SUSE Linux Enterprise Server 15 SP7

NVIDIA Virtual GPU for KVM Guests

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1 Introduction

NVIDIA virtual GPU (vGPU) is a graphics virtualization solution that provides multiple virtual machines (VMs) simultaneous access to one physical Graphics Processing Unit (GPU) on the VM Host Server. This article refers to the Volta and Ampere GPU architecture.

2 Configuring vGPU manager in VM Host Server

2.1 Prepare VM Host Server environment

1. Verify that you have a compatible server and GPU cards. Check specifications for details:

   - https://docs.nvidia.com/grid/gpus-supported-by-vgpu.html
   - https://docs.nvidia.com/grid/index.html

2. Verify that VM Host Server is SUSE Linux Enterprise Server 15 SP3 or newer:

   ```
   > cat /etc/issue
   Welcome to SUSE Linux Enterprise Server 15 SP3  (x86_64) - Kernel \r (\l).
   ```

3. Get the vGPU drivers from NVIDIA. To get the software, please follow the steps at https://docs.nvidia.com/grid/latest/grid-software-quick-start-guide/index.html#redeeming-pak-and-downloading-grid-software. For example, to install vGPU 13.0, you need the following files:

   ```
   NVIDIA-Linux-x86_64-470.63-vgpu-kvm.run  # vGPU manager for the VM host
   NVIDIA-Linux-x86_64-470.63.01-grid.run   # vGPU driver for the VM guest
   ```

4. If you are using Ampere architecture GPU cards, verify that VM Host Server supports VT-D/IOMMU and SR-IOV technologies, and that they are enabled in BIOS.

5. Enable IOMMU. Verify that it is included in the boot command line:

   ```
   cat /proc/cmdline
   BOOT_IMAGE=/boot/vmlinuz-default [...] intel_iommu=on [...]
   ```

   If not, add the following line to `/etc/default/grub`.

- For Intel CPUs:

  ```
  GRUB_CMDLINE_LINUX="intel_iommu=on"
  ```

  For AMD CPUs:

  ```
  GRUB_CMDLINE_LINUX="amd_iommu=on"
  ```

Then generate new GRUB 2 configuration file and reboot:

```
> sudo grub2-mkconfig -o /boot/grub2/grub.cfg
> sudo systemctl reboot
```

Tip

You can verify that IOMMU is loaded by running the following command:

```
sudo dmesg | grep -e IOMMU
```

6. Enable SR-IOV. Refer to https://docs.nvidia.com/grid/13.0/grid-vgpu-user-guide/index.html#vgpu-types-tesla-v100-pcie for useful information.
7. Disable the nouveau kernel module by adding the following line it to the top of the `/etc/modprobe.d/50-blacklist.conf` file:

   ```
   blacklist nouveau
   ```

2.2 Remove conflicting and pre-installed NVIDIA drivers

On a fresh installation of SUSE Linux Enterprise Server 15 SP7, the open-source NVIDIA desktop driver such as `nvidia-open-driver-G06-signed-kmp-default` is often automatically installed if an NVIDIA GPU is detected. This pre-installed driver can conflict with the installation of the proprietary NVIDIA vGPU driver. The conflict can lead to errors during the build process of the vGPU kernel modules and/or issues with the correct driver being loaded, preventing the vGPU functionality from working correctly. This section describes how to identify and remove conflicting drivers before proceeding with the NVIDIA vGPU driver installation.

1. Check for pre-installed NVIDIA drivers that can potentially conflict with the vGPU driver that you want to install.

a. Check for the presence of automatically installed open source NVIDIA driver.

```
> zypper info nvidia-open-driver-G06-signed-kmp-default
```

Note

If the package is *not installed*, you can skip the rest of this section and proceed to *Section 2.3, "Install the NVIDIA KVM driver"*. However, if it is *installed*, perform the rest of the steps to uninstall conflicting drivers and clean up any residues.

b. List all installed NVIDIA-related packages to identify any other potential conflicts:

```
> zypper search --installed-only nvidia*
```

Look for any packages that might conflict with the vGPU driver, such as other desktop driver versions.

2. Remove the conflicting NVIDIA drivers.

a. Remove the open source NVIDIA driver that is automatically installed.

```
> sudo  zypper remove nvidia-open-driver-G06-signed-kmp-default
```

b. If you identified other conflicting packages in the previous step, remove them similarly.

```
> sudo zypper remove CONFLICTING-NVIDIA-PACKAGE CONFLICTING-NVIDIA-PACKAGE
```

3. Uninstall any manually installed proprietary NVIDIA drivers that you have installed using `.run` files downloaded from NVIDIA's Web site.

```
> sudo /PATH/TO/NVIDIA-Linux-x86_64-XXX.XX.XX.run --uninstall
```

4. *OPTIONAL but RECOMMENDED:* Sometimes, driver installations can leave behind configuration files. To ensure a clean state, remove any potentially conflicting configuration files.

Warning

Remove driver configuration files only when you are absolutely sure that it relates to a potentially conflicting NVIDIA driver that you have already uninstalled.

a. Search for NVIDIA-related configuration directories.

```
> sudo find /etc/ -name "*nvidia*"
```

b. Remove the directories related to conflicting uninstalled NVIDIA drivers.

```
> sudo rm -rf /etc/CONFLICTING/NVIDIA/DIRECTORY
```

5. Manually load the `nvidia-modprobe` utility before attempting the vGPU driver installation:

```
> sudo modprobe nvidia-modprobe
```

2.3 Install the NVIDIA KVM driver

1. Exit from the graphical mode:

```
> sudo init 3
```

2. Install `kernel-default-devel` and `gcc` packages and their dependencies:

```
> sudo zypper in kernel-default-devel gcc
```

3. Download the vGPU software from the NVIDIA portal. Make the NVIDIA vGPU driver executable and run it:

```
> chmod +x NVIDIA-Linux-x86_64-450.55-vgpu-kvm.run
> sudo ./NVIDIA-Linux-x86_64-450.55-vgpu-kvm.run
```

You can find detailed information about the installation process in the log file `/var/log/nvidia-installer.log`

Tip

To enable dynamic kernel-module support, and thus have the module rebuilt automatically when a new kernel is installed, add the `--dkms` option:

```
> sudo ./NVIDIA-Linux-x86_64-450.55-vgpu-kvm.run --dkms
```

4. When the driver installation is finished, reboot the system:

```
> sudo systemctl reboot
```

2.4 Verify the driver installation

1. Verify loaded kernel modules:

```
> lsmod | grep nvidia
nvidia_vgpu_vfio       49152  9
nvidia              14393344  229 nvidia_vgpu_vfio
mdev                   20480  2 vfio_mdev,nvidia_vgpu_vfio
vfio                   32768  6 vfio_mdev,nvidia_vgpu_vfio,vfio_iommu_type1
```

   The modules containing the `vfio` string are required dependencies.

2. Print the GPU device status with the **`nvidia-smi`** command. The output should be similar to the following one:

```
> nvidia-smi
+-----------------------------------------------------------------------------+
| NVIDIA-SMI 470.63       Driver Version: 470.63       CUDA Version: N/A      |
|-------------------------------+----------------------+----------------------+
| GPU  Name        Persistence-M| Bus-Id        Disp.A | Volatile Uncorr. ECC |
| Fan  Temp  Perf  Pwr:Usage/Cap|         Memory-Usage | GPU-Util  Compute M. |
|                               |                      |               MIG M. |
|===============================+======================+======================|
|   0  NVIDIA A40          Off  | 00000000:31:00.0 Off |                    0 |
|  0%   46C    P0    39W / 300W |      0MiB / 45634MiB |      0%      Default |
|                               |                      |                  N/A |
+-------------------------------+----------------------+----------------------+

+-----------------------------------------------------------------------------+
| Processes:                                                                  |
|  GPU   GI   CI        PID   Type   Process name                  GPU Memory |
|        ID   ID                                                   Usage      |
|=============================================================================|
|  No running processes found                                                 |
+-----------------------------------------------------------------------------+
```

3. Check the sysfs file system. For Volta and earlier GPU cards, new directory `mdev_supported_types` is added, for example:

```
cd /sys/bus/pci/devices/00000000\:31\:00.0/mdev_supported_types
```

For Ampere GPU cards, the directory gets created automatically for each virtual function after SR-IOV is enabled.

3 Creating a vGPU device

3.1 Create a legacy vGPU device without support for SR-IOV

All the NVIDIA Volta and earlier architecture GPUs work in this mode.

1. Obtain the Bus/Device/Function (BDF) numbers of the host GPU device:

```
> lspci | grep NVIDIA
84:00.0 3D controller: NVIDIA Corporation GV100GL [Tesla V100 PCIe 16GB] (rev a1)
```

2. Check for the mdev supported devices and detailed information:

```
> ls /sys/bus/pci/devices/0000:84:00.0/mdev_supported_types/
nvidia-105  nvidia-106  nvidia-107  nvidia-108  nvidia-109  nvidia-110 [...]
```

   The map of vGPU mdev devices and their type is as follows:

   - nvidia-105 to nvidia-109: 1Q 2Q 4Q 8Q 16Q
   - nvidia-110 to nvidia-114: 1A 2A 4A 8A 16A
   - nvidia-115, nvidia-163, nvidia-217, nvidia-247: 1B 2B 2B4 1B4
   - nvidia-299 to nvidia-301: 4C 8C 16C

   Refer to https://docs.nvidia.com/grid/latest/grid-vgpu-user-guide/index.html#vgpu-types-tesla-v100-pcie for more details.

3. Inspect a vGPU device:

```
> cd /sys/bus/pci/devices/0000:03:00.0/mdev_supported_types/
> ls nvidia-105
> cat nvidia-105/description
num_heads=2, frl_config=60, framebuffer=1024M, max_resolution=4096x2160,
 max_instance=16
> cat nvidia-105/name
GRID V100-1Q
```

4. Generate a unique ID and create an mdev device based on it:

```
> uuidgen
4f3b6e47-0baa-4900-b0b1-284c1ecc192f
> sudo echo "4f3b6e47-0baa-4900-b0b1-284c1ecc192f" > nvidia-105/create
```

5. Verify the new mdev device. You can inspect the content of the `/sys/bus/mdev/devices` directory:

```
> cd /sys/bus/mdev/devices
> ls -l
lrwxrwxrwx 1 root root 0 Aug 30 23:03 86380ffb-8f13-4685-9c48-0e0f4e65fb87 \
 -> ../../../devices/
pci0000:80/0000:80:02.0/0000:84:00.0/86380ffb-8f13-4685-9c48-0e0f4e65fb87
lrwxrwxrwx 1 root root 0 Aug 30 23:03 86380ffb-8f13-4685-9c48-0e0f4e65fb88 \
 -> ../../../devices/
pci0000:80/0000:80:02.0/0000:84:00.0/86380ffb-8f13-4685-9c48-0e0f4e65fb88
lrwxrwxrwx 1 root root 0 Aug 30 23:03 86380ffb-8f13-4685-9c48-0e0f4e65fb89 \
 -> ../../../devices/
pci0000:80/0000:80:02.0/0000:84:00.0/86380ffb-8f13-4685-9c48-0e0f4e65fb89
lrwxrwxrwx 1 root root 0 Aug 30 23:03 86380ffb-8f13-4685-9c48-0e0f4e65fb90 \
 -> ../../../devices/
pci0000:80/0000:80:02.0/0000:84:00.0/86380ffb-8f13-4685-9c48-0e0f4e65fb90
```

Or you can use the **`mdevctl`** command:

```
> sudo mdevctl list
86380ffb-8f13-4685-9c48-0e0f4e65fb90 0000:84:00.0 nvidia-299
86380ffb-8f13-4685-9c48-0e0f4e65fb89 0000:84:00.0 nvidia-299
86380ffb-8f13-4685-9c48-0e0f4e65fb87 0000:84:00.0 nvidia-299
86380ffb-8f13-4685-9c48-0e0f4e65fb88 0000:84:00.0 nvidia-299
```

6. Query the new vGPU device capability:

```
> sudo nvidia-smi vgpu -q
GPU 00000000:84:00.0
Active vGPUs                      : 1
vGPU ID                           : 3251634323
   VM UUID                        : ee7b7a4b-388a-4357-a425-5318b2c65b3f
   VM Name                        : sle15sp3
   vGPU Name                      : GRID V100-4C
   vGPU Type                      : 299
   vGPU UUID                      : d471c7f2-0a53-11ec-afd3-38b06df18e37
   MDEV UUID                      : 86380ffb-8f13-4685-9c48-0e0f4e65fb87
   Guest Driver Version           : 460.91.03
   License Status                 : Licensed
```

```
    GPU Instance ID                : N/A
    Accounting Mode                : Disabled
    ECC Mode                       : N/A
    Accounting Buffer Size         : 4000
    Frame Rate Limit               : N/A
    FB Memory Usage
        Total                      : 4096 MiB
        Used                       : 161 MiB
        Free                       : 3935 MiB
    Utilization
        Gpu                        : 0 %
        Memory                     : 0 %
        Encoder                    : 0 %
        Decoder                    : 0 %
    Encoder Stats
        Active Sessions            : 0
        Average FPS                : 0
        Average Latency            : 0
    FBC Stats
        Active Sessions            : 0
        Average FPS                : 0
        Average Latency            : 0
```

3.2 Create a vGPU device with support for SR-IOV

All NVIDIA Ampere and newer architecture GPUs work in this mode.

1. Obtain the Bus/Device/Function (BDF) numbers of the host GPU device:

```
> lspci | grep NVIDIA
b1:00.0 3D controller: NVIDIA Corporation GA100 [A100 PCIe 40GB] (rev a1)
```

2. Enable virtual functions:

```
> sudo /usr/lib/nvidia/sriov-manage -e 00:b1:0000.0
```

Note

This configuration is not persistent and must be re-enabled after the host reboot.

3. Obtain the Bus/Domain/Function (BDF) of virtual functions on the GPU:

```
> ls -l /sys/bus/pci/devices/0000:b1:00.0/ | grep virtfn
lrwxrwxrwx 1 root root           0 Sep 21 11:58 virtfn0 -> ../0000:b1:00.4
```

```
lrwxrwxrwx 1 root root           0 Sep 21 11:58 virtfn1 -> ../0000:b1:00.5
lrwxrwxrwx 1 root root           0 Sep 21 11:58 virtfn10 -> ../0000:b1:01.6
lrwxrwxrwx 1 root root           0 Sep 21 11:58 virtfn11 -> ../0000:b1:01.7
lrwxrwxrwx 1 root root           0 Sep 21 11:58 virtfn12 -> ../0000:b1:02.0
lrwxrwxrwx 1 root root           0 Sep 21 11:58 virtfn13 -> ../0000:b1:02.1
lrwxrwxrwx 1 root root           0 Sep 21 11:58 virtfn14 -> ../0000:b1:02.2
lrwxrwxrwx 1 root root           0 Sep 21 11:58 virtfn15 -> ../0000:b1:02.3
lrwxrwxrwx 1 root root           0 Sep 21 11:58 virtfn2 -> ../0000:b1:00.6
lrwxrwxrwx 1 root root           0 Sep 21 11:58 virtfn3 -> ../0000:b1:00.7
lrwxrwxrwx 1 root root           0 Sep 21 11:58 virtfn4 -> ../0000:b1:01.0
lrwxrwxrwx 1 root root           0 Sep 21 11:58 virtfn5 -> ../0000:b1:01.1
lrwxrwxrwx 1 root root           0 Sep 21 11:58 virtfn6 -> ../0000:b1:01.2
lrwxrwxrwx 1 root root           0 Sep 21 11:58 virtfn7 -> ../0000:b1:01.3
lrwxrwxrwx 1 root root           0 Sep 21 11:58 virtfn8 -> ../0000:b1:01.4
lrwxrwxrwx 1 root root           0 Sep 21 11:58 virtfn9 -> ../0000:b1:01.5
```

4. *Create a vGPU device.* Select the virtual function (VF) that you want to use to create the vGPU device and assign it a unique ID.

Important

Each VF can only create one vGPU instance. To create more vGPU instances, you need to use a different VF.

```
> cd /sys/bus/pci/devices/0000:b1:00.0/virtfn1/mdev_supported_types
> for i in *; do echo "$i" $(cat $i/name) available: $(cat $i/avail*); done
nvidia-468 GRID A100-4C available: 0
nvidia-469 GRID A100-5C available: 0
nvidia-470 GRID A100-8C available: 0
nvidia-471 GRID A100-10C available: 1
nvidia-472 GRID A100-20C available: 0
nvidia-473 GRID A100-40C available: 0
nvidia-474 GRID A100-1-5C available: 0
nvidia-475 GRID A100-2-10C available: 0
nvidia-476 GRID A100-3-20C available: 0
nvidia-477 GRID A100-4-20C available: 0
nvidia-478 GRID A100-7-40C available: 0
nvidia-479 GRID A100-1-5CME available: 0
> uuidgen
f715f63c-0d00-4007-9c5a-b07b0c6c05de
> sudo echo "f715f63c-0d00-4007-9c5a-b07b0c6c05de" > nvidia-471/create
> sudo dmesg | tail
[...]
[ 3218.491843] vfio_mdev f715f63c-0d00-4007-9c5a-b07b0c6c05de: Adding to iommu group
 322
```

```
[ 3218.499700] vfio_mdev f715f63c-0d00-4007-9c5a-b07b0c6c05de: MDEV: group_id = 322
[ 3599.608540] vfio_mdev f715f63c-0d00-4007-9c5a-b07b0c6c05de: Removing from iommu
 group 322
[ 3599.616753] vfio_mdev f715f63c-0d00-4007-9c5a-b07b0c6c05de: MDEV: detaching iommu
[ 3626.345530] vfio_mdev f715f63c-0d00-4007-9c5a-b07b0c6c05de: Adding to iommu group
 322
[ 3626.353383] vfio_mdev f715f63c-0d00-4007-9c5a-b07b0c6c05de: MDEV: group_id = 322
```

5. Verify the new vGPU device:

```
> cd /sys/bus/mdev/devices/
> ls
f715f63c-0d00-4007-9c5a-b07b0c6c05de
```

6. Query the new vGPU device capability:

```
> sudo nvidia-smi vgpu -q
GPU 00000000:B1:00.0
Active vGPUs                      : 1
vGPU ID                           : 3251634265
  VM UUID                     : b0d9f0c6-a6c2-463e-967b-06cb206415b6
  VM Name                     : sles15sp2-gehc-vm1
  vGPU Name                   : GRID A100-10C
  vGPU Type                   : 471
  vGPU UUID                   : 444f610c-1b08-11ec-9554-ebd10788ee14
  MDEV UUID                   : f715f63c-0d00-4007-9c5a-b07b0c6c05de
  Guest Driver Version        : N/A
  License Status              : N/A
  GPU Instance ID             : N/A
  Accounting Mode             : N/A
  ECC Mode                    : Disabled
  Accounting Buffer Size      : 4000
  Frame Rate Limit            : N/A
  FB Memory Usage
      Total                   : 10240 MiB
      Used                    : 0 MiB
      Free                    : 10240 MiB
  Utilization
      Gpu                     : 0 %
      Memory                  : 0 %
      Encoder                 : 0 %
      Decoder                 : 0 %
  Encoder Stats
      Active Sessions         : 0
      Average FPS             : 0
      Average Latency         : 0
  FBC Stats
```

```
      Active Sessions           : 0
      Average FPS               : 0
      Average Latency           : 0
```

3.3 Creating a MIG-backed vGPU

Important

SR-IOV must be enabled to create vGPUs and assign them to guest VMs.

1. Enable MIG mode for a GPU:

```
> sudo nvidia-smi -i 0 -mig 1
Enabled MIG Mode for GPU 00000000:B1:00.0
All done.
```

2. Query the GPU instance profile:

```
> sudo nvidia-smi mig -lgip
+-----------------------------------------------------------------------------+
| GPU instance profiles:                                                      |
| GPU   Name             ID    Instances   Memory     P2P    SM    DEC   ENC  |
|                              Free/Total   GiB              CE    JPEG  OFA  |
|=============================================================================|
|   0  MIG 1g.5gb        19     7/7         4.75       No     14     0     0   |
|                                                             1     0     0   |
+-----------------------------------------------------------------------------+
|   0  MIG 1g.5gb+me     20     1/1         4.75       No     14     1     0   |
|                                                             1     1     1   |
+-----------------------------------------------------------------------------+
|   0  MIG 2g.10gb       14     3/3         9.75       No     28     1     0   |
|                                                             2     0     0   |
+-----------------------------------------------------------------------------+
|   0  MIG 3g.20gb        9     2/2         19.62      No     42     2     0   |
|                                                             3     0     0   |
+-----------------------------------------------------------------------------+
|   0  MIG 4g.20gb        5     1/1         19.62      No     56     2     0   |
|                                                             4     0     0   |
+-----------------------------------------------------------------------------+
|   0  MIG 7g.40gb        0     1/1         39.50      No     98     5     0   |
|                                                             7     1     1   |
+-----------------------------------------------------------------------------+
```

3. Create a GPU instance specifying '5' as a GPU profile instance ID and optionally create a Compute Instance on it, either on the host server or within the guest:

```
> sudo nvidia-smi mig -cgi 5
Successfully created GPU instance ID  1 on GPU  0 using profile MIG 4g.20gb (ID  5)
> sudo nvidia-smi mig -cci -gi 1
Successfully created compute instance ID  0 on GPU  0 GPU instance ID  1 using
 profile MIG 4g.20gb (ID  3)
```

4. Verify the GPU instance:

```
> sudo nvidia-smi
Tue Sep 21 11:19:36 2021
+-----------------------------------------------------------------------------+
| NVIDIA-SMI 470.63       Driver Version: 470.63       CUDA Version: N/A      |
|-------------------------------+----------------------+----------------------+
| GPU  Name        Persistence-M| Bus-Id        Disp.A | Volatile Uncorr. ECC |
| Fan  Temp  Perf  Pwr:Usage/Cap|         Memory-Usage | GPU-Util  Compute M. |
|                               |                      |               MIG M. |
|===============================+======================+======================|
|   0  NVIDIA A100-PCI...  On   | 00000000:B1:00.0 Off |                   On |
| N/A   38C    P0    38W / 250W |      0MiB / 40536MiB |     N/A      Default |
|                               |                      |              Enabled |
+-------------------------------+----------------------+----------------------+

+-----------------------------------------------------------------------------+
| MIG devices:                                                                |
+------------------+----------------------+-----------+----------------------+
| GPU  GI  CI  MIG |         Memory-Usage |        Vol|         Shared       |
|      ID  ID  Dev |           BAR1-Usage | SM     Unc| CE  ENC  DEC  OFA  JPG|
|                  |                      |        ECC|                      |
|==================+======================+===========+======================|
|  0    1   0   0  |      0MiB / 20096MiB | 56      0 |  4   0    2    0    0 |
|                  |      0MiB / 32767MiB |           |                      |
+------------------+----------------------+-----------+----------------------+

+-----------------------------------------------------------------------------+
| Processes:                                                                  |
|  GPU   GI   CI        PID   Type   Process name                  GPU Memory |
|        ID   ID                                                   Usage      |
|=============================================================================|
|  No running processes found                                                 |
+-----------------------------------------------------------------------------+
```

5. Use the MIG instance. You can use the instance directly with the UUID—for example, assign it to a container or CUDA process.

You can also create a vGPU on top of it and assign it to a VM guest. The procedure is the same as for the vGPU with SR-IOV support. Refer to *Section 3.2, "Create a vGPU device with support for SR-IOV"*.

```
> sudo nvidia-smi -L
GPU 0: NVIDIA A100-PCIE-40GB (UUID: GPU-ee14e29d-dd5b-2e8e-eeaf-9d3debd10788)
 MIG 4g.20gb     Device  0: (UUID: MIG-fed03f85-fd95-581b-837f-d582496d0260)
```

4 Assign the vGPU device to a VM Guest

4.1 Assign by `libvirt`

1. Create a `libvirt`-based virtual machine (VM) with UEFI support and a normal VGA display.
2. Edit the VM's configuration by running **`virsh edit`** *VM-NAME*.
3. Add the new mdev device with the unique ID you used when creating the vGPU device to the <devices/> section.

Note

If you are using Q-series, use `display='on'` instead.

```
<hostdev mode='subsystem' type='mdev' managed='no' model='vfio-pci' display='off'>
  <source>
    <address uuid='4f3b6e47-0baa-4900-b0b1-284c1ecc192f'/>
  </source>
  <address type='pci' domain='0x0000' bus='0x00' slot='0x0a' function='0x0'/>
</hostdev>
```

4.2 Assign by QEMU

Add the following device to the QEMU command line. Use the unique ID that you used when creating the vGPU device:

```
-device vfio-pci,sysfsdev=/sys/bus/mdev/devices/4f3b6e47-0baa-4900-b0b1-284c1ecc192f
```

5 Configuring vGPU in VM Guest

5.1 Prepare the VM Guest

- During VM Guest installation, disable secure boot, enable the SSH service, and select `wicked` for networking.
- Disable the `nouveau` video driver. Edit the file `/etc/modprobe.d/50-blacklist.conf` and add the following line to its upper section:

```
blacklist nouveau
```

> **Important**
>
> Disabling `nouveau` works after you re-generate the initrd image with dracut, and then reboot the VM Guest.

5.2 Install the vGPU driver in the VM Guest

1. Install the following packages and their dependencies:

```
> sudo zypper install kernel-default-devel libglvnd-devel
```

2. Download the vGPU software from the NVIDIA portal. Make the NVIDIA vGPU driver executable and run it:

```
> chmod +x NVIDIA-Linux-x86_64-470.63.01-grid.run
> sudo ./NVIDIA-Linux-x86_64-470.63.01-grid.run
```

> **Tip**
>
> To enable dynamic kernel module support to get the module rebuilt automatically when a new kernel is installed, add the `--dkms` option:
>
> ```
> > sudo ./NVIDIA-Linux-x86_64-470.63.01-grid.run --dkms
> ```

3. During driver installation, select to run the **`nvidia-xconfig`** utility.

4. Verify the driver installation by checking the output of the **nvidia-smi** command:

```
> sudo nvidia-smi
+-----------------------------------------------------------------------------+
| NVIDIA-SMI 470.63.01    Driver Version: 470.63.01    CUDA Version: 11.4     |
|-------------------------------+----------------------+----------------------+
| GPU  Name        Persistence-M| Bus-Id        Disp.A | Volatile Uncorr. ECC |
| Fan  Temp  Perf  Pwr:Usage/Cap|         Memory-Usage | GPU-Util  Compute M. |
|                               |                      |               MIG M. |
|===============================+======================+======================|
|   0  GRID A100-10C       On   | 00000000:07:00.0 Off |                    0 |
| N/A   N/A    P0    N/A /  N/A |    930MiB / 10235MiB |      0%      Default |
|                               |                      |             Disabled |
+-------------------------------+----------------------+----------------------+

+-----------------------------------------------------------------------------+
| Processes:                                                                  |
|  GPU   GI   CI        PID   Type   Process name                  GPU Memory |
|        ID   ID                                                   Usage      |
|=============================================================================|
|  No running processes found                                                 |
+-----------------------------------------------------------------------------+
```

6 Licensing vGPU in the VM Guest

1. Create the configuration file `/etc/nvidia/gridd.conf` based on `/etc/nvidia/gridd.conf.template`.

2. a. For licenses that are served from the NVIDIA License System, update the following options:

   FeatureType

   For GPU passthrough, set `FeatureType` to `4` for computing and `2` for graphic purposes. In case of a virtual GPU, whatever vGPU type is created via **mdev** determines the feature set that is enabled in VM Guest.

ClientConfigTokenPath

Optional: To store the client configuration token in a custom location, add the `ClientConfigTokenPath` configuration parameter on a new line as `ClientConfigTokenPath="PATH_TO_TOKEN"`. By default, the client searches for the client configuration token in the `/etc/nvidia/ClientConfigToken/` directory.

Copy the client configuration token to the directory in which you want to store it.

b. For licenses that are served from the legacy NVIDIA vGPU software license server, update the following options:

ServerAddress

Add your license server IP address.

ServerPort

Use the default "7070" or the port configured during the server setup.

FeatureType

For GPU passthrough, set `FeatureType` to `4` for computing and `2` for graphic purposes. In case of a virtual GPU, whatever vGPU type is created via **`mdev`** determines the feature set that is enabled in VM Guest.

3. Restart the `nvidia-gridd` service:

```
> sudo systemctl restart nvidia-gridd.service
```

4. Inspect the log file for possible errors:

```
> sudo grep gridd /var/log/messages
[...]
Aug 5 15:40:06 localhost nvidia-gridd: Started (4293)
Aug 5 15:40:24 localhost nvidia-gridd: License acquired successfully.
```

7 Configuring a graphics mode

7.1 Create or update the `/etc/X11/xorg.conf` file

1. If there is no `/etc/X11/xorg.conf` on the VM Guest, run the **`nvidia-xconfig`** utility.
2. Query the GPU device for detailed information:

```
> nvidia-xconfig --query-gpu-info
Number of GPUs: 1

GPU #0:
Name      : GRID V100-16Q
UUID      : GPU-089f39ad-01cb-11ec-89dc-da10f5778138
PCI BusID : PCI:0:10:0

Number of Display Devices: 0
```

3. Add GPU's BusID to `/etc/X11/xorg.conf`, for example:

```
Section "Device"
Identifier "Device0"
Driver "nvidia"
BusID "PCI:0:10:0"
VendorName "NVIDIA Corporation"
EndSection
```

7.2 Verify the graphics mode

Verify the following:

- A graphic desktop is booted correctly.
- The 'X' process of a running X-server is running in GPU:

```
> nvidia-smi
+-----------------------------------------------------------------------------+
| NVIDIA-SMI 470.63.01    Driver Version: 470.63.01    CUDA Version: 11.4     |
|-------------------------------+----------------------+----------------------+
| GPU  Name        Persistence-M| Bus-Id        Disp.A | Volatile Uncorr. ECC |
| Fan  Temp  Perf  Pwr:Usage/Cap|         Memory-Usage | GPU-Util  Compute M. |
|                               |                      |               MIG M. |
```

```
|=============================+======================+======================|
|   0  GRID V100-4C        On   | 00000000:00:0A.0 Off |                  N/A |
| N/A   N/A    P0    N/A /  N/A |    468MiB /  4096MiB |      0%      Default |
|                              |                      |                  N/A |
+------------------------------+----------------------+----------------------+

+-----------------------------------------------------------------------------+
| Processes:                                                                  |
|  GPU   GI   CI        PID   Type   Process name                  GPU Memory |
|        ID   ID                                                   Usage      |
|=============================================================================|
|    0   N/A  N/A      1921      G   /usr/bin/X                         76MiB |
|    0   N/A  N/A      1957      G   /usr/bin/gnome-shell               87MiB |
+-----------------------------------------------------------------------------+
```

7.3 Remote display

You need to install and configure the VNC server package `x11vnc` inside the VM Guest, and start it with the following command:

```
> sudo x11vnc -display :0 -auth /run/user/1000/gdm/Xauthority -forever -shared -ncache -
bg -usepw -geometry 1900x1080
```

You can use **`virt-manager`** or **`virt-viewer`** to display the graphical output of a VM Guest.

Important

For a `libvirt`-based VM Guest, verify that its XML configuration includes `display=on` as suggested in *Section 4.1, "Assign by* `libvirt`*"*.

8 Configuring compute mode

1. Download and install the CUDA toolkit. You can find it at https://developer.nvidia.com/cuda-downloads?target_os=Linux&target_arch=x86_64&Distribution=SLES&target_version=15&target_type=runfile_local.
2. Download CUDA samples from https://github.com/nvidia/cuda-samples.
3. Run CUDA sampling example:

   ```
   > cd YOUR_GIT_CLONE_LOCATION/cuda-samples/Samples/0_Introduction/clock
   ```

```
>  make
/usr/local/cuda/bin/nvcc -ccbin g++ -I../../common/inc  -m64    --threads 0 -gencode
 arch=compute_35,code=sm_35 -gencode arch=compute_37,code=sm_37 -gencode
[...]
mkdir -p ../../bin/x86_64/linux/release
cp clock ../../bin/x86_64/linux/release
> ./clock
CUDA Clock sample
GPU Device 0: "Volta" with compute capability 7.0
Average clocks/block = 2820.718750
```

9 Additional tasks

This section introduces additional procedures that may be helpful after you have configured your vGPU.

9.1 Disabling Frame Rate Limiter

Frame Rate Limiter (FRL) is enabled by default. It limits the vGPU to a fixed frame rate, for example, 60fps. If you experience a bad graphic display, you may need to disable FRL, for example:

```
> sudo echo "frame_rate_limiter=0" > /sys/bus/mdev/
devices/86380ffb-8f13-4685-9c48-0e0f4e65fb87/nvidia/vgpu_params
```

9.2 Enabling/Disabling Error Correcting Code (ECC)

Since the NVIDIA Pascal architecture, NVIDIA GPU Cards support ECC memory to improve data integrity. ECC is also supported by software since NVIDIA vGPU 9.0.

To enable ECC:

```
> sudo nvidia-smi –e 1
> nvidia-smi -q
Ecc Mode
   Current                           : Enabled
   Pending                           : Enabled
```

To disable ECC:

```
> sudo nvidia-smi –e 0
```

9.3 Black screen in Virt-manager

If you see only a black screen in Virt-manager, press `Alt` – `Ctrl` – `2` from Virt-manager viewer. You should be able to get in the display again.

9.4 Black screen in VNC client when using a non-QEMU VNC server

Use the xvnc server.

9.5 Kernel panic occurs because the Nouveau and NVIDIA drivers compete on GPU resources

The boot messages looks as follows:

```
[ 16.742439] Hardware name: QEMU Standard PC (Q35 + ICH9, 2009), BIOS rel-1.14.0-0-
g155821a1990b-prebuilt.qemu.org 04/01/2014
[ 16.742441] RIP: 0010:__pci_enable_msi_range+0x3a9/0x3f0
[ 16.742443] Code: 76 60 49 8d 56 50 48 89 df e8 73 f6 fc ff e9 3b fe ff ff 31 f6 48 89
 df e8 64 73 fd ff e9 d6 fe ff ff 44 89 fd e9 1a ff ff ff <0f> 0b bd ea ff ff ff e9 0e ff
 ff ff bd ea ff ff ff e9 04 ff f
f ff
[ 16.742444] RSP: 0018:ffffb04bc052fb28 EFLAGS: 00010202
[ 16.742445] RAX: 0000000000000010 RBX: ffff9e93a85bc000 RCX: 0000000000000001
[ 16.742457] RDX: 0000000000000000 RSI: 0000000000000001 RDI: ffff9e93a85bc000
[ 16.742458] RBP: ffff9e93a2550800 R08: 0000000000000002 R09: ffffb04bc052fb1c
[ 16.742459] R10: 0000000000000050 R11: 0000000000000020 R12: ffff9e93a2550800
[ 16.742459] R13: 0000000000000001 R14: ffff9e93a2550ac8 R15: 0000000000000001
[ 16.742460] FS: 00007f9f26889740(0000) GS:ffff9e93bfdc0000(0000) knlGS:0000000000000000
[ 16.742461] CS: 0010 DS: 0000 ES: 0000 CR0: 0000000080050033
[ 16.742462] CR2: 00000000008aeb90 CR3: 0000000286470003 CR4: 0000000000170ee0
[ 16.742465] Call Trace:
[ 16.742503] ? __pci_find_next_cap_ttl+0x93/0xd0
[ 16.742505] pci_enable_msi+0x16/0x30
[ 16.743039] nv_init_msi+0x1a/0xf0 [nvidia]
[ 16.743154] nv_open_device+0x81b/0x890 [nvidia]
[ 16.743248] nvidia_open+0x2f7/0x4d0 [nvidia]
[ 16.743256] ? kobj_lookup+0x113/0x160
[ 16.743354] nvidia_frontend_open+0x53/0x90 [nvidia]
[ 16.743361] chrdev_open+0xc4/0x1a0
[ 16.743370] ? cdev_put.part.2+0x20/0x20
[ 16.743374] do_dentry_open+0x204/0x3a0
[ 16.743378] path_openat+0x2fc/0x1520
[ 16.743382] ? unlazy_walk+0x32/0xa0
```

```
[ 16.743383] ? terminate_walk+0x8c/0x100
[ 16.743385] do_filp_open+0x9b/0x110
[ 16.743387] ? chown_common+0xf7/0x1c0
[ 16.743390] ? kmem_cache_alloc+0x18a/0x270
[ 16.743392] ? do_sys_open+0x1bd/0x260
[ 16.743394] do_sys_open+0x1bd/0x260
[ 16.743400] do_syscall_64+0x5b/0x1e0
[ 16.743409] entry_SYSCALL_64_after_hwframe+0x44/0xa9
[ 16.743418] RIP: 0033:0x7f9f2593961d
[ 16.743420] Code: f0 25 00 00 41 00 3d 00 00 41 00 74 48 64 8b 04 25 18 00 00 00 85 c0
 75 64 89 f2 b8 01 01 00 00 48 89 fe bf 9c ff ff ff 0f 05 <48> 3d 00 f0 ff ff 0f 87 97 00
 00 00 48 8b 4c 24 28 64 48 33 0
c 25
[ 16.743420] RSP: 002b:00007ffcfa214930 EFLAGS: 00000246 ORIG_RAX: 0000000000000101
[ 16.743422] RAX: ffffffffffffffda RBX: 00007ffcfa214c30 RCX: 00007f9f2593961d
[ 16.743422] RDX: 0000000000080002 RSI: 00007ffcfa2149b0 RDI: 00000000ffffff9c
[ 16.743423] RBP: 00007ffcfa2149b0 R08: 0000000000000000 R09: 0000000000000000
[ 16.743424] R10: 0000000000000000 R11: 0000000000000246 R12: 0000000000000000
[ 16.743424] R13: 00007ffcfa214abc R14: 0000000000925ae0 R15: 0000000000000000
[ 16.743426] ---[ end trace 8bf4d15315659a3e ]---
[ 16.743431] NVRM: GPU 0000:00:0a.0: Failed to enable MSI; falling back to PCIe virtual-
wire interrupts.
```

Make sure to run **`mkintrd`** and reboot after disabling the Nouveau driver. Refer to *Section 5.1, "Prepare the VM Guest"*.

9.6 Filing an NVIDIA vGPU bug

While filing an NVIDIA vGPU-related bug report to us, please attach the vGPU configuration data `nvidia-bug-report.log.gz` collected by the **`nvidia-bug-report.sh`** utility. Make sure you cover both VM Host Server and VM Guest.

9.7 Configuring a License Server

Refer to https://docs.nvidia.com/grid/ls/latest/grid-license-server-user-guide/index.html.

10 For more information

NVIDIA has an extensive documentation on vGPU. Refer to https://docs.nvidia.com/grid/latest/grid-vgpu-user-guide/index.html for details.

11 NVIDIA virtual GPU background

11.1 NVIDIA GPU architectures

There are two types of GPU architectures:

Time-sliced vGPU architecture

Introduced on GPUs that are based on the NVIDIA Ampere GPU architecture. Only Ampere GPU cards can support MIG-backed vGPU.

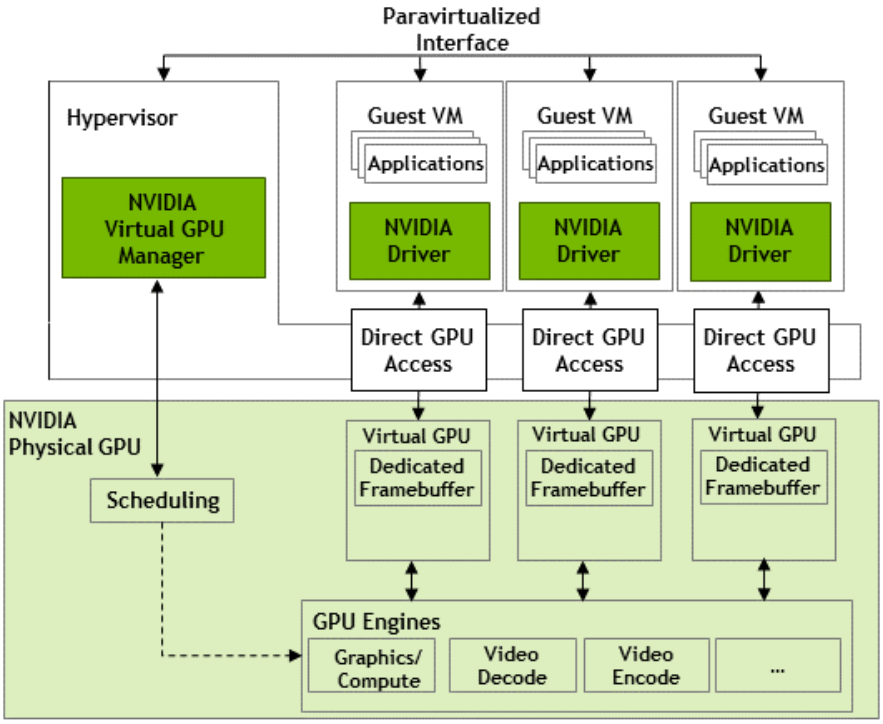

FIGURE 1: TIME-SLICED ARCHITECTURE (SOURCE: HTTPS://DOCS.NVIDIA.COM/GRID/LATEST/GRID-VGPU-USER-GUIDE/INDEX.HTML)

Multi-Instance GPU (MIG) vGPU architecture

All GPU cards support time-sliced vGPU. To do so, Ampere GPU cards use the Single Root I/O Virtualization (SR-IOV) mechanism, while Volta and the earlier GPU cards use the mediated device mechanism. Volta and the earlier architecture are based on mediated device mechanism. These two mechanisms are transparent to a VM. However, they need different configurations from the host side.

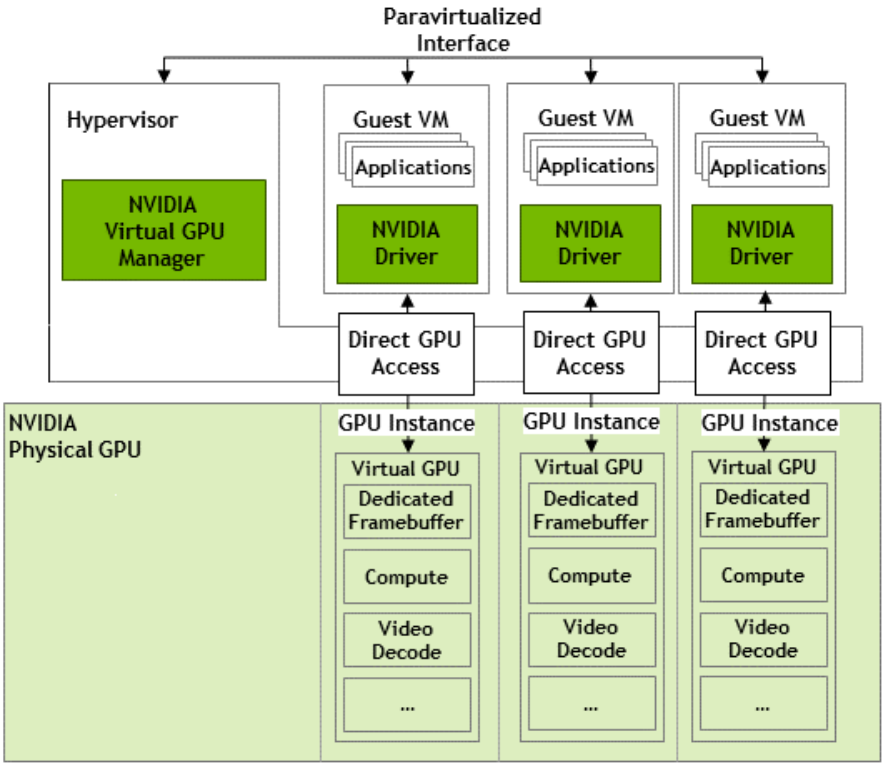

FIGURE 2: MIG-BACKED ARCHITECTURE (SOURCE: HTTPS://DOCS.NVIDIA.COM/GRID/LATEST/GRID-VGPU-USER-GUIDE/INDEX.HTML)

11.2 vGPU types

Each physical GPU can support several different types of vGPUs. vGPU types have a fixed amount of framebuffer, the number of supported display heads, and maximum resolutions. NVIDIA has four types of vGPUs: A, B, C and Q-series. SUSE currently supports Q and C-series.

TABLE 1: VGPU TYPES

vGPU series	Optimal workload
Q-series	Virtual workstations for creative and technical professionals who require the performance and features of the NVIDIA Quadro technology.
C-series	Compute-intensive server workloads, for example, artificial intelligence (AI), deep learning, or high-performance computing (HPC).
B-series	Virtual desktops for business professionals and knowledge workers.

vGPU series	Optimal workload
A-series	Application streaming or session-based solutions for virtual applications users.

11.3 Valid vGPU configurations on a single GPU

11.3.1 Time-sliced vGPU configurations

For time-sliced vGPUs, all vGPUs types must be the same:

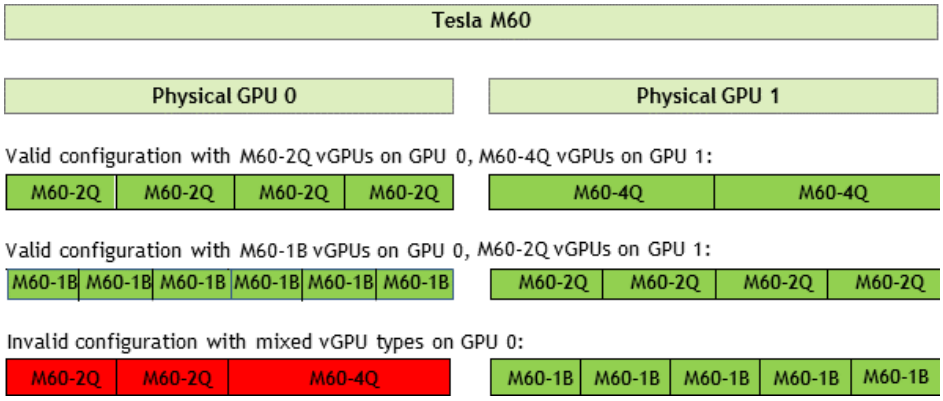

FIGURE 3: EXAMPLE TIME-SLICED VGPU CONFIGURATIONS ON NVIDIA TESLA M60 (SOURCE: HTTPS://DOCS.NVIDIA.COM/GRID/LATEST/GRID-VGPU-USER-GUIDE/INDEX.HTML)

11.3.2 MIG-backed vGPU configurations

For MIG-backed vGPUs, vGPUs can be both homogeneous and mixed-type:

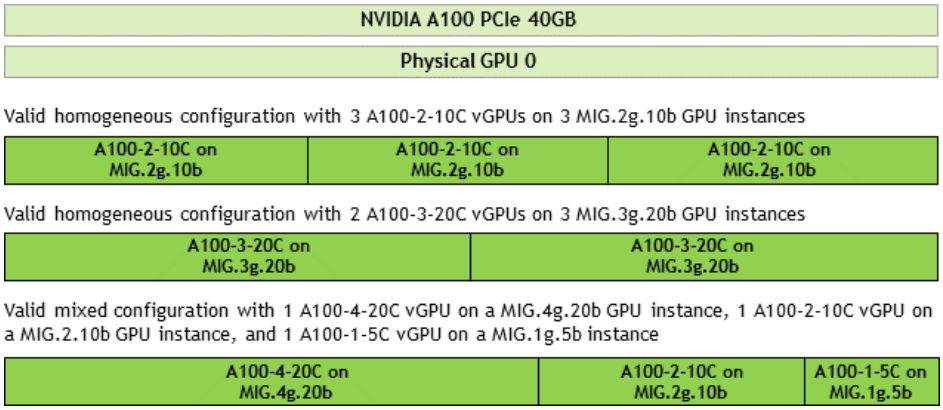

FIGURE 4: EXAMPLE MIG-BACKED VGPU CONFIGURATIONS ON NVIDIA A100 PCIE 40 GB (SOURCE: HTTPS://DOCS.NVIDIA.COM/GRID/LATEST/GRID-VGPU-USER-GUIDE/INDEX.HTML)

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