

Illinois Institute of Technology

Advanced Operating System
(CS-550)

WA-1

Submitted By:

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TA: Mr. Lan Nguyen

TA: Ms. Sonal Gaikwad

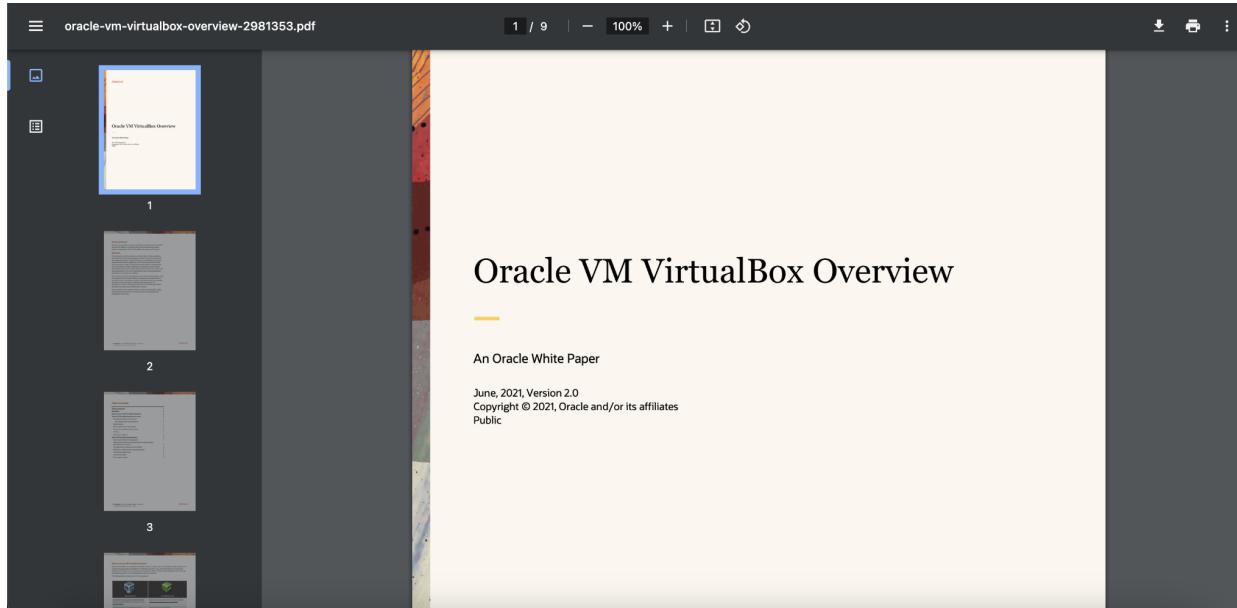
TA: Mr. Adarsh Agrawal



Machine used: Macbook M2 air

1. (30 points) Setup VM, Linux, and basic testing – must take screen shots at each step to receive points

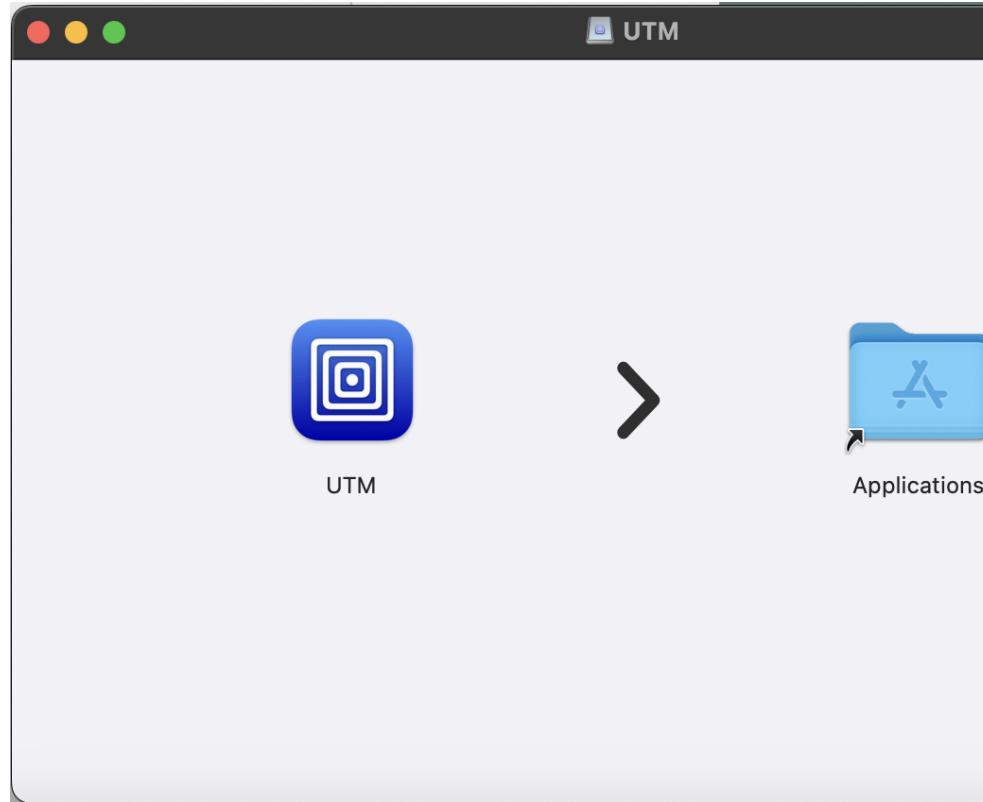
- Read Oracle VirtualBox White Paper



- Download Oracle VirtualBox 7.0 (UTM)



- c. Install VirtualBox 7.0 (for M1/M2 Apple, use UTM)



- d. Download Ubuntu 22.04 Linux ISO image

A screenshot of a web page from "ubuntu releases". The main title is "Ubuntu 22.04.3 LTS (Jammy Jellyfish)". Below the title, there is a section titled "Select an image". It says "Ubuntu is distributed on four types of images described below." There are four options: "Server install image", "64-bit ARM (ARMv8/AArch64) server install image", "PowerPC64 Little-Endian server install image", and "IBM System z server install image".

ubuntu[®] releases

Ubuntu 22.04.3 LTS (Jammy Jellyfish)

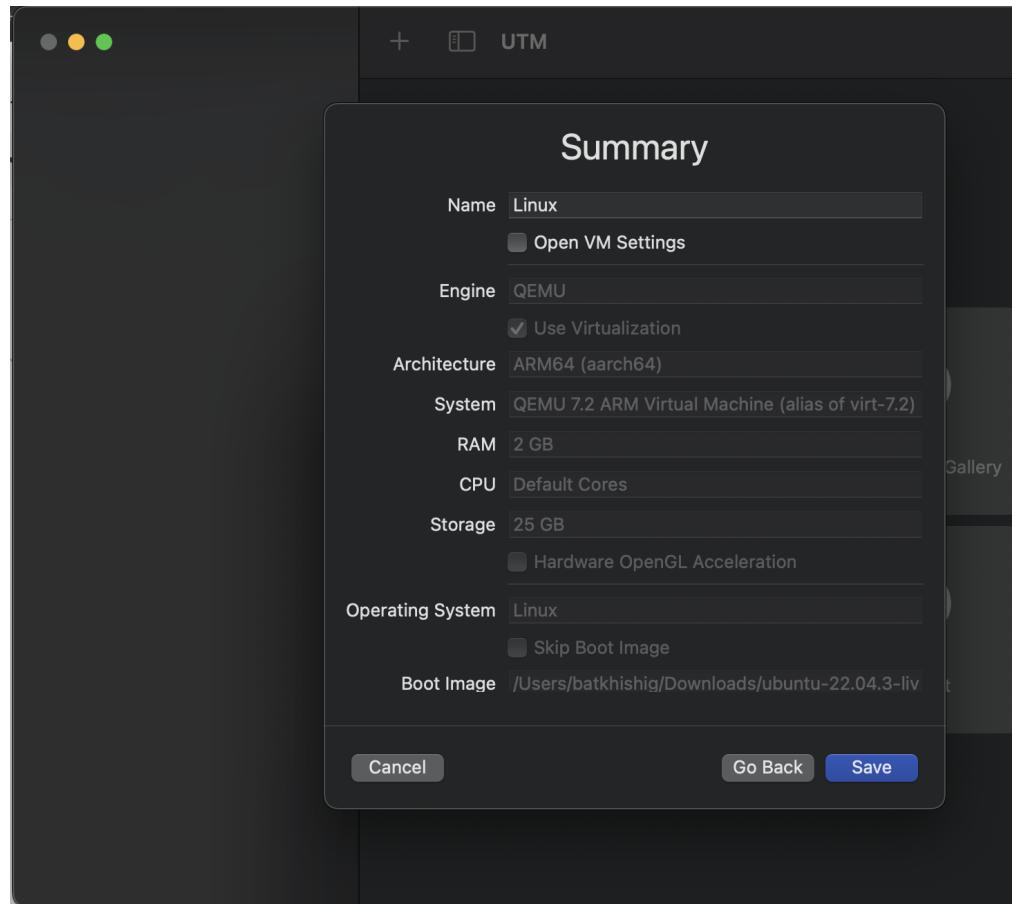
Select an image

Ubuntu is distributed on four types of images described below.

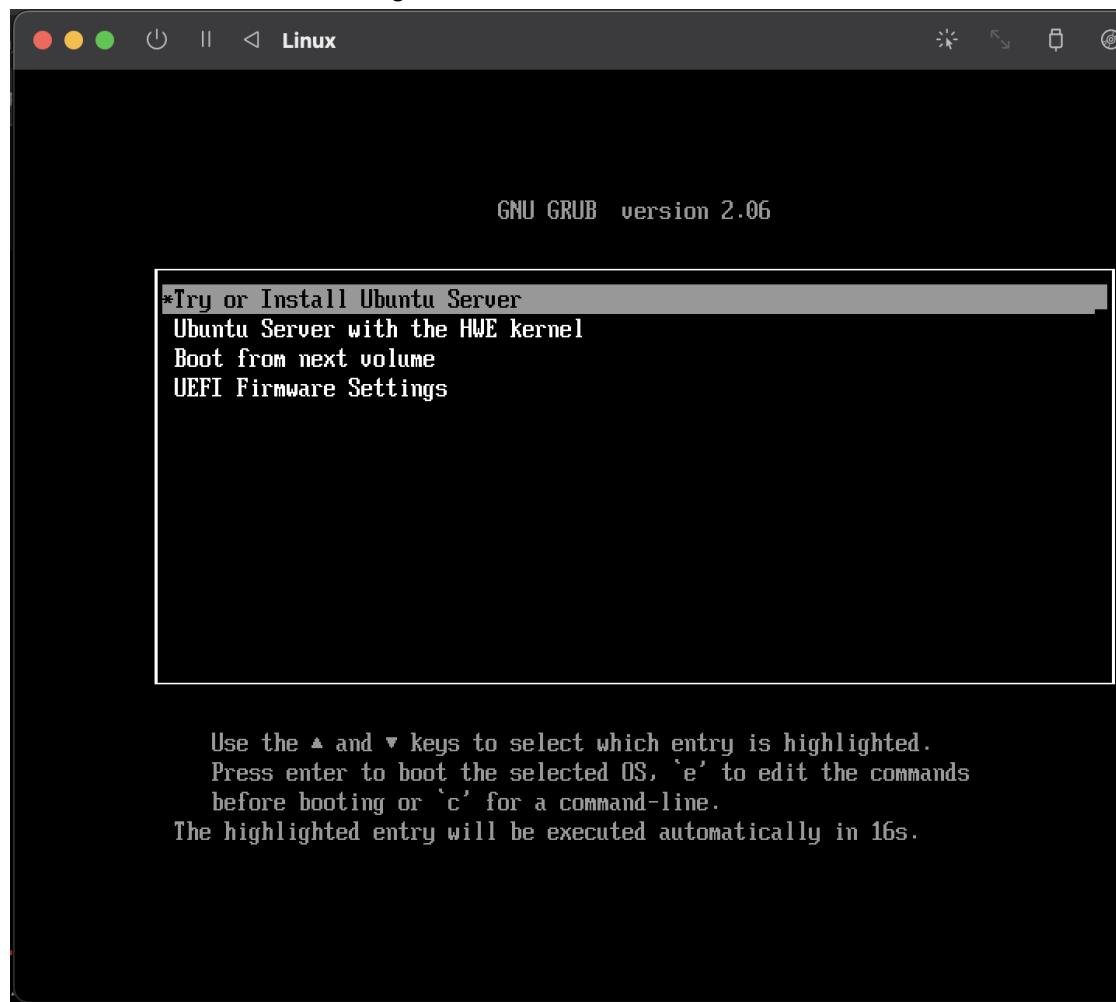
Server install image The server install image allows you to install Ubuntu permanently on a computer for use as a server. It will not install a graphical user interface.	64-bit ARM (ARMv8/AArch64) server install image For 64-bit ARMv8 processors and above.
PowerPC64 Little-Endian server install image For POWER9 and POWER10 Little-Endian systems.	IBM System z server install image For IBM System z series mainframes, such as IBM LinuxONE.

- e. Create Virtual Machine (VM), to support Linux, Ubuntu, 64-bit, 4GB RAM, Virtual Disk 25GB, VDI image, dynamically allocated, 2-core, and a network interface (1GbE or WiFi) with Bridged Adapter

I installed the server version(without GUI). Therefore, I allocated 2GB RAM.



f. Install Linux from the ISO image



g. Create a user id and password



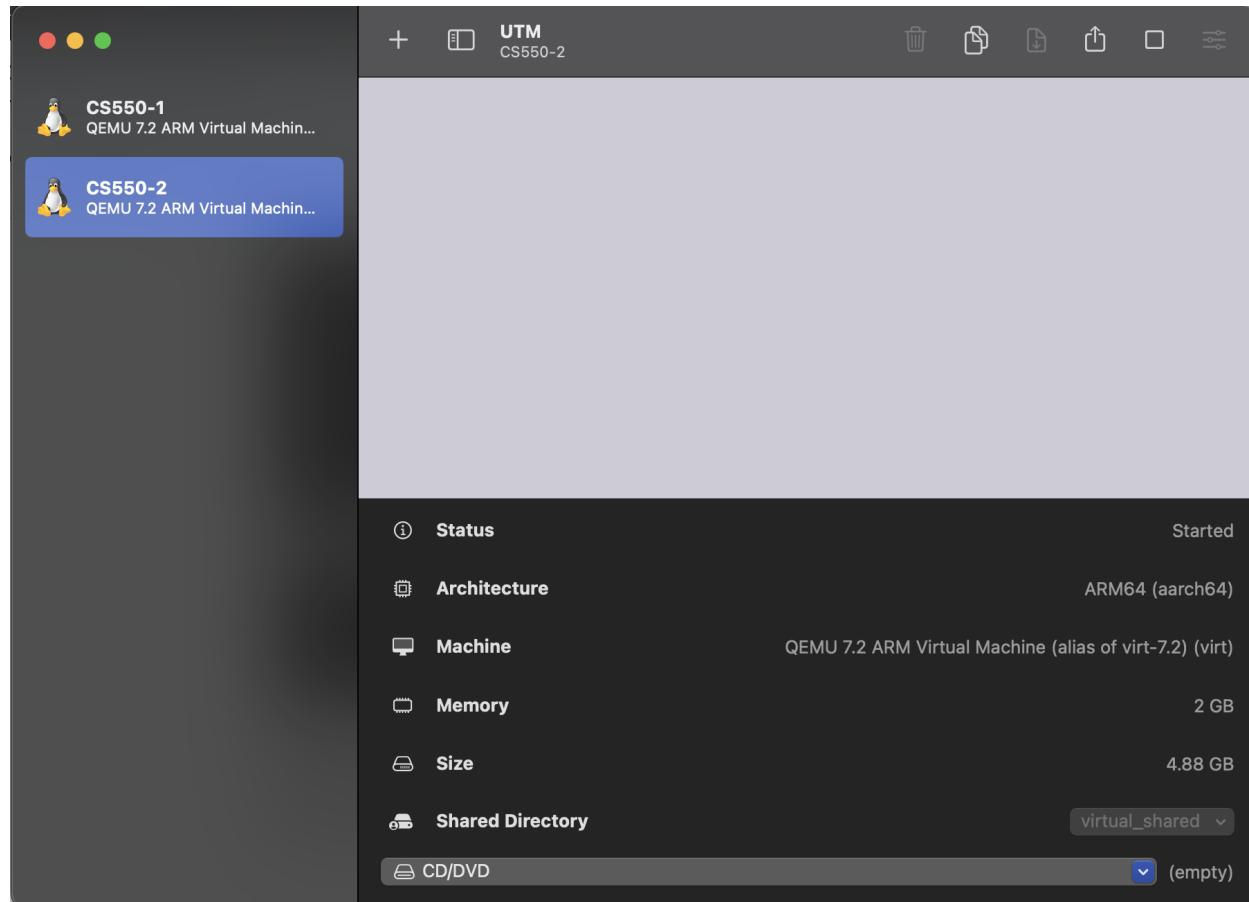
- h. Turn on Firewall and block all ports

```
bk@cs550-1:~$ sudo ufw status
Status: inactive
bk@cs550-1:~$ sudo ufw enable
Firewall is active and enabled on system startup
bk@cs550-1:~$ sudo ufw default deny incoming
Default incoming policy changed to 'deny'
(be sure to update your rules accordingly)
bk@cs550-1:~$
```

- i. Enable SSH access to your new Linux installation; open SSH port in firewall

```
bk@cs550-1:~$ sudo ufw allow OpenSSH
Rule added
Rule added (v6)
bk@cs550-1:~$
```

- j. Repeat steps 5 through 9, and create another VM with the same specifications as the first one



k. Create private/public keys and install them properly in both of your new VMs

```
[bk@cs550-1:~/.ssh$ ssh-keygen
Generating public/private rsa key pair.
[Enter file in which to save the key (/home/bk/.ssh/id_rsa):
[Enter passphrase (empty for no passphrase):
[Enter same passphrase again:
Your identification has been saved in /home/bk/.ssh/id_rsa
Your public key has been saved in /home/bk/.ssh/id_rsa.pub
The key fingerprint is:
SHA256:7ABeZGsU2tLk5+SLlRVuqqH28kG9eyF4gIvXeraHMNA bk@cs550-1
The key's randomart image is:
+---[RSA 3072]---+
|   * . |
| X . . |
| .+B o + |
| ..E=B = |
| o.o+oS |
| .ooBoo. |
| .o+o+. |
| .o+.+.. |
| +o... |
+---[SHA256]---+
[bk@cs550-1:~/.ssh$ ssh-copy-id bk@192.168.64.5
/usr/bin/ssh-copy-id: INFO: Source of key(s) to be installed: "/home/bk/.ssh/id_rsa.pub"
The authenticity of host '192.168.64.5 (192.168.64.5)' can't be established.
ED25519 key fingerprint is SHA256:MydiuOXAoQn2Q0vgdILnfhQijawXv3Wc4t1bdyyRV6s.
This key is not known by any other names
[Are you sure you want to continue connecting (yes/no/[fingerprint])? yes
/usr/bin/ssh-copy-id: INFO: attempting to log in with the new key(s), to filter
out any that are already installed
/usr/bin/ssh-copy-id: INFO: 1 key(s) remain to be installed -- if you are prompt
ed now it is to install the new keys
[bk@192.168.64.5's password:
Number of key(s) added: 1

Now try logging into the machine, with: "ssh 'bk@192.168.64.5'"
and check to make sure that only the key(s) you wanted were added.

bk@cs550-1:~/.ssh$ ]]

[bk@cs550-2:~/.ssh$ ssh-keygen
Generating public/private rsa key pair.
[Enter file in which to save the key (/home/bk/.ssh/id_rsa):
[Enter passphrase (empty for no passphrase):
[Enter same passphrase again:
Your identification has been saved in /home/bk/.ssh/id_rsa
Your public key has been saved in /home/bk/.ssh/id_rsa.pub
The key fingerprint is:
SHA256:Q2qljt1DSa3HMKRadJl4U7jT5+4IfTyeQpXjNrbP2A bk@cs550-2
The key's randomart image is:
+---[RSA 3072]---+
|   . |
|   . *
| + O . o |
| + S + o o |
| o = + * E . |
| . . = X O + |
| o . . B @ *.. |
| ..o . + Bo.o |
+---[SHA256]---+
[bk@cs550-2:~/.ssh$ ssh-copy-id bk@192.168.64.2
/usr/bin/ssh-copy-id: INFO: Source of key(s) to be installed: "/home/bk/.ssh/id_rsa.pub"
/usr/bin/ssh-copy-id: INFO: attempting to log in with the new key(s), to filter
out any that are already installed
/usr/bin/ssh-copy-id: INFO: 1 key(s) remain to be installed -- if you are prompt
ed now it is to install the new keys
[bk@192.168.64.2's password:
Number of key(s) added: 1

Now try logging into the machine, with: "ssh 'bk@192.168.64.2'"
and check to make sure that only the key(s) you wanted were added.

bk@cs550-2:~/.ssh$ ]]
```

l. Test that you can connect remotely to your VMs with your keys, from one VM to the other VM

```
[bk@cs550-1:~/.ssh$ ssh bk@192.168.64.5
Welcome to Ubuntu 22.04.3 LTS (GNU/Linux 5.15.0-83-generic aarch64)

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

System information as of Wed Sep 13 02:24:01 AM UTC 2023

System load:          0.0
Usage of /:           45.1% of 10.70GB
Memory usage:         13%
Swap usage:           0%
Processes:            109
Users logged in:     1
IPv4 address for enp0s1: 192.168.64.5
IPv6 address for enp0s1: fd24:12e1:c242:563d:14db:f9ff:febfb:f49a

* 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

*** System restart required ***
Last login: Wed Sep 13 02:19:43 2023 from 192.168.64.1
bk@cs550-1:~$ ]]

[bk@cs550-2:~/.ssh$ ssh bk@192.168.64.2
Welcome to Ubuntu 22.04.3 LTS (GNU/Linux 5.15.0-83-generic aarch64)

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

System information as of Wed Sep 13 02:24:13 AM UTC 2023

System load:          0.0
Usage of /:           45.7% of 10.70GB
Memory usage:         11%
Swap usage:           0%
Processes:            124
Users logged in:     1
IPv4 address for enp0s1: 192.168.64.2
IPv6 address for enp0s1: fd24:12e1:c242:563d:9010:4ff:feb2:6ec0

Expanded Security Maintenance for Applications is not enabled.

12 updates can be applied immediately.
To see these additional updates run: apt list --upgradable

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

Last login: Wed Sep 13 02:20:49 2023 from 192.168.64.1
bk@cs550-2:~$ ]]
```



2. (16 points) Show an example of using the following commands (hint: you can use man to find more information about each one); take screen shots of your commands; make sure to clear the screen between each command; explain in your own words what these commands do:

- a. ssh - remotely logins to another machine

```
● ○ ● batkhishig — bk@cs550-2: ~ — ssh bk@192.168.64.2 — 80x33

[bk@cs550-1:~$] ssh bk@192.168.64.5
Welcome to Ubuntu 22.04.3 LTS (GNU/Linux 5.15.0-83-generic aarch64)

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

 System information as of Wed Sep 13 04:02:13 PM UTC 2023

 System load:          0.0615234375
 Usage of /:           45.2% of 10.70GB
 Memory usage:         10%
 Swap usage:           0%
 Processes:            114
 Users logged in:     0
 IPv4 address for enp0s1: 192.168.64.5
 IPv6 address for enp0s1: fd24:12e1:c242:563d:14db:f9ff:febff49a

 * 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.

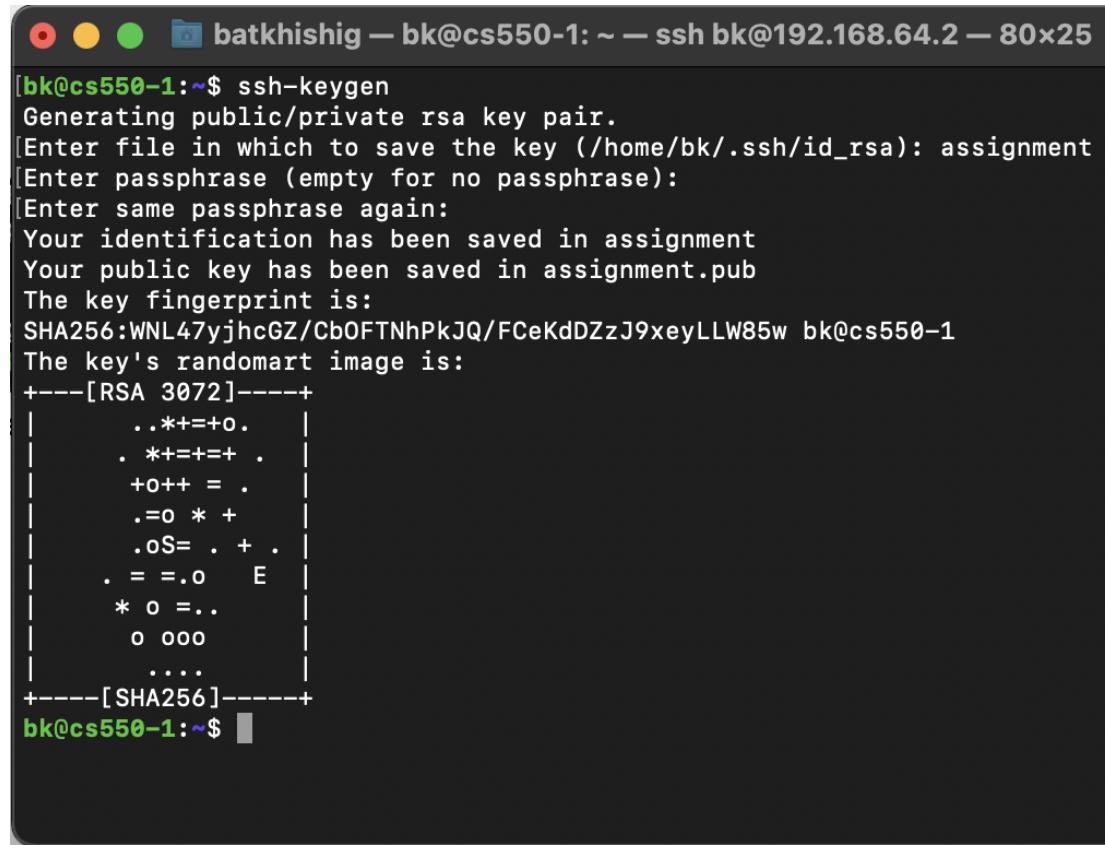
 0 updates can be applied immediately.

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

 Last login: Wed Sep 13 02:26:32 2023 from 192.168.64.2
 bk@cs550-2:~$
```

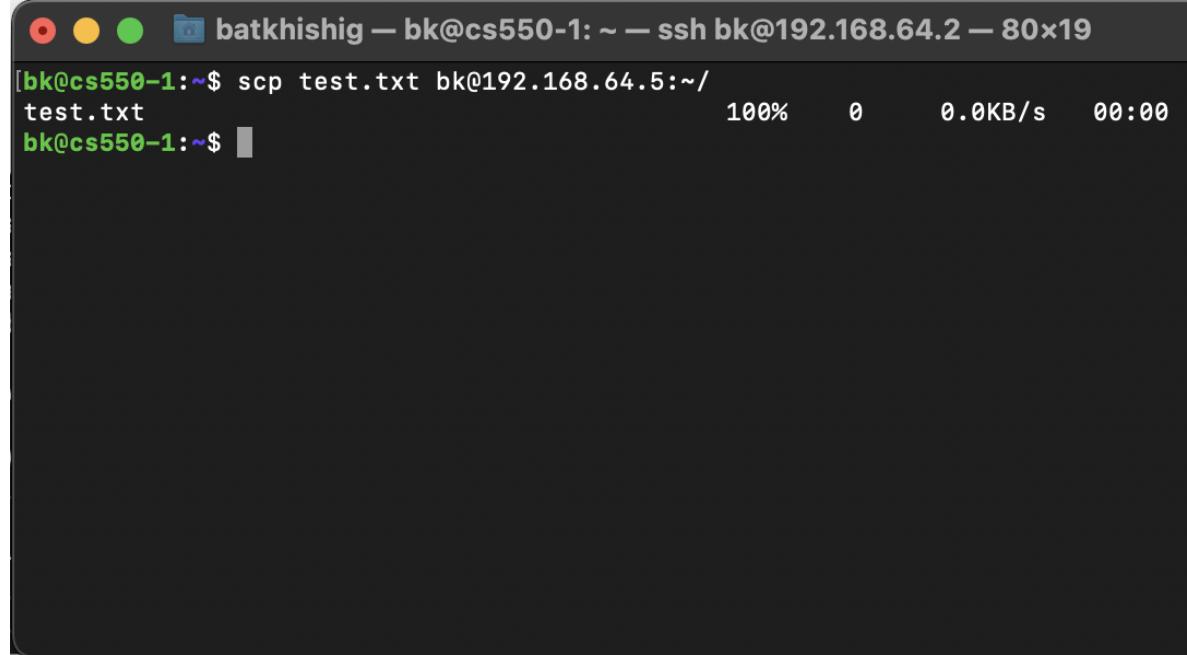


- b. ssh-keygen - generates rsa key pair that can be used to authenticate the user via ssh



```
[bk@cs550-1:~$ ssh-keygen
Generating public/private rsa key pair.
[Enter file in which to save the key (/home/bk/.ssh/id_rsa): assignment
[Enter passphrase (empty for no passphrase):
[Enter same passphrase again:
Your identification has been saved in assignment
Your public key has been saved in assignment.pub
The key fingerprint is:
SHA256:WNL47yjhcGZ/CbOFTNhPkJQ/FCeKdDZzJ9xeyLLW85w bk@cs550-1
The key's randomart image is:
+---[RSA 3072]---+
 ..*+=+o.
 . *+=+=+
 +o++ = .
 .=o * +
 .oS= . +
 . = =.o E
 * o =..
 o 000
 ...
+---[SHA256]---+
bk@cs550-1:~$ ]
```

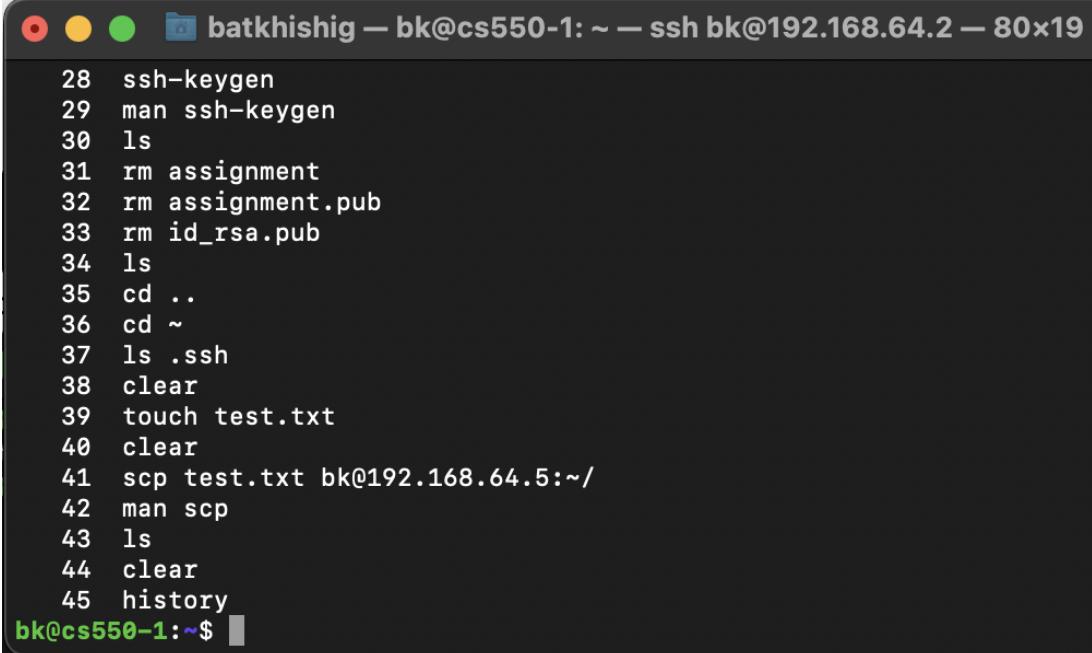
- c. scp - used to copy files or directories over ssh connection



```
[bk@cs550-1:~$ scp test.txt bk@192.168.64.5:~
test.txt                                                 100%    0     0.0KB/s   00:00
bk@cs550-1:~$ ]
```

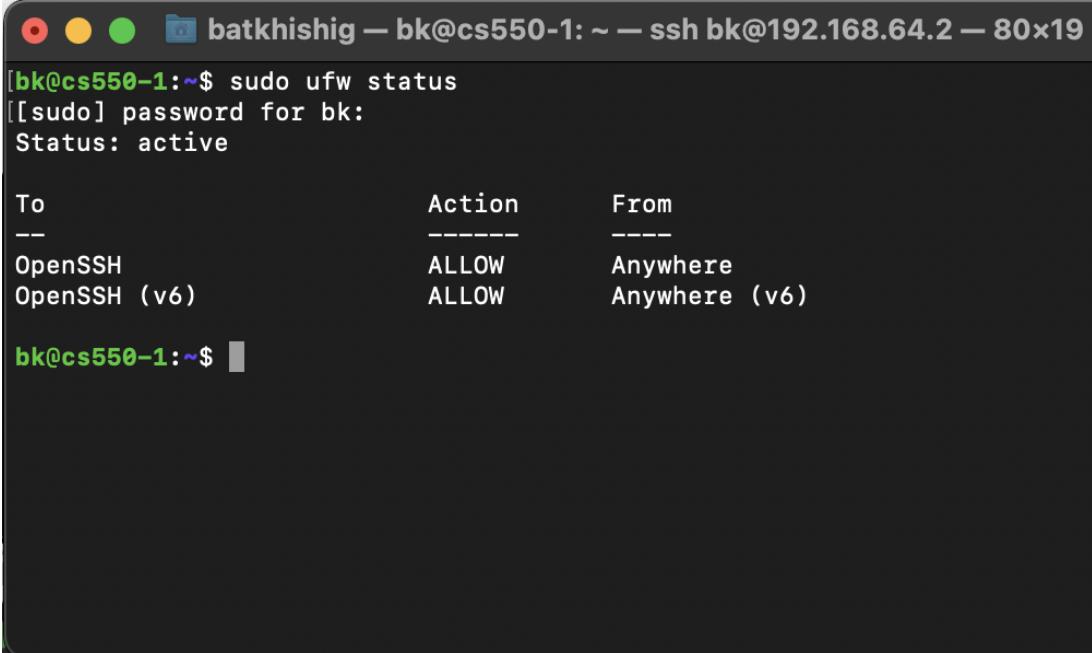


- d. history - shows command history



```
● ○ ● batkhishig — bk@cs550-1: ~ — ssh bk@192.168.64.2 — 80x19
28 ssh-keygen
29 man ssh-keygen
30 ls
31 rm assignment
32 rm assignment.pub
33 rm id_rsa.pub
34 ls
35 cd ..
36 cd ~
37 ls .ssh
38 clear
39 touch test.txt
40 clear
41 scp test.txt bk@192.168.64.5:~
42 man scp
43 ls
44 clear
45 history
bk@cs550-1:~$
```

- e. sudo - runs commands with administrator privilege



```
● ○ ● batkhishig — bk@cs550-1: ~ — ssh bk@192.168.64.2 — 80x19
[bk@cs550-1:~$ sudo ufw status
[[sudo] password for bk:
Status: active

To                         Action      From
--                         --          --
OpenSSH                      ALLOW      Anywhere
OpenSSH (v6)                  ALLOW      Anywhere (v6)

bk@cs550-1:~$
```



- f. ip - used to configure network interface

```
[bk@cs550-1:~$ ip a
1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue state UNKNOWN group default
    qlen 1000
        link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
        inet 127.0.0.1/8 scope host lo
            valid_lft forever preferred_lft forever
        inet6 ::1/128 scope host
            valid_lft forever preferred_lft forever
2: enp0s1: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc fq_codel state UP group default
    qlen 1000
        link/ether 92:10:04:b2:6e:c0 brd ff:ff:ff:ff:ff:ff
        inet 192.168.64.2/24 metric 100 brd 192.168.64.255 scope global dynamic enp0s1
            valid_lft 84055sec preferred_lft 84055sec
            inet6 fd24:12e1:c242:563d:9010:4ff:feb2:6ec0/64 scope global dynamic mngtmpa
                ddrr nobroadcast
                    valid_lft 2591953sec preferred_lft 604753sec
                    inet6 fe80::9010:4ff:feb2:6ec0/64 scope link
                        valid_lft forever preferred_lft forever
bk@cs550-1:~$ ]
```

- g. touch - creates new file and changes timestamp of existing file

```
[bk@cs550-1:~$ touch test.txt
[bk@cs550-1:~$ ls
test.txt
bk@cs550-1:~$ ]
```

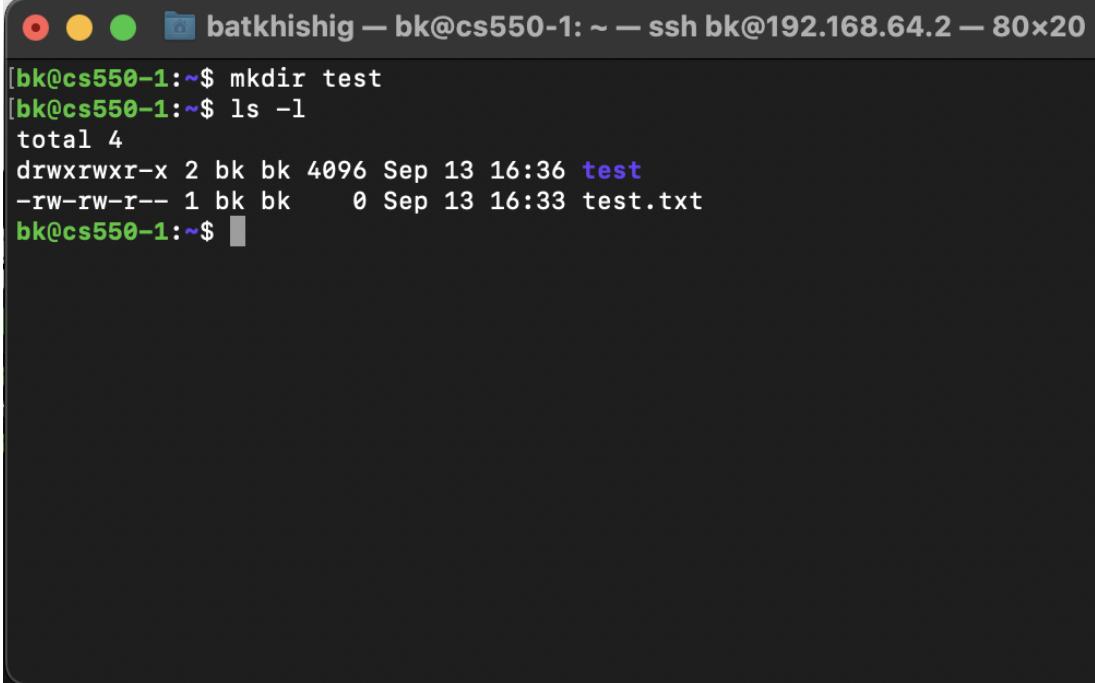


- h. ls - shows files and directories in a directory



```
[bk@cs550-1:~$ ls
test.txt
bk@cs550-1:~$ ]
```

- i. mkdir - creates a directory



```
[bk@cs550-1:~$ mkdir test
[bk@cs550-1:~$ ls -l
total 4
drwxrwxr-x 2 bk bk 4096 Sep 13 16:36 test
-rw-rw-r-- 1 bk bk     0 Sep 13 16:33 test.txt
bk@cs550-1:~$ ]
```

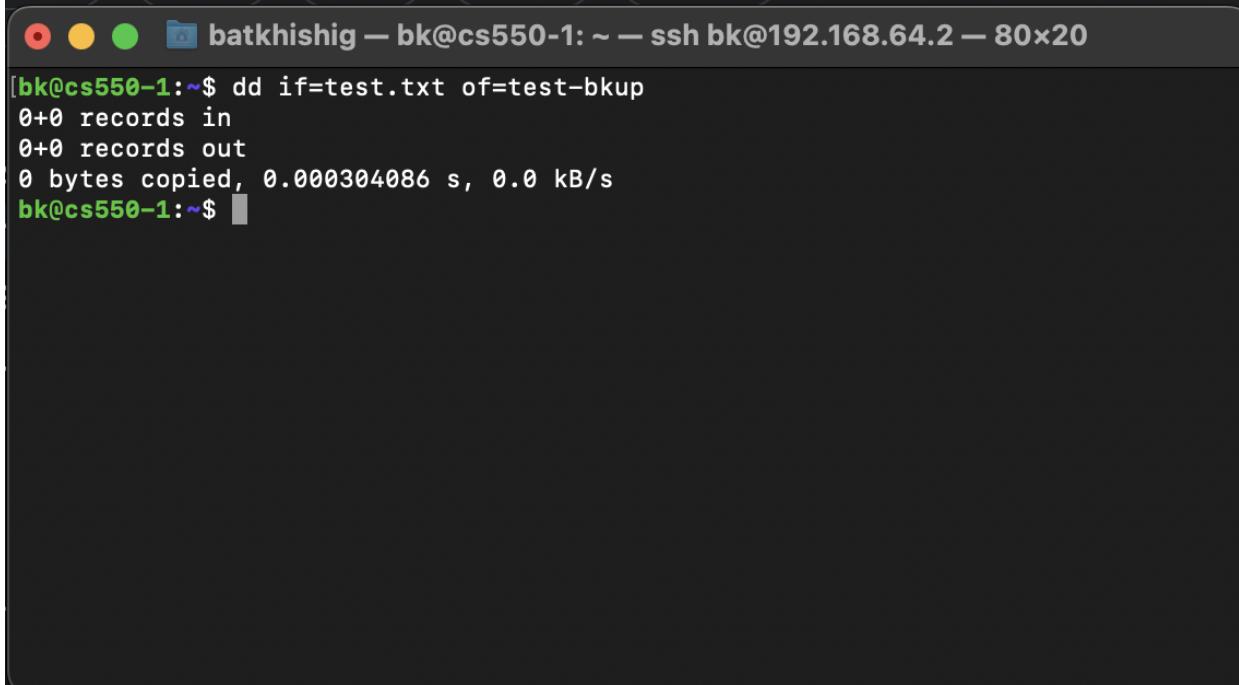


- j. cd - changes current directory



```
batkhishig — bk@cs550-1: /etc/systemd — ssh bk@192.168.64.2 — 80x20
[bk@cs550-1:~$ cd /etc/systemd/
bk@cs550-1:/etc/systemd$ ]
```

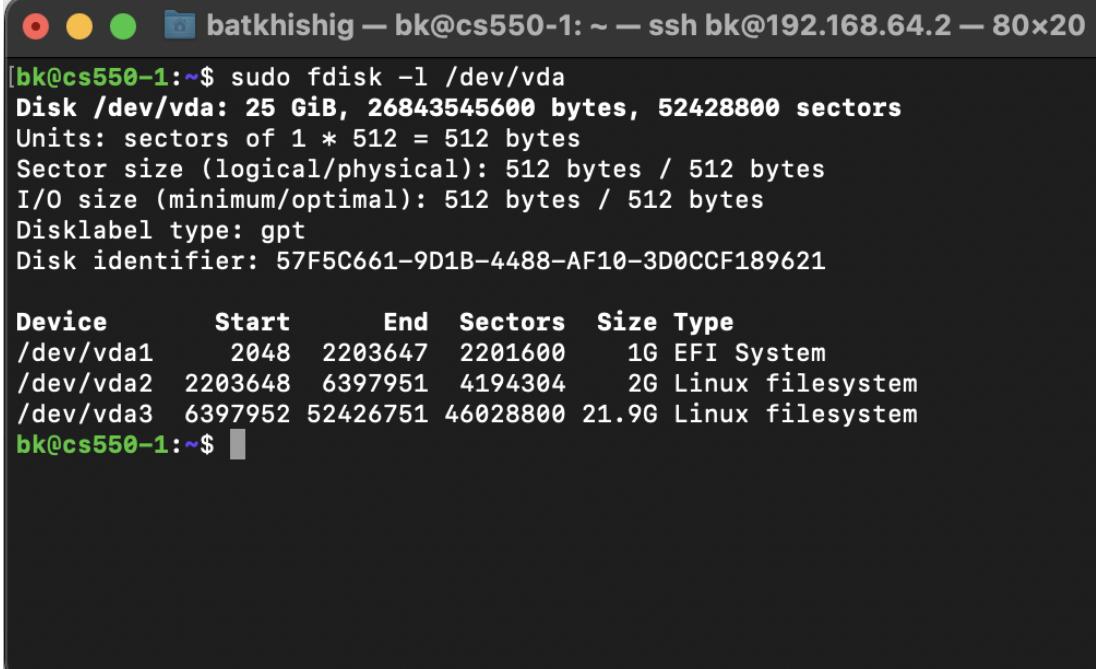
- k. dd - used to copy and change files, usually used for backups



```
batkhishig — bk@cs550-1: ~ — ssh bk@192.168.64.2 — 80x20
[bk@cs550-1:~$ dd if=test.txt of=test-bkup
0+0 records in
0+0 records out
0 bytes copied, 0.000304086 s, 0.0 kB/s
bk@cs550-1:~$ ]
```



I. fdisk - used to manage disk partitioning



```
[bk@cs550-1:~$ sudo fdisk -l /dev/vda
Disk /dev/vda: 25 GiB, 26843545600 bytes, 52428800 sectors
Units: sectors of 1 * 512 = 512 bytes
Sector size (logical/physical): 512 bytes / 512 bytes
I/O size (minimum/optimal): 512 bytes / 512 bytes
Disklabel type: gpt
Disk identifier: 57F5C661-9D1B-4488-AF10-3D0CCF189621

Device      Start    End  Sectors  Size Type
/dev/vda1     2048  2203647  2201600    1G EFI System
/dev/vda2   2203648  6397951  4194304    2G Linux filesystem
/dev/vda3   6397952 52426751 46028800 21.9G Linux filesystem
bk@cs550-1:~$ ]
```



m. apt - a package management tool for debian based linux systems

```
[bk@cs550-1:~]$ sudo apt update
Hit:1 http://ports.ubuntu.com/ubuntu-ports jammy InRelease
Get:2 http://ports.ubuntu.com/ubuntu-ports jammy-updates InRelease [119 kB]
Get:3 http://ports.ubuntu.com/ubuntu-ports jammy-backports InRelease [109 kB]
Get:4 http://ports.ubuntu.com/ubuntu-ports jammy-security InRelease [110 kB]
Get:5 http://ports.ubuntu.com/ubuntu-ports jammy-updates/main arm64 Packages [86
6 kB]
Get:6 http://ports.ubuntu.com/ubuntu-ports jammy-updates/main Translation-en [22
3 kB]
Get:7 http://ports.ubuntu.com/ubuntu-ports jammy-updates/main arm64 c-n-f Metada
ta [15.3 kB]
Get:8 http://ports.ubuntu.com/ubuntu-ports jammy-updates/universe arm64 Packages
[887 kB]
Get:9 http://ports.ubuntu.com/ubuntu-ports jammy-updates/universe Translation-en
[213 kB]
Get:10 http://ports.ubuntu.com/ubuntu-ports jammy-updates/universe arm64 c-n-f M
etadata [19.1 kB]
Get:11 http://ports.ubuntu.com/ubuntu-ports jammy-security/main arm64 Packages [
663 kB]
Get:12 http://ports.ubuntu.com/ubuntu-ports jammy-security/universe arm64 Packag
es [692 kB]
Get:13 http://ports.ubuntu.com/ubuntu-ports jammy-security/universe Translation-
en [143 kB]
Get:14 http://ports.ubuntu.com/ubuntu-ports jammy-security/universe arm64 c-n-f
Metadata [14.0 kB]
Fetched 4073 kB in 3s (1362 kB/s)
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
12 packages can be upgraded. Run 'apt list --upgradable' to see them.
bk@cs550-1:~$
```

n. vi - used to edit contents of a file



- o. time - measures time to execute a given command

```
● ● ● batkhishig — bk@cs550-1: ~ — ssh bk@192.168.64.2 — 80x12  
[bk@cs550-1:~$ time cat test.txt  
testing vi command  
  
real    0m0.005s  
user    0m0.000s  
sys     0m0.005s  
bk@cs550-1:~$ ]
```

- p. tar - an archive tool

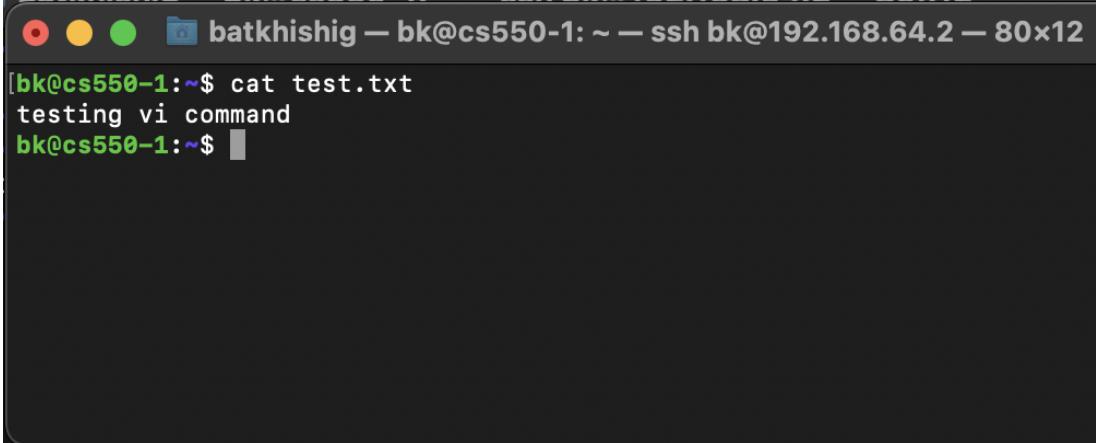
```
● ● ● batkhishig — bk@cs550-1: ~ — ssh bk@192.168.64.2 — 80x12  
[bk@cs550-1:~$ tar -czvf test-archive.tar.gz test.txt  
test.txt  
[bk@cs550-1:~$ ls  
test  test-archive.tar.gz  test.txt  
bk@cs550-1:~$ ]
```

- q. rm - used to delete files

```
● ● ● batkhishig — bk@cs550-1: ~ — ssh bk@192.168.64.2 — 80x12  
[bk@cs550-1:~$ rm test  
test/          test-archive.tar.gz  test.txt  
[bk@cs550-1:~$ rm test-archive.tar.gz  
[bk@cs550-1:~$ ls  
test  test.txt  
bk@cs550-1:~$ ]
```

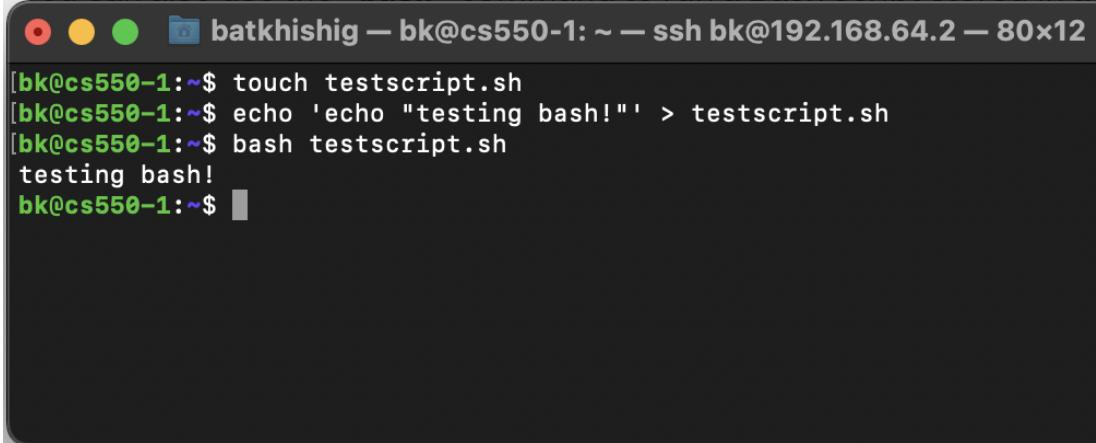


- r. cat - shows content of a file



```
[bk@cs550-1:~$ cat test.txt
testing vi command
bk@cs550-1:~$ ]
```

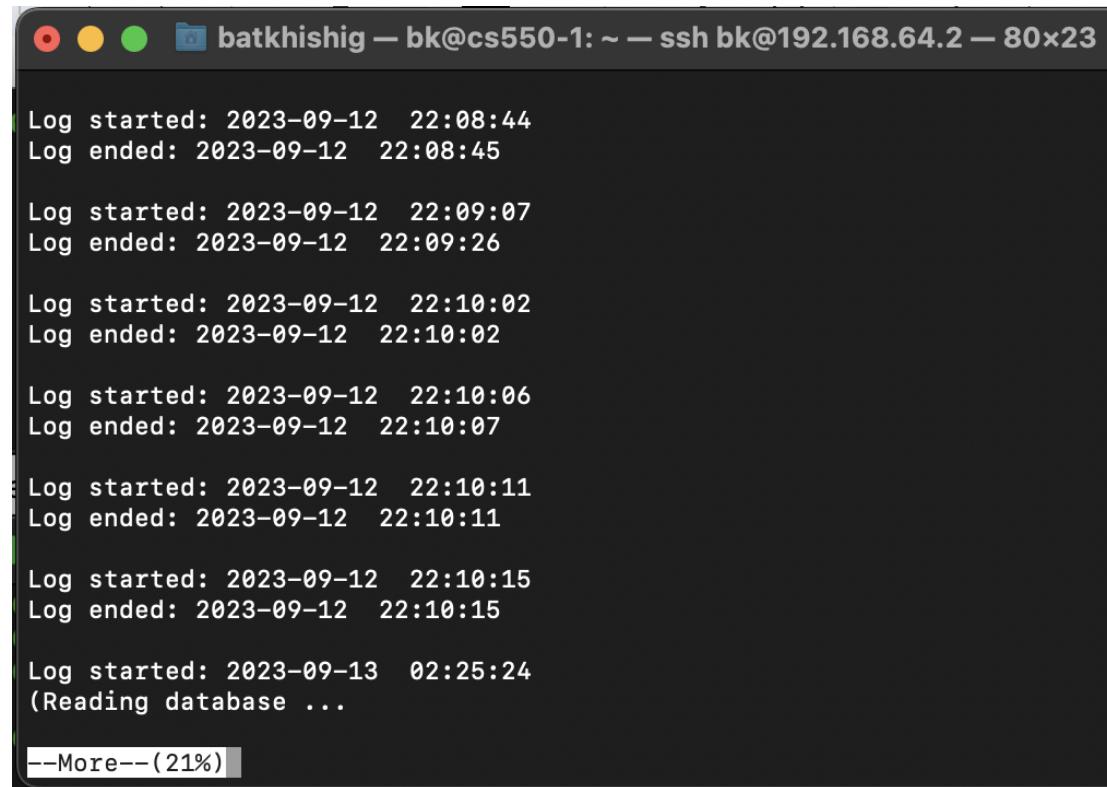
- s. bash - used to run bash scripts



```
[bk@cs550-1:~$ touch testscript.sh
[bk@cs550-1:~$ echo 'echo "testing bash!"' > testscript.sh
[bk@cs550-1:~$ bash testscript.sh
testing bash!
bk@cs550-1:~$ ]
```



- t. more - used to view content of a file one page at a time. Useful for logs.



batkhisig — bk@cs550-1: ~ — ssh bk@192.168.64.2 — 80x23

```
Log started: 2023-09-12 22:08:44
Log ended: 2023-09-12 22:08:45

Log started: 2023-09-12 22:09:07
Log ended: 2023-09-12 22:09:26

Log started: 2023-09-12 22:10:02
Log ended: 2023-09-12 22:10:02

Log started: 2023-09-12 22:10:06
Log ended: 2023-09-12 22:10:07

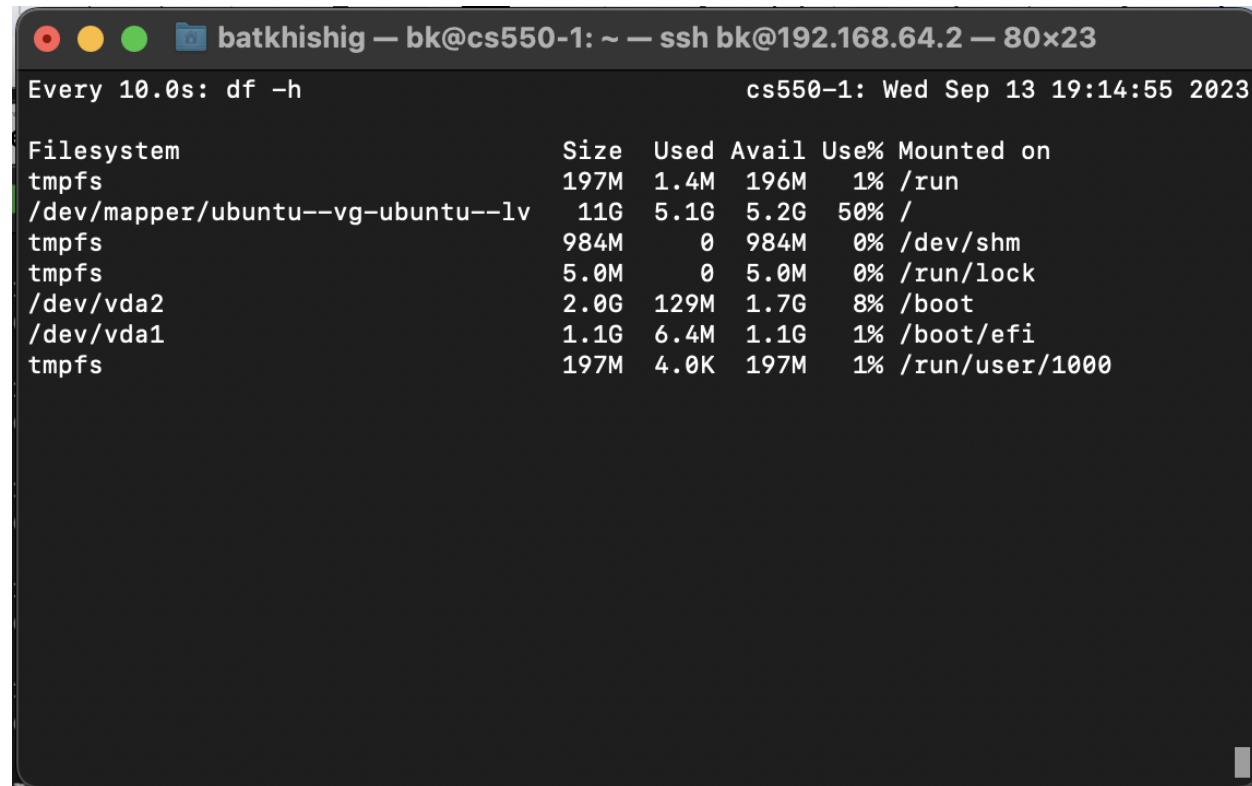
Log started: 2023-09-12 22:10:11
Log ended: 2023-09-12 22:10:11

Log started: 2023-09-12 22:10:15
Log ended: 2023-09-12 22:10:15

Log started: 2023-09-13 02:25:24
(Reading database ...

--More--(21%)
```

- u. watch - periodically executes command and display its output



batkhisig — bk@cs550-1: ~ — ssh bk@192.168.64.2 — 80x23

```
Every 10.0s: df -h                                     cs550-1: Wed Sep 13 19:14:55 2023

Filesystem      Size  Used Avail Use% Mounted on
tmpfs           197M  1.4M  196M  1% /run
/dev/mapper/ubuntu--vg-ubuntu--lv    11G  5.1G  5.2G  50% /
tmpfs           984M    0  984M  0% /dev/shm
tmpfs           5.0M    0  5.0M  0% /run/lock
/dev/vda2        2.0G 129M  1.7G  8% /boot
/dev/vda1        1.1G  6.4M  1.1G  1% /boot/efi
tmpfs           197M  4.0K  197M  1% /run/user/1000
```



v. ps - shows current working processes

```

root      768  0.0  0.5 320784 11180 ?          Ssl 15:51  0:00 /usr/sbin/Mod
root      770  0.0  0.3 15136  7976 ?          Ss  15:51  0:00 sshd: /usr/sb
root      779  0.0  1.0 109568 20172 ?          Ssl 15:51  0:00 /usr/bin/pyth
root      984  0.0  0.4 18368  9616 ?          Ss  15:51  0:00 sshd: bk [pri
bk       987  0.0  0.4 17212  9068 ?          Ss  15:51  0:00 /lib/systemd/
bk       988  0.0  0.2 170756  5228 ?          S   15:51  0:00 (sd-pam)
bk      1088  0.0  0.3 18504  6444 ?          R   15:51  0:01 sshd: bk@pts/
bk      1089  0.0  0.3 10376  6544 pts/0        Ss  15:51  0:01 -bash
root     1261  0.0  1.4 1466432 29192 ?          Ssl 15:56  0:03 /usr/lib/snap
root     1553  0.0  0.0    0   0 ?          I   16:06  0:00 [kworker/3:0-
root     2266  0.0  0.0    0   0 ?          I   17:05  0:03 [kworker/0:0-
root     2380  0.0  0.9 297044 19020 ?          Ssl 17:05  0:00 /usr/libexec/
root     2655  0.0  0.0    0   0 ?          I   17:50  0:01 [kworker/u8:2
root     2661  0.0  3.4 436396 70260 ?          Ssl 17:52  0:01 /usr/libexec/
root     2685  0.0  0.1 80692  2316 ?          Ss  17:52  0:00 gpg-agent --h
root     2704  0.0  0.0    0   0 ?          I   18:06  0:00 [kworker/2:1]
root     2705  0.0  0.0    0   0 ?          I   18:06  0:00 [kworker/1:2-
root     2708  0.0  0.0    0   0 ?          I   18:06  0:01 [kworker/1:3-
root     2709  0.0  0.0    0   0 ?          I   18:06  0:00 [kworker/0:2]
root     2744  0.0  0.0    0   0 ?          I   18:44  0:00 [kworker/u8:0
root     2947  0.0  0.0    0   0 ?          I   18:56  0:00 [kworker/u8:1
bk      3289  0.0  0.0    0   0 ?          R+  19:16  0:00 ps aux

```

w. top - shows current resource usages, updates realtime (like task manager in windows)

```

top - 19:18:15 up  3:27,  1 user,  load average: 0.04, 0.02, 0.00
Tasks: 120 total,   1 running, 119 sleeping,   0 stopped,   0 zombie
%Cpu(s): 0.1 us, 0.1 sy, 0.0 ni, 99.8 id, 0.0 wa, 0.0 hi, 0.0 si, 0.0 st
MiB Mem : 1967.1 total, 944.4 free, 216.4 used, 806.4 buff/cache
MiB Swap: 2048.0 total, 2048.0 free, 0.0 used. 1656.3 avail Mem


```

PID	USER	PR	NI	VIRT	RES	SHR	S	%CPU	%MEM	TIME+	COMMAND
14	root	20	0	0	0	0	I	0.3	0.0	0:00.27	rcu_sch+
27	root	rt	0	0	0	0	S	0.3	0.0	0:00.17	migrati+
3295	bk	20	0	10372	3292	2692	R	0.3	0.2	0:00.02	top
1	root	20	0	167952	11260	7508	S	0.0	0.6	0:01.30	systemd
2	root	20	0	0	0	0	S	0.0	0.0	0:00.01	kthreadd
3	root	0	-20	0	0	0	I	0.0	0.0	0:00.00	rcu_gp
4	root	0	-20	0	0	0	I	0.0	0.0	0:00.00	rcu_par+
5	root	0	-20	0	0	0	I	0.0	0.0	0:00.00	slub_f1+
6	root	0	-20	0	0	0	I	0.0	0.0	0:00.00	netns
8	root	0	-20	0	0	0	I	0.0	0.0	0:00.00	kworker+
10	root	0	-20	0	0	0	I	0.0	0.0	0:00.00	mm_perc+
11	root	20	0	0	0	0	S	0.0	0.0	0:00.00	rcu_tas+
12	root	20	0	0	0	0	S	0.0	0.0	0:00.00	rcu_tas+
13	root	20	0	0	0	0	S	0.0	0.0	0:00.07	ksoftir+
15	root	rt	0	0	0	0	S	0.0	0.0	0:00.16	migrati+
16	root	-51	0	0	0	0	S	0.0	0.0	0:00.00	idle_in+



- x. htop - more user-friendly version of top command

The screenshot shows the htop command running in a terminal window. At the top, it displays system information: Tasks: 30, 36 thr; 1 running, Load average: 0.03 0.03 0.00, Uptime: 03:28:27. Below this is a memory usage bar showing Mem[|||||] 221M/1.92G and Swap[] 0K/2.00G. The main part of the screen is a table listing processes. The columns are PID, USER, PRI, NI, VIRT, RES, SHR, S, CPU%, MEM%, TIME+, and Command. The processes listed include root tasks and systemd threads. At the bottom of the table, there are function keys: F1Help, F2Setup, F3Search, F4Filter, F5Tree, F6SortBy, F7Nice -F8Nice +F9Kill, and F10Quit.

PID	USER	PRI	NI	VIRT	RES	SHR	S	CPU%	MEM%	TIME+	Command
3296	bk	20	0	7640	3328	2740	R	0.7	0.2	0:00.05	htop
1	root	20	0	164M	11260	7508	S	0.0	0.6	0:01.30	/sbin/init
412	root	19	-1	48104	15500	14428	S	0.0	0.8	0:00.31	/lib/systemd/sy
454	root	RT	0	282M	25668	7392	S	0.0	1.3	0:03.12	/sbin/multipath
458	root	20	0	11260	6108	3884	S	0.0	0.3	0:00.22	/lib/systemd/sy
460	root	20	0	282M	25668	7392	S	0.0	1.3	0:00.00	/sbin/multipath
461	root	RT	0	282M	25668	7392	S	0.0	1.3	0:00.00	/sbin/multipath
462	root	RT	0	282M	25668	7392	S	0.0	1.3	0:00.00	/sbin/multipath
463	root	RT	0	282M	25668	7392	S	0.0	1.3	0:00.05	/sbin/multipath
464	root	RT	0	282M	25668	7392	S	0.0	1.3	0:02.41	/sbin/multipath
465	root	RT	0	282M	25668	7392	S	0.0	1.3	0:00.00	/sbin/multipath
596	systemd-t	20	0	88664	6416	5596	S	0.0	0.3	0:00.19	/lib/systemd/sy
614	systemd-t	20	0	88664	6416	5596	S	0.0	0.3	0:00.00	/lib/systemd/sy

- y. gcc - used to compile C and C++ languages.

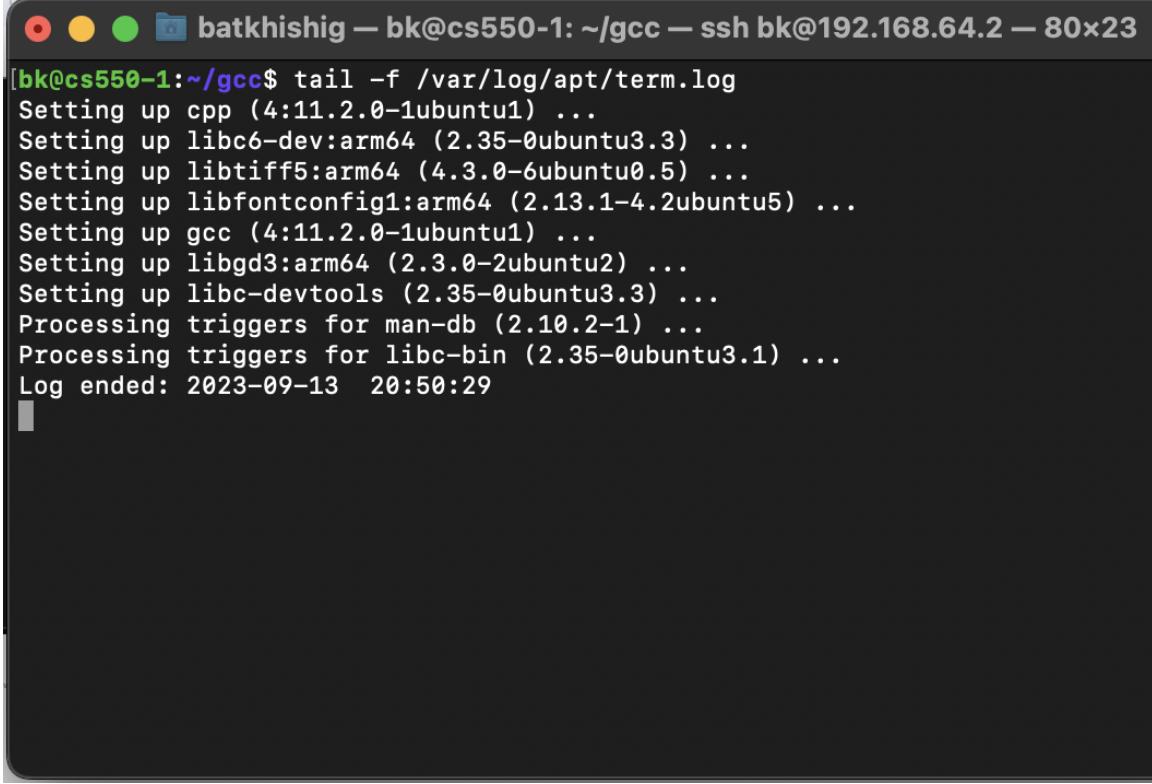
The screenshot shows the gcc command being used to compile a C program named main.c. The terminal output shows the compilation command [bk@cs550-1:~/gcc\$ gcc main.c], the resulting executable [bk@cs550-1:~/gcc\$ ls a.out main.c], and the execution of the program [bk@cs550-1:~/gcc\$./a.out]. The output of the program is "Hello World".

```
[bk@cs550-1:~/gcc$ gcc main.c
[bk@cs550-1:~/gcc$ ls
a.out  main.c
[bk@cs550-1:~/gcc$ ./a.out

Hello World
bk@cs550-1:~/gcc$ ]
```

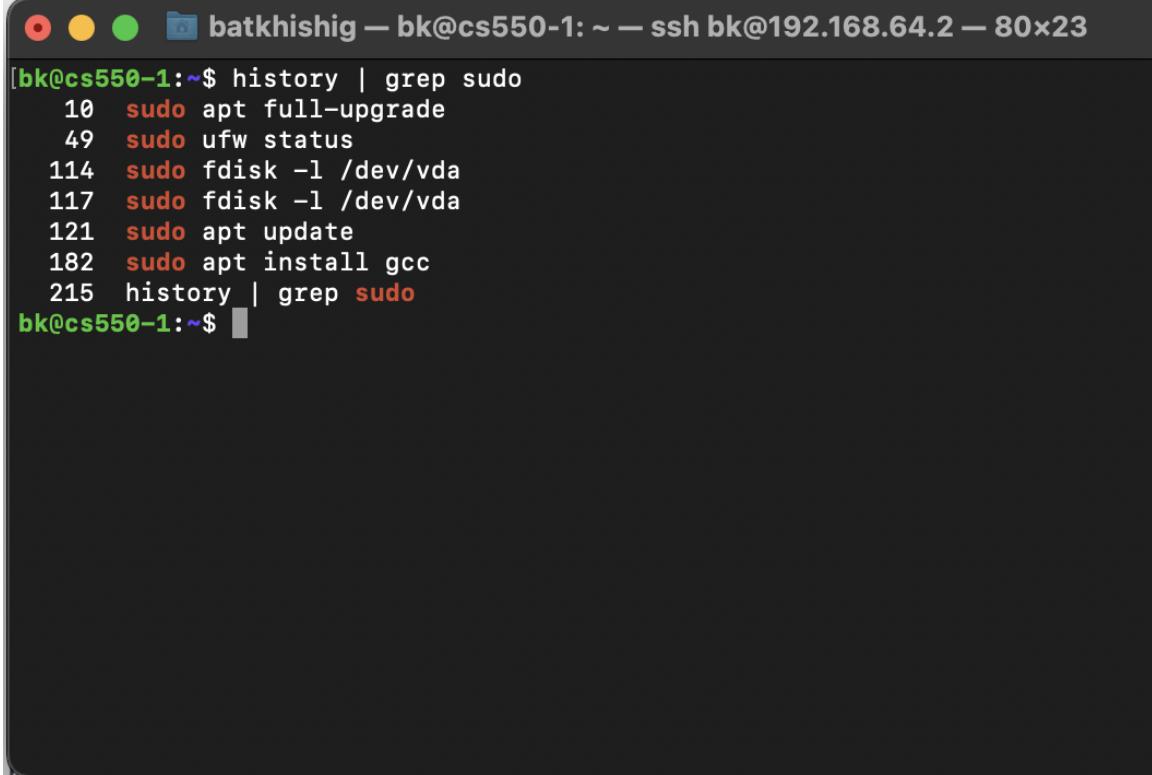


- z. tail - used to show the last lines of a file. Can show realtime changes



```
[bk@cs550-1:~/gcc$ tail -f /var/log/apt/term.log
Setting up cpp (4:11.2.0-1ubuntu1) ...
Setting up libc6-dev:arm64 (2.35-0ubuntu3.3) ...
Setting up libtiff5:arm64 (4.3.0-6ubuntu0.5) ...
Setting up libfontconfig1:arm64 (2.13.1-4.2ubuntu5) ...
Setting up gcc (4:11.2.0-1ubuntu1) ...
Setting up libgd3:arm64 (2.3.0-2ubuntu2) ...
Setting up libc-devtools (2.35-0ubuntu3.3) ...
Processing triggers for man-db (2.10.2-1) ...
Processing triggers for libc-bin (2.35-0ubuntu3.1) ...
Log ended: 2023-09-13 20:50:29
```

- aa. grep - searches text and pattern from text files or stream



```
[bk@cs550-1:~$ history | grep sudo
 10 sudo apt full-upgrade
 49 sudo ufw status
114 sudo fdisk -l /dev/vda
117 sudo fdisk -l /dev/vda
121 sudo apt update
182 sudo apt install gcc
215 history | grep sudo
bk@cs550-1:~$
```

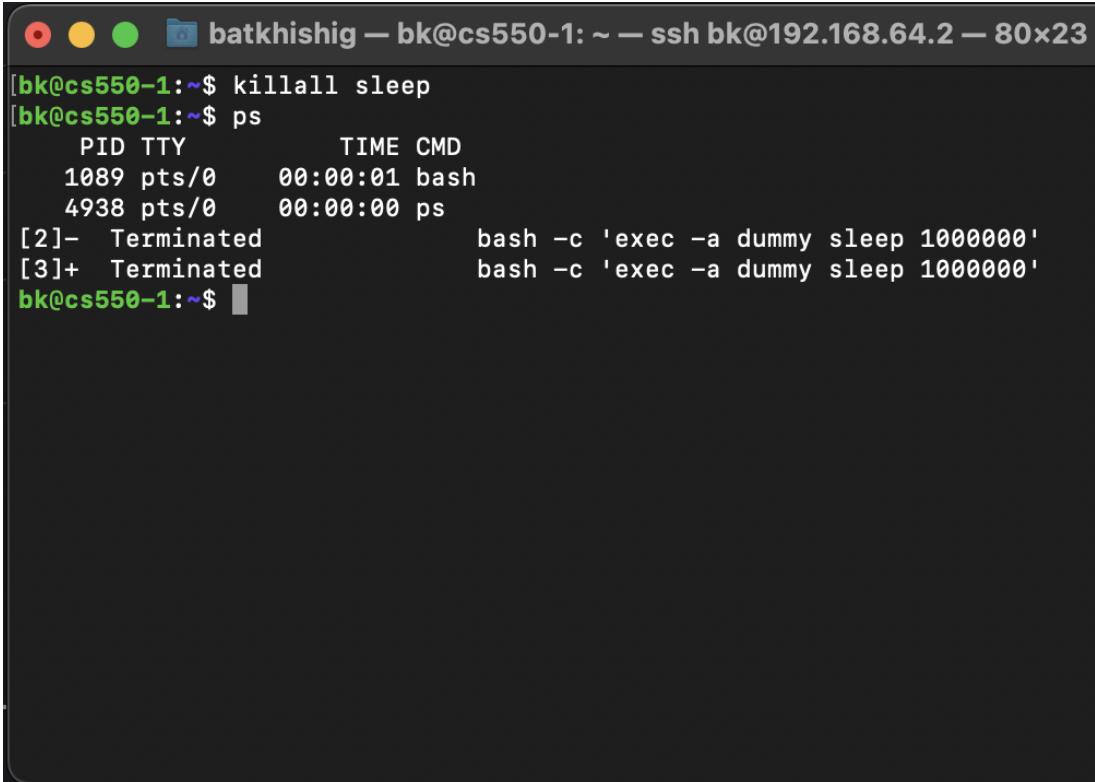


bb. kill - used to kill a process with PID



A screenshot of a terminal window titled "batkhishig — bk@cs550-1: ~ — ssh bk@192.168.64.2 — 80x23". The window shows a single line of text: "[bk@cs550-1:~\$ kill 4922". The background of the terminal is dark.

cc. killall - kills all processes using name



A screenshot of a terminal window titled "batkhishig — bk@cs550-1: ~ — ssh bk@192.168.64.2 — 80x23". The window shows several commands: "[bk@cs550-1:~\$ killall sleep", "[bk@cs550-1:~\$ ps", and a table of processes:

PID	TTY	TIME	CMD
1089	pts/0	00:00:01	bash
4938	pts/0	00:00:00	ps

Followed by two terminated processes:

[2]- Terminated	bash -c 'exec -a dummy sleep 1000000'
[3]+ Terminated	bash -c 'exec -a dummy sleep 1000000'

The final prompt is "[bk@cs550-1:~\$]".



dd. du - shows disk usage

```
● ● ● batkhisig — bk@cs550-1: ~ — ssh bk@192.168.64.2 — 80x23
[bk@cs550-1:~$] du -sh /home/
116K    /home/
bk@cs550-1:~$
```

ee. df - shows available disk space

```
● ● ● batkhisig — bk@cs550-1: ~ — ssh bk@192.168.64.2 — 80x23
[bk@cs550-1:~$] df -H
Filesystem           Size  Used  Avail Use% Mounted on
tmpfs                207M  1.4M  205M   1% /run
/dev/mapper/ubuntu--vg-ubuntu--lv  12G  5.6G  5.4G  51% /
tmpfs                1.1G    0  1.1G   0% /dev/shm
tmpfs                5.3M    0  5.3M   0% /run/lock
/dev/vda2              2.1G 135M  1.8G   8% /boot
/dev/vda1              1.2G  6.7M  1.2G   1% /boot/efi
tmpfs                207M  4.1k  207M   1% /run/user/1000
bk@cs550-1:~$
```



- ff. screen - used to create new terminal session within the terminal. It is possible to move between screens, attach and detach them.

```
bk@cs550-1:~$ exit  
exit  
  
[screen is terminating]  
bk@cs550-1:~$
```

gg. vim - vim is a text editor, which has more features than vi



hh. chmod - changes permissions of a file or a directory

```
● ● ● batkhisig — bk@cs550-1: ~ — ssh bk@192.168.64.2 — 80x23
```

```
bk@cs550-1:~$ chmod 666 test.txt
bk@cs550-1:~$ ls -l test.txt
-rw-rw-rw- 1 bk bk 39 Sep 13 22:04 test.txt
bk@cs550-1:~$
```

ii. chown - used to change ownership of a file or a directory

```
● ● ● batkhisig — bk@cs550-1: ~ — ssh bk@192.168.64.2 — 80x23
```

```
bk@cs550-1:~$ ls -l test.txt
-rw-rw-rw- 1 bk bk 39 Sep 13 22:04 test.txt
bk@cs550-1:~$ sudo chown root test.txt
bk@cs550-1:~$ ls -l test.txt
-rw-rw-rw- 1 root bk 39 Sep 13 22:04 test.txt
bk@cs550-1:~$
```



jj. useradd - used to add new user

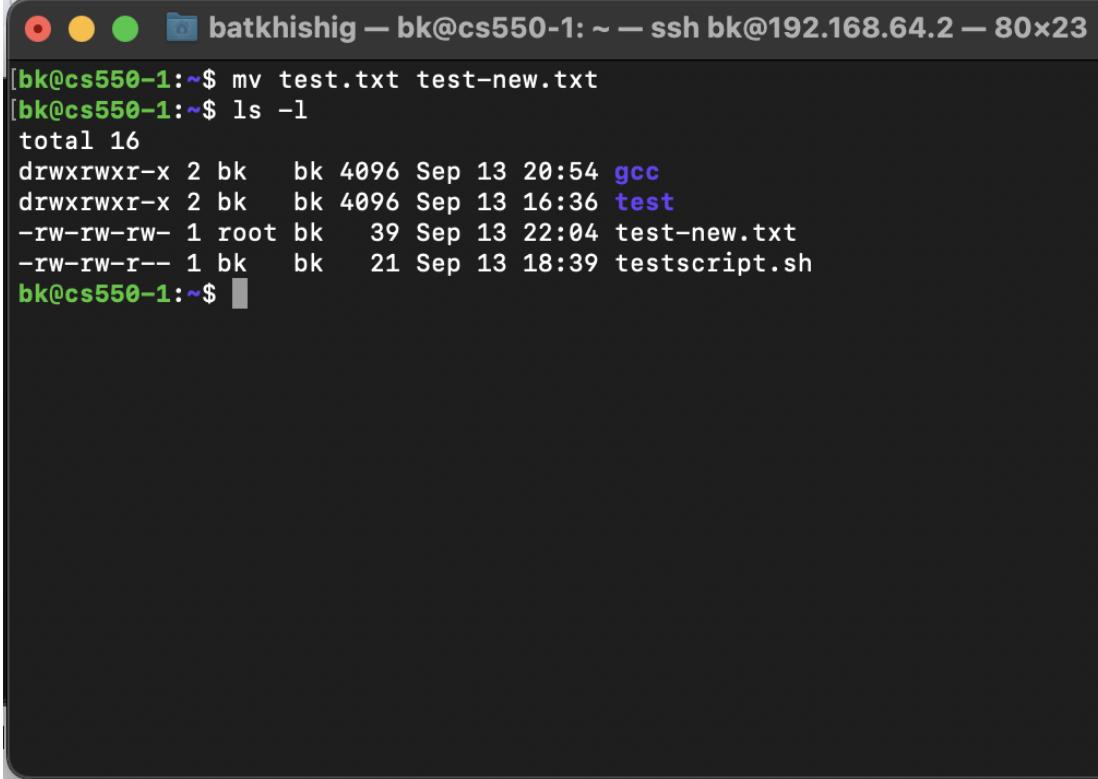
```
● ● ● batkhisig — bk@cs550-1: ~ — ssh bk@192.168.64.2 — 80x23
[bk@cs550-1:~$ sudo useradd guest
[bk@cs550-1:~$ ]
```

kk. mv - used to change a file name or move it from one directory to another

```
● ● ● batkhisig — bk@cs550-1: ~ — ssh bk@192.168.64.2 — 80x23
[bk@cs550-1:~$ mv test.txt test-new.txt
[bk@cs550-1:~$ ls -l
total 16
drwxrwxr-x 2 bk    bk 4096 Sep 13 20:54 gcc
drwxrwxr-x 2 bk    bk 4096 Sep 13 16:36 test
-rw-rw-rw- 1 root bk    39 Sep 13 22:04 test-new.txt
-rw-rw-r-- 1 bk    bk   21 Sep 13 18:39 testscript.sh
bk@cs550-1:~$ ]
```

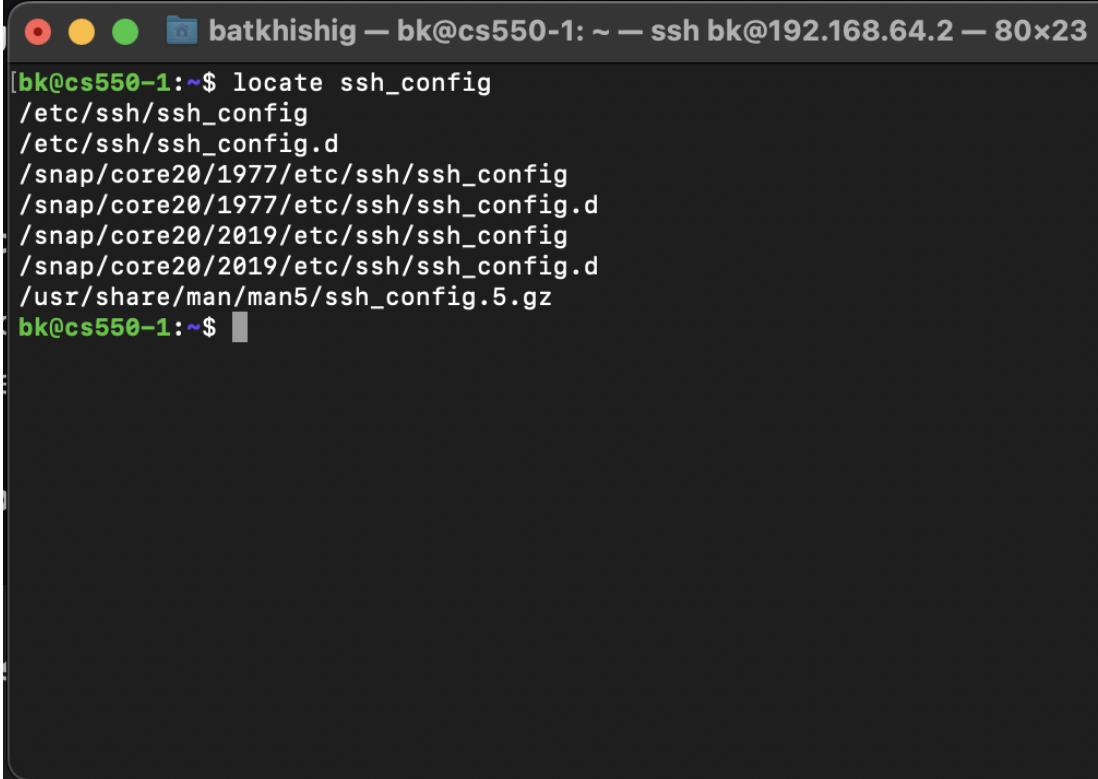


II. man - system manual for commands



```
[bk@cs550-1:~$ mv test.txt test-new.txt
[bk@cs550-1:~$ ls -l
total 16
drwxrwxr-x 2 bk    bk 4096 Sep 13 20:54 gcc
drwxrwxr-x 2 bk    bk 4096 Sep 13 16:36 test
-rw-rw-rw- 1 root  bk   39 Sep 13 22:04 test-new.txt
-rw-rw-r-- 1 bk    bk   21 Sep 13 18:39 testscript.sh
bk@cs550-1:~$ ]
```

mm. locate - searches for files or directories from database



```
[bk@cs550-1:~$ locate ssh_config
/etc/ssh/ssh_config
/etc/ssh/ssh_config.d
/snap/core20/1977/etc/ssh/ssh_config
/snap/core20/1977/etc/ssh/ssh_config.d
/snap/core20/2019/etc/ssh/ssh_config
/snap/core20/2019/etc/ssh/ssh_config.d
/usr/share/man/man5/ssh_config.5.gz
bk@cs550-1:~$ ]
```



nn. find - used to find files and directories in the hierarchy. Slower than locate



```
batkhishig — bk@cs550-1: ~ — ssh bk@192.168.64.2 — 80x23
[~]$ find . -name test
./test
[~]$
```

oo. sed - used to edit a file, replace text



```
batkhishig — bk@cs550-1: ~ — ssh bk@192.168.64.2 — 80x23
[~]$ cat test-new.txt
testing vi command
testing vim command
[~]$ sed 's/testing/tested/' test-new.txt
tested vi command
tested vim command
[~]$
```



pp. awk - a tool used to process files, like csv

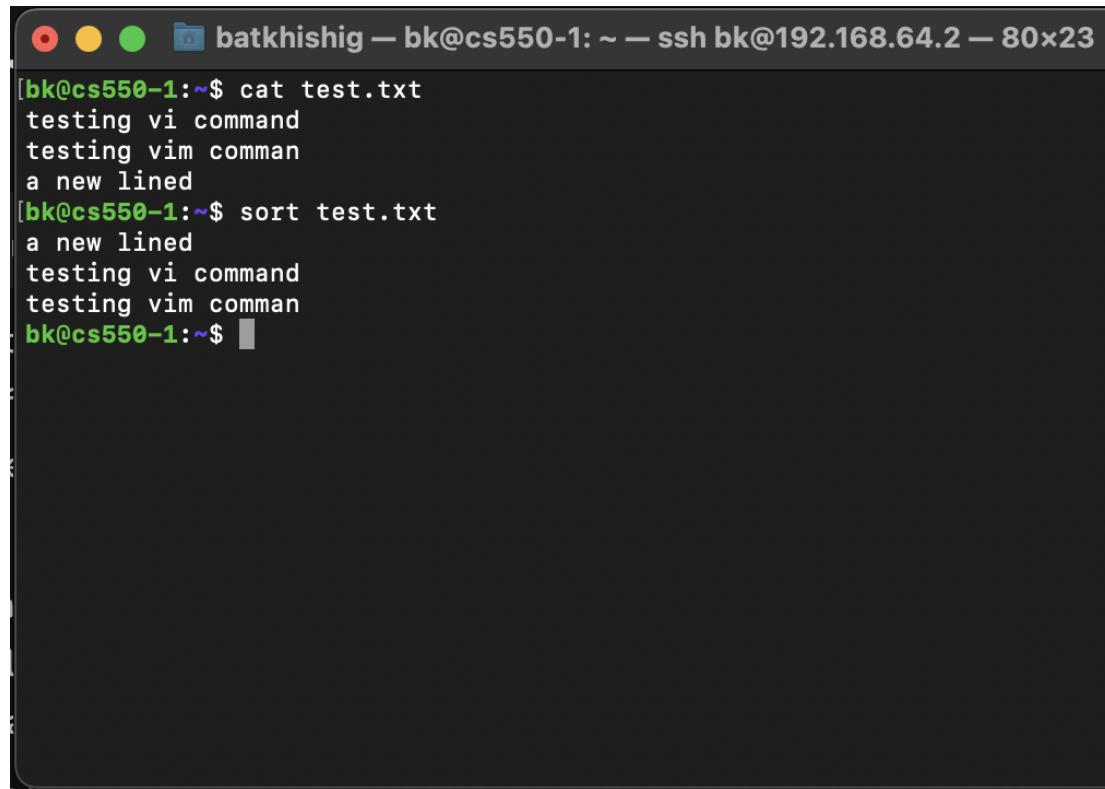
```
● ● ● batkhisig — bk@cs550-1: ~ — ssh bk@192.168.64.2 — 80x23
[bk@cs550-1:~$ awk '/groupadd/ {print}' /var/log/auth.log
Sep 13 22:30:47 cs550-1 groupadd[5418]: group added to /etc/group: name=plocate,
  GID=119
Sep 13 22:30:47 cs550-1 groupadd[5418]: group added to /etc/gshadow: name=plocate
Sep 13 22:30:47 cs550-1 groupadd[5418]: new group: name=plocate, GID=119
bk@cs550-1:~$
```

qq. diff - tells the difference between two files, line by line

```
● ● ● batkhisig — bk@cs550-1: ~ — ssh bk@192.168.64.2 — 80x23
[bk@cs550-1:~$ diff test.txt test-new.txt
1,2c1,2
< testing vi command
< testing vim command
---
> tested vi command
> tested vim command
bk@cs550-1:~$
```



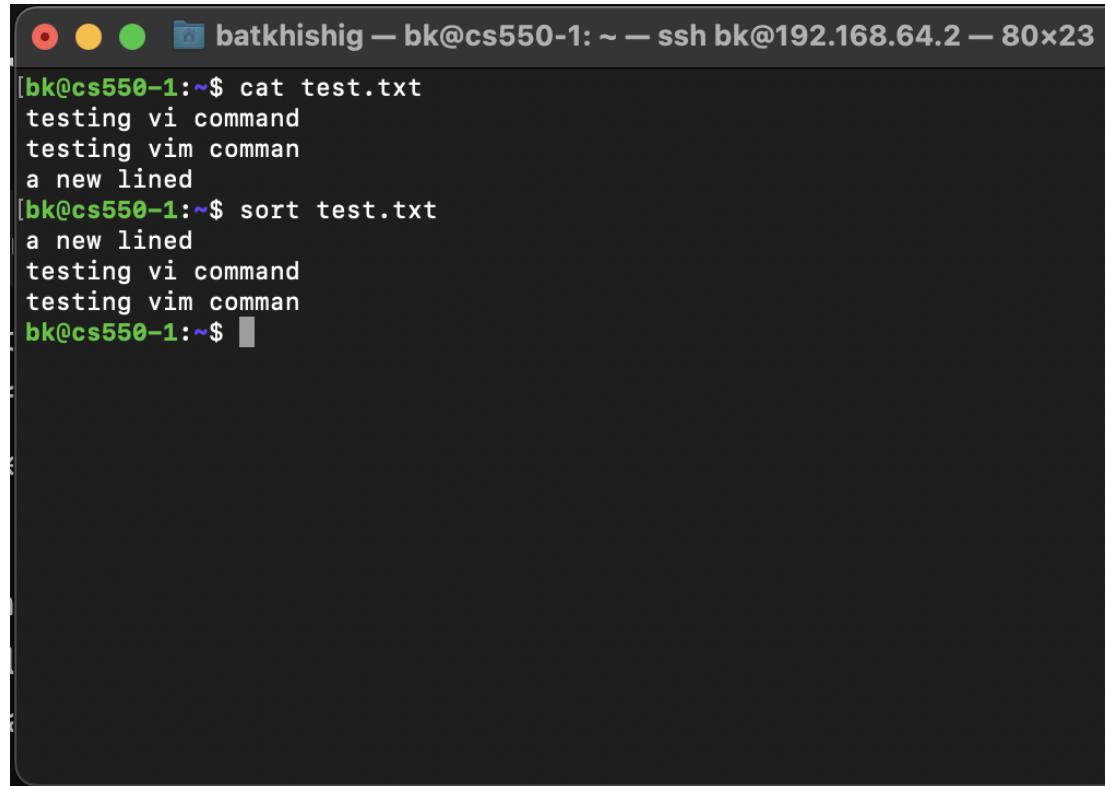
rr. sort - sorts lines in a file



A screenshot of a terminal window titled "batkhishig — bk@cs550-1: ~ — ssh bk@192.168.64.2 — 80x23". The window shows the following command sequence:

```
[bk@cs550-1:~$ cat test.txt
testing vi command
testing vim comman
a new lined
[bk@cs550-1:~$ sort test.txt
a new lined
testing vi command
testing vim comman
bk@cs550-1:~$ ]
```

ss. export - shows list of environment variables



A screenshot of a terminal window titled "batkhishig — bk@cs550-1: ~ — ssh bk@192.168.64.2 — 80x23". The window shows the following command sequence:

```
[bk@cs550-1:~$ cat test.txt
testing vi command
testing vim comman
a new lined
[bk@cs550-1:~$ sort test.txt
a new lined
testing vi command
testing vim comman
bk@cs550-1:~$ ]
```



tt. `pwd` - prints current working directory



```
batkhishig — bk@cs550-1: ~ — ssh bk@192.168.64.2 — 80x23
[bk@cs550-1:~$ pwd
/home/bk
bk@cs550-1:~$ ]
```

uu. `crontab` - schedules cron job in the system



```
batkhishig — bk@cs550-1: ~ — ssh bk@192.168.64.2 — 80x23
[bk@cs550-1:~$ crontab -l
no crontab for bk
bk@cs550-1:~$ ]
```



vv. mount - mounts folders and filesystems

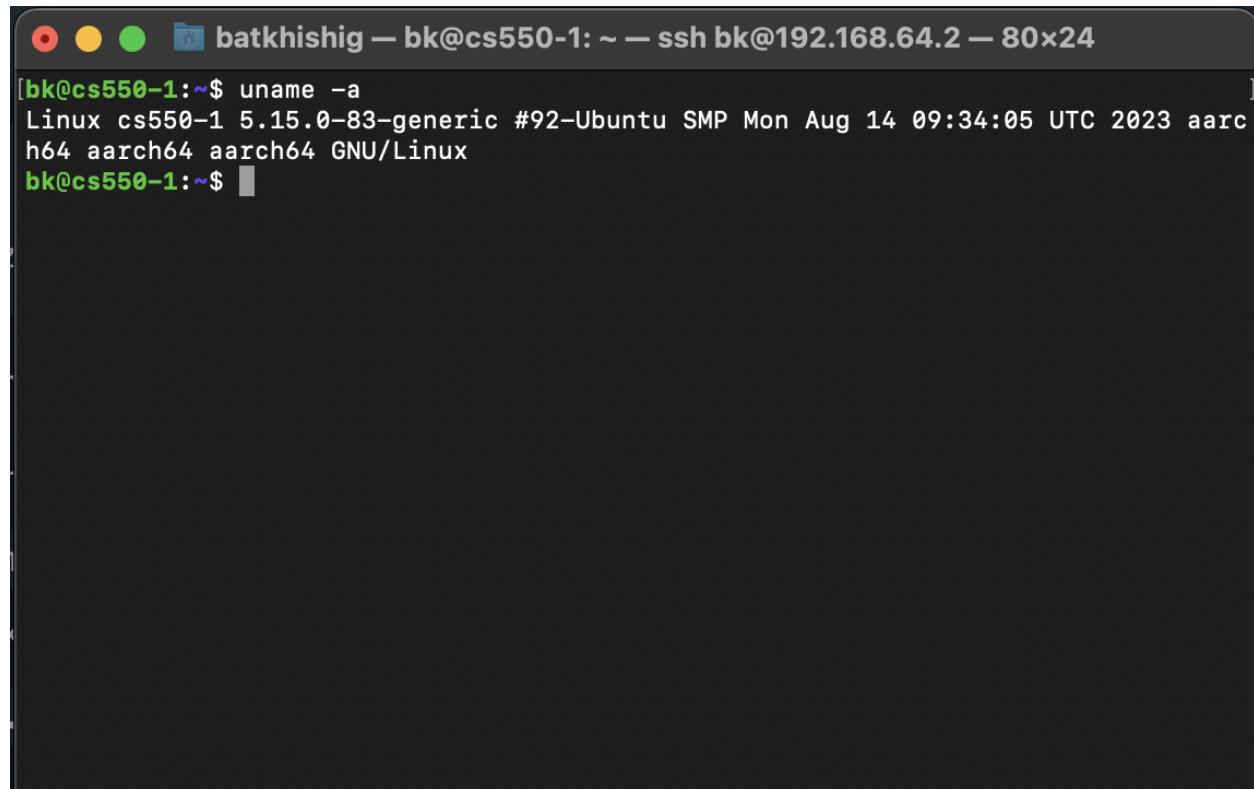
```
batkhishig — bk@cs550-1: ~ — ssh bk@192.168.64.2 — 80x24
[bk@cs550-1:~]$ mount -l
sysfs on /sys type sysfs (rw,nosuid,nodev,noexec,relatime)
proc on /proc type proc (rw,nosuid,nodev,noexec,relatime)
udev on /dev type devtmpfs (rw,nosuid,relatime,size=935068k,nr_inodes=233767,mode=755,inode64)
devpts on /dev/pts type devpts (rw,nosuid,noexec,relatime,gid=5,mode=620,ptmxmode=000)
tmpfs on /run type tmpfs (rw,nosuid,nodev,noexec,relatime,size=201436k,mode=755,inode64)
efivarfs on /sys/firmware/efi/efivars type efivarfs (rw,nosuid,nodev,noexec,relatime)
/dev/mapper/ubuntu--vg-ubuntu--lv on / type ext4 (rw,relatime)
securityfs on /sys/kernel/security type securityfs (rw,nosuid,nodev,noexec,relatime)
tmpfs on /dev/shm type tmpfs (rw,nosuid,nodev,inode64)
tmpfs on /run/lock type tmpfs (rw,nosuid,nodev,noexec,relatime,size=5120k,inode64)
cgroup2 on /sys/fs/cgroup type cgroup2 (rw,nosuid,nodev,noexec,relatime,nsdelegate,memory_recursiveprot)
pstore on /sys/fs/pstore type pstore (rw,nosuid,nodev,noexec,relatime)
bpf on /sys/fs/bpf type bpf (rw,nosuid,nodev,noexec,relatime,mode=700)
systemd-1 on /proc/sys/fs/binfmt_misc type autofs (rw,relatime,fd=29,pgrp=1,time_out=0,minproto=5,maxproto=5,direct,pipe_ino=13841)
basetlfs on /dev/basetlfs type basetlfs (rw,relatime,pagesize=2M)
```

ww. passwd - used to change password of a user

```
batkhishig — root@cs550-1: ~ — ssh bk@192.168.64.2 — 80x24
[root@cs550-1:~# passwd guest
[New password:
[Retype new password:
passwd: password updated successfully
root@cs550-1:~# ]
```

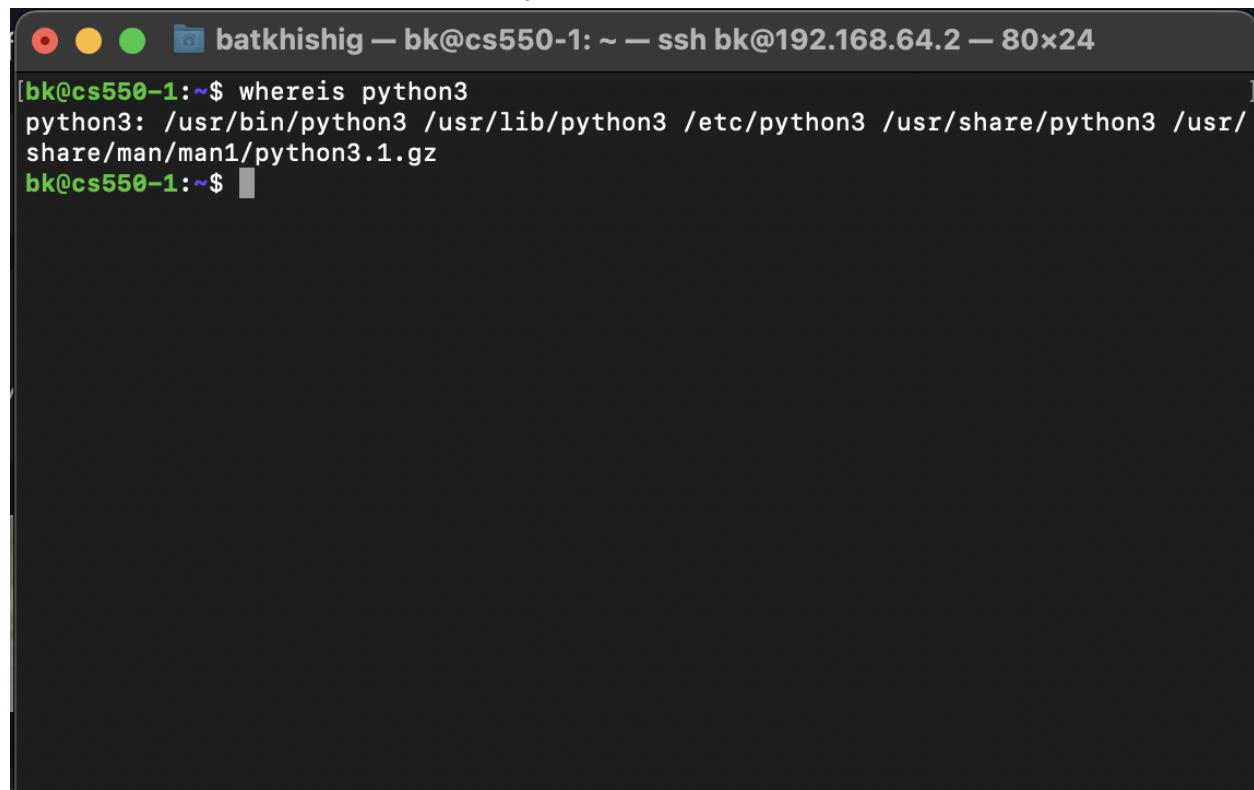


xx. uname - shows information about the current operating system



```
[bk@cs550-1:~$ uname -a
Linux cs550-1 5.15.0-83-generic #92-Ubuntu SMP Mon Aug 14 09:34:05 UTC 2023 aarc
h64 aarch64 aarch64 GNU/Linux
bk@cs550-1:~$ ]
```

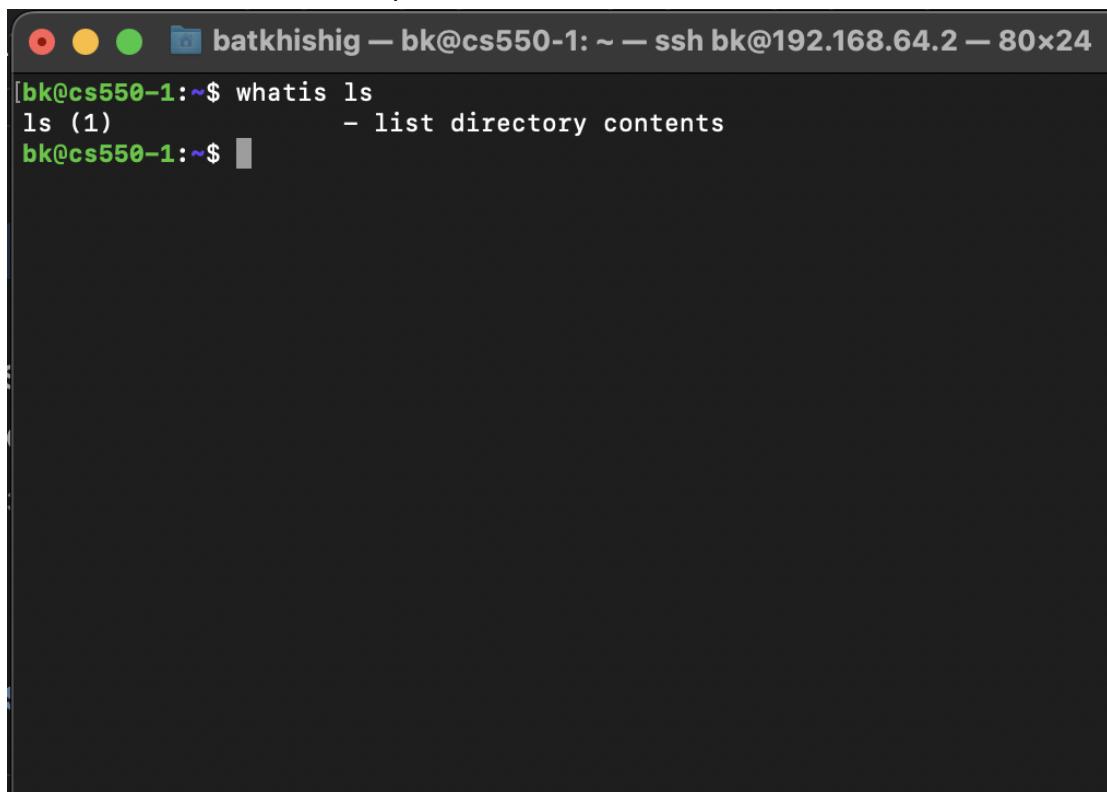
yy. whereis - used to find location of a binary source of a command



```
[bk@cs550-1:~$ whereis python3
python3: /usr/bin/python3 /usr/lib/python3 /etc/python3 /usr/share/python3 /usr/
share/man/man1/python3.1.gz
bk@cs550-1:~$ ]
```

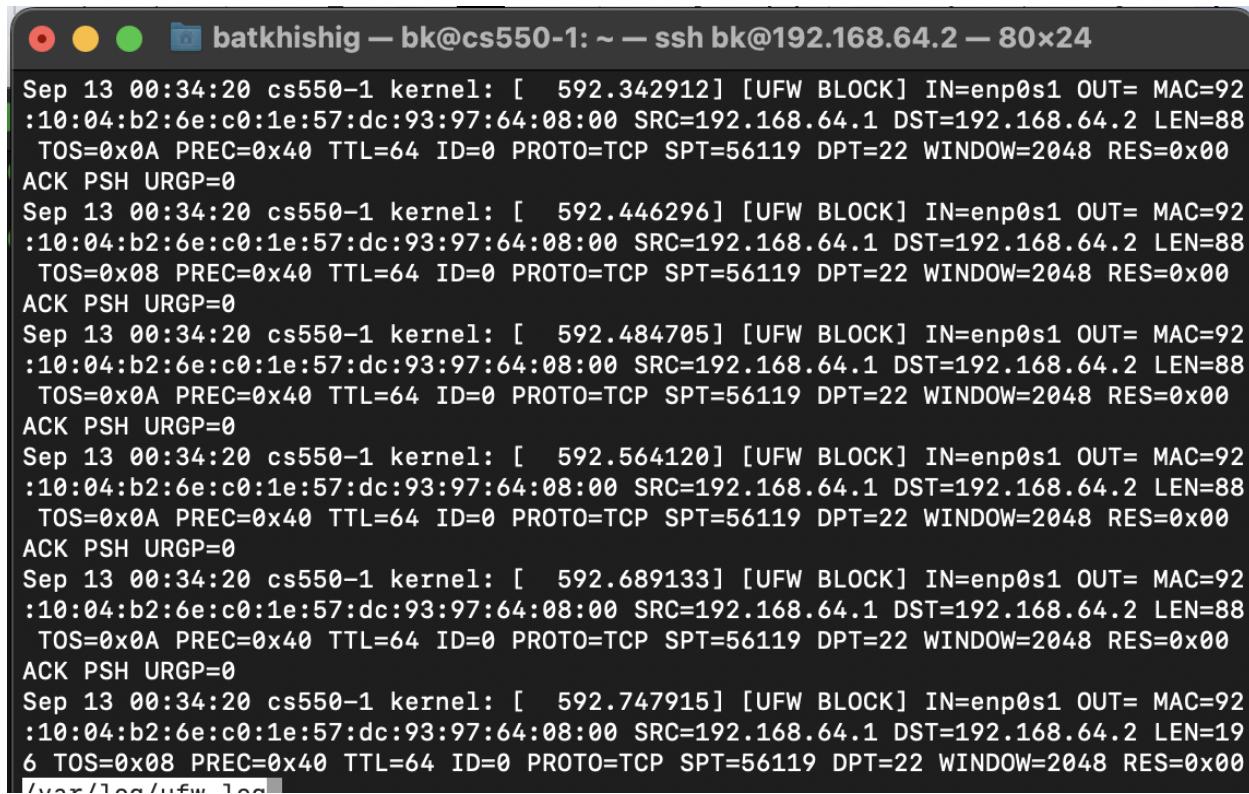


zz. whatis - shows one line description of a command



```
[bk@cs550-1:~$ whatis ls
ls (1)                  - list directory contents
bk@cs550-1:~$ ]
```

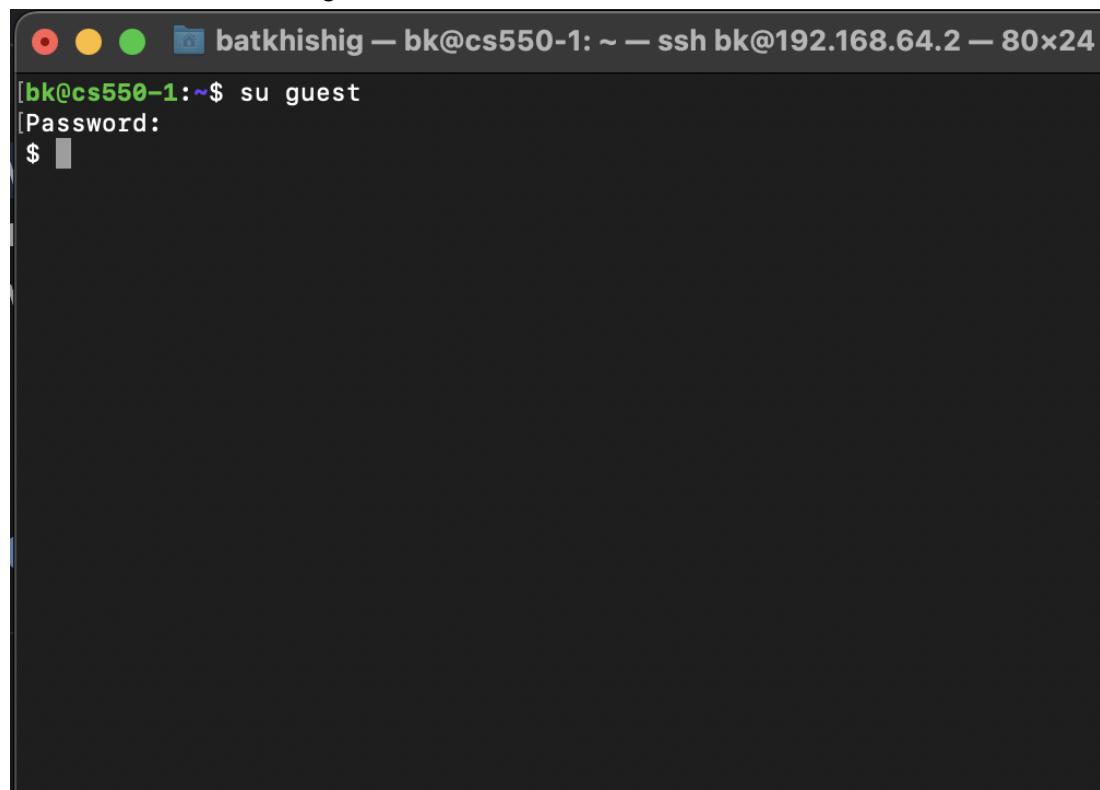
aaa. less - similar to more command but faster



```
Sep 13 00:34:20 cs550-1 kernel: [ 592.342912] [UFW BLOCK] IN=enp0s1 OUT= MAC=92 :10:04:b2:6e:c0:1e:57:dc:93:97:64:08:00 SRC=192.168.64.1 DST=192.168.64.2 LEN=88 TOS=0x0A PREC=0x40 TTL=64 ID=0 PROTO=TCP SPT=56119 DPT=22 WINDOW=2048 RES=0x00 ACK PSH URGP=0
Sep 13 00:34:20 cs550-1 kernel: [ 592.446296] [UFW BLOCK] IN=enp0s1 OUT= MAC=92 :10:04:b2:6e:c0:1e:57:dc:93:97:64:08:00 SRC=192.168.64.1 DST=192.168.64.2 LEN=88 TOS=0x08 PREC=0x40 TTL=64 ID=0 PROTO=TCP SPT=56119 DPT=22 WINDOW=2048 RES=0x00 ACK PSH URGP=0
Sep 13 00:34:20 cs550-1 kernel: [ 592.484705] [UFW BLOCK] IN=enp0s1 OUT= MAC=92 :10:04:b2:6e:c0:1e:57:dc:93:97:64:08:00 SRC=192.168.64.1 DST=192.168.64.2 LEN=88 TOS=0x0A PREC=0x40 TTL=64 ID=0 PROTO=TCP SPT=56119 DPT=22 WINDOW=2048 RES=0x00 ACK PSH URGP=0
Sep 13 00:34:20 cs550-1 kernel: [ 592.564120] [UFW BLOCK] IN=enp0s1 OUT= MAC=92 :10:04:b2:6e:c0:1e:57:dc:93:97:64:08:00 SRC=192.168.64.1 DST=192.168.64.2 LEN=88 TOS=0x0A PREC=0x40 TTL=64 ID=0 PROTO=TCP SPT=56119 DPT=22 WINDOW=2048 RES=0x00 ACK PSH URGP=0
Sep 13 00:34:20 cs550-1 kernel: [ 592.689133] [UFW BLOCK] IN=enp0s1 OUT= MAC=92 :10:04:b2:6e:c0:1e:57:dc:93:97:64:08:00 SRC=192.168.64.1 DST=192.168.64.2 LEN=88 TOS=0x0A PREC=0x40 TTL=64 ID=0 PROTO=TCP SPT=56119 DPT=22 WINDOW=2048 RES=0x00 ACK PSH URGP=0
Sep 13 00:34:20 cs550-1 kernel: [ 592.747915] [UFW BLOCK] IN=enp0s1 OUT= MAC=92 :10:04:b2:6e:c0:1e:57:dc:93:97:64:08:00 SRC=192.168.64.1 DST=192.168.64.2 LEN=196 TOS=0x08 PREC=0x40 TTL=64 ID=0 PROTO=TCP SPT=56119 DPT=22 WINDOW=2048 RES=0x00
[...]
```

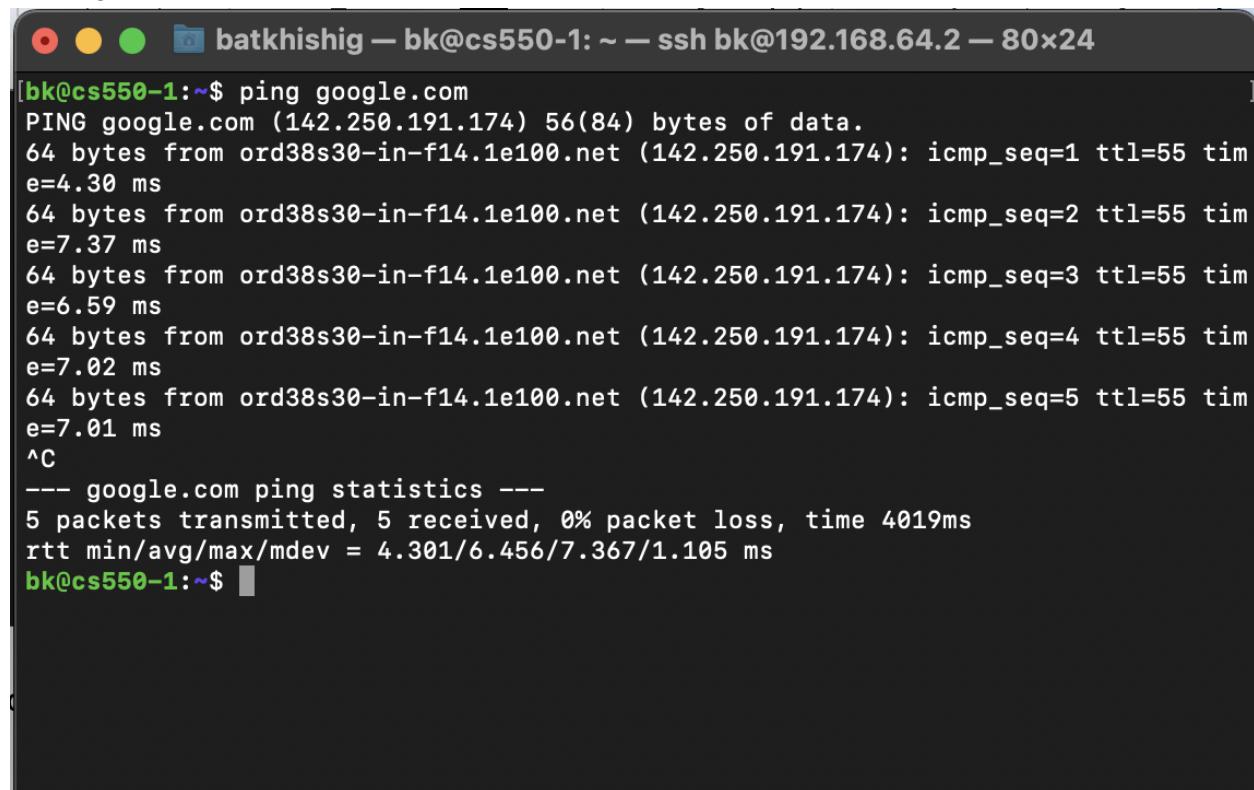


bbb. su - allows user to login to another user



A screenshot of a terminal window titled "batkhishig — bk@cs550-1: ~ — ssh bk@192.168.64.2 — 80x24". The window shows the command [bk@cs550-1:~\$ su guest] followed by a password prompt [Password:]. The terminal background is dark gray.

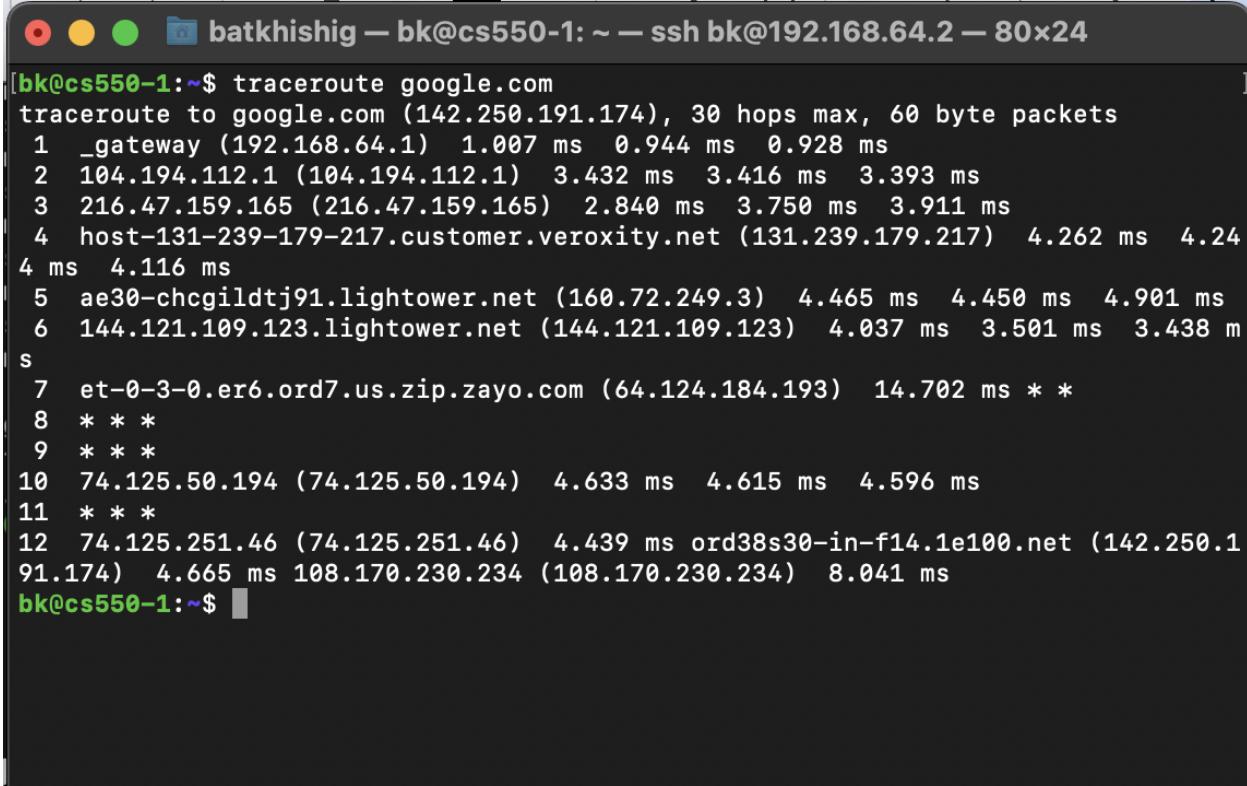
ccc. ping - checks network connection with a server



A screenshot of a terminal window titled "batkhishig — bk@cs550-1: ~ — ssh bk@192.168.64.2 — 80x24". The window shows the command [bk@cs550-1:~\$ ping google.com] followed by a series of ping responses. The output includes: PING google.com (142.250.191.174) 56(84) bytes of data., 64 bytes from ord38s30-in-f14.1e100.net (142.250.191.174): icmp_seq=1 ttl=55 time=4.30 ms, 64 bytes from ord38s30-in-f14.1e100.net (142.250.191.174): icmp_seq=2 ttl=55 time=7.37 ms, 64 bytes from ord38s30-in-f14.1e100.net (142.250.191.174): icmp_seq=3 ttl=55 time=6.59 ms, 64 bytes from ord38s30-in-f14.1e100.net (142.250.191.174): icmp_seq=4 ttl=55 time=7.02 ms, 64 bytes from ord38s30-in-f14.1e100.net (142.250.191.174): icmp_seq=5 ttl=55 time=7.01 ms, ^C, --- google.com ping statistics ---, 5 packets transmitted, 5 received, 0% packet loss, time 4019ms, rtt min/avg/max/mdev = 4.301/6.456/7.367/1.105 ms. The terminal background is dark gray.



ddd. traceroute - as the name suggests, it traces route to the destination



```
[bk@cs550-1:~$ traceroute google.com
traceroute to google.com (142.250.191.174), 30 hops max, 60 byte packets
 1 _gateway (192.168.64.1)  1.007 ms  0.944 ms  0.928 ms
 2 104.194.112.1 (104.194.112.1)  3.432 ms  3.416 ms  3.393 ms
 3 216.47.159.165 (216.47.159.165)  2.840 ms  3.750 ms  3.911 ms
 4 host-131-239-179-217.customer.veroxity.net (131.239.179.217)  4.262 ms  4.24
4 ms  4.116 ms
 5 ae30-chcgildtj91.lightower.net (160.72.249.3)  4.465 ms  4.450 ms  4.901 ms
 6 144.121.109.123.lightower.net (144.121.109.123)  4.037 ms  3.501 ms  3.438 m
s
 7 et-0-3-0.er6.ord7.us.zip.zayo.com (64.124.184.193)  14.702 ms * *
 8 * * *
 9 * * *
10 74.125.50.194 (74.125.50.194)  4.633 ms  4.615 ms  4.596 ms
11 * * *
12 74.125.251.46 (74.125.251.46)  4.439 ms ord38s30-in-f14.1e100.net (142.250.1
91.174)  4.665 ms 108.170.230.234 (108.170.230.234)  8.041 ms
bk@cs550-1:~$
```

eee. date - shows current date of the system



```
[bk@cs550-1:~$ date
Thu Sep 14 16:55:48 UTC 2023
bk@cs550-1:~$
```



fff. time - measures time to execute a given command

```
● ● ● batkhisig — bk@cs550-1: ~ — ssh bk@192.168.64.2 — 80x12
[bk@cs550-1:~$ time cat test.txt
testing vi command

real    0m0.005s
user    0m0.000s
sys     0m0.005s
bk@cs550-1:~$ ]
```

ggg. wget

```
● ● ● batkhisig — bk@cs550-1: ~ — ssh bk@192.168.64.2 — 80x24
[bk@cs550-1:~$ wget google.png https://www.google.com/images/branding/goolelogo/2x/googlelogo_light_color_272x92dp.png
--2023-09-14 20:26:55-- http://google.png/
Resolving google.png (google.png)... failed: Name or service not known.
wget: unable to resolve host address 'google.png'
--2023-09-14 20:26:56-- https://www.google.com/images/branding/goolelogo/2x/go
oglelogo_light_color_272x92dp.png
Resolving www.google.com (www.google.com)... 142.250.190.132, 2607:f8b0:4009:814
::2004
Connecting to www.google.com (www.google.com)|142.250.190.132|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 7108 (6.9K) [image/png]
Saving to: 'googlelogo_light_color_272x92dp.png'

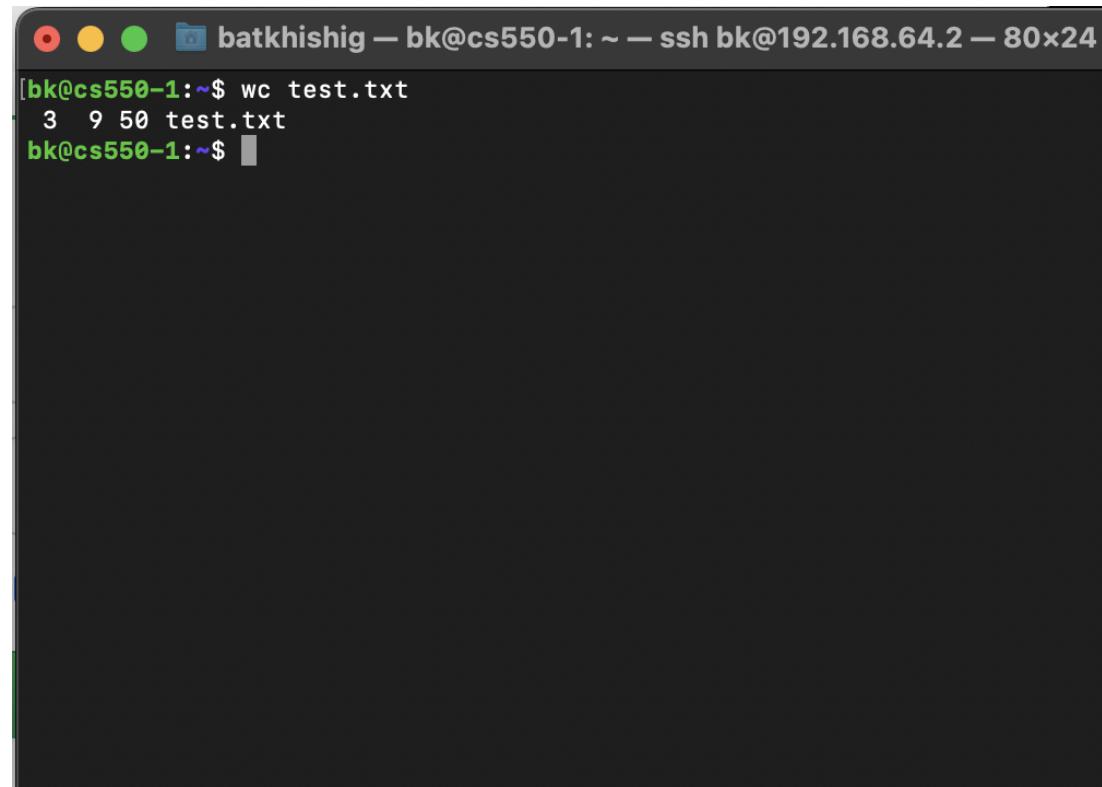
googlelogo_light_co 100%[=====] 6.94K --.-KB/s in 0s

2023-09-14 20:26:56 (15.2 MB/s) - 'googlelogo_light_color_272x92dp.png' saved [7
108/7108]

FINISHED --2023-09-14 20:26:56--
Total wall clock time: 0.6s
Downloaded: 1 files, 6.9K in 0s (15.2 MB/s)
bk@cs550-1:~$ ]
```

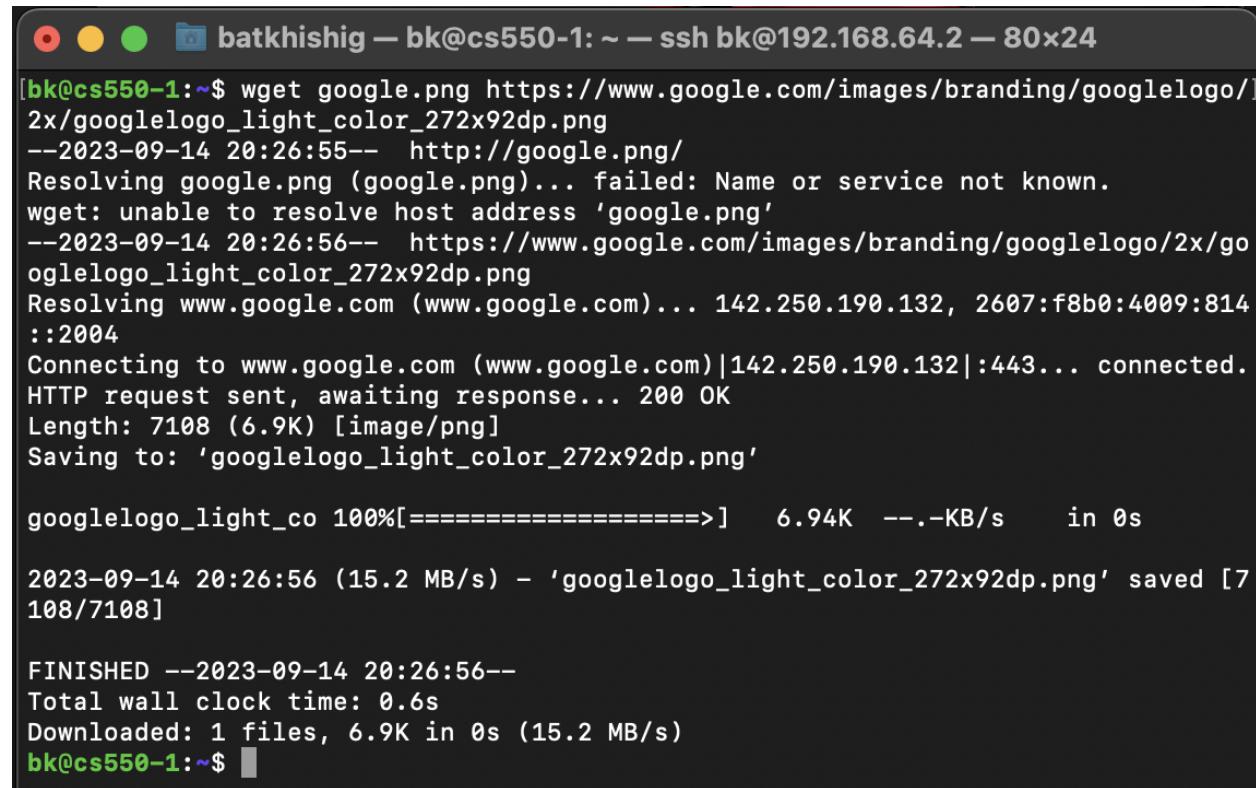


hhh. wc - returns word count of the file



```
[bk@cs550-1:~$ wc test.txt
 3 9 50 test.txt
bk@cs550-1:~$ ]
```

iii. clear - clears the screen



```
[bk@cs550-1:~$ wget google.png https://www.google.com/images/branding/goolelogo/2x/googlelogo_light_color_272x92dp.png
--2023-09-14 20:26:55-- http://google.png/
Resolving google.png (google.png)... failed: Name or service not known.
wget: unable to resolve host address 'google.png'
--2023-09-14 20:26:56-- https://www.google.com/images/branding/goolelogo/2x/goolelogo_light_color_272x92dp.png
Resolving www.google.com (www.google.com)... 142.250.190.132, 2607:f8b0:4009:814
::2004
Connecting to www.google.com (www.google.com)|142.250.190.132|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 7108 (6.9K) [image/png]
Saving to: 'googlelogo_light_color_272x92dp.png'

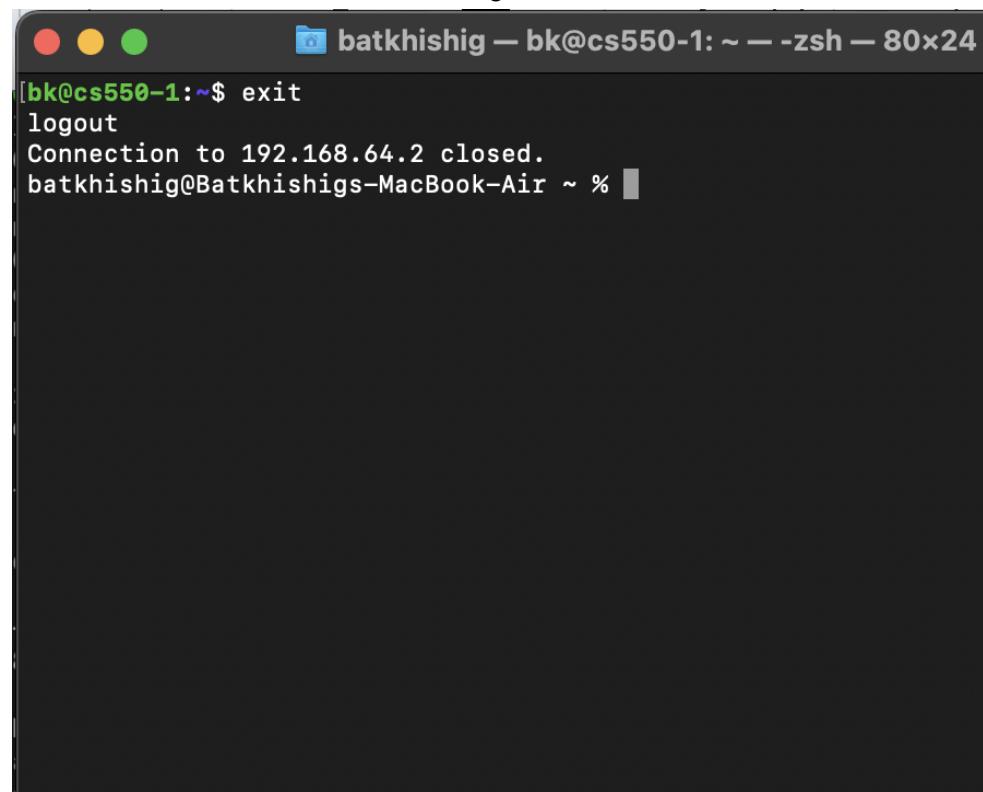
googlelogo_light_co 100%[=====] 6.94K --.-KB/s in 0s

2023-09-14 20:26:56 (15.2 MB/s) - 'googlelogo_light_color_272x92dp.png' saved [7108/7108]

FINISHED --2023-09-14 20:26:56--
Total wall clock time: 0.6s
Downloaded: 1 files, 6.9K in 0s (15.2 MB/s)
bk@cs550-1:~$ ]
```



- jjj. exit - exits from the current shell or logs out of the ssh connection



A screenshot of a terminal window titled "batkhishig — bk@cs550-1: ~ — zsh — 80x24". The window shows a black background with white text. At the top, there are three colored circles (red, yellow, green) followed by the title. The main area contains the following text:
[bk@cs550-1:~\$ exit
logout
Connection to 192.168.64.2 closed.
batkhishig@Batkhishigs-MacBook-Air ~ %]



3. (15 points) Write bash scripts to do the following:

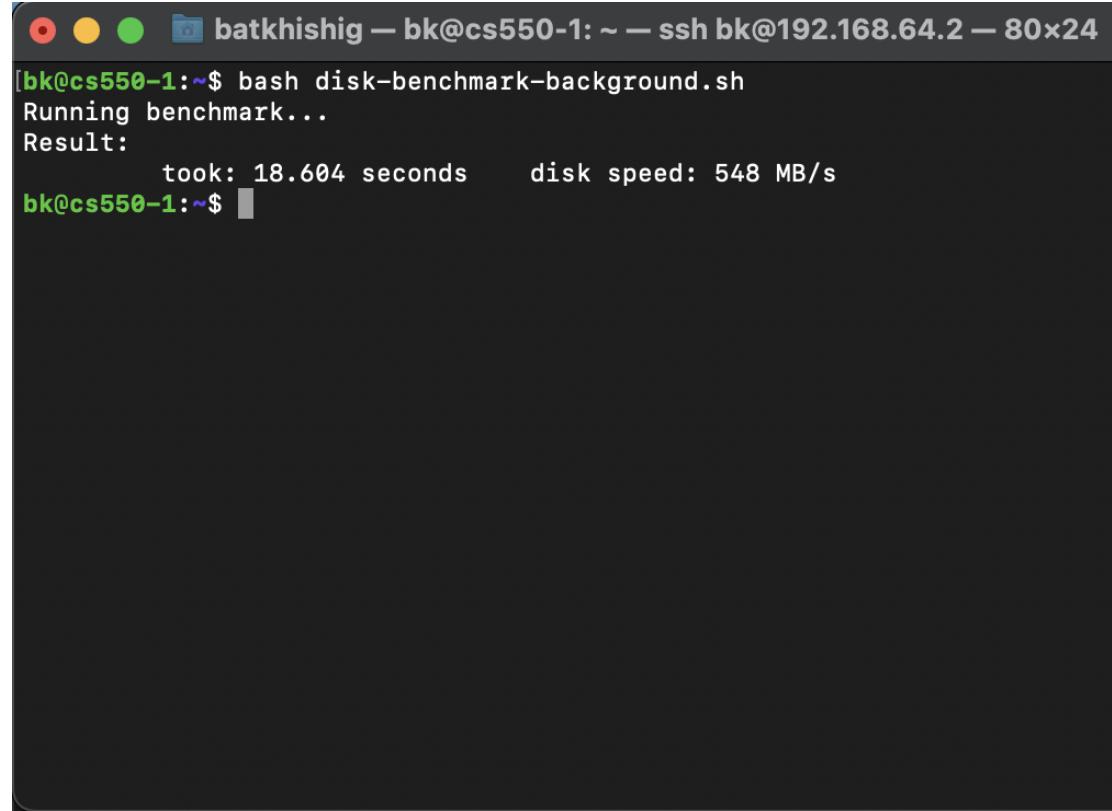
- a. Write a script called “disk-benchmark-background.sh” that uses the dd command to run a benchmark against the local disk in the background, that captures all the output (both standard out and error output) to a file “disk-benchmark-background-log.txt”. Use the “time” command to show how long the benchmark took to complete. The benchmark should run for at least 10 seconds, and it should complete even if the ssh (or bash) session is terminated.

```
#!/bin/bash

# CS550 Assignment 1
# Team: Batkhisig Dulamsurankhor, Nitin Singh, Vaishnavi Papudesi Babu

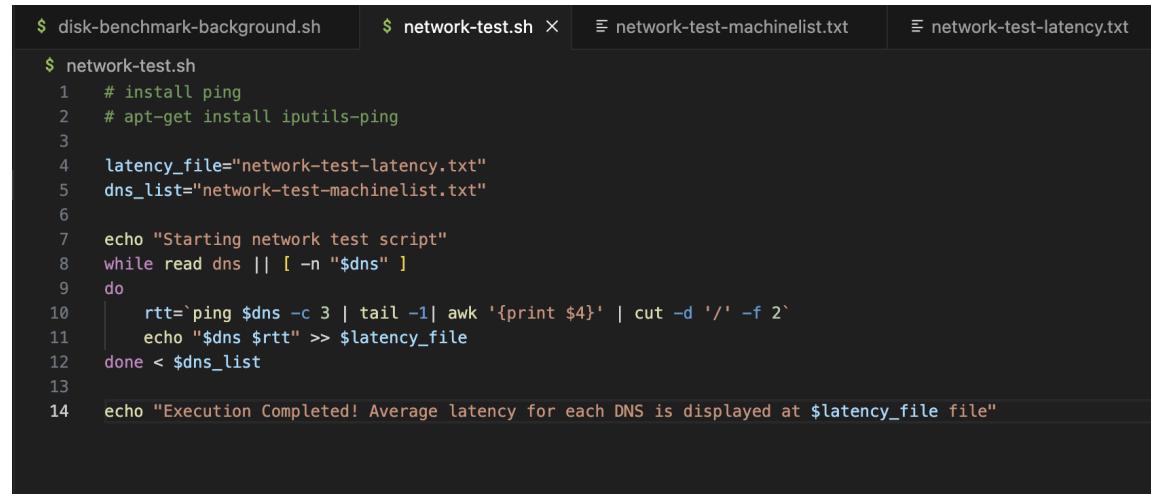
elapsed_time="0"
sum="0"
count="0"
run_benchmark() {
    # runs dd command for benchmarking
    (time dd if=/dev/zero of=/tmp/test1.img bs=1GB count=5 oflag=dsync) 2>&1
}
extract_time() {
    # extracts time in seconds from time command
    echo "$output" | grep real | awk '{split($2,a,"m"); print (a[1]*60)+a[2]}'
}
extract_speed() {
    # extracts disk speed from dd command result
    speed=$(echo "$output" | grep -oE '[0-9.]+ [MG]B/s')
    unit=$(echo "$speed" | sed 's/[MG]/g')
    value=$(echo "$speed" | sed 's/[0-9.]/g')
    # convert GB/s to MB/s
    if [ "$unit" = "G" ]
    then
        value=$(bc <<< "value * 1024")
    fi
    echo "$value"
}
echo "Running benchmark..."
# runs benchmark for at least 10 seconds
while [ $(bc <<< "$elapsed_time < 10") -eq 1 ]
do
    output=$(run_benchmark)
    echo "$output" >> ./disk-benchmark-background-log.txt
    real_time=$(extract_time "$output")
    value=$(extract_speed)
    sum=$(bc <<< "$sum + $value")
    count=$(bc <<< "$count + 1")
    elapsed_time=$(bc <<< "$elapsed_time + $real_time")
    sleep 0.1
done
average_speed=$(bc <<< "$sum / $count")
# convert MB/s to GB/s if the speed is over 1024MB/s
if [ $(bc <<< "$average_speed >= 1024") -eq 1 ]
then
    average_speed=$(echo "scale=2; $average_speed / 1024" | bc)
    average_speed=$(echo "$average_speed GB/s")
else
    average_speed=$(echo "$average_speed MB/s")
fi
echo -e "Result: \n \t took: $elapsed_time seconds \t disk speed: $average_speed" >> ./disk-benchmark-background-log.txt
echo -e "Result: \n \t took: $elapsed_time seconds \t disk speed: $average_speed"
```





```
[bk@cs550-1:~$ bash disk-benchmark-background.sh
Running benchmark...
Result:
    took: 18.604 seconds    disk speed: 548 MB/s
bk@cs550-1:~$ ]
```

- b. Write a script called “network-test.sh” that takes input a file “network-test-machinelist.txt” with a list of DNS names (e.g. google.com, iit.edu, anl.gov), each name on a separate line, and runs the ping utility collecting 3 samples from each DNS name, and writing the RTT (round trip time) average latency into a file “network-test-latency.txt” where each line will have the DNS name and average RTT separated by a space. Make sure it works with at least 10 DNS names, but it should work for an unspecified number of DNS names



```
$ disk-benchmark-background.sh      $ network-test.sh ✘      ✎ network-test-machinelist.txt      ✎ network-test-latency.txt
$ network-test.sh
1  # install ping
2  # apt-get install iputils-ping
3
4  latency_file="network-test-latency.txt"
5  dns_list="network-test-machinelist.txt"
6
7  echo "Starting network test script"
8  while read dns || [ -n "$dns" ]
9  do
10   rtt=`ping $dns -c 3 | tail -1| awk '{print $4}' | cut -d '/' -f 2` 
11   echo "$dns $rtt" >> $latency_file
12 done < $dns_list
13
14 echo "Execution Completed! Average latency for each DNS is displayed at $latency_file file"
```



```
≡ network-test-machinelist.txt
1 google.com
2 iit.edu
3 ubuntu.com
4 stackoverflow.com
5 kaggle.com
6 youtube.com
7 edx.org
8 coursera.org
9 udemy.com
10 udacity.com
```

```
≡ network-test-latency.txt
1 google.com 14.167
2 iit.edu 26.052
3 ubuntu.com 174.523
4 stackoverflow.com 4.204
5 kaggle.com 14.574
6 youtube.com 5.212
7 edx.org 5.351
8 coursera.org 4.807
9 udemy.com 14.727
10 udacity.com 5.109
11
```

- c. Write a Python matplotlib script to generate a graph of the “network-test-latency.txt” data. The graph should automatically adjust to the number of entries, and the scale of the data.

```
# CS550 Assignment 1
# Team: Batkhishig Dulamsurankhor, Nitin Singh, Vaishnavi Papudesi Babu

import numpy as np
import matplotlib.pyplot as plt

networkLatencyDict = {}

latencyLookup = open('network-test-latency.txt', 'r')

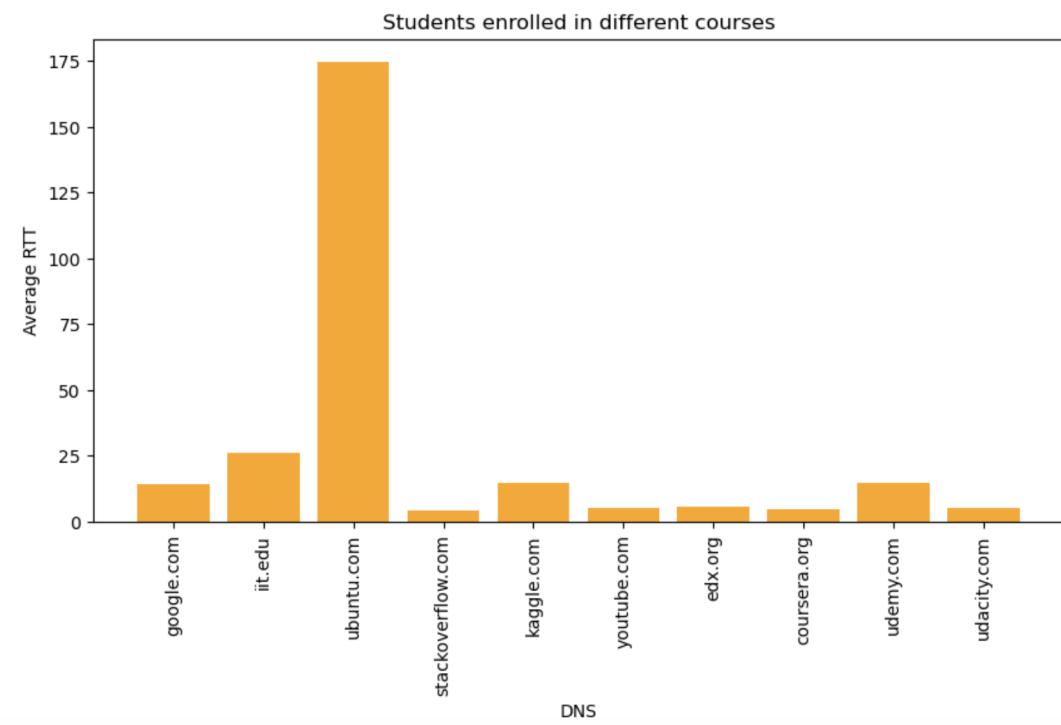
latencyLookupLines = latencyLookup.readlines()

for line in latencyLookupLines:
    dns = line.split(" ")
    networkLatencyDict[dns[0]] = float(dns[1])

fig = plt.figure(figsize = (10, 5))
plt.xticks(rotation='vertical')
plt.bar(list(networkLatencyDict.keys()), list(networkLatencyDict.values()), color ='orange')

plt.xlabel("DNS")
plt.ylabel("Average RTT")
plt.title("Students enrolled in different courses")
plt.show()
```





4. (15 points) Answer the following questions about VMs:

- In the system configuration of the VM, explain how changing the number of processors changes the behavior of your VM. Explain a scenario where you want to set this to the minimum, and a scenario where you want to set it to the maximum. Why is setting it to the maximum potentially a bad idea?

Allocating more processors to a VM can impact the performance significantly. It allows creating multiple virtual CPUs that improves performance of complex applications. A lightweight micro service hosted in a VM require minimum resources to perform operations whereas a complex application such as a computer-aided design application (eg. autocad) or a gaming software requires more resources for better performance.

However, setting a VM's resources to maximum is a bad idea because it impacts the overall performance of the host OS itself . We cannot scale multiple VMs for different purposes due to resource crunch. It causes resource contention. It increases the maintenance costs. It is always a good practice to consider the requirements and plan resources thoughtfully in order to make use of VMs efficiently.

- In the system configuration of the VM, under the Acceleration Tab, explain the difference between the paravirtualization options: None, Legacy, Minimal,

Hyper-V, and KVM. Explain which one would be best to use with Ubuntu Linux, and why.

Answer: None - Disables paravirtualization.

Legacy - A legacy paravirtualization support for the VMs that do not support modern paravirtualization models like Hyper-V.

Minimal - Suitable for lightweight operations like I/O operations.

Hyper-V - Suitable for windows-based VMs, provides optimized performance for the VMs.

KVM - Suitable for linux-based VMs, provides advanced paravirtualization support to VMs.

For Ubuntu Linux based virtual box, KVM is the right choice as KVM is a modern paravirtualization model that provides excellent performance, compatibility and it is open source.

- c. In storage devices when configuring the VM, there are multiple types of storage controllers: explain the difference between the IDE, SATA, and NVMe controller. Give an example for each type of storage controller of a scenario where you may want to use this type of controller.

IDE: Suitable for legacy versions of windows and linux distributions that do not support modern storage controllers. Eg. vintage distribution of linux.

SATA: SATA controller emulates SATA interface commonly used in physical systems, it offers better performance than IDE. Suitable for latest operating systems, like windows 10.

NVMe: A latest controller that provides low latency and high throughput emulating NVMe interface used by high-speed SSDs. Suitable for VMs that hosts complex applications like gaming.

- d. In the network configuration of the VM, there are multiple types of network adapters: explain the difference between NAT, Bridged Adapter, Internal Network, and Host-only Network. Give an example for each type of network of a scenario where you may want to use this type of network.

NAT: Network Address Translation allows VM to use host's IP address and network connection where host translates the network traffic between external network and the VM. Suitable to allow access to the internet from the VM. Eg. Application that needs access to public APIs.

Bridge Adapter: Connects to a physical network like any other physical systems, suitable for allowing networking access across multiple physical systems and VMs that are connected through the same network. Eg. A large scale system that hosts different components in individual VMs, like web server hosted in VM1, Storage hosted in VM2, Backend daemon jobs configured in VM3.



Internal Network: An isolated network, separated from the host's or external networks ideal for software development or tests. Internal networks can be shared among multiple VMs. Eg. An isolated network to communicate between VMs that host software applications in isolated VMs that do not require external or host's network.

Host-only Network: A Host-only network allows VM to share a network of host and the internal network, separating out from external networks. Suitable for virtualized environments.

- e. For the USB configuration of the VM, explain the difference between USB 1.1, 2.0, and 3.0 controllers.

USB 1.1 is known as USB Full-speed, it can transfer data up to 12Mbps speed.

USB 2.0 is known as USB High-speed, data transfer rate is up to 480Mbps.

USB 3.0 is known as USB Super-speed, data transfer rate is 5Gbps.

5. (12 points) Answer the following questions about computer processors:

- a. Today's commodity processors have 1 to 96 cores, and specialized GPUs having 10000+ CUDA-cores. About how many cores/threads are expected to be in future commodity processors in the next five years?

Future commodity processors and specialized GPUs will have more cores, as the number has been increasing for the past decades. Although it is hard to predict the future, I think common processors can get up to 150 and GPUs can reach 20000 cores.

- b. Describe what a core and hardware thread is on a modern processor, and the difference between them?

Processor core is a physical unit that can execute instructions using its ALUs and registers. Multiple cores can run programs in parallel. On the other hand, hardware thread is more like a virtual core in the actual processor core that can process multiple instructions. In multithreading, it looks like the machine is processing instructions in parallel, but actually just better utilizing the physical core.

In general, cores are more powerful than hardware threads. For example, when deploying server applications, if you add more cores, it is going to handle more requests in parallel but becomes resource intensive, while adding more threads might not be as fast as adding more cpu cores, however it can utilize CPU better.

- c. Compare GPU and CPU chips in terms of their strength and weakness. In particular, discuss the tradeoffs between power efficiency, programmability and performance.



GPU generally consumes more power than CPU, however it can process many simultaneous tasks, like graphic rendering in computer games, which CPU struggles with. CPUs are more suited for fewer simultaneous tasks.

When it comes to programming, CPUs are much simpler because a program runs fewer concurrent tasks, mostly a single task. For GPUs, it can be more complex than programming CPUs, but can achieve much higher parallelism. It is mainly used for rendering, machine learning tasks and crypto mining.

Performance wise, both are efficient and effective on their dedicated tasks, GPUs on multiple concurrent tasks and CPUs on single threaded tasks.

- d. Why do we not have processors running at 100GHz today (as might have been predicted in the year 2000)?

I think heating is a problem. When the CPU runs intensively, it generally heats up, achieving higher clock speed extremely hard. Therefore, it is commonplace to use cooling to prevent the CPU from damaging itself. Also, on a physical level, the transistors are becoming smaller and smaller, and manufacturing even smaller transistors is scientifically challenging. Because of these issues, manufacturers are bending towards multiprocessing and producing CPUs with more cores to increase their performance.

6. (12 points) Answer the following questions about threading:

- a. Why is threading useful on a single-core processor?

A single core CPU can execute only one thread at a time, but implementing threading improves efficiency and responsiveness enabling quick context switching between threads.

- b. Do more threads always mean better performance?

With increase in threads, the load on CPU increases due to many reasons including context switching and contention of resources like memory. So, more threads does not mean a better performance. It depends on the system's overall architecture.

- c. Is super-linear speedup possible? Explain why or why not.

Generally, achieving super-linear speedup is not common when using threading to parallelise a task. Speedup, which measures the performance improvement gained through parallelisation, typically does not exceed expectations in the context of threading.



- d. Why are locks needed in a multi-threaded program?

Locks are essential in multi-threaded programs to manage access to shared resources and prevent race conditions.

- e. Would it make sense to limit the number of threads in a server process?

As stated above, more threads does not guarantee a better performance. It could lead to worse performance issues and slowness. Hence, limiting the number of threads is a good practice to ensure efficient utilization of resources.

