Operating System Concepts

- OS Concepts
- Linux commands
- Shell scripts
- Linux System call Programming

Learning OS

- step 1: End user
  - Linux commands
- step 2: Administrator
  - Install OS (Linux)
  - Configuration - Users, Networking, Storage, ...
  - Shell scripts
- step 3: Programmer
  - Linux System call programming
- step 4: Designer/Internals
  - UNIX & Linux internals

What is OS?

- Interface between end user and computer hardware.
- Interface between Programs and computer hardware.
- Control program that controls execution of all other programs.
- Resource manager/allocator that manage all hardware resources.
- Bootable CD/DVD = Core OS + Applications + Utilities
- Core OS = Kernel -- Performs all basic functions of OS.

OS Functions

- CPU scheduling
- Process Management
- Memory Management
- File & IO Management
- Hardware abstraction
- User interfacing
- Security & Protection
- Networking

Process Management

Program

- Set of instructions given to the computer --> Executable file.
- Program --> Sectioned binary --> "objdump" & "readelf".

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    - Exe header --> Magic number, Address of entry-point function, Information about all sections. (objdump -h program.out)
    - Text --> Machine level code (objdump -S program.out)
    - Data --> Global and Static variables (Initialized)
    - BSS --> Global and Static variables (Uninitialized)
    - RoData --> String constants
    - Symbol Table --> Information about the symbols (Name, Size, section, Flags, Address) (objdump -t program.out)
- Program (Executable File) Format
    - Windows -- PE
    - Linux -- ELF
- Program are stored on disk (storage).

Process

- Progam under execution
- Process execute in RAM.
- Process control block contains information about the process (required for the execution of process).
    - Process id
    - Exit status
        - 0 - Indicate successful execution
        - Non-zero - Indicate failure
    - Scheduling information (State, Priority, Sched algorithm, Time, ...)
    - Memory information (Base & Limit, Segment table, or Page table)
    - File information (Open files, Current directory, ...)
    - IPC information (Signals, ...)
    - Execution context (Values of CPU registers)
    - Kernel stack
- PCB is also called as process descriptor (PD), uarea (UNIX), or task_struct (Linux).
- In Linux size of task_struct is approx 4KB

Process

- Process is program in execution.
- Process has multiple sections i.e. text, data, rodata, heap, stack. ... into user space and its metadata is stored into kernel space in form of PCB struct.
- PCB contains
    - id, exit status,
    - scheduling info (state, priority, time left, scheduling policy, ...),
    - files info (current directory, root directory, open file descriptor table, ...),
    - memory information (base & limit, segment table, or page table),
    - ipc information (signals, ...),
    - execution context, kernel stack, ...

File Management

File

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- File is collection of data/information on storage device.
  - File = Contents (Data) + Information (Metadata)
  - The data is stored in zero or more Data blocks (in FS), while metadata is stored in the FCB (in filesystem).
- FCB is called as "inode" on UNIX/Linux. It contains
  - type: UNIX/Linux has 7 types of files
    - -: regular, d: directory, l: symbolic link, p: pipe, s: socket, c: char device, b: block device
  - size: number of bytes
  - links: number of hard links
  - mode (permissions): (u) rwx, (g) rwx, (o) rwx
  - user & group
  - time-stamps: modification, creation, access.
  - info about data blocks
- terminal> ls -l
  - type, mode, links, user, group, size, timestamp, name.
- terminal> stat filepath

File System

- Files are stored on storage device. Arrangement of files in storage device is called as "File System".
- e.g. FAT, NTFS, EXT2/3/4, ReiserFS, XFS, HFS, etc.
- File System logically divide partition into 4 sections.
  - Boot block/Boot sector
    - Contains programs/info required for booting of OS
    - Typically contains bootstrap program and bootloader program
  - Super block/Volume control block
    - Contains information of whole partition.
    - Capacity, Label.
    - terminal> df -h
      - Total number of data blocks/inodes.
      - Number of used/free data blocks/inodes.
      - Information of free data blocks/inodes.
  - Inode List/Master file table
    - Inodes (FCB) for each file
  - Data blocks
    - Stores data of the file.
    - Each file have zero or more data blocks.
    - Size of data blocks can be configured while creating file system
- File system is created by the format utility while formatting the partition.
  - Windows: format.exe
  - Linux: mkfs
    - terminal> sudo mkfs -t ext3 /dev/sdb1
    - terminal> sudo mkfs -t vfat /dev/sdb1
    - -t fs_type e.g. ext3, ext4, vfat, ntfs, ...

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        - partition e.g. /dev/sdb1

- Disk/partition naming conventions
    - Windows:
        - Disks are named as disk0, disk1, ...
        - partitions are named as drives i.e. C:, D:, E:, ...
    - Linux:
        - Disks are named as /dev/sda, /dev/sdb, /dev/sdc, etc.
        - Partitions per disk are named as
            - sda partitions: sda1, sda2, sda3, ...
            - sdb partitions: sdb1, ...

Linux File Structure

- Linux follows "/" (root) file system.
- "/" is a starting point of Linux file system.
- All your data is stored in this partition.
- / contains boot, bin, sbin, etc, root, home, dev, proc, mnt, media, opt
- In Linux everything is a file.
- Mainly there are two types of files in Linux
    - File
    - Directory (Folder)
- Linux Directories
    - boot - files related to booting
        - vmlinuz - kernel Image
        - grub - boot loader
        - config - kernel configuration
        - initrd/initramfs - initail root file system
    - bin - user commands in binary format
    - sbin - all admin/system commands in binary format
    - etc - configuration files
    - root - home directory of root user
    - home - it contains sub directories for each user with its name
        - devendra -> /home/devendra
        - sunbeam -> /home/sunbeam
        - osboxes -> /home/osboxes
    - dev - it contains all device related files
    - lib - shared program libraries required by kernel
    - mnt - it is temporary mount point
    - media - it is mount point for media eg cdrom
    - opt - stores optional files of large softwares
    - proc - virtual file system - it contains information about system or processes
    - sys - entries of each block devices, subdirectories for each physical bus type supported, every device class registered with the kernel, global device hierarchy of all devices
    - tmp - temporary files that may be lost on system shutdown
    - usr - read only directory that stores small programs and files accessible to all users

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User interfacing

- UI of OS is a program (Shell) that interface between End user and Kernel.
- Shell -- Commmand interpreter
  - End user --> Command --> Shell --> Kernel
- User interfacing (Shell)
  - Graphical User Interface (GUI)
  - Command Line Interface (CLI)

Example shells

- Windows
  - GUI shell: explorer.exe
  - CLI shell: cmd.exe, powershell.exe
- DOS
  - CLI shell: command.com
- Unix/Linux
  - CLI shell: bsh, "bash", ksh, csh, zsh, ...
    - ls /bin/*sh
    - echo $SHELL
  - shell of current user can be changed using "chsh" command.
- GUI shell/standards
  - GNOME: GNU Network Object Model Environment (e.g. Ubuntu, Redhat, CentOS, ...)
  - KDE: Kommon Desktop Environment (e.g. Kubuntu, SuSE, ...)

Path

- It is a unique location of any file in the file system.
- It is represented by character strings with few delimiters (“/”, “\”, “:”)
- Types of path
  - There are two types of paths in linux
  - Absolute path
    - Path which starts with “/” is called as absolute path.
    - E.g. /home/devendra/MyData/Demos/demo01.sh
  - Relative path
    - Path with respect to current directory is called as relative path
    - E.g. MyData/Assignments/assign02.pdf

Types of files

- Regular file (-)
- Directory file (d)
- Link file (l)
- Socket file (s)
- Pipe file (p)

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- Character Special file (c)
- Block Special file (b)

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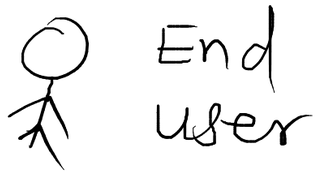
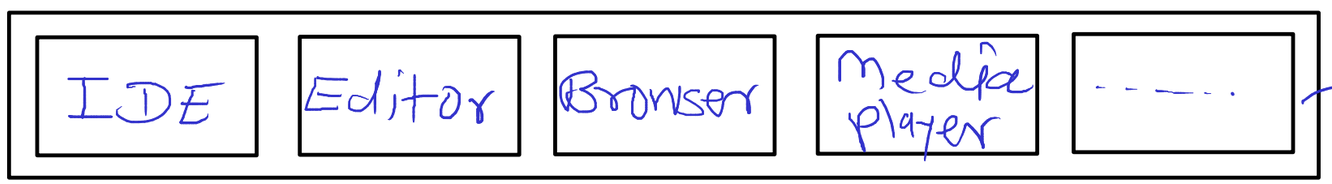
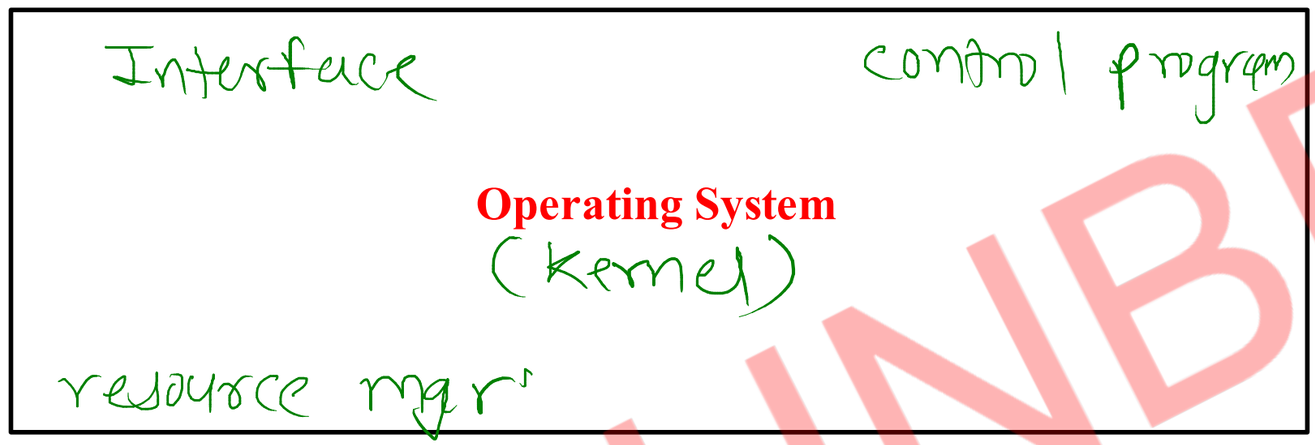
Operating System







- interface betn end user and computer h/w
- interface betn Appln s/w & computer h/w
- control program which controls execution of all appln/programs running on the top it.
- resource manager/ allocator which allocates h/w resource to all the programs one by one.

- CD/DVD/ISO - Core OS (kernel) + Appln s/w + System Utilities

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Functions of Operating System

1) Process Management
2) CPU scheduling
3) Memory Management
4) File & IO Management
5) Hardware Abstraction
6) User Interfacing
7) Networking
8) Security & Protection

Compulsory

optional

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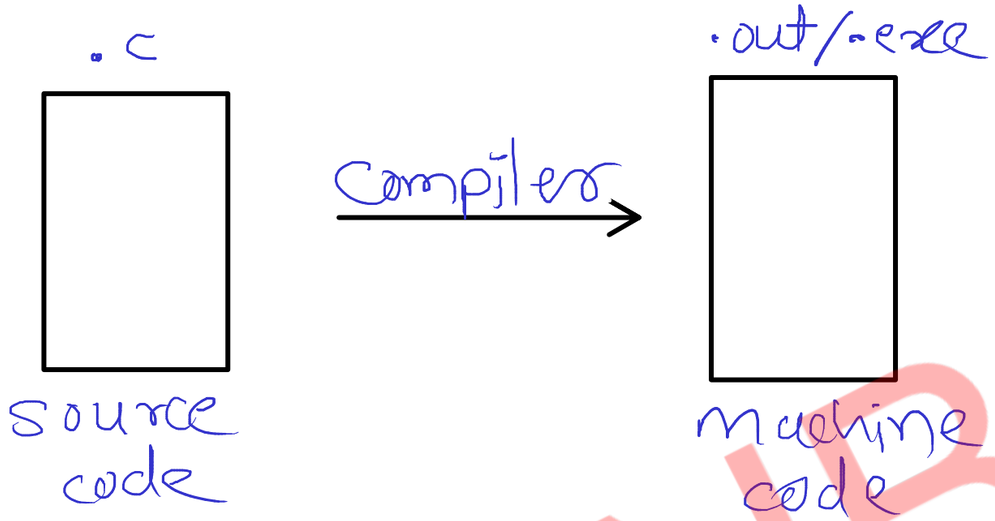
Process Management

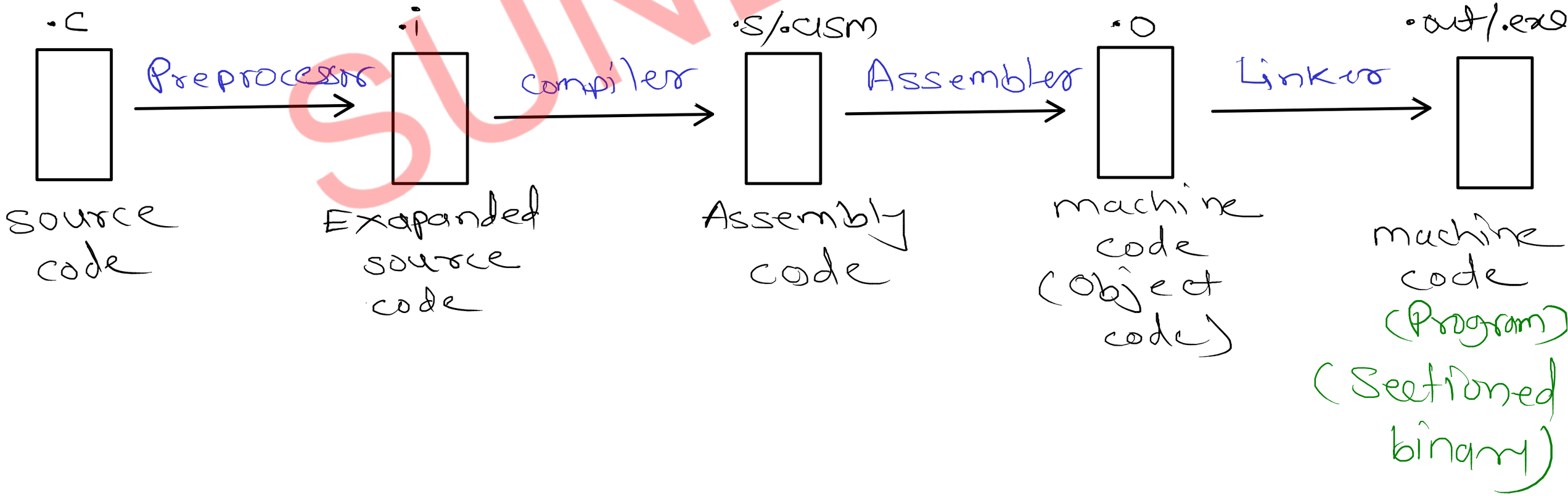
Process — Program in execution

Program — set of instructions to machine (CPU)



GCC — (GNU compiler collection)
- set of tools (tool chain)

1> Preprocessor
2> Compiler
3> Assembler
4> Linker
5> debugger
6> ----



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Program

tools – objdump / readelf

Exe Header

- info about application
- info about remaining sections of executable
  - name, start, end, size
- type of application (CLI / GUI / Library)
- address of entry point function
- magic number – identify to file format
  - Windows – Portable Executable (PE) – MZ
  - Linux – Executable Linking Format (ELF) – 0x7F ELF

Text (Code)

- instructions of the program in machine code format are stored.

Data – static & global variables (initialised) int arr[] = {...};

BSS – static & global variables (uninitialised) int arr[];

RO Data (Read Only)

- string constants

char *ptr = "sunbeam";

Symbol Table

- info about symbols
- symbols are variables & functions of the program

symbols
- variables – name, type, size, address, section ----
- functions – name, address, return type, no./type of arg ----

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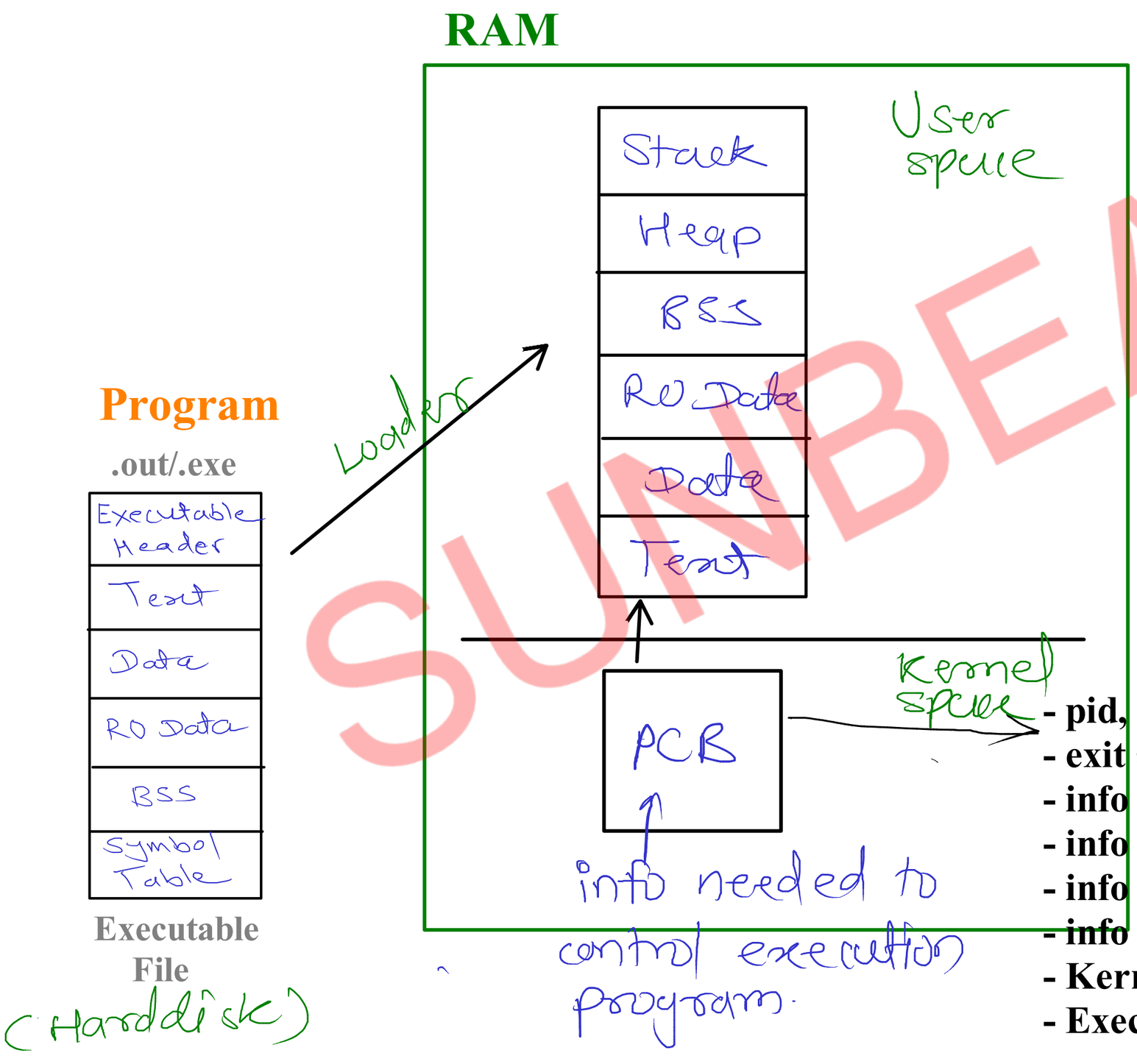
Process

Process = sections + PCB



PCB
- task_struct
- uarea (UNIX)
- process descriptor

- pid, ppid
- exit status
- info sched (Priority, Algo, state)
- info mem (base and limit, segment/page table)
- info file (opened file, current directory)
- info IPC (signal...)
- Kernel stack
- Execution context

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File Management

File – collection of data/information

File = data + metadata

(Actual contents) (information about file)

(data block)

- name
- size
- type
- time stamp
  (create, modify, access
- owner/group
- permissions
  (r-read, w-write, x-execute
  -user/group/other
- link count
- info about data blocks

(File Control Block) (FCB)

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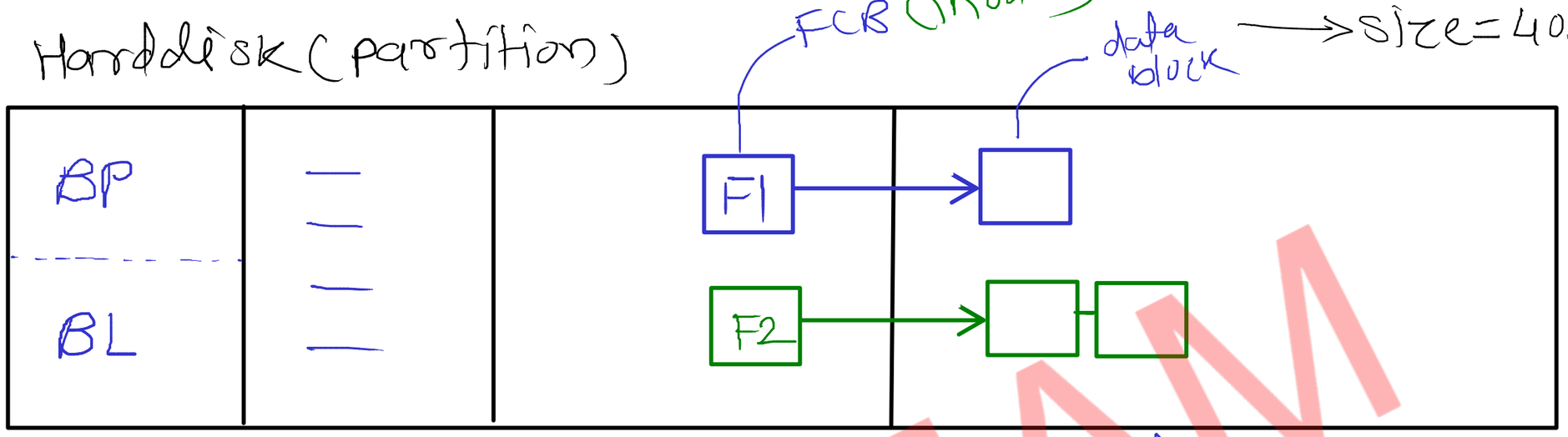
File System



→ size = 4096 bytes (default)
↓
configurable
↓
at the time formating

(boot Boot block) sector
↓
Booting related programs
1) Bootstrap program
2) Bootloader

Volume control block (superblock)
↳ info about volume/partition
- label
- size
- filled/empty
- info about free data blocks of partition

Master file Table (inode list)

Data blocks

File system – Orgnising files on harddisk partitions

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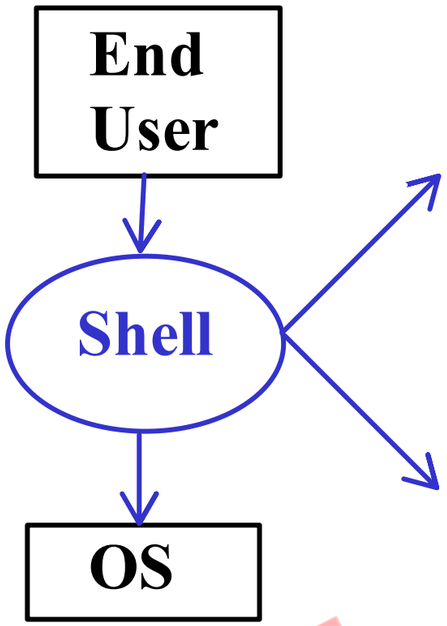
User Interfacing

Shell - intermediate between End user and OS

Shell - Command Interpretor



CLI (Command Line Interface)

Windows - cmd.exe, powershell.exe
Linux - bsh(sh), bash, csh, ksh, zsh

GUI (Graphical User Interface)

Windows - explorer.exe
Linux - KDE(Komman Desktop Env)
- GNOME(GNU Network Object Model Env)

- In Linux, default shell is bash(Bourne Again Shell)
- echo $SHELL
- to change shell - chsh

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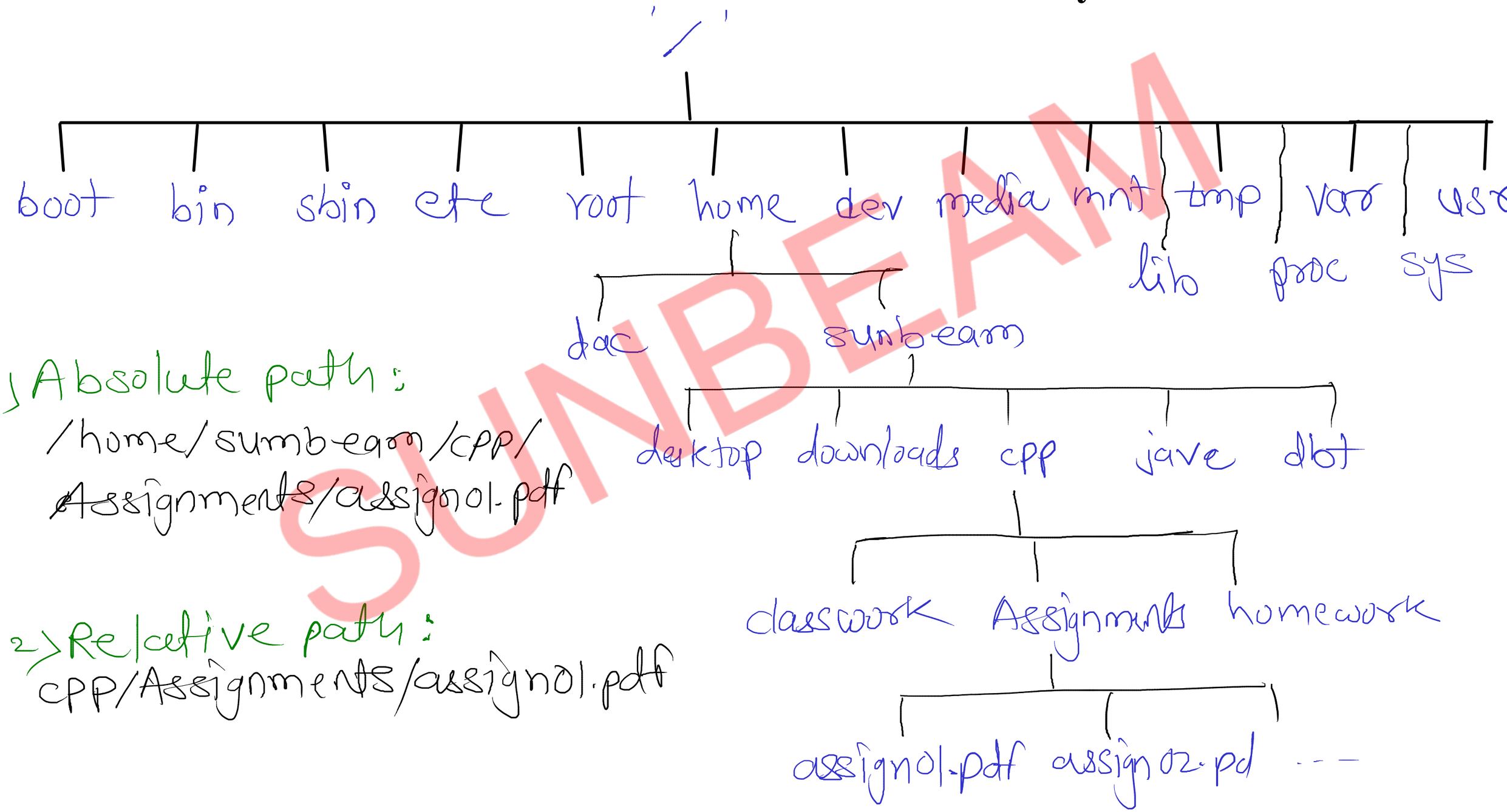
admin - administrator
root - superuser

Linux File Structure

- **Linux follows root "/" file structure**
- **In Linux file -> file and folder -> directory**



1) Absolute path :

/home/sumbeam/cpp/Assignments/assign01.pdf

2) Relative path :

cpp/Assignments/assign01.pdf

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permissions of file | user/owner | size | name

-rw-rw-r-- 1 sunbeam sunbeam 0 May 20 09:30 file1.txt

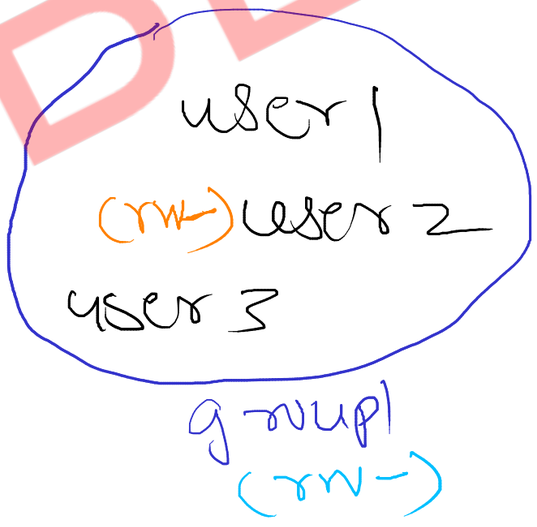
type of file | link count | group | timestamp

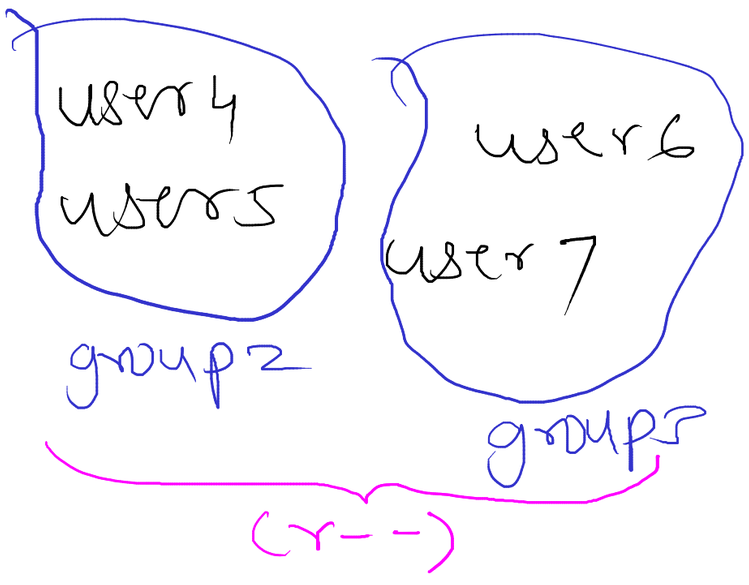
Types of files :

1) Regular (-)
2) Directory (d)
3) Link (l)
4) pipe (p)
5) socket (s)
6) char special (c)
7) block special (b)

Permission types – r-read, w-write, x-execute

levels – user/owner, group, other





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```
chmod +x file.txt

    + : add        r
    - : remove     w
                   x
```

000-0
001-1
010-2
011-3
100-4
101-5
110-6
111-7

```
chmod g-x file.txt

    + : add        r        u - user/owner
    - : remove     w        g - group
                   x        o - others
```

```
rw-   rw-   r--
110   110   100
---   ---   ---
 6     6     4
```

664

```
rw-   rw-   r--
rwx   r--   r--
111   100   100
---   ---   ---
 7     4     4
```

744

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