

LINUX FUNDAMENTALS

OVERVIEW

History of Linux

What is kernel

Linux System architecture

Linux file systems

Linux Folders

Linux commands

File Permissions

History of Linux

- Before talking of Linux, we first have to go back in time to learn about another name, which is Unix.

1969 -Ken Thompson and Dennis Ritchie

- Unix is an operating system that has been around for a long time, at AT&T Bell Labs. The project was led by Ken Thompson and Dennis Ritchie, two famous computer scientists.
- **Motivation**-That time there were very few operating systems those that were available often highly specific to particular hardware architectures.
- Unix is multi-tasking, multi-user operating system but is not free to use and is not open source.



1983-Richard Stallman ,GNU (GNU's Not Unix) project

- Main Goal-create a free, Unix-like operating system, where people have the freedom to copy, develop, modify and distribute software

Linus and Linux

- Linus Torvalds, he was a computer science at the university of Helsinki, he wanted to make a free and open source operating system that anyone could use and improve .

1991

- Finally Linus Torvalds introduced a personal product, which later became the Linux Kernel.
- The combination of the Linux kernel and the GNU(**GNU's Not Unix**) software created the first completely free operating system. It is named **GNU/Linux**.



Important things of Linux

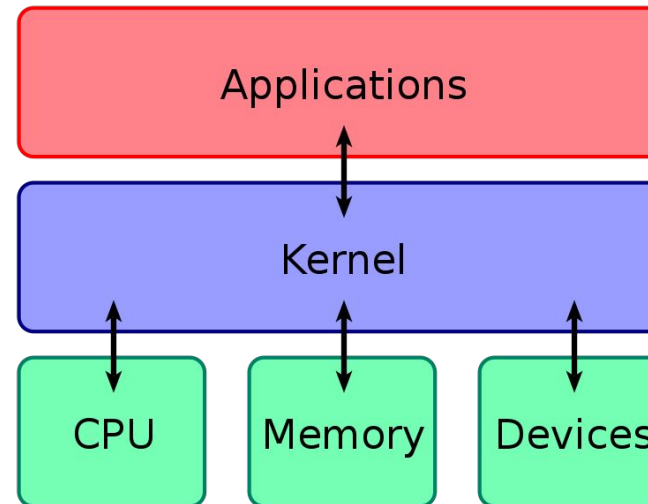
- Linux itself is just a kernel, it is not a complete operating system.
-
- The operating system that we still using on our computer is called GNU / Linux,
- Linux operating system does not use or share any part of Unix,It was built entirely new by Linus and the GNU Project .

What is Kernel

A kernel is the core component of an operating system. It is also a system program. It is the part of Operating System which translates the application commands in to hardware command

It provides an interface between application and hardware.

The main purpose of a kernel is to manage memory, disk and task.



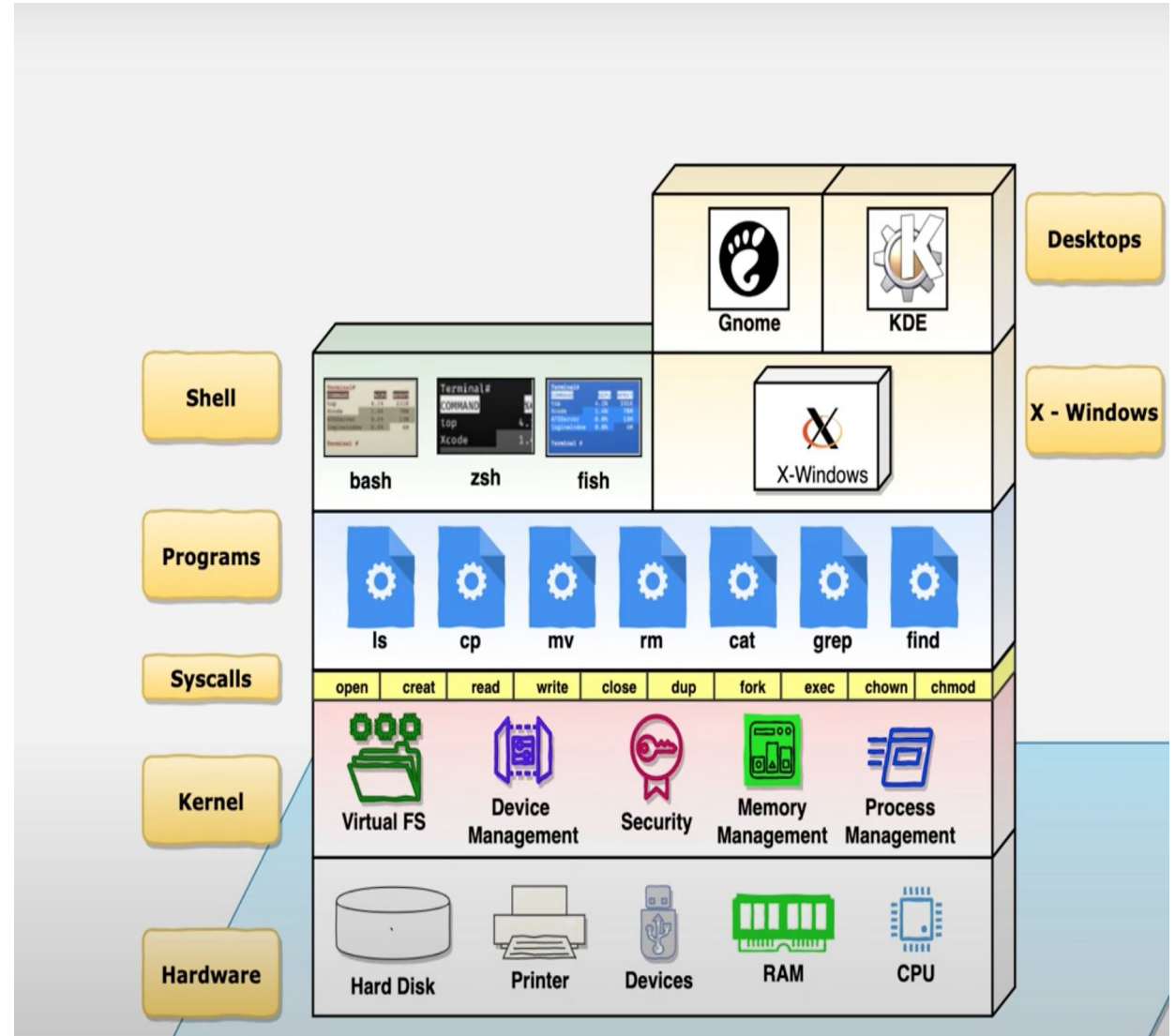
Linux System Architecture

Divided in to two levels

- User space
- Kernel space

user space is the area of memory where applications and user-level programs run. It contains the code and data that are executed by user-level processes, and it provides access to system resources through **system calls**.

Kernel space It is responsible for managing hardware resources and providing services to user-level programs through **system calls**.



system calls-It is a **request for the kernel to access a resource**

open() - opens a file and returns a file descriptor

read() - reads data from a file descriptor

write() - writes data

close() - closes a file descriptor

System calls provide an interface between the user-level application and the kernel

Programs-This includes the user application and utilities(commands that are used to perform various tasks on the system)

Shell-This is a program that provides a command-line interface for users to interact with the operating system

Gnome-It is a desktop environment in Linux. It is a graphical user interface (GUI) that provides an user-friendly interface for users to interact with the operating system

When a user types a command like **cat test.txt** in the terminal, the shell decodes the command and uses **system calls** to send this to kernel, In this case, the shell would use the **open() ,read() ,write() and close()** system calls to perform this task(**cat) test.txt**

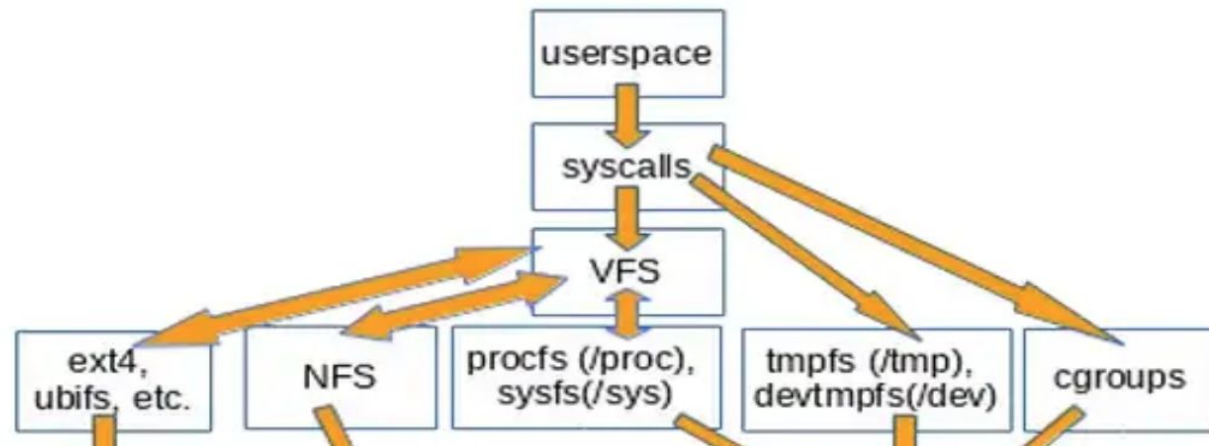
```
$ strace cat test.txt
execve("/bin/cat", ["cat", "test.txt"], [/* 60 vars */) = 0
...
open("test.txt", O_RDONLY) = 3
...
read(3, "This is a test file.\n", 32768) = 21
...
write(1, "This is a test file.\n", 21) = 21
...
close(3) = 0
...
```

Linux File System

In Linux, a file system is a way of organizing and storing files and folders on a storage device such as hard disk drive (HDD) .

Linux abstracts file systems operations through the Virtual File System (VFS),This provides a standard way of interacting with different file systems

It provides a uniform view of the file system to user applications.



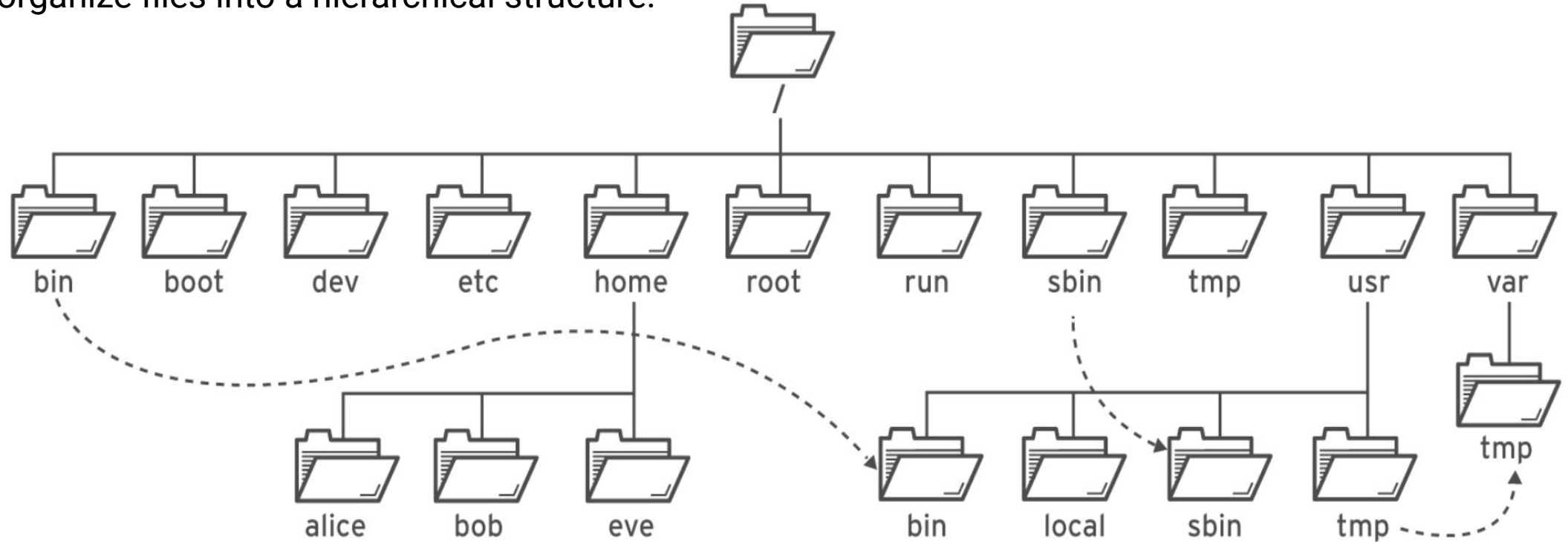
So a user program which uses the **write()** **syscall** doesn't execute a **syscall** in the kernel immediately, the VFS handles the request to the appropriate file system based on the file descriptor,

Each file system has its own features and limitations, and the choice of file system depends on factors such as the type of storage device

- Ext
- Ext2
- Ext3
- Ext4
- JFS
- XFS
- btrfs
- swap

Folder/Directory Structure

In Linux, a folder is a special type of file that is used to organize files into a hierarchical structure.



- (/) folder: also known as the root directory, is the top-level directory in the file system hierarchy. All other directories and files in the file system are located within the root directory or one of its subdirectories

```
mercy@mercy:/$ cd /
mercy@mercy:/$ ls
bin  dev  home  lib32  libx32  media  opt  root  sbin  srv  sys  usr
boot  etc  lib  lib64  lost+found  mnt  proc  run  snap  swap.img  tmp  var
mercy@mercy:/$
```

/bin : binary files and executable programs that are required for basic system functionality, such as the **shell** (**ls, cp, mkdir, rm** and **etc**) commands.

```
root@mercy:/bin# ls l*
landscape-sysinfo  lessfile  linux-version  loginctl  lsipc  lzcmp
last  lesskey  ln  logname  lslocks  lzdiff
lastb  lesspipe  lstat  look  lslogins  lzegrep
lastlog  lexgrog  loadkeys  lowntfs-3g  lsmem  lzfgrep
lcf  libnetcfg  loadunimap  ls  lsmmod  lzgrep
ld  link  locale  lsattr  lsns  lzless
ld.bfd  linux32  locale-check  lsblk  lsof  lzma
ldd  linux64  localectl  lsb_release  lspci  lzmainfo
ld.gold  linux-boot-prober  localedef  lscpu  lspgpot  lzmore
less  linux-check-removal  logger  lshw  lsusb
lessecho  linux-update-symlinks  login  lsinitramfs  lzcat
root@mercy:/bin# _
```

- **/boot** : contains files required for booting the system, including the kernel, initial ramdisk, and boot loader configuration files..

```
root@mercy:/boot# ls
config-5.15.0-69-generic  initrd.img-5.15.0-69-generic  System.map-5.15.0-69-generic  vmlinuz.old
grub                    initrd.img.old                vmlinuz
initrd.img              lost+found                    vmlinuz-5.15.0-69-generic
```

- **/dev** : contains device files that represent physical and virtual devices connected to the system, such as disks, terminals, and printers.

```
mercy@mercy:/tmp$ cd ../dev
mercy@mercy:/dev$ ls
autofs          hugepages      port           stdin          tty27          tty49          ttyS11         ttyS5          vcsa4
block           hwrng          ppp            stdout         tty28          tty5           ttyS12         ttyS6          vcsa5
bsg             i2c-0          psaux         test           tty29          tty50          ttyS13         ttyS7          vcsa6
btrfs-control  initctl        ptmx          tty            tty3           tty51          ttyS14         ttyS8          vcsu
bus            input          pts           tty0           tty30          tty52          ttyS15         ttyS9          vcsu1
cdrom           kmsg          random        tty1           tty31          tty53          ttyS16         ubuntu-vg     vcsu2
char            kvm            rfkill        tty10          tty32          tty54          ttyS17         udmabuf       vcsu3
console         log            rtc            tty11          tty33          tty55          ttyS18         uhid           vcsu4
core            loop0          rtc0           tty12          tty34          tty56          ttyS19         uinput        vcsu5
cpu             loop1          sda            tty13          tty35          tty57          ttyS2           urandom       vcsu6
cpu_dma_latency loop2          sda1           tty14          tty36          tty58          ttyS20         userio        vfio
cuse            loop3          sda2           tty15          tty37          tty59          ttyS21         vboxguest    vga_arbiter
disk            loop4          sda3           tty16          tty38          tty6           ttyS22         vboxuser     vhci
dm-0            loop5          sdb            tty17          tty39          tty60          ttyS23         vcs           vhost-net
dm-1            loop6          sdb1           tty18          tty4           tty61          ttyS24         vcs1          vhost-vsock
dma_heap        loop7          sdb2           tty19          tty40          tty62          ttyS25         vcs2          zero
dri             loop-control  sg0            tty2           tty41          tty63          ttyS26         vcs3          zfs
ecryptfs        mapper         sg1            tty20          tty42          tty7           ttyS27         vcs4
fb0             mcelog         sg2            tty21          tty43          tty8           ttyS28         vcs5
fd              mem            shm            tty22          tty44          tty9           ttyS29         vcs6
full            mqueue         snapshot       tty23          tty45          ttyprintk      ttyS3           vcsa
fuse            net            snd            tty24          tty46          ttyS0          ttyS30         vcsa1
hidraw0         null           sr0            tty25          tty47          ttyS1          ttyS31         vcsa2
hpet            nvram          stderr         tty26          tty48          ttyS10         ttyS4          vcsa3
```


- **/etc** : Most important system configuration files are in /etc, this directory contains data similar to those in the Control Panel in Windows.

```

alternatives          fuupd                login.defs           passwd              subgid
apparmor              gai.conf            logrotate.conf      passwd-            subgid-
apparmor.d           groff               logrotate.d         perl               subuid
appport              group               lsb-release         pki                subuid-
apt                  group-             lvm                 pm                 sudo.conf
bash.bashrc          grub.d             machine-id          polkit-1           sudoers
bash_completion      gshadow            magic               pollinate          sudoers.d
bash_completion.d   gshadow-          magic.mime          profile            sudo_logsrvd.conf
bindresvport.blacklist gss                manpath.config     profile.d          sysctl.conf
binfmt.d             hdparm.conf        mdadm               protocols          sysctl.d
byobu                 host.conf          mime.types          python3            systemd
ca-certificates      hostname           mke2fs.conf        python3.10         terminfo
ca-certificates.conf hosts              ModemManager       rc0.d              thermald
cloud                 hosts.allow        modprobe.d          rc1.d              timezone
console-setup        hosts.deny         modules             rc2.d              tmpfiles.d
cron.d               init.d             modules-load.d     rc3.d              ubuntu-advantage
cron.daily           initramfs-tools   mtab                rc4.d              ucf.conf
cron.hourly          inputrc            multipath           rc5.d              udev
cron.monthly         iproute2           multipath.conf      rc6.d              udisks2
crontab              iscsi              nanorc              rc8.d              ufw
cron.weekly          issue              needrestart         resolv.conf       update-manager
cryptsetup-initramfs issue.net           netconfig           rmt                update-motd.d
crypttab             kernel             netplan             rpc                 update-notifier
dbus-1                landscape          network             rsyslog.conf      UPower
debconf.conf         ldap               networkd-dispatcher rsyslog.d          usb_modeswitch.conf
debian_version       ld.so.cache        NetworkManager     screenrc           usb_modeswitch.d
default              ld.so.conf         newt                 selinux            vim
deluser.conf         legal              nftables.conf      services           vmware-tools
depmod.d             libaudit.conf     nsswitch.conf      shadow             vtrgb
dhcp                 libblockdev        os-release          shadow-            wgetrc
dpkg                 libn1-3            overlayroot.conf   shadow-            X11
e2scrub.conf         locale.alias       PackageKit          shells             xattr.conf
environment          locale.gen         pam.conf            skel                xdg
ethertypes           localtime          passwd              sos                 zsh_command_not_found
fstab                 localtime          subgid              ssh

```

- **/home** : Home folders of the common users.

```

mercy@mercy:~$ pwd
/home/mercy

```

/lib: Library files, includes files for all kinds of programs needed by the system and the users.

```
mercy@mercy:~$ cd /lib
mercy@mercy:/lib$ ls
apparmor          klibc-K8e6D0mVI9JpyGMLR7qNe5iZeBk.so  pkgconfig
apt               libdmmp.so                               pm-utils
binfmt.d         libdmmp.so.0.2.0                         policykit-1
pyobu            libhandle.so.1                           polkit-1
cloud-init       libhandle.so.1.0.3                       python2.7
cnf-update-db   libmpathcmd.so                           python3
command-not-found libmpathcmd.so.0                         python3.10
compat-ld       libmpathpersist.so                       python3.11
console-setup   libmpathpersist.so.0                     recovery-mode
crda            libmultipath.so                          rsyslog
cryptsetup      libmultipath.so.0                        sasl2
dbus-1.0        linux                                     sftp-server
dpkg            linux-boot-probes                         snapd
dracut          locale                                   software-properties
environment.d   lsb                                       ssl
file           man-db                                    sysctl.d
finalrd        mime                                       systemd
libuser       redhatcpd.d                              xz-utils
```

- /usr : directory in Linux contains user-related programs, libraries, documentation

```
mercy@mercy:/usr/lib$ cd ../
mercy@mercy:/usr$ ls -ll
total 92
drwxr-xr-x  2 root root 36864 Apr 16 16:20 bin
drwxr-xr-x  2 root root  4096 Apr 18 2022 games
drwxr-xr-x  5 root root  4096 Apr 16 16:20 include
drwxr-xr-x 83 root root  4096 Apr 16 16:17 lib
drwxr-xr-x  2 root root  4096 Feb 17 17:19 lib32
drwxr-xr-x  2 root root  4096 Feb 17 17:22 lib64
drwxr-xr-x  9 root root  4096 Apr 16 16:17 libexec
drwxr-xr-x  2 root root  4096 Feb 17 17:19 libx32
drwxr-xr-x 10 root root  4096 Feb 17 17:19 local
drwxr-xr-x  2 root root 16384 Apr 16 16:21 sbin
drwxr-xr-x 110 root root  4096 Apr 16 16:17 share
drwxr-xr-x  4 root root  4096 Apr 16 16:17 src
```

- /tmp: contains temporary files that are created by applications and the system, and are typically deleted when system reboot.

```
mercy@mercy:/usr$ cd ../tmp
mercy@mercy:/tmp$ ls
snap-private-tmp
systemd-private-b145a234a24d4a4aae68e43acfd88689-ModemManager.service-XTVKEe
systemd-private-b145a234a24d4a4aae68e43acfd88689-systemd-logind.service-587CgA
systemd-private-b145a234a24d4a4aae68e43acfd88689-systemd-resolved.service-XAn0V3
systemd-private-b145a234a24d4a4aae68e43acfd88689-systemd-timesyncd.service-aqIoWq
mercy@mercy:/tmp$
```

Common Commands

- **Useradd**- add a new user
- **Passwd**-change the current password or add a password for new user
- **ls** : List the contents of a directory
- **pwd** : Present working directory
- **cd** : Change directory
- **mkdir** : Make a directory
- **cp** : Copy
- **cp -r** :Copy a directory and its contents

Common Commands

mv : Move

rm : Remove

rm -r directory: Remove a directory containing files

rmdir directory: Remove an empty directory

Shell Shortcuts for bash

Ctrl-A (jump to start of line)

Ctrl-E (jump to end of line)

Ctrl-K (delete (kill) everything from the cursor onwards)

Ctrl-W (delete the previous word only)

Ctrl-Y (paste whatever was just deleted)

Ctrl-C (kill/exit a running process)

Ctrl-L (clear the screen)

Ctrl-R (search for previously executed commands)

Tab (auto-complete command or file/directory name)

↑ / ↓ (scroll back / forwards through previously entered commands)

Types of Users

Root User-The root user is also known as the superuser and has complete control over the system

System users: System users are created by the system for running specific services or processes. These users do not have login privileges, and their accounts are locked by default.

Regular users: Regular users are created by the system administrator or by other regular users. These users have limited privileges and cannot perform tasks that require root access, such as modifying system files or installing software


```
root:x:0:0:root:/root:/bin/bash
daemon:x:1:1:daemon:/usr/sbin:/usr/sbin/nologin
bin:x:2:2:bin:/bin:/usr/sbin/nologin
sys:x:3:3:sys:/dev:/usr/sbin/nologin
sync:x:4:65534:sync:/bin:/bin/sync
games:x:5:60:games:/usr/games:/usr/sbin/nologin
man:x:6:12:man:/var/cache/man:/usr/sbin/nologin
lp:x:7:7:lp:/var/spool/lpd:/usr/sbin/nologin
mail:x:8:8:mail:/var/mail:/usr/sbin/nologin
news:x:9:9:news:/var/spool/news:/usr/sbin/nologin
uucp:x:10:10:uucp:/var/spool/uucp:/usr/sbin/nologin
proxy:x:13:13:proxy:/bin:/usr/sbin/nologin
www-data:x:33:33:www-data:/var/www:/usr/sbin/nologin
backup:x:34:34:backup:/var/backups:/usr/sbin/nologin
list:x:38:38:Mailing List Manager:/var/list:/usr/sbin/nologin
irc:x:39:39:ircd:/run/ircd:/usr/sbin/nologin
gnats:x:41:41:Gnats Bug-Reporting System (admin):/var/lib/gnats:/usr/sbin/nologin
nobody:x:65534:65534:nobody:/nonexistent:/usr/sbin/nologin
_apt:x:100:65534::/nonexistent:/usr/sbin/nologin
systemd-network:x:101:102:systemd Network Management,,,:/run/systemd:/usr/sbin/nologin
systemd-resolve:x:102:103:systemd Resolver,,,:/run/systemd:/usr/sbin/nologin
messagebus:x:103:104::/nonexistent:/usr/sbin/nologin
systemd-timesync:x:104:105:systemd Time Synchronization,,,:/run/systemd:/usr/sbin/nologin
pollinate:x:105:1::/var/cache/pollinate:/bin/false
sshd:x:106:65534::/run/sshd:/usr/sbin/nologin
syslog:x:107:113::/home/syslog:/usr/sbin/nologin
uidd:x:108:114::/run/uidd:/usr/sbin/nologin
tcpdump:x:109:115::/nonexistent:/usr/sbin/nologin
tss:x:110:116:TPM software stack,,,:/var/lib/tpm:/bin/false
landscape:x:111:117::/var/lib/landscape:/usr/sbin/nologin
fwupd-refresh:x:112:118:fwupd-refresh user,,,:/run/systemd:/usr/sbin/nologin
usbmux:x:113:46:usbmux daemon,,,:/var/lib/usbmux:/usr/sbin/nologin
mercy:x:1000:1000:mercy:/home/mercy:/bin/bash
ixd:x:999:100::/var/snap/ixd/common/ixd:/bin/false
```


File Permission

```
shum@sol1:~$ ls -l
total 20
drwx----- 2 shum      staff    4096 Jan 16 22:04 Mail
drwx----- 3 shum      staff    4096 Jan 16 14:15 csc128
drwxr-xr-x  2 shum      staff    4096 Jan 13 16:42 public
drwxr-xr-x  2 shum      staff    4096 Jan 16 14:07 public_html
-rw-r--r--  1 shum      staff    628  Jan 15 20:04 verse
```

The diagram illustrates the components of the `ls -l` command output. The output is shown as a table with columns for file type, number of hard links, user (owner) name, group name, size, date/time last modified, and filename. Arrows point from each column to its corresponding label. A separate diagram breaks down the permissions `rwx` into readable, writeable, and executable.

file type	number of hard links	user (owner) name	group name	size	date/time last modified	filename
<code>drwx-----</code>	2	shum	staff	4096	Jan 16 22:04	Mail
<code>drwx-----</code>	3	shum	staff	4096	Jan 16 14:15	csc128
<code>drwxr-xr-x</code>	2	shum	staff	4096	Jan 13 16:42	public
<code>drwxr-xr-x</code>	2	shum	staff	4096	Jan 16 14:07	public_html
<code>-rw-r--r--</code>	1	shum	staff	628	Jan 15 20:04	verse

Permissions Breakdown:

`rwx`

- `r`: readable
- `w`: writeable
- `x`: executable

File Permission in Detail

-



"-" indicates a file
"d" indicates directory
"l" indicates a link

rwx



Read, write, and
execute permissions
for the owner of the
file

rwx



Read, write, and
execute permissions
for members of the
group owning the file

rwx



Read, write, and
execute permissions
for other users

Access Rights

- Files are owned by a user and a group (ownership)
- Files have permissions for the user, the group, and other
- “Other” permission is often referred to as “world”
- The permissions are Read, Write and Execute (r, w, x)
- The user who owns a file is always allowed to change its permissions

Changing File Permissions

File permissions can be change using “**chmod**” command There are two ways to use this command

- *Symbolic mode*
- *Absolute mode*

Symbolic Mode

Uses letters and “+” , ”-” to give permissions

- Letters are used as following

u	User
g	Group
o	Other
r	Read
w	Write
e	Execute
+	To add permission
-	To remove a permission

Symbolic mode (Examples)

- `$ chmod g+x testfile`
- `$ chmod u+wx testfil`
- `$ chmod ug-x testfile`

u=user, g=group, o=other (world)

Absolute Mode

We use octal (base eight) values represented like this

For each column, User, Group or Other you can set values from 0 to 7

Number	Permission Type
0	No Permissions
1	Execute
2	Write
3	Execute+Write
4	Read
5	Read+Execute
6	Read+Write
7	Read+Write+Execute

Symbolic Mode (Example)

- \$ chmod 445 testfile ==> -r--r-xr—
- \$ chmod 754 testfile ==> -rwxr-xr—
- \$ chmod 644 testfile ==> -rw--r--r—