

## CMPE283 Assignment 2: KVM Exit Statistics

### Team Members

- Sheetal Yadav : <https://github.com/SheetalYadav01/linux>
- Amrutha

### Question 1

**Sheetal Yadav** took the lead in implementing the project setup. She ensured the Google Cloud Platform (GCP) project was created with nested virtualization enabled, and the outer VM was successfully set up on Google Cloud Platform. She also installed KVM and the necessary development tools, and configured the Linux server.

**Amrutha Junnuri** focused on researching and supporting the project steps. This included providing guidance and documentation support throughout the process. She also installed and configured the inner VM, ensuring it was set up correctly and ready for testing.

We both worked together in test the process and troubleshooting any configuration or environment-related issues.

### Question 2

#### Development Steps

**Step 1:** Performed the setup of Google Cloud Platform (GCP) account

1. Created a new project named "nested-virt"
2. Install Google Cloud SDK on local machine
3. Enable Compute Engine API , after installing logged into gcloud

```
gcloud config set project nested-virt
```

**Step 2: Created the nested Outer VM in us-central1-a**

```
gcloud compute instances create outer-vm \ --machine-type=e2-standard-4 \ --image-family=ubuntu-2204-lts \ --image-project=ubuntu-os-cloud \ --zone=us-central1-a
```

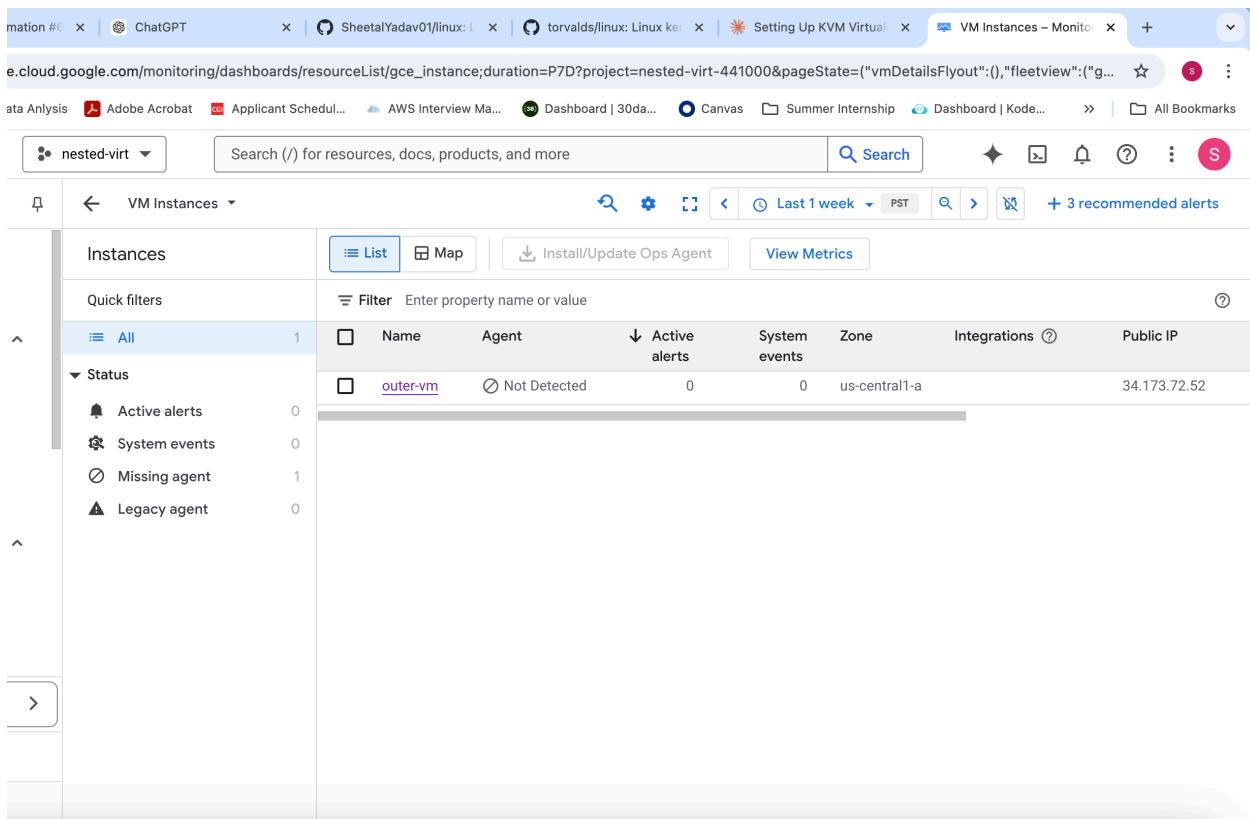
Running outer VM

```
bin — spartan@outer-vm: ~/linux_source/linux — ssh - gcloud.py compute ssh outer-vm --zone...
--image-project=ubuntu-os-cloud \
--zone=us-central1-a

API [compute.googleapis.com] not enabled on project [nested-virt-441000]. Would
you like to enable and retry (this will take a few minutes)? (y/N)? y

[Enabling service [compute.googleapis.com] on project [nested-virt-441000]...]
Operation "operations/acf.p2-132716371559-36aca101-8b52-4101-bbbf-6e57f630a402" finished successfully.
Created [https://www.googleapis.com/compute/v1/projects/nested-virt-441000/zones/us-central1-a/instances/outer-vm].
NAME: outer-vm
ZONE: us-central1-a
MACHINE_TYPE: e2-standard-4
PREEMPTIBLE:
INTERNAL_IP: 10.128.0.2
EXTERNAL_IP: 34.173.72.52
STATUS: RUNNING
spartan@IMS-051MBA bin % gcloud compute instances list

NAME: outer-vm
ZONE: us-central1-a
MACHINE_TYPE: e2-standard-4
PREEMPTIBLE:
INTERNAL_IP: 10.128.0.2
EXTERNAL_IP: 34.173.72.52
STATUS: RUNNING
```



**Step 3: Performed the SSH into Outer VM**

gcloud compute ssh --zone "us-central1-a" "outer-vm" --project "nested-virt-441000"

```
bin — spartan@outer-vm: ~/linux_source/linux — ssh ◀ gcloud.py compute ssh outer-vm --zone...
[spartan@IMS-051MBA bin % gcloud compute ssh outer-vm --zone=us-central1-a

WARNING: The private SSH key file for gcloud does not exist.
WARNING: The public SSH key file for gcloud does not exist.
WARNING: You do not have an SSH key for gcloud.
WARNING: SSH keygen will be executed to generate a key.
Generating public/private rsa key pair.
Enter passphrase (empty for no passphrase):
Enter same passphrase again:
Your identification has been saved in /Users/spartan/.ssh/google_compute_engine
Your public key has been saved in /Users/spartan/.ssh/google_compute_engine.pub
The key fingerprint is:
SHA256:r6R4eVuVzvXSLOVAXTNhkduEK2SRWkVath7HknreYMI spartan@IMS-051MBA.attlocal.net
The key's randomart image is:
+----[RSA 3072]-----+
|      .B*+OX|
|      +o+.+=|
|      o* = .|
|      ..o B |
|      S E B o .|
|      . O + B |
|      .. o + + =|
|      .oo.o   o |
|      ....o.   |
+----[SHA256]-----+
Updating project ssh metadata...workingUpdated [https://www.googleapis.com/compute/v1/projects/nested-virt-441000].
Updating project ssh metadata...done.
Waiting for SSH key to propagate.
Warning: Permanently added 'compute.3658776178926546250' (ED25519) to the list of known hosts.
Welcome to Ubuntu 22.04.5 LTS (GNU/Linux 6.8.0-1018-gcp x86_64)

 * Documentation:  https://help.ubuntu.com
[ * Management:   https://landscape.canonical.com
 * Support:       https://ubuntu.com/pro

System information as of Wed Nov 20 21:28:06 UTC 2024

System load:  0.04          Processes:            137
Usage of /:   20.2% of 9.51GB Users logged in:          0
Memory usage: 1%           IPv4 address for ens4: 10.128.0.2
Swap usage:   0%
```

**Step 4: Performed the necessary update and installation of tool on VM Environment to to build the linux kernel**

sudo apt update && sudo apt upgrade -y  
sudo apt install -y build-essential git fakeroot libncurses5-dev libssl-dev bc bison flex libelf-dev

**Step 5: Fork the code into the github repo for Linux kernel build from below mentioned link**

<https://github.com/torvalds/linux>

<https://github.com/SheetalYadav01/linux>

## Step 6: Performed the new Kernal installation

- Configured the kernel for the VM: make defconfig
- Build the kernel : make -j\$(nproc)
- 
- Installed the new kernel: sudo make modules\_install  
sudo make install
- Update the bootloader and reboot:  
sudo update-grub  
sudo reboot
- Reconnect the VM after reboot: gcloud compute ssh outer-vm --zone=us-central1-a

```
bin — spartan@outer-vm: ~/linux_source/linux — ssh - gcloud.py compute ssh outer-vm --zone...
CC      arch/x86/boot/regs.o
AS      arch/x86/boot/compressed/head_64.o
VOFFSET arch/x86/boot/compressed/./voffset.h
CC      arch/x86/boot/string.o
CC      arch/x86/boot/compressed/string.o
CC      arch/x86/boot/tty.o
CC      arch/x86/boot/compressed/cmdline.o
CC      arch/x86/boot/video.o
CC      arch/x86/boot/compressed/error.o
OBJCOPY arch/x86/boot/compressed/vmlinux.bin
CC      arch/x86/boot/video-mode.o
HOSTCC  arch/x86/boot/compressed/mkpiggy
CC      arch/x86/boot/version.o
CC      arch/x86/boot/compressed/cpuflags.o
CC      arch/x86/boot/compressed/early_serial_console.o
CC      arch/x86/boot/video-vga.o
CC      arch/x86/boot/compressed/kaslr.o
CC      arch/x86/boot/video-vesa.o
CC      arch/x86/boot/compressed/ident_map_64.o
CC      arch/x86/boot/video-bios.o
CC      arch/x86/boot/compressed/idt_64.o
HOSTCC  arch/x86/boot/tools/build
AS      arch/x86/boot/compressed/idt_handlers_64.o
CC      arch/x86/boot/compressed/pgtable_64.o
CC      arch/x86/boot/compressed/acpi.o
CC      arch/x86/boot/compressed/efi.o
AS      arch/x86/boot/compressed/efi_mixed.o
CC      arch/x86/boot/compressed/misc.o
CPUSTR  arch/x86/boot/cpustr.h
GZIP    arch/x86/boot/compressed/vmlinux.bin.gz
CC      arch/x86/boot/cpu.o
MKPIGGY arch/x86/boot/compressed/piggy.S
AS      arch/x86/boot/compressed/piggy.o
LD      arch/x86/boot/compressed/vmlinux
ZOFFSET arch/x86/boot/zoffset.h
OBJCOPY arch/x86/boot/vmlinux.bin
AS      arch/x86/boot/header.o
LD      arch/x86/boot/setup.elf
OBJCOPY arch/x86/boot/setup.bin
BUILD   arch/x86/boot/bzImage
Kernel: arch/x86/boot/bzImage is ready (#1)
spartan@outer-vm:~/linux_source/linux$
```

```

Sourcing file `/etc/default/grub'
Sourcing file `/etc/default/grub.d/40-force-partuuid.cfg'
Sourcing file `/etc/default/grub.d/50-cloudimg-settings.cfg'
Sourcing file `/etc/default/grub.d/init-select.cfg'
Generating grub configuration file ...
GRUB_FORCE_PARTUUID is set, will attempt initrdless boot
Found linux image: /boot/vmlinuz-6.12.0-g80db457e8d28
Found initrd image: /boot/initrd.img-6.12.0-g80db457e8d28
Warning: os-prober will not be executed to detect other bootable partitions.
Systems on them will not be added to the GRUB boot configuration.
Check GRUB_DISABLE_OS_PROBER documentation entry.
Adding boot menu entry for UEFI Firmware Settings ...
done
spartan@outer-vm:~/linux_source/linux$

```

```

bin — spartan@outer-vm: ~/linux_source/linux — ssh • gcloud.py compute ssh outer-vm --zone=us-central1-a — 125x39
spartan@IMS-051MBA bin % gcloud compute ssh outer-vm --zone=us-central1-a
Welcome to Ubuntu 22.04.5 LTS (GNU/Linux 6.12.0-g80db457e8d28 x86_64)

 * Documentation:  https://help.ubuntu.com
 * Management:    https://landscape.canonical.com
 * Support:       https://ubuntu.com/pro

System information as of Thu Nov 21 00:26:54 UTC 2024

System load:  0.9               Processes:    104
Usage of /:   1.0% of 968.99GB   Users logged in: 0
Memory usage: 1%               IPv4 address for ens4: 10.128.0.2
Swap usage:   0%

 * Strictly confined Kubernetes makes edge and IoT secure. Learn how MicroK8s
   just raised the bar for easy, resilient and secure K8s cluster deployment.

https://ubuntu.com/engage/secure-kubernetes-at-the-edge

Expanded Security Maintenance for Applications is not enabled.

0 updates can be applied immediately.

Enable ESM Apps to receive additional future security updates.
See https://ubuntu.com/esm or run: sudo pro status

New release '24.04.1 LTS' available.
Run 'do-release-upgrade' to upgrade to it.

Last login: Wed Nov 20 21:28:08 2024 from 162.195.240.180
spartan@outer-vm:~$ cd linux
grep -r "vmexit" arch/ | grep handler
-bash: cd: linux: No such file or directory
grep: arch/: No such file or directory
spartan@outer-vm:~$ ls
linux_source
spartan@outer-vm:~$ cd linux_source

```

## Step 7: Modified the KVM code

- Located the KVM exit handler code in the kernel source code at path arch/x86/kvm/vmx/vmx.c
- Added counters for each exit type and printed statistics every 10,000 exits.
- Rebuilt and installed the modified kernel.

```

6466     }
6467
6468     /* Modify the vmx handle exit function */
6469     static int _vmx_handle_exit(struct kvm_vcpu *vcpu, fastpath_t exit_fastpath) {
6470         struct vcpu_vmx *vmx = to_vmx(vcpu);
6471         union vmx_exit_reason exit_reason = vmx->exit_reason;
6472         u32 vectoring_info = vmx->idt_vectoring_info;
6473         u16 exit_handler_index;
6474
6475         /* Add the counters at the start of the function */
6476         int exit_type = exit_reason.basic; // Get the exit type number
6477
6478         kvm_exit_counters[exit_type]++; // Increment the exit type counter
6479         kvm_total_exits++; // Increment the total exit counter
6480
6481         /* Print every 10,000 total exits */
6482         if (kvm_total_exits % 10000 == 0) {
6483             int i;
6484             for (i = 0; i < 256; i++) {
6485                 if (kvm_exit_counters[i] > 0) {
6486                     printk(KERN_INFO "KVM Exit: %d (%s) occurred %llu times\n", i, kvm_exit_reason_to_string(i), kvm_exit_counters[i]);
6487                 }
6488             }
6489         }
6490
6491         /*

```

## Step 8: Rebuild the Kernel with new changes

```

make -j$(nproc)
sudo make modules_install
sudo make install
sudo update-grub
sudo reboot

```

- Reconnected to the VM after reboot:  
gcloud compute ssh outer-vm --zone=us-central1-a

## Step 9: Tested the Modified Kernel

Created an **inner VM** on the outer VM:





SSH-in-browser

↑ UPLOAD FILE

↓ DOWNLOAD FILE



```
.iso
--2024-11-21 07:38:48-- https://releases.ubuntu.com/22.04/ubuntu-22.04.1-live-server-amd64.iso
Resolving releases.ubuntu.com (releases.ubuntu.com)... 185.125.190.40, 91.189.91.124, 91.189.91.123, ...
Connecting to releases.ubuntu.com (releases.ubuntu.com)|185.125.190.40|:443... connected.
HTTP request sent, awaiting response... 404 Not Found
2024-11-21 07:38:49 ERROR 404: Not Found.

amrutha_junnuri@outer-vm:~$ wget https://releases.ubuntu.com/22.04/ubuntu-22.04.1-live-server-amd64.iso -O ubuntu
.iso
--2024-11-21 07:38:55-- https://releases.ubuntu.com/22.04/ubuntu-22.04.1-live-server-amd64.iso
Resolving releases.ubuntu.com (releases.ubuntu.com)... 91.189.91.124, 185.125.190.40, 185.125.190.37, ...
Connecting to releases.ubuntu.com (releases.ubuntu.com)|91.189.91.124|:443... connected.
HTTP request sent, awaiting response... 404 Not Found
2024-11-21 07:38:55 ERROR 404: Not Found.

amrutha_junnuri@outer-vm:~$ ^C
amrutha_junnuri@outer-vm:~$ wget https://releases.ubuntu.com/22.04/ubuntu-22.04.3-live-server-amd64.iso -O ubuntu
.iso
--2024-11-21 07:39:38-- https://releases.ubuntu.com/22.04/ubuntu-22.04.3-live-server-amd64.iso
Resolving releases.ubuntu.com (releases.ubuntu.com)... 185.125.190.40, 91.189.91.124, 91.189.91.123, ...
Connecting to releases.ubuntu.com (releases.ubuntu.com)|185.125.190.40|:443... connected.
HTTP request sent, awaiting response... 404 Not Found
2024-11-21 07:39:38 ERROR 404: Not Found.

amrutha_junnuri@outer-vm:~$ wget https://releases.ubuntu.com/22.04/ubuntu-22.04.5-live-server-amd64.iso -O ubuntu
.iso
--2024-11-21 07:41:37-- https://releases.ubuntu.com/22.04/ubuntu-22.04.5-live-server-amd64.iso
Resolving releases.ubuntu.com (releases.ubuntu.com)... 185.125.190.37, 185.125.190.40, 91.189.91.124, ...
Connecting to releases.ubuntu.com (releases.ubuntu.com)|185.125.190.37|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 2136926208 (2.0G) [application/x-iso9660-image]
Saving to: 'ubuntu.iso'

ubuntu.iso          100%[=====>] 1.99G  13.9MB/s   in 70s

2024-11-21 07:42:47 (29.3 MB/s) - 'ubuntu.iso' saved [2136926208/2136926208]

amrutha_junnuri@outer-vm:~$ ls -lh ubuntu.iso
-rw-rw-r-- 1 amrutha_junnuri amrutha_junnuri 2.0G Sep 11 18:46 ubuntu.iso
amrutha_junnuri@outer-vm:~$
```

Installed QEMU and KVM:

```
sudo apt install -y qemu-kvm libvirt-daemon-system libvirt-clients bridge-utils
```

Started a virtual machine using QEMU:

```
qemu-system-x86_64 -enable-kvm -m 2048 -hda <inner-vm.img >
```

Constantly monitored the kernel logs to see the VM exit stats in interval of time

```
dmesg | tail -n 50
```

### Question 3: Frequency of Exits

The number of exits generally increases at a steady rate during normal VM operations. However, specific activities like booting the VM or performing heavy I/O operations cause noticeable spikes in exit counts. These spikes are due to the intensive processes involved in these operations. For example, exit types such as 30 (Unknown) and 28 (Unknown) are among the most frequently observed, each exceeding a million instances, because they are often invoked during critical operations managed by the hypervisor. Additionally, exit types like 1 (External Interrupt) and 10 (CPUID) also significantly contribute to the overall exit count. On average, a complete VM boot involves approximately 1.5 to 2 million exits, with periods of heightened

activity reflecting the intensive tasks being performed.

**Question 4: Most and Least Frequent Exit Types**

Among the various exit types observed during VM runtime, Exit Reason 30 (Unknown) and Exit Reason 28 (Unknown) are the most frequent. These exit types occur often during operations such as CPU initialization and interrupt handling, making them the bulk of the exit events.

Collectively, these exits surpass a million instances. On the other hand, the least frequent exit type observed is Exit Reason 0 (Exception or NMI), which rarely occurs, indicating that exception handling and non-maskable interrupts are not commonly needed during regular VM operations.