

Building GPU-enabled Kubernetes single node cluster for MLOps experiments with new+second hand components

1. **SUPERMICRO MBD-X11SAE-M-O Micro ATX Server Motherboard LGA 1151 Intel C236** from newegg.com - \$200 ([Link to Newegg](#))
2. **Intel Xeon E3-1275 V6 Kaby Lake 3.8 GHz (4.2 GHz Turbo) LGA 1151 Server Processor Intel HD Graphics P630** - \$360 ([Link to Newegg](#))
3. 64GB of RAM: four DIMMs of **16GB DDR4-2400 UDIMM 1.2V CL17** (SKU: CT16G4DFD824A) from Crucial: \$250 ([Link to Crucial](#))
4. **Sabrent Rocket Q 1TB NVMe PCIe M.2 2280 Internal SSD High Performance Solid State Drive R/W 3200/2000MB/s (SB-RKTQ-1TB)**: \$110 ([Link to Amazon](#))
5. **Supermicro SNK-P0046A4 Heatsink 2U+ Active Heatsink LGA1156 & LGA1155**: \$25 ([Link to Supermicro store](#))
6. **Nvidia Tesla M40 12GB** (Second hand): \$125([Link to Ebay](#))
7. Dual 8 to 8 Graphics Power Cable (SKU: 030-0571-000): \$6 ([Link to Ebay](#))

Really old components:

8. HDD and SSD: Western Digital HDD 250GB SATA3 6.0Gb/s 7.2K (Used): \$0, SSD 120 GB SATA3 6.0 Gb/s 2.5" (Used): \$0, SSD 120 GB SATA3 6.0 Gb/s 2.5" (Used): \$0
9. SuperMicro Chassis 733I-500B with 500W PSU (Used): \$0 ([Link to SuperMicro](#))

Final configuration: 1 x Xeon E3-1275, 64GB RAM, 1.5TB storage with 1TB on NVMe, NVIDIA GPU (Maxwell architecture) with 12GB GDDR5 for **total: \$1076.0 (Ouch!)**

Additional Notes:

The 500W power supply coming with the mid tower chassis seems adequate for the graphics card provided you do not plan to reach frequently the max 250W which the card may need in peak memory and GPU utilization. The CPU drains no more than 73W, and the motherboard with the chipset and 64GB of RAM. Note that the chassis has an extension space allowing mounting larger power supply in case the one with 500W is not sufficient.

Use Ubuntu 20.04 and upgrade to 20.10.

Change the runlevel to 3 which will disable the XWindows subsystem as the NVIDIA GPU will not be used by default and NVIDIA kernel module will not be loaded. With runlevel set to 3 install the latest NVIDIA drivers for Ubuntu as:

```
dimitar@xeon-ubuntu:~/Downloads$ sudo ./NVIDIA-Linux-x86_64-460.32.03.run
```

Connect all disks (NVMe, SSD1, SSD2, and HDD) in a single file system using the supplied with the Ubuntu 20.10 logical volume manager **LVM2**.

Do not configure swap partition in case you are going to run Kubernetes locally using microk8s or minikube.

Do install the Nvidia container toolkit on Ubuntu 20.10. Note: while [Ubuntu 20.10 is not yet official supported](#) the Nvidia Container Toolkit [can be installed without issue on 20.10](#) using the following instructions:

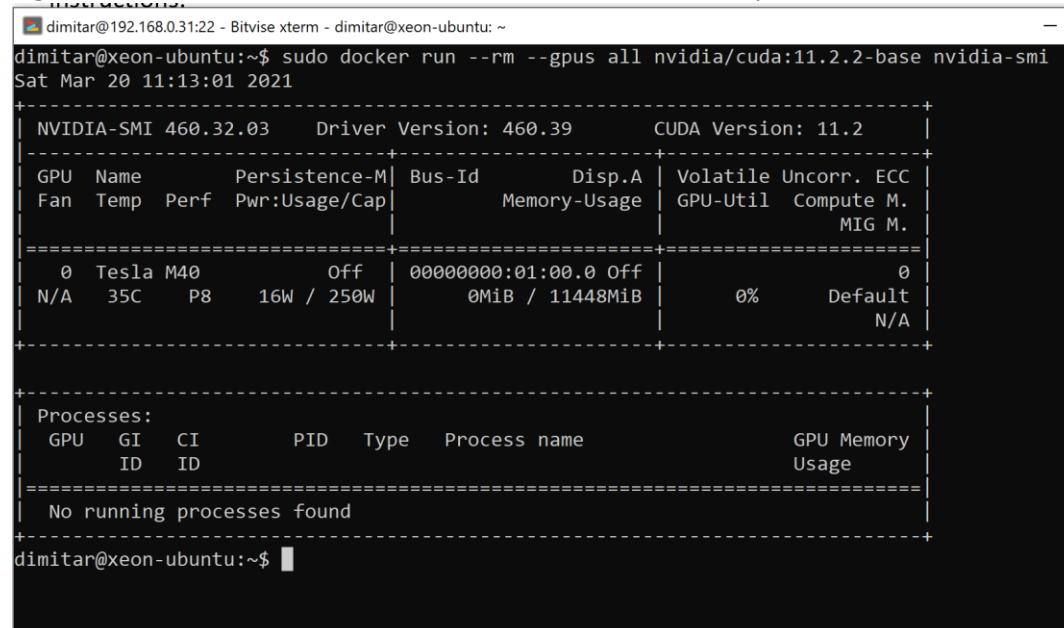
```
curl -s -L https://nvidia.github.io/nvidia-docker/gpgkey | \
  sudo apt-key add -
distribution=$(. /etc/os-release;echo ${ID}20.04)
curl -s -L https://nvidia.github.io/nvidia-docker/${distribution}/nvidia-docker.list | \
  sudo tee /etc/apt/sources.list.d/nvidia-docker.list
sudo apt-get update
sudo apt-get install -y nvidia-docker2
```

Finally, to verify the successful installation run the following commands:

```
sudo systemctl restart docker
sudo docker run --rm --gpus all nvidia/cuda:11.2.2-base nvidia-smi
```

You should be seeing an output like the one on the Figure below:

Figure : execution of **nvidia-smi** from a docker container with preinstalled cuda-11.2 base image



```
dimitar@192.168.0.31:22 - Bitwise xterm - dimitar@xeon-ubuntu: ~
dimitar@xeon-ubuntu:~$ sudo docker run --rm --gpus all nvidia/cuda:11.2.2-base nvidia-smi
Sat Mar 20 11:13:01 2021

+-----+
| NVIDIA-SMI 460.32.03      Driver Version: 460.39      CUDA Version: 11.2      |
+-----+-----+-----+
| GPU   Name                Persistence-M| Bus-Id        Disp.A | Volatile Uncorr. ECC |
| Fan  Temp  Perf    Pwr:Usage/Cap|      Memory-Usage | GPU-Util  Compute M. |
|=====+=====+=====+
| 0   Tesla M40              Off        | 00000000:01:00.0 Off  |          0%          0 |
| N/A   35C    P8         16W / 250W   | 0MiB / 11448MiB |           Default     |
|=====+=====+=====+
+-----+-----+-----+

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

dimitar@xeon-ubuntu:~$
```

Possible error which can be received while executing **nvidia-smi** in a container or directly on the OS is:

```
failed to initialize NVML: Driver/Library version mismatch
```

This error is discussed on StackOverflow [here](#). The solution is to identify the duplicate versions of the installed nvidia drivers via `dpkg -l | grep -i nvidia` and update the nvidia driver which was installed on the OS with:

```
sudo apt install nvidia-driver-440
```

Figure: Shown are the top power consuming processes obtained by using the tool **PowerTOP**

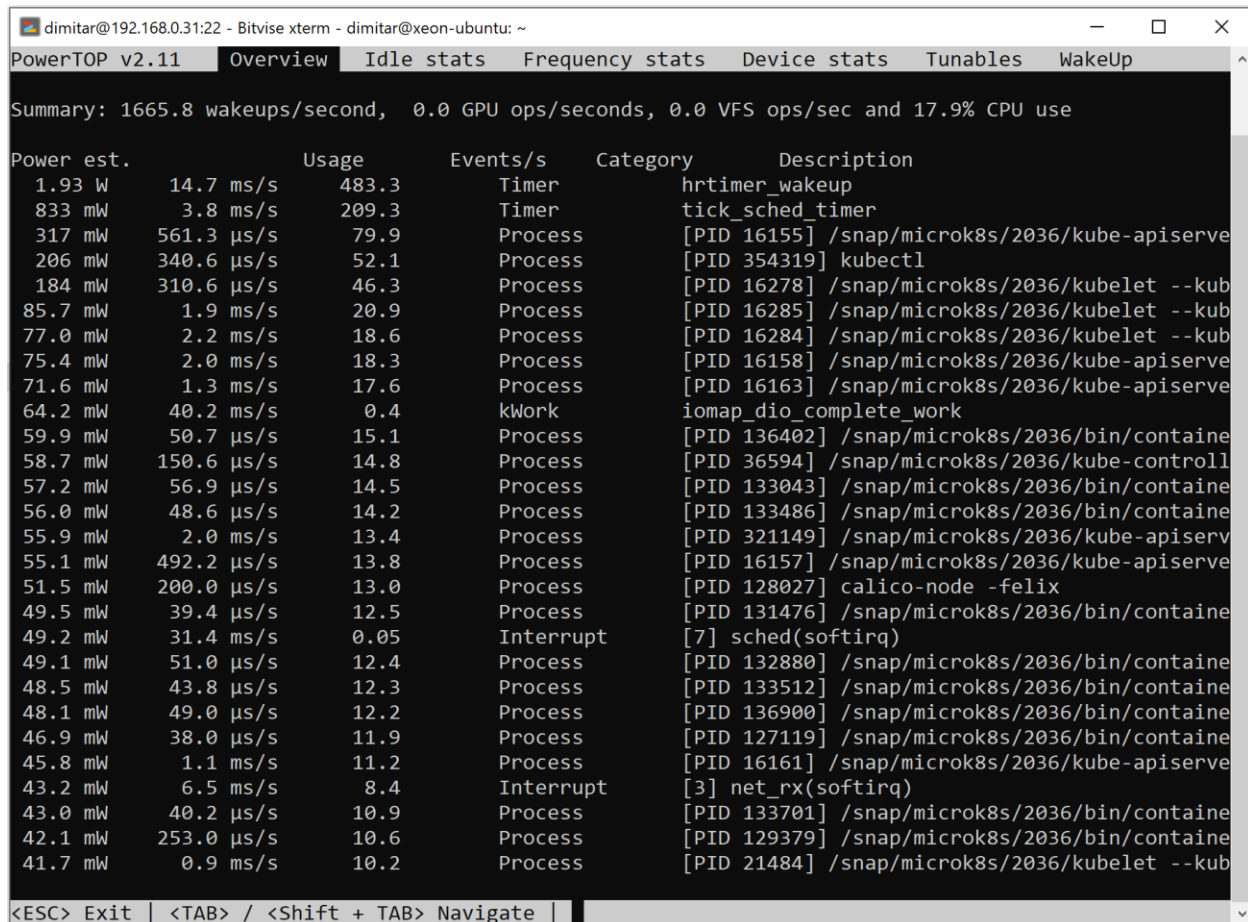


Figure: the total system memory and other memory related stats obtained by `vmstat -s`:

```
dimitar@192.168.0.31:22 - Bitvise xterm - dimitar@xeon-ubuntu: ~
dimitar@xeon-ubuntu:~$ vmstat -s
65621300 K total memory
5790344 K used memory
10494432 K active memory
4936536 K inactive memory
48952300 K free memory
289344 K buffer memory
10589312 K swap cache
0 K total swap
0 K used swap
0 K free swap
369710 non-nice user cpu ticks
1180 nice user cpu ticks
179386 system cpu ticks
3873103 idle cpu ticks
460538 IO-wait cpu ticks
0 IRQ cpu ticks
7295 softirq cpu ticks
0 stolen cpu ticks
10289743 pages paged in
15741731 pages paged out
0 pages swapped in
0 pages swapped out
58038029 interrupts
156949247 CPU context switches
1613699613 boot time
410207 forks
```

Figure: Querying the GPU and obtaining GPU configuration info by using Cuda 11.2 utility `deviceQuery`

```
dimitar@192.168.0.31:22 - Bitvise xterm - dimitar@xeon-ubuntu: /usr/local/cuda-11.2/samples/1_Uutilities/deviceQuery
dimitar@xeon-ubuntu:/usr/local/cuda-11.2/samples/1_Uutilities/deviceQuery$ ./deviceQuery
./deviceQuery Starting...

  CUDA Device Query (Runtime API) version (CUDA RT API V8.6.0)

Detected 1 CUDA Capable device(s)

Device 0: "Tesla M40"
  CUDA Driver Version / Runtime Version      11.2 / 11.2
  CUDA Capability Major/Minor version number: 5.2
  Total amount of global memory:              11449 MBytes (12004753408 bytes)
  (24) Multiprocessors, (128) CUDA Cores/MP: 3072 CUDA Cores
  GPU Max Clock rate:                        1112 MHz (1.11 GHz)
  Memory Clock rate:                          3004 Mhz
  Memory Bus Width:                           384-bit
  L2 Cache Size:                             3145728 bytes
  Maximum Texture Dimension Size (x,y,z)     1D=(65536), 2D=(65536, 65536), 3D=(4096, 4096, 4096)
  Maximum Layered 1D Texture Size, (num) layers 1D=(16384), 2048 layers
  Maximum Layered 2D Texture Size, (num) layers 2D=(16384, 16384), 2048 layers
  Total amount of constant memory:            65536 bytes
  Total amount of shared memory per block:    49152 bytes
  Total shared memory per multiprocessor:     98304 bytes
  Total number of registers available per block: 65536
  Warp size:                                 32
  Maximum number of threads per multiprocessor: 2048
  Maximum number of threads per block:        1024
  Max dimension size of a thread block (x,y,z): (1024, 1024, 64)
  Max dimension size of a grid size    (x,y,z): (2147483647, 65535, 65535)
  Maximum memory pitch:                       2147483647 bytes
  Texture alignment:                          512 bytes
  Concurrent copy and kernel execution:       Yes with 2 copy engine(s)
  Run time limit on kernels:                   Yes
  Integrated GPU sharing Host Memory:          No
  Support host page-locked memory mapping:    Yes
  Alignment requirement for Surfaces:          Yes
```

Figure: Running bandwidth test with the CUDA utility **bandwidthTest**

```
dimitar@192.168.0.31:22 - Bitwise xterm - dimitar@xeon-ubuntu: /usr/local/cuda-11.2/samples/1_Uutilities/bandwidthTest
dimitar@xeon-ubuntu:/usr/local/cuda-11.2/samples/1_Uutilities/bandwidthTest$ ./bandwidthTest
[CUDA Bandwidth Test] - Starting...
Running on...

Device 0: Tesla M40
Quick Mode

Host to Device Bandwidth, 1 Device(s)
PINNED Memory Transfers
Transfer Size (Bytes)      Bandwidth(GB/s)
32000000                  12.2

Device to Host Bandwidth, 1 Device(s)
PINNED Memory Transfers
Transfer Size (Bytes)      Bandwidth(GB/s)
32000000                  12.9

Device to Device Bandwidth, 1 Device(s)
PINNED Memory Transfers
Transfer Size (Bytes)      Bandwidth(GB/s)
32000000                  216.8

Result = PASS

NOTE: The CUDA Samples are not meant for performance measurements. Results may vary when GPU Boost is enabled.
dimitar@xeon-ubuntu:/usr/local/cuda-11.2/samples/1_Uutilities/bandwidthTest$
```

Figure: NVMe 1 TB mounted as **/dev/nvme0n1**

```
dimitar@xeon-ubuntu:~$ sudo nvme list
Node      SN                      Model                      Namespace Usage              Format              FW Rev
-----
/dev/nvme0n1  0546070A1EF388282021 Sabrent Rocket Q           1              1.00 TB / 1.00 TB  512 B + 0 B      RKT30Q.2
dimitar@xeon-ubuntu:~$
```

Figure: rotating disk drive WDC 250GB mounted as /dev/sda

```
dimitar@192.168.0.31:22 - Bitvise xterm - dimitar@xeon-ubuntu: ~
dimitar@xeon-ubuntu:~$ sudo hdparm -I /dev/sda

/dev/sda:

ATA device, with non-removable media
  Model Number:      WDC WD2500AAJS-00B4A0
  Serial Number:     WD-WCAT10585931
  Firmware Revision: 01.03A01
  Transport:         Serial, SATA 1.0a, SATA II Extensions, SATA Rev 2.5
Standards:
  Supported: 8 7 6 5
  Likely used: 8
Configuration:
  Logical          max      current
  cylinders         16383   16383
  heads             16      16
  sectors/track     63      63
  --
  CHS current addressable sectors: 16514064
  LBA  user addressable sectors: 268435455
  LBA48 user addressable sectors: 488397168
  Logical/Physical Sector size: 512 bytes
  device size with M = 1024*1024: 238475 MBytes
  device size with M = 1000*1000: 250059 MBytes (250 GB)
  cache/buffer size = 8192 KBytes
```

Figure: Solid State Disk MKN 120GB mounted as /dev/sdb

```
dimitar@192.168.0.31:22 - Bitvise xterm - dimitar@xeon-ubuntu: ~
dimitar@xeon-ubuntu:~$ sudo hdparm -I /dev/sdb

/dev/sdb:

ATA device, with non-removable media
  Model Number:      MKNSSDCR120GB
  Serial Number:     MKN1210A0000055250
  Firmware Revision: 501ABBF0
  Transport:         Serial, ATA8-AST, SATA 1.0a, SATA II Extensions, SATA Rev 2.5, SATA Rev
2.6, SATA Rev 3.0
Standards:
  Used: unknown (minor revision code 0x0110)
  Supported: 8 7 6 5
  Likely used: 8
Configuration:
  Logical          max      current
  cylinders         16383   16383
  heads             16      16
  sectors/track     63      63
  --
  CHS current addressable sectors: 16514064
  LBA  user addressable sectors: 234441648
  LBA48 user addressable sectors: 234441648
  Logical Sector size: 512 bytes
  Physical Sector size: 512 bytes
  Logical Sector-0 offset: 0 bytes
  device size with M = 1024*1024: 114473 MBytes
  device size with M = 1000*1000: 120034 MBytes (120 GB)
  cache/buffer size = unknown
  Nominal Media Rotation Rate: Solid State Device
```

Figure : Solid State Disk OSZ-VERTEX3 120GB mounted as `/dev/sdc`

```
dimitar@192.168.0.31:22 - Bitvise xterm - dimitar@xeon-ubuntu: ~
dimitar@xeon-ubuntu:~$ sudo hdparm -I /dev/sdc

/dev/sdc:

ATA device, with non-removable media
    Model Number:      OCZ-VERTEX3
    Serial Number:     OCZ-QYVTL4SXQ484P9GT
    Firmware Revision: 2.15
    Transport:         Serial, ATA8-AST, SATA 1.0a, SATA II Extensions, SATA Rev 2.5, SATA Rev
2.6, SATA Rev 3.0
Standards:
    Used: unknown (minor revision code 0x0110)
    Supported: 8 7 6 5
    Likely used: 8
Configuration:
    Logical          max      current
    cylinders        16383    16383
    heads            16       16
    sectors/track    63       63
    --
    CHS current addressable sectors: 16514064
    LBA  user addressable sectors: 234441648
    LBA48 user addressable sectors: 234441648
    Logical Sector size:             512 bytes
    Physical Sector size:            512 bytes
    Logical Sector-0 offset:         0 bytes
    device size with M = 1024*1024:  114473 MBytes
    device size with M = 1000*1000:  120034 MBytes (120 GB)
    cache/buffer size  = unknown
    Nominal Media Rotation Rate: Solid State Device
```

Figure: Mounted partitions obtained via lsblk

```
dimitar@192.168.0.31:22 - Bitvise xterm - dimitar@xeon-ubuntu: /opt/test
dimitar@xeon-ubuntu:/opt/test$ sudo lsblk
NAME                                MAJ:MIN RM  SIZE RO TYPE MOUNTPOINT
loop0                               7:0      0   97.9M  1 loop /snap/core/10583
loop1                               7:1      0   98.4M  1 loop /snap/core/10823
loop2                               7:2      0   55.4M  1 loop /snap/core18/1944
loop3                               7:3      0   55.5M  1 loop /snap/core18/1988
loop4                               7:4      0    9.5M  1 loop /snap/helm/328
loop5                               7:5      0    9.5M  1 loop /snap/helm/325
loop6                               7:6      0   69.6M  1 loop /snap/juju/15429
loop7                               7:7      0   69.4M  1 loop /snap/juju/15283
loop8                               7:8      0   21.4M  1 loop /snap/kube-apiserver/1997
loop9                               7:9      0   21.4M  1 loop /snap/kube-apiserver/1926
loop10                              7:10     0   69.9M  1 loop /snap/lxd/19188
loop11                              7:11     0   67.8M  1 loop /snap/lxd/18150
loop12                              7:12     0  205.7M  1 loop /snap/microk8s/2036
loop13                              7:13     0  206.9M  1 loop /snap/microk8s/1856
loop14                              7:14     0    52M  1 loop /snap/minikube/4
sda                                  8:0      0  232.9G  0 disk
├─sda1                              8:1      0   487M  0 part /boot
├─sda2                              8:2      0     1K  0 part
├─sda5                              8:5      0  232.4G  0 part
│   └─xeon--ubuntu--vg-root 253:0     0   1.3T  0 lvm /
│       └─xeon--ubuntu--vg-swap_1 253:1     0    24G  0 lvm
sdb                                  8:16     0  111.8G  0 disk
├─sdb1                              8:17     0  111.8G  0 part
│   └─xeon--ubuntu--vg-root 253:0     0   1.3T  0 lvm /
sdc                                  8:32     0  111.8G  0 disk
├─sdc1                              8:33     0  111.8G  0 part
│   └─xeon--ubuntu--vg-root 253:0     0   1.3T  0 lvm /
sr0                                  11:0     1  1024M  0 rom
nvme0n1                             259:0     0  931.5G  0 disk
└─xeon--ubuntu--vg-root 253:0     0   1.3T  0 lvm /
dimitar@xeon-ubuntu:/opt/test$
```


Figure: Physical volumes under LVM2 obtained by `pvdisplay`

```
dimitar@192.168.0.31:22 - Bitwise xterm - dimitar@xeon-ubuntu: /opt/test
dimitar@xeon-ubuntu:/opt/test$ sudo pvdisplay
--- Physical volume ---
PV Name                /dev/sda5
VG Name                xeon-ubuntu-vg
PV Size                <232.41 GiB / not usable 2.00 MiB
Allocatable           yes (but full)
PE Size                4.00 MiB
Total PE              59496
Free PE                0
Allocated PE          59496
PV UUID               uSQadT-eXat-Hq8V-rTU0-yey1-h5Qe-oypIb0

--- Physical volume ---
PV Name                /dev/sdb1
VG Name                xeon-ubuntu-vg
PV Size                <111.79 GiB / not usable 4.00 MiB
Allocatable           yes (but full)
PE Size                4.00 MiB
Total PE              28617
Free PE                0
Allocated PE          28617
PV UUID               ncrCwa-uSF7-F2b0-OM1E-Whdw-YiVf-LgLxoe

--- Physical volume ---
PV Name                /dev/sdc1
VG Name                xeon-ubuntu-vg
PV Size                <111.79 GiB / not usable 4.00 MiB
Allocatable           yes (but full)
PE Size                4.00 MiB
Total PE              28617
Free PE                0
Allocated PE          28617
PV UUID               n9zSsx-MADA-a95B-D9As-QXkE-tM0Y-ls1wfh

--- Physical volume ---
PV Name                /dev/nvme0n1
VG Name                xeon-ubuntu-vg
PV Size                931.51 GiB / not usable 1.71 MiB
Allocatable           yes (but full)
PE Size                4.00 MiB
Total PE              238467
Free PE                0
Allocated PE          238467
PV UUID               kS2dJY-q9uj-MeYN-bK5K-U4l0-urFX-h0zgwG
```

Figure: Snapshots from the assembly of the system including the new mother board, The NVIDIA Tesla card, memory DIMMs, the Xeon CPU and the PCIe NVMe module

