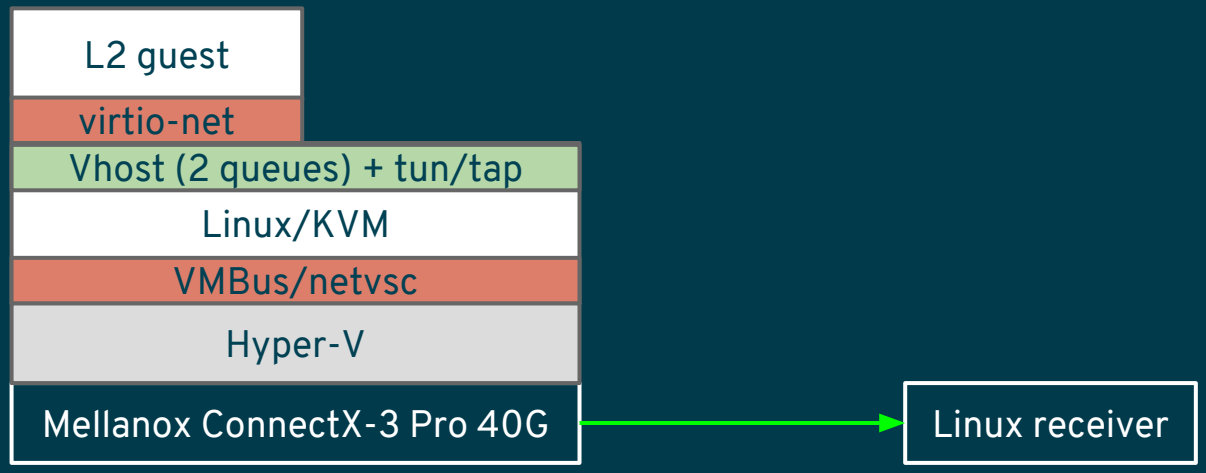
Things to play with

- L2 -> L1 vcpu pinning
  - <vcpupin vcpu='0' cpuset='8'/>
- Vhost settings
  - <driver name='vhost' txmode='iothread' ioeventfd='on' queues='2'/>
- VF queues in L1, CPU assignment
  - Mlx4 defaults are OK
- ...

Benchmark: iperf without SR-IOV

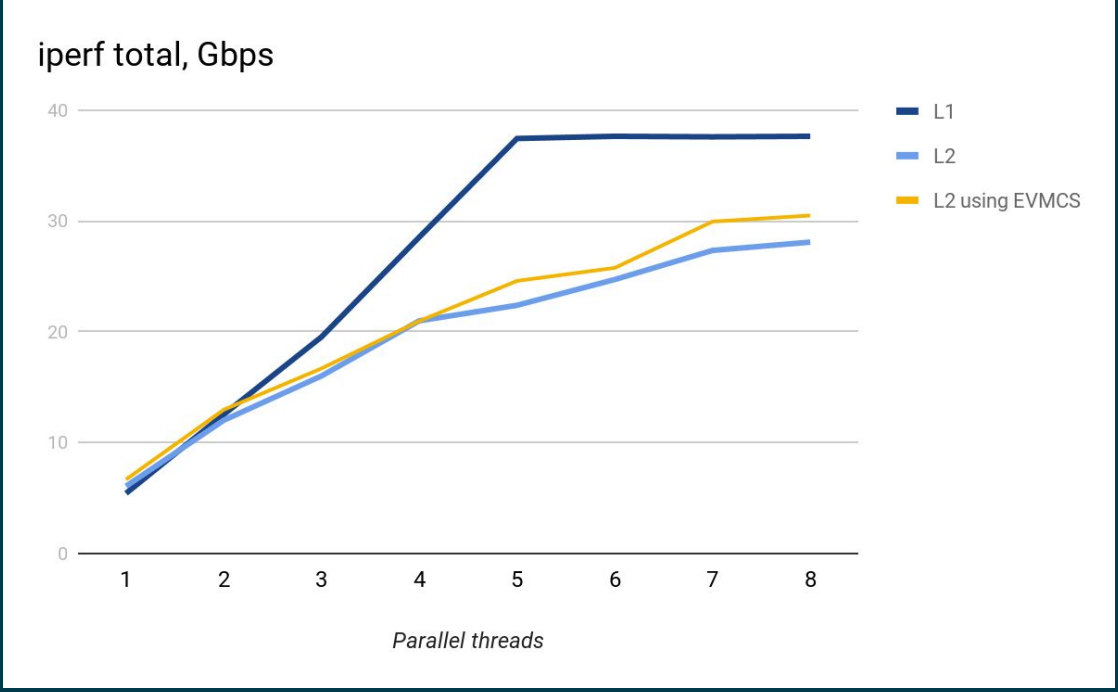
Setup

- L1: 16 cores, 2 NUMA nodes, netvsc, 4.15.0-rc8+ eVMCS/clocksource patchsets
- L2: 8 cores, 1 NUMA node, virtio-net, 4.14.11-300.fc27



Benchmark: iperf without SR-IOV

Results



Benchmark: iperf without SR-IOV

Things to play with

- L2 -> L1 vcpu pinning
- Vhost settings
- VMBus channel pinning (automatic only)

```
# lsvmbus -vv
…
VMBUS ID 17: Class_ID = {f8615163-df3e-46c5-913f-f2d2f965ed0e} - Synthetic network
adapter
        Device_ID = {21938293-957d-4e27-a53b-ae35f90aba2b}
        Sysfs path: /sys/bus/vmbus/devices/21938293-957d-4e27-a53b-ae35f90aba2b
        Rel_ID=17, target_cpu=9
        Rel_ID=35, target_cpu=10
        Rel_ID=36, target_cpu=3
        Rel_ID=37, target_cpu=11
        Rel_ID=38, target_cpu=4
        Rel_ID=39, target_cpu=12
        Rel_ID=40, target_cpu=5
        Rel_ID=41, target_cpu=13
```

- Can be re-shuffled with “ethtool -L”

Benchmark: kernel build

Setup

- L1: 8 cores Intel(R) Xeon(R) CPU E5-2667 v4 @ 3.20GHz, 1 NUMA node, 30G RAM (16G tmpfs)
  - 4.14.11-300.fc27 for kernel build
  - 4.15.0-rc8+EVMCS/stable clocksource patchsets when running L2
- L2: 8 cores, 1 NUMA node, 30G RAM (16G tmpfs), 4.14.11-300.fc27
- Test: building linux kernel

```
# make clean && time make -j8
```

Benchmark: kernel build

Results:

L1	real 26m42.187s user 131m18.664s sys 21m53.760s
L2	real 26m54.887s user 139m19.752s sys 21m31.111s
L2 (Enlightened VMCS in use)	real 27m53.110s user 138m27.416s sys 21m3.839s

FURTHER IMPROVEMENTS

Nested Hyper-V features we don’t use

- Enlightened MSR bitmap
  - Natural extension of Enlightened VMCS
- Direct Virtual Flush
  - Paravirtual TLB flush for L2 guests

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