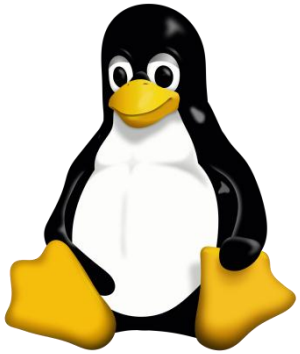
Linux Fundamentals

VERSION 3
November-2022

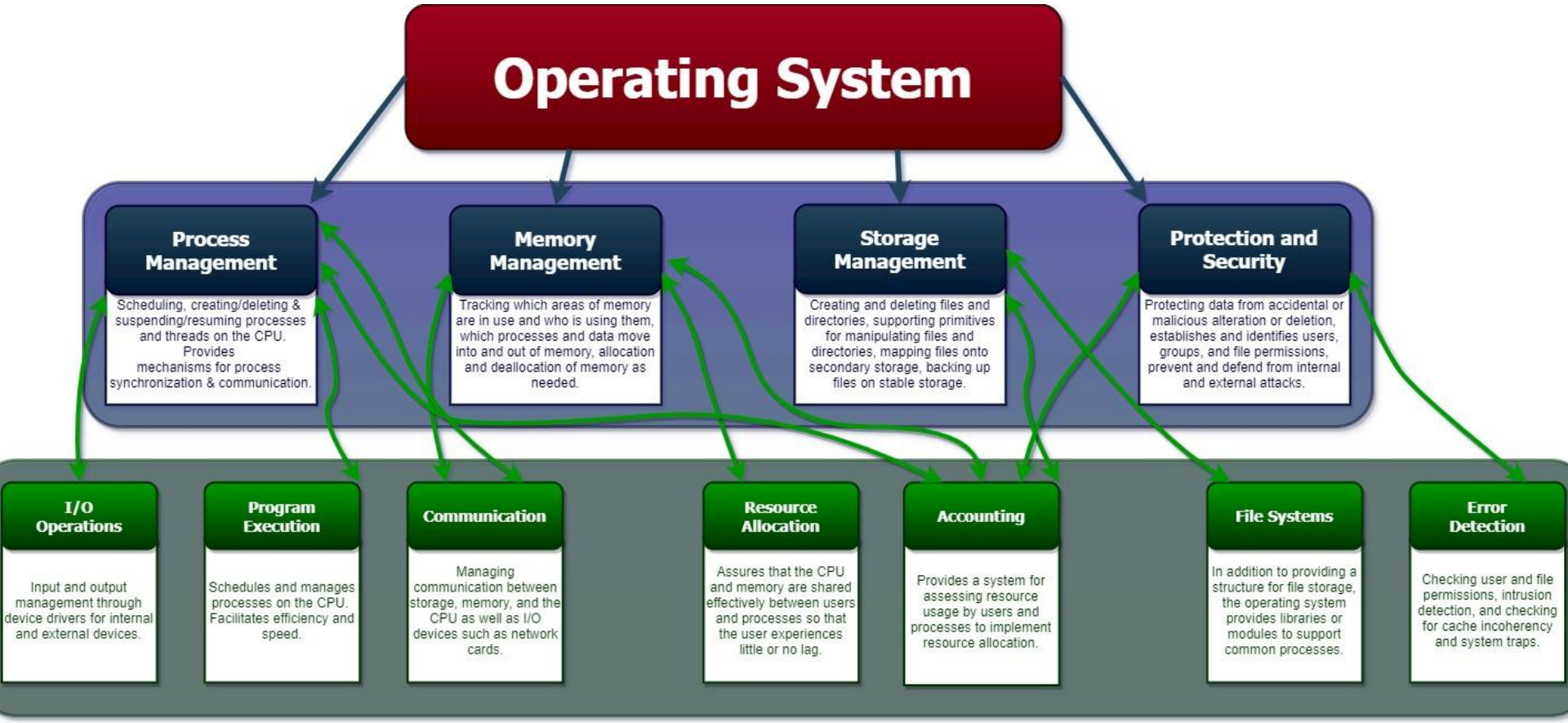


Part 1

Eng Ali Mohammad. Bani Bakkar

Operating System

- An operating system is a program on which application programs are executed and acts as an communication bridge (interface) between the user and the computer hardware.
- The main task an operating system carries out is the allocation of resources and services, such as allocation of: memory, devices, processors and information. The operating system also includes programs to manage these resources, such as a traffic controller, a scheduler, memory management module, I/O programs, and a file system.


Operating System
Process Management
Scheduling, creating/deleting & suspending/resuming processes and threads on the CPU. Provides mechanisms for process synchronization & communication.
Memory Management
Tracking which areas of memory are in use and who is using them, which processes and data move into and out of memory, allocation and deallocation of memory as needed.
Storage Management
Creating and deleting files and directories, supporting primitives for manipulating files and directories, mapping files onto secondary storage, backing up files on stable storage.
Protection and Security
Protecting data from accidental or malicious alteration or deletion, establishes and identifies users, groups, and file permissions, prevent and defend from internal and external attacks.
I/O Operations
Input and output management through device drivers for internal and external devices.
Program Execution
Schedules and manages processes on the CPU. Facilitates efficiency and speed.
Communication
Managing communication between storage, memory, and the CPU as well as I/O devices such as network cards.
Resource Allocation
Assures that the CPU and memory are shared effectively between users and processes so that the user experiences little or no lag.
Accounting
Provides a system for assessing resource usage by users and processes to implement resource allocation.
File Systems
In addition to providing a structure for file storage, the operating system provides libraries or modules to support common processes.
Error Detection
Checking user and file permissions, intrusion detection, and checking for cache incoherency and system traps.

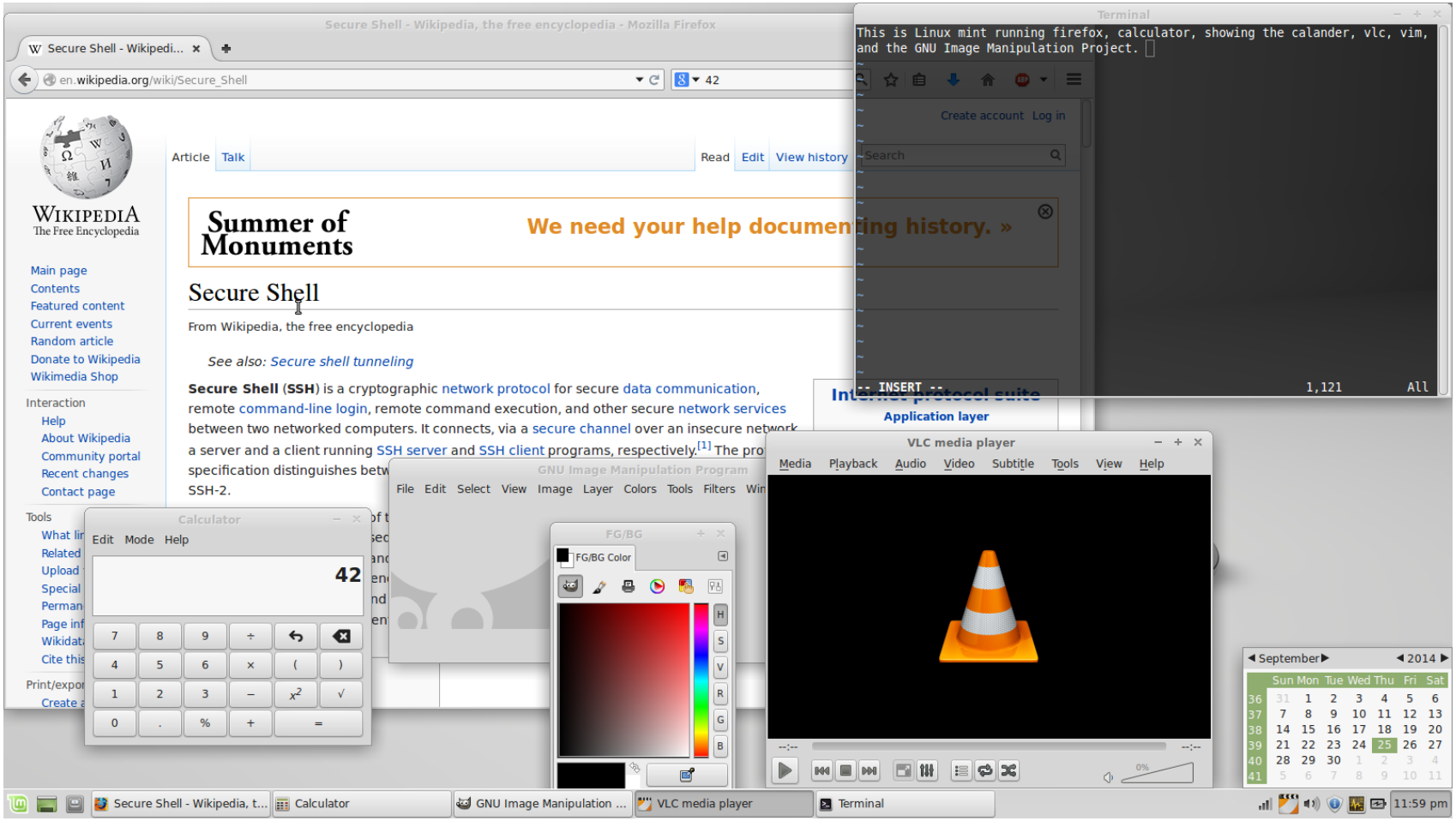
Operaring System Functions

- **Security**
- **Control over system performance**
- **Job accounting**
- **Error detecting aids**
- **Memory Management**
- **Processor Management**
- **Device Management**
- **File Management**

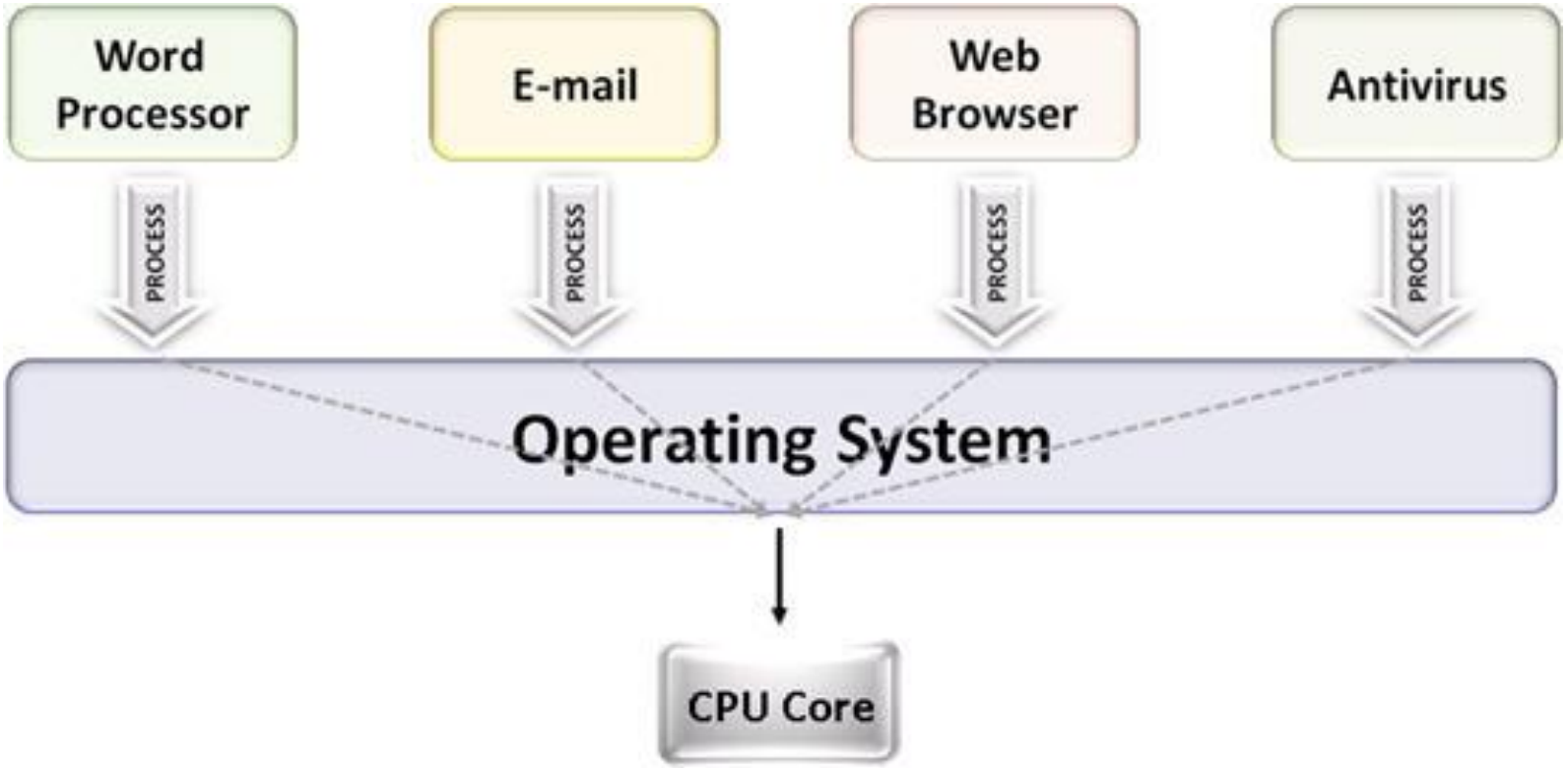
Manages the CPU processing time and priority

- **Processing Applications**
- **multitasking** = ability of the operating system run multiple software programs (only one programs gets processed at a time)
- **multiprocessing** = ability of the operating system to run multiple software programs at the same time
- **Number of users with simultaneous access**
- **multiuser** = ability of the operating system to allow multiple users access to the same computer at the same time
- **single user** = the operating system only allows a single user at a time access to the computer
- **Multithreading**

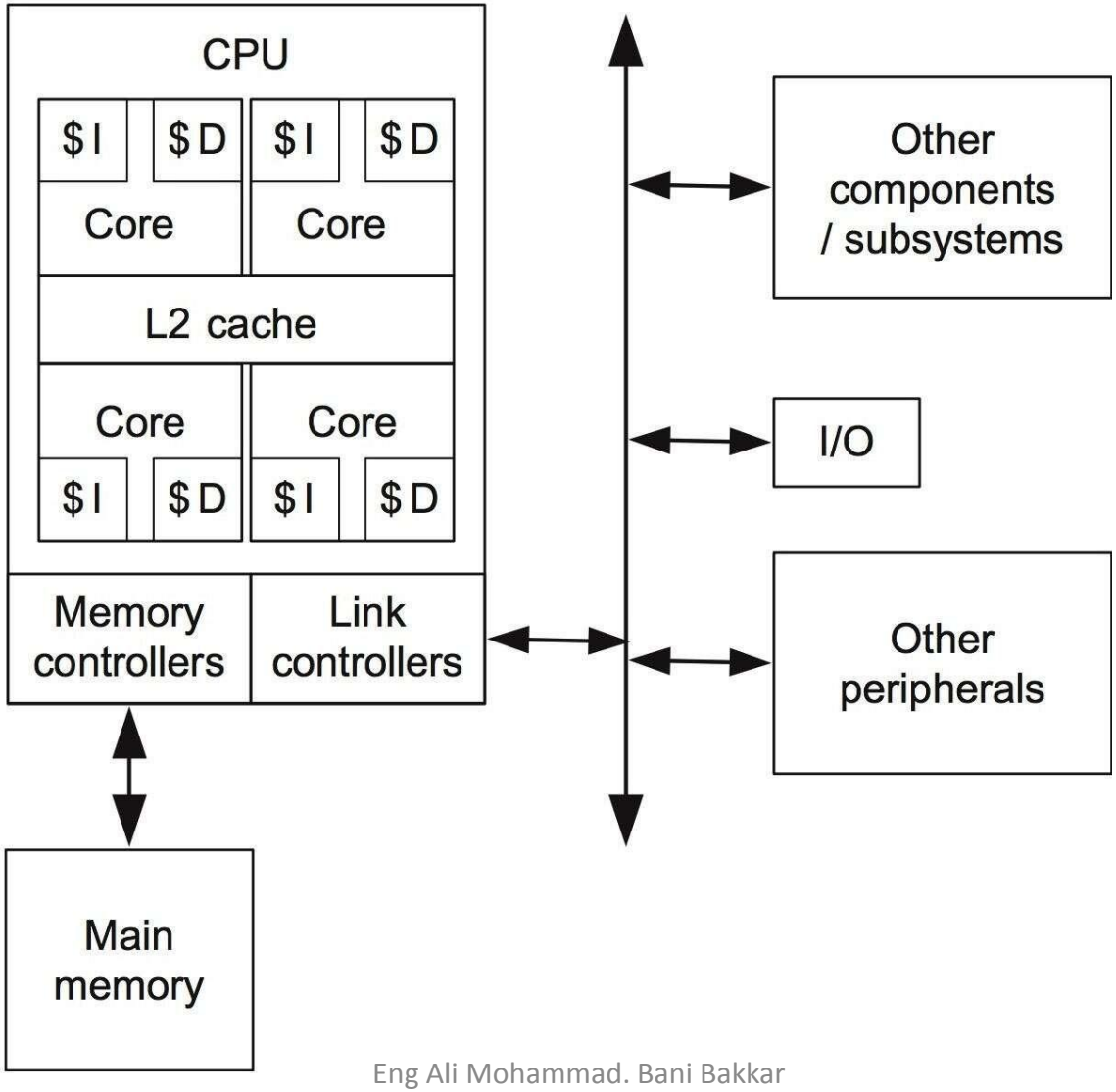
multitasking



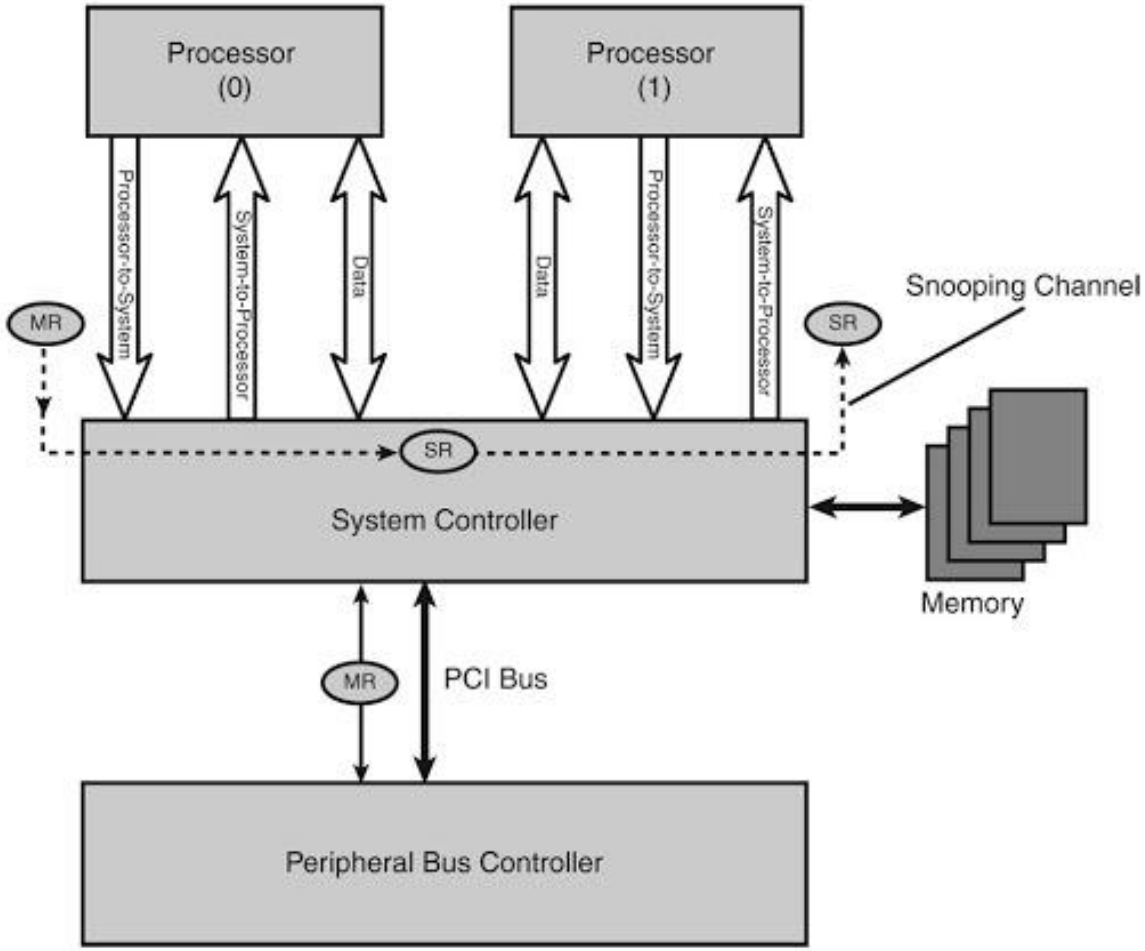
multitasking



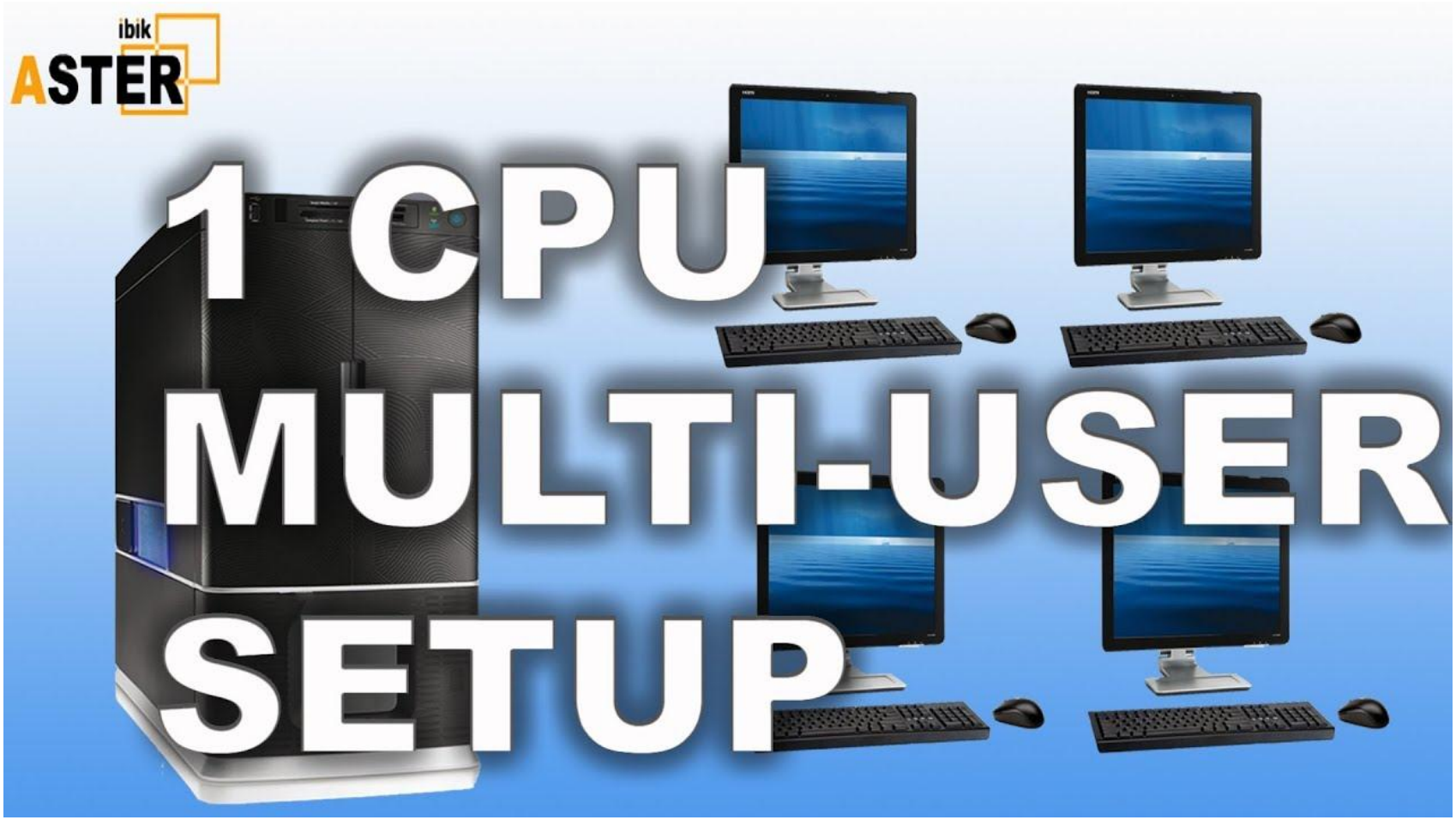
multiprocessing



multiprocessing



multiuser



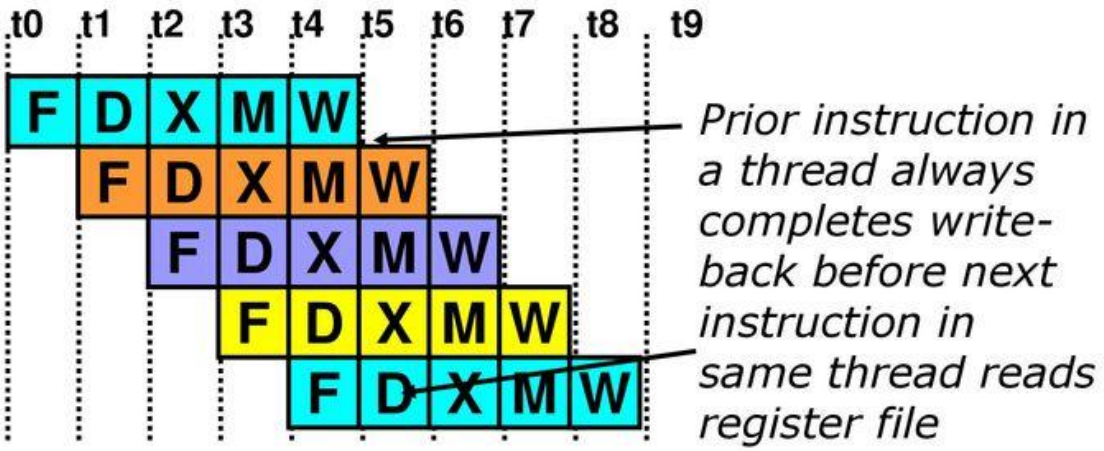
Multithreading

How can we guarantee no dependencies between instructions in a pipeline?

-- One way is to interleave execution of instructions from different program threads on same pipeline

Interleave 4 threads, T1-T4, on non-bypassed 5-stage pipe

T1: LW r1, 0(r2)
T2: ADD r7, r1, r4
T3: XORI r5, r4, #12
T4: SW 0(r7), r5
T1: LW r5, 12(r1)



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Manages and Interacts with Computer Hardware

- Provides the interface for **storage devices** and manages how data is stored on those devices
  - in charge of formatting disks
  - creates sectors and clusters
  - creates F.A.T. \
  - sends message when disk is full or there is some other problem with writing data to the disk
- virtual memory
- CD-ROM, DVD-ROM
- Flash drive

Provides the Interface for **Input and Output Devices**

Provides the System Interface

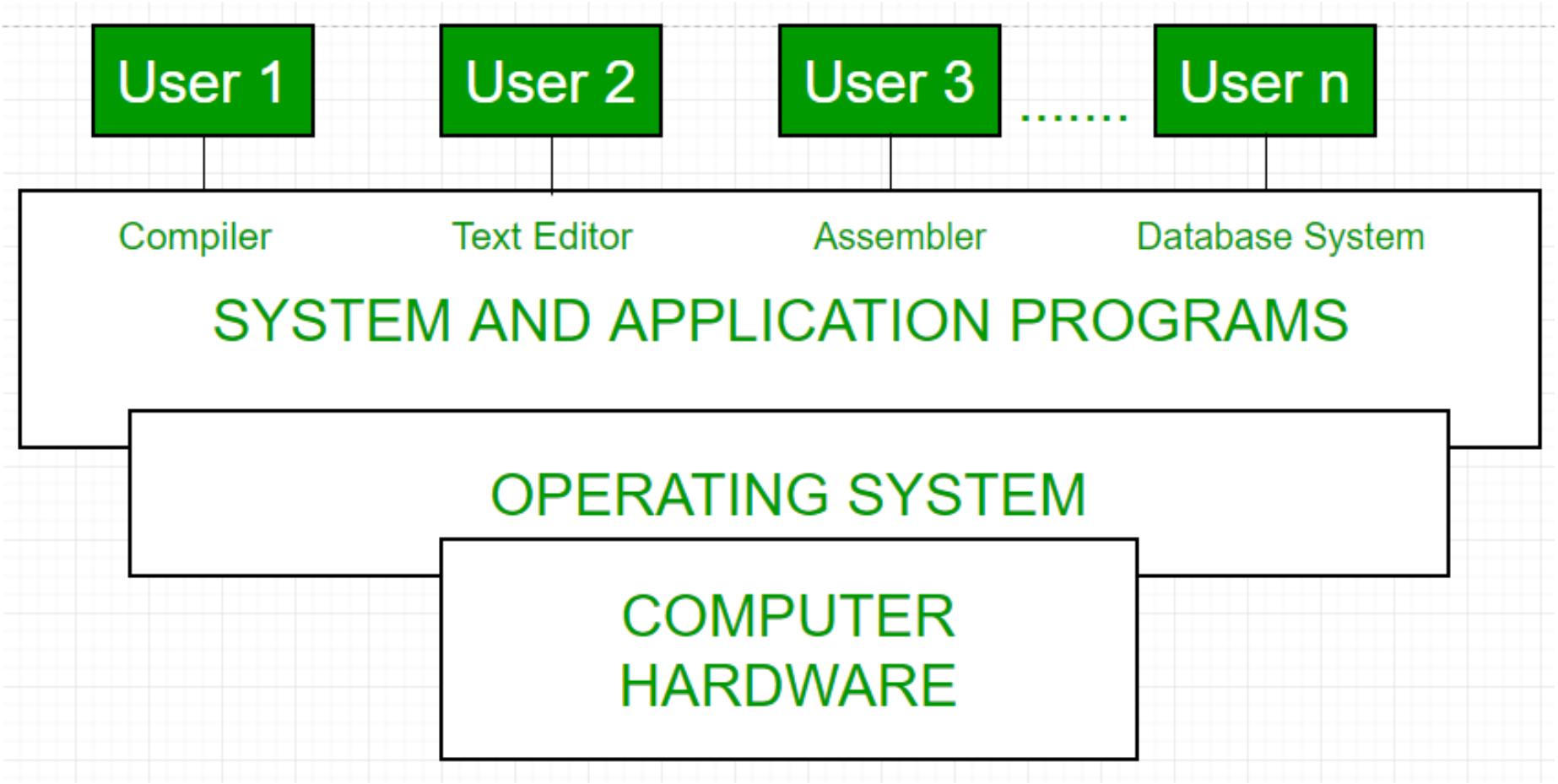
- **System Interface** or **shell** = the interface between the computer
- Command Line Interface (CLI)(sh, ksh, csh, tcsh, zsh, Bash, etc.)
- Graphical User Interface (GUI)(KDE, GNOME, XFCE, LXDE and MATE.)

Explain and Send Screenshots

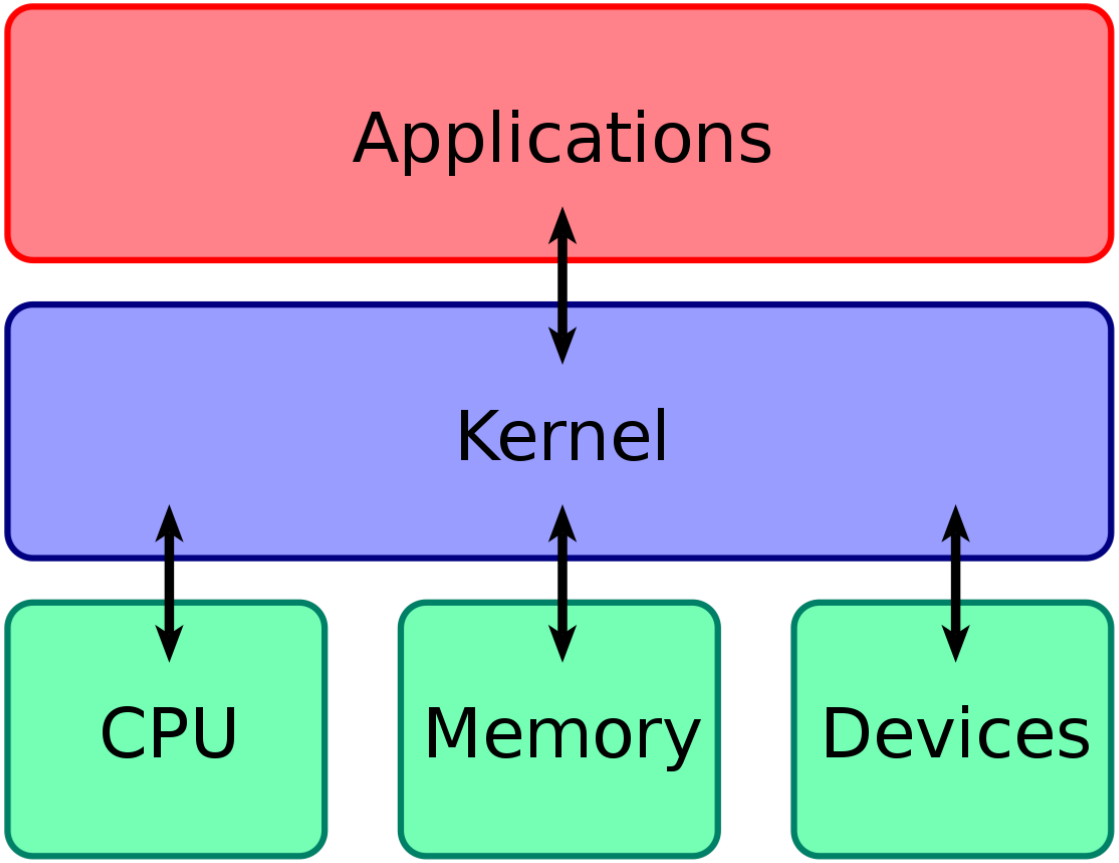
Topic	Command line (CLI)	GUI
Ease	Because of the memorization and familiarity needed to operate a command line interface, new users have a difficult time navigating and operating a command line interface.	Although new users may have a difficult time learning to use the mouse and all GUI features, most users pick up this interface much easier when compared to a command line interface.
Control	Users have much more control of their file system and operating system in a command line interface. For example, users can copy a specific file from one location to another with a one-line command.	Although a GUI offers plenty of control of a file system and operating system, the more advanced tasks may still need a command line.
Multitasking	Although many command line environments are capable of multitasking, they do not offer the same ease and ability to view multiple things at once on one screen.	GUI users have windows that enable a user to view, control, and manipulate multiple things at once and is much faster to navigate when compared with a command line.
Speed	Command line users only need to use their keyboards to navigate a command line interface and often only need to execute a few lines to perform a task.	A GUI may be easier to use because of the mouse. However, using a mouse and keyboard to navigate and control your operating system for many things is going to be much slower than someone who is working in a command line.
Resources	A computer that is only using the command line takes a lot less of the computers system resources than a GUI.	A GUI requires more system resources because of each of the elements that need to be loaded such as icons, fonts, etc. In addition, video drivers, mouse drivers, and other drivers that need to be loaded will also take additional resources.
Scripting	A command line interface enables a user to script a sequence of commands to perform a task or execute a program.	Although A GUI enables a user to create shortcuts, tasks, or other similar actions, it doesn't even come close in comparison to what is available through a command line.

http://www.computerhope.com/issues/ch000619.htm

Computer System



WHAT IS KERNAL?



WHAT IS KERNAL?

- A kernel is the core component of an operating system. Using interprocess communication and system calls, it acts as a bridge between applications and the data processing performed at the hardware level.

  When an operating system is loaded into memory, the kernel loads first and remains in memory until the operating system is shut down again. The kernel is responsible for low-level tasks such as disk management, task management and memory management.

Operating System	Kernel
Operating System is a system software.	Kernel is system software which is part of operating system.
Operating System provides interface between user and hardware.	Kernel provides interface between applications and hardware.
It also provides protection and security.	It's main purpose is memory management, disk management, process management and task management.
All system needs operating system to run.	All operating systems need kernel to run.
Type of operating system includes single and multiuser OS, multiprocessor OS, Realtime OS, Distributed OS.	Type of kernel includes Monolithic and Micro kernel.
It is the first program to load when computer boots up.	It is the first program to load when operating system loads.

Linux


slackware linux
xubuntu
freeBS
OpenBSD
puppy linux
sabayon
yellow dog linux
fedora
ubuntu
linux for human beings
xandros
Making Linux Work For You
gentoo linux
open source
debian
archlinux
opensolaris
mythbuntu
KNOPPIX
PCLinuxOS
CentOS
redhat
Mandriva
kubuntu

Overview

- Initially created as a hobby by a young student, Linus Torvalds, at the University of Helsinki in Finland.
- Linus had an interest in Minix, a small UNIX system, and decided to develop a system that exceeded the Minix standards.
- He began his work in 1991 when he released version 0.02 and worked steadily until 1994 when version 1.0 of the Linux Kernel was released.
- The kernel, at the heart of all Linux systems, is developed and released under the GNU General Public License (GNU's Not Unix!‘),
- Linus Torvalds re-implemented a UNIX API (Application Programming Interface) under the GPL license.

Discussion 1

Linux history

1964:
Bellbs (AT&T)
GE
MIT Multics

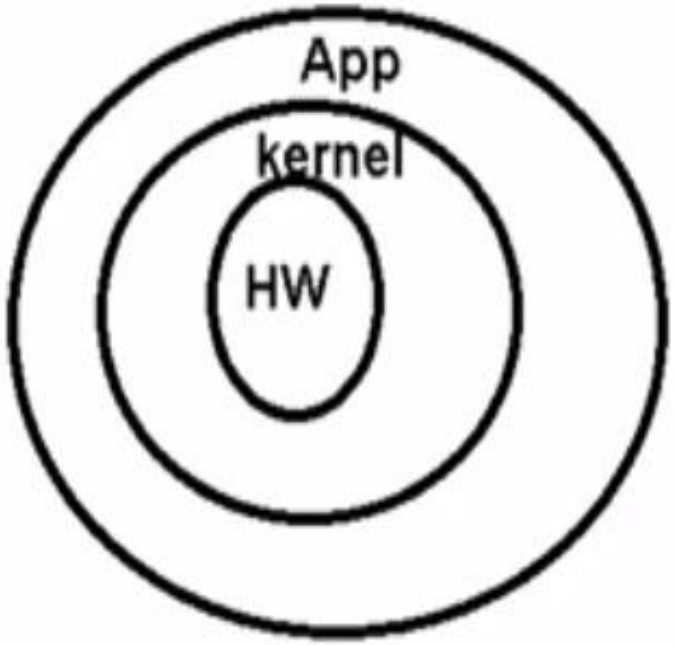
B language UNICS
C language NNIX

BSD berkely software distribution **kernal**
I
NDA Non-distribution aggrement
Sun solaris
IBM AIX
HP HP/unix
apple MAC

GNU Gnu not UNIX Richard Stallman
FSF free software foundation
GPL general public license

Discussion 2

Minix



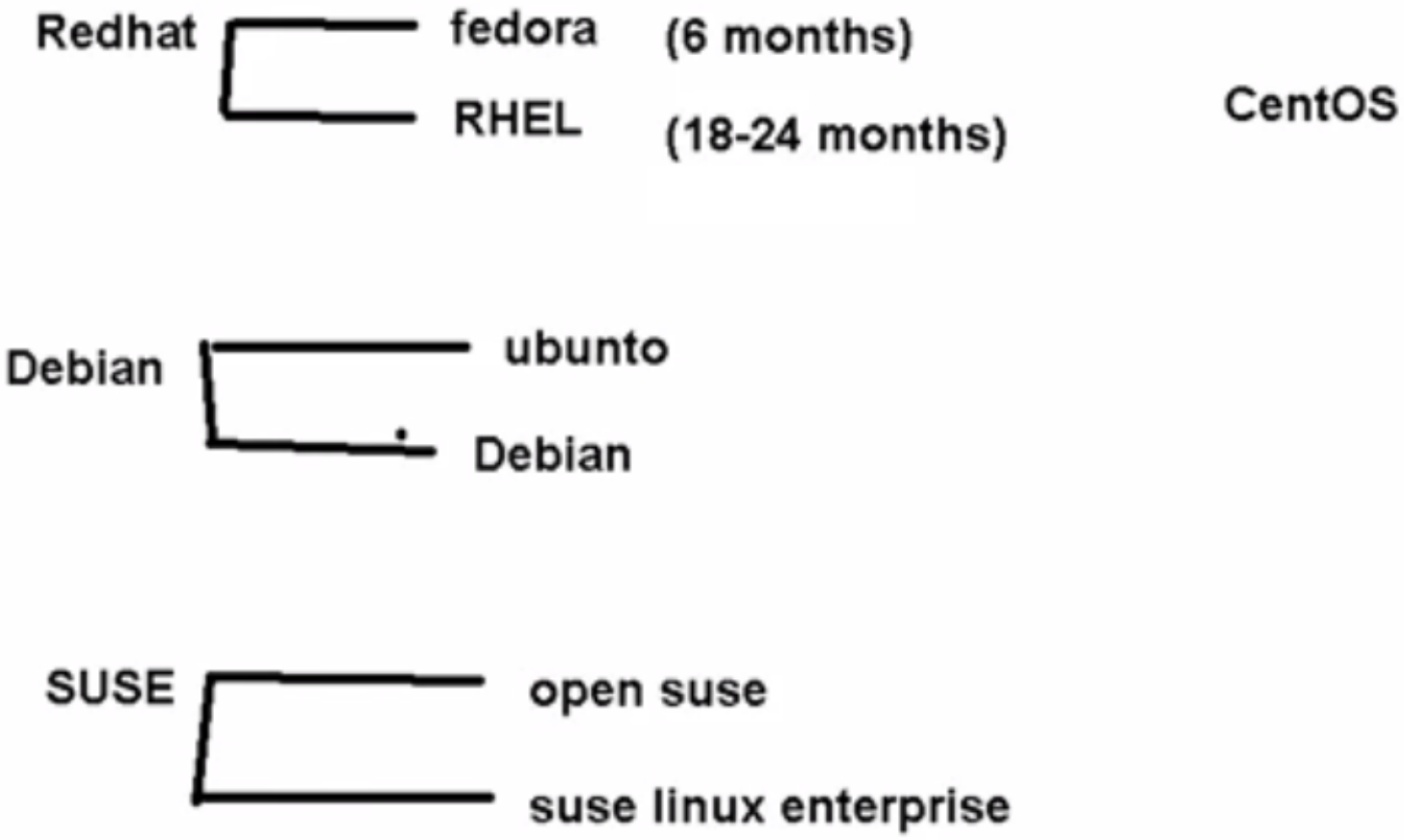
kernel:
1- resource mgmt
2- memory mgmt
3- storage mgmt
4- job schadule
multi tasking

GNU/linux

Debian
slackware
Redhat
Xorg

Discussion 3

RHL1,2,3 9



Overview cont.

- Popular Linux distributions include Debian, Fedora, and Ubuntu. Commercial distributions include Red Hat
- Enterprise Linux and SUSE Linux Enterprise Server.
- Desktop Linux distributions include a windowing system such as X11 or Wayland, and a desktop environment such as GNOME or KDE Plasma 5.
- Distributions intended for servers may omit graphics altogether. Because Linux is freely redistributable, anyone may create a distribution for any purpose.

Common Linux Distributions

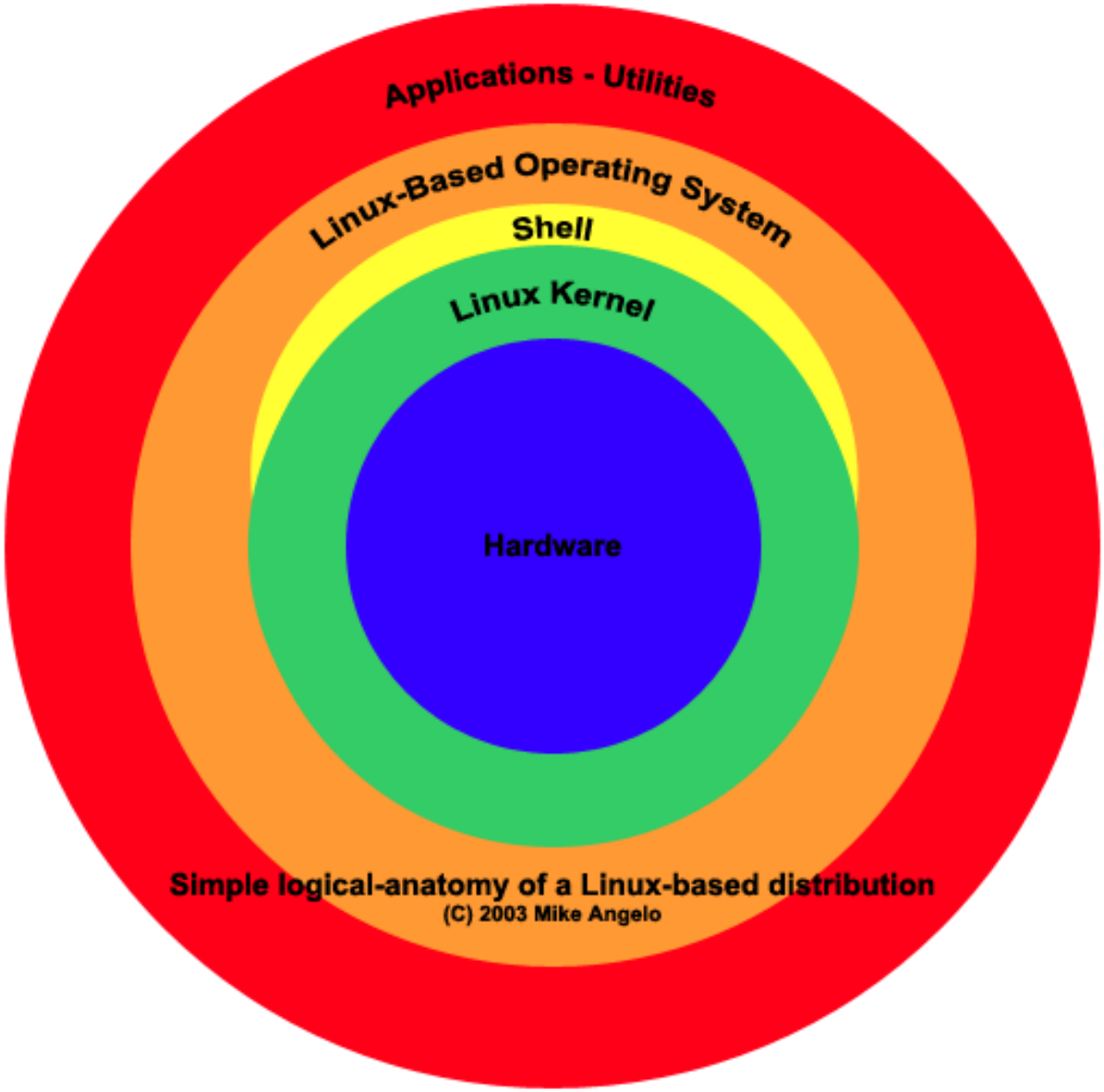
- **Debian** is one of the oldest Linux distributions, dating back to 1993. It can be used as a desktop or server OS. While it is described by sources as user friendly, its installation and initial configuration require additional steps that might make it a little complex for an entry level user. It can downloaded from: https://www.debian.org/distrib/.
- **Ubuntu** is the most popular and user friendly version of Linux, according to most sources. It is based on Debian. It is easier to install and configure than Debian, and can be downloaded here: https://www.ubuntu.com/download/desktop.
- **Linux Mint** is another user friendly, lightweight distribution. Some sources say it responds much faster and makes less use of hardware resources as compared to Windows. It can be downloaded from: https://linuxmint.com/download.php.
- **Fedora** is considered relatively easy to install and is based on the once popular but now discontinued Red Hat Linux distribution. Home, server, and cloud versions are offered. It can be downloaded from: https://getfedora.org.
- A note about Red Hat: While it was discontinued in 2003, Red Hat Enterprise is still active and is commercially sold. Many distros are free.
- **Kali**, as previously mentioned, is a distribution developed primarily for security and penetration testing. It can be downloaded from: https://www.kali.org/downloads/.
- **CentOS** is another distribution based on the now discontinued Red Hat distro. Sources differ as to how easy it is to use and whether it is best suited for new users or for more experienced admin-type users. It can be download from: https://www.centos.org/download/.
- **openSUSE** is offered in two sub-distributions: **Leap** and **Tumbleweed**. Sources say Leap is an easy and user friendly distro which makes a good starting point for users new to Linux. Tumbleweed, on the other hand, is better suited to developers. Both can be downloaded from: https://software.opensuse.org/.

Basic Features of Linux

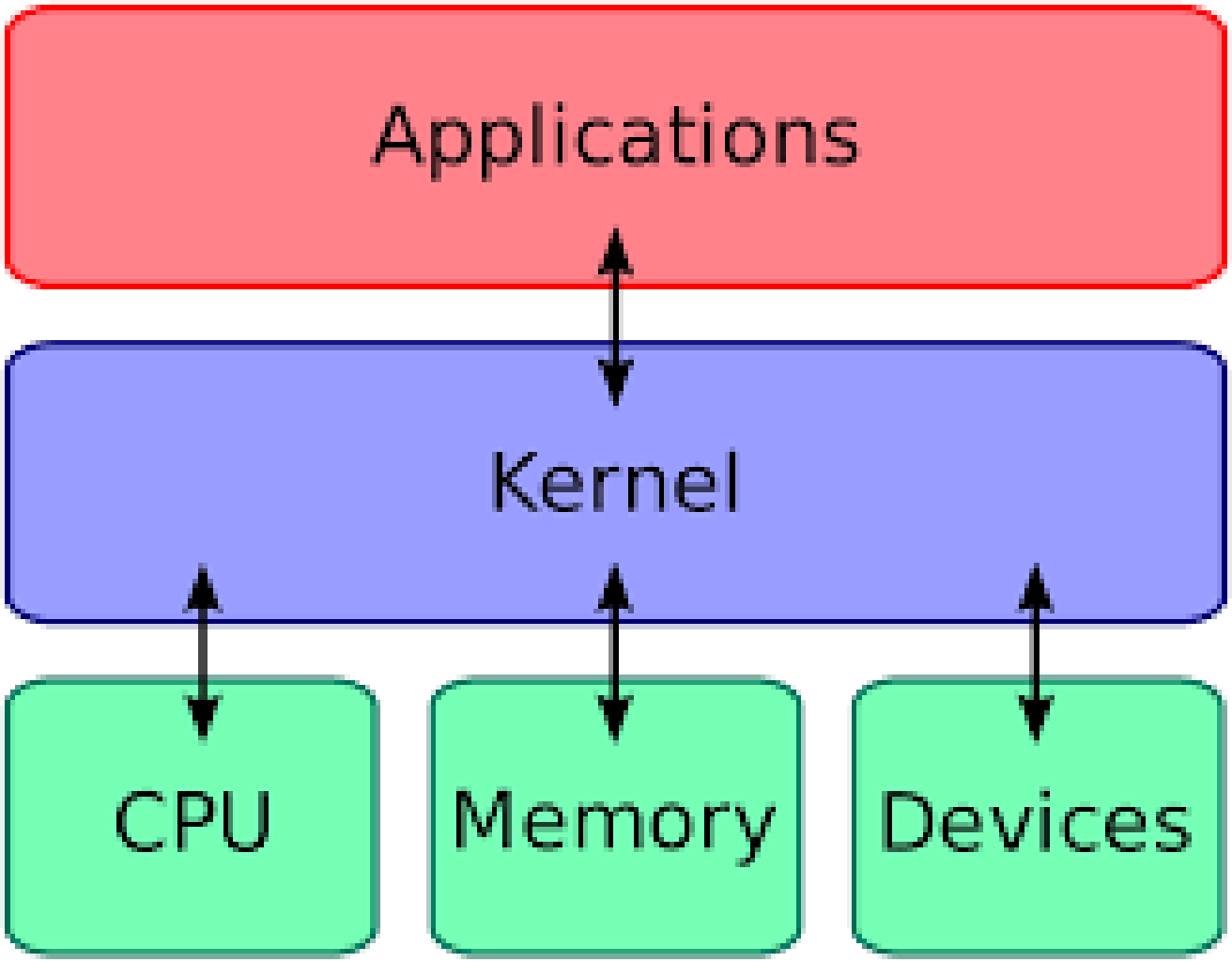
- **Portable** – Portability means softwares can works on different types of hardwares in same way.Linux kernel and application programs supports their installation on any kind of hardware platform.
- **Open Source** – Linux source code is freely available and it is community based development project. Multiple teams works in collaboration to enhance the capability of Linux operating system and it is continuously evolving.
- **Multi-User** – Linux is a multiuser system means multiple users can access system resources like memory/ ram/ application programs at same time.
- **Multiprogramming** – Linux is a multiprogramming system means multiple applications can run at same time.
- **Hierarchical File System** – Linux provides a standard file structure in which system files/ user files are arranged.
- **Shell** – Linux provides a special interpreter program which can be used to execute commands of the operating system. It can be used to do various types of operations, call application programs etc.
- **Security** – Linux provides user security using authentication features like password protection/ controlled access to specific files/ encryption of data.
- **Performance** -- very fast

The four essential freedoms of linux

- The freedom to run the program as you wish, for any purpose (freedom 0).
- The freedom to study how the program works, and change it so it does your computing as you wish (freedom 1). Access to the source code is a precondition for this.
- The freedom to redistribute copies so you can help others (freedom 2).
- The freedom to distribute copies of your modified versions to others (freedom 3).
- By doing this you can give the whole community a chance to benefit from your changes. Access to the source code is a precondition for this.

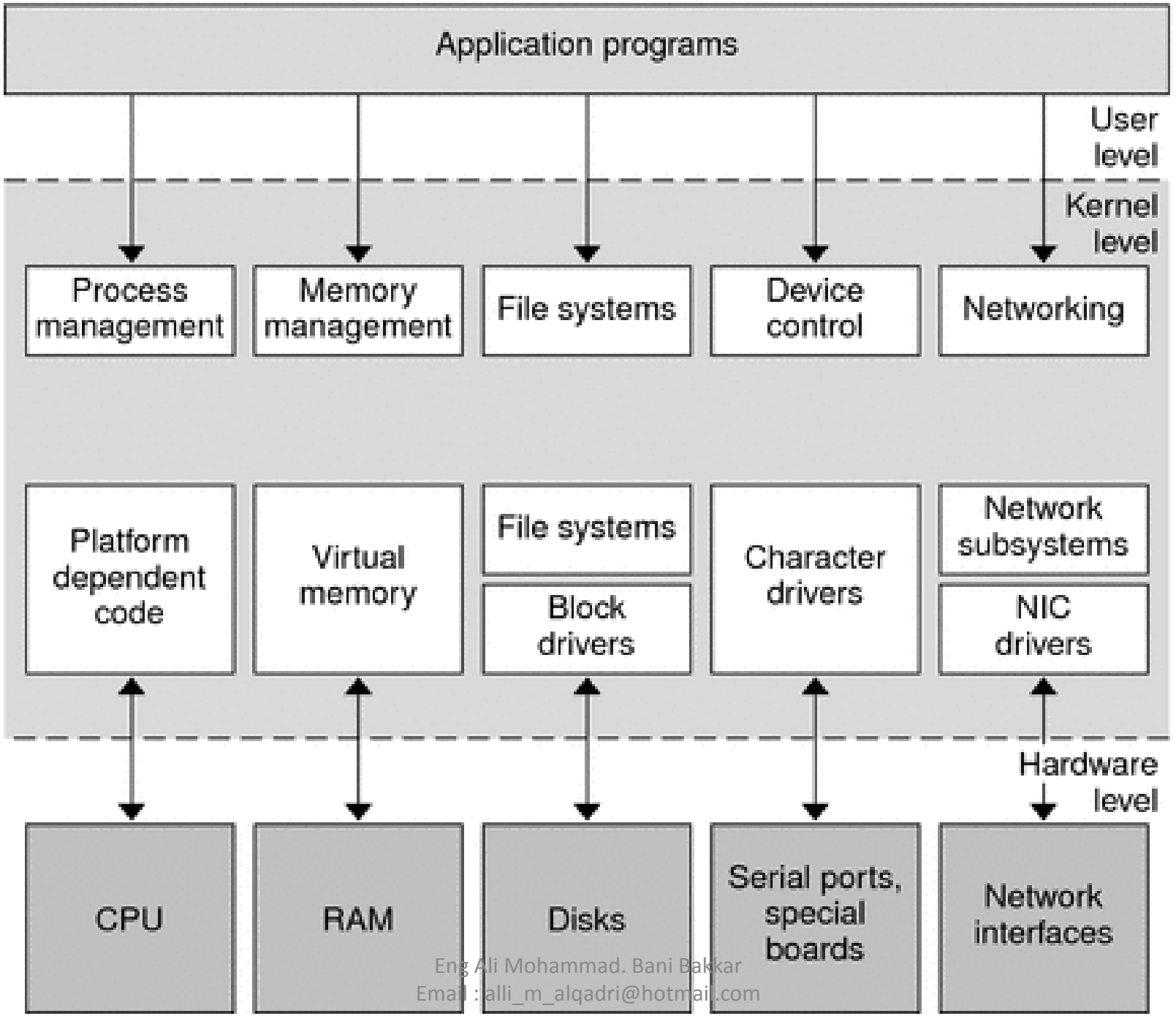

Applications - Utilities
Linux-Based Operating System
Shell
Linux Kernel
Hardware
Simple logical-anatomy of a Linux-based distribution
(C) 2003 Mike Angelo

Linux kernel (1)

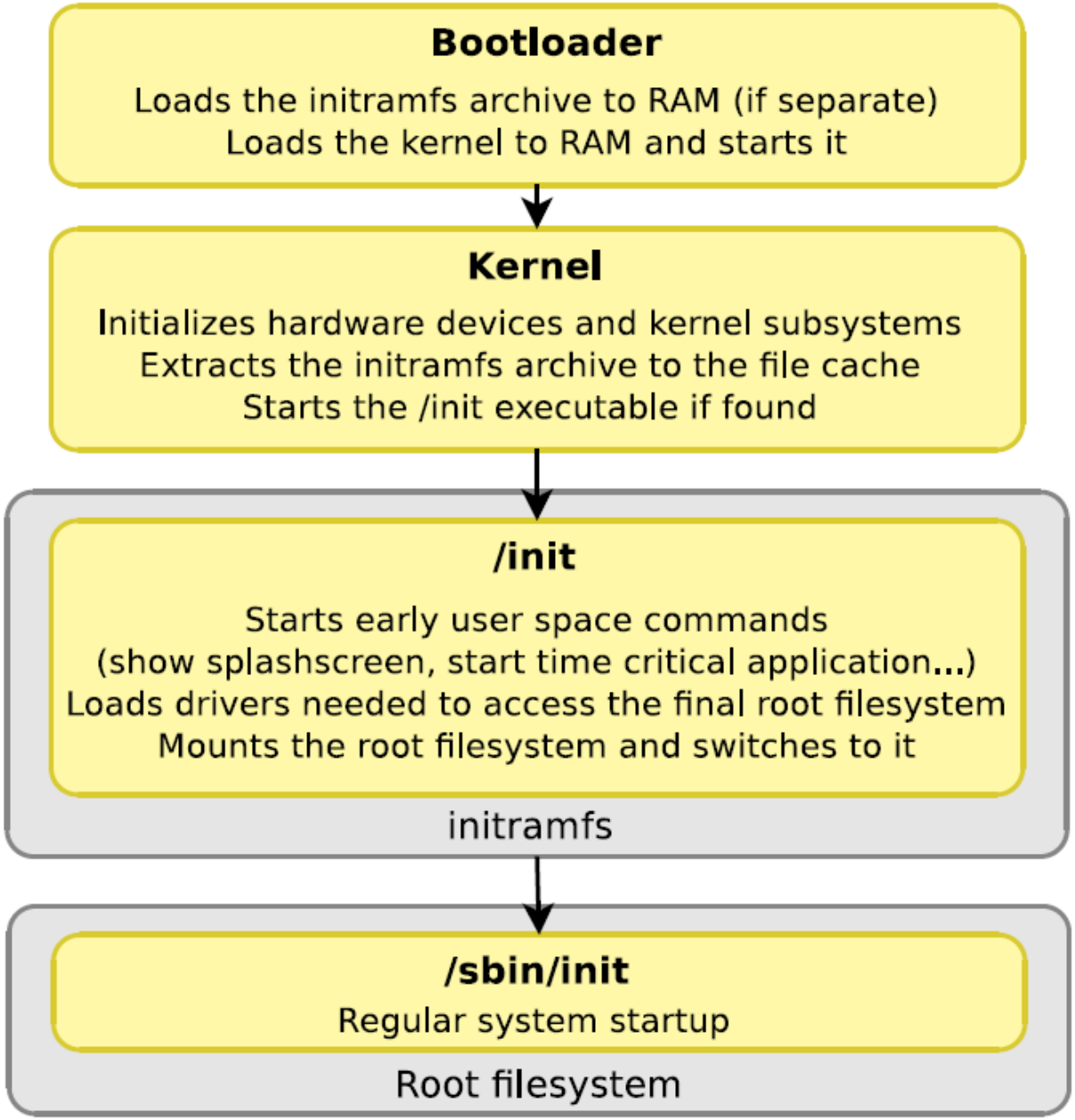


Linux kernal (2)

- The operating system software file (program) which is **copied into RAM**, usually from the hard disk drive, during the **boot-up**.
- The kernel remains in RAM while the computer is on and is **in charge of the overall operation** of the computer system.
- The kernel contains the "**internal programs**" for the most often used operations like copying files.


Application programs
User level
Kernel level
Process management
Memory management
File systems
Device control
Networking
Platform dependent code
Virtual memory
File systems
Block drivers
Character drivers
Network subsystems
NIC drivers
Hardware level
CPU
RAM
Disks
Serial ports, special boards
Network interfaces

booting


Bootloader
Loads the initramfs archive to RAM (if separate)
Loads the kernel to RAM and starts it
Kernel
Initializes hardware devices and kernel subsystems
Extracts the initramfs archive to the file cache
Starts the /init executable if found
/init
Starts early user space commands
(show splashscreen, start time critical application...)
Loads drivers needed to access the final root filesystem
Mounts the root filesystem and switches to it
initramfs
/sbin/init
Regular system startup
Root filesystem

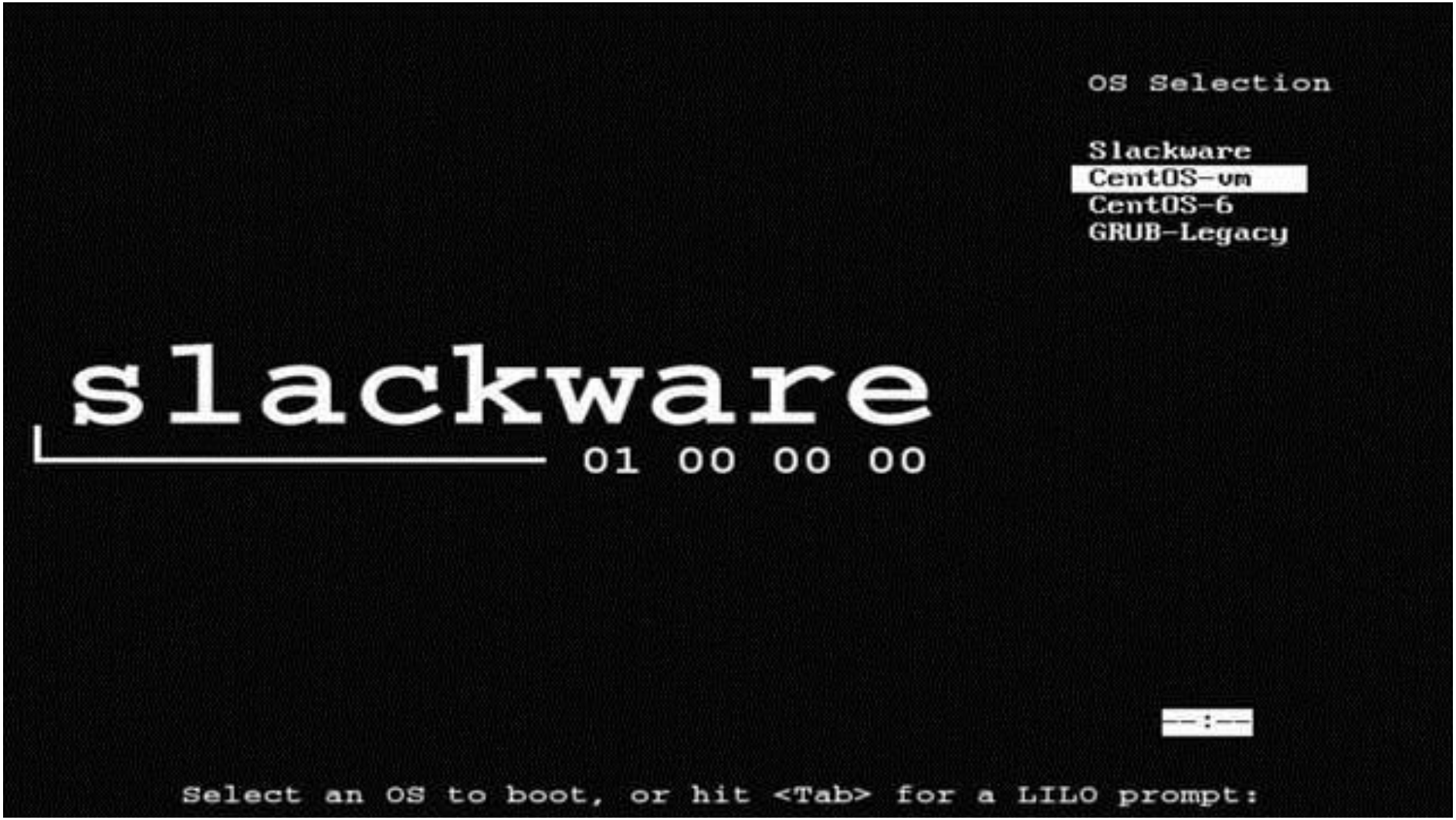
Boot Loader

- **Booting is a process that starts operating systems when the user turns on a computer system.**
- **A boot sequence is the initial set of operations that the computer performs when it is switched on.**
- **The bootloader typically loads the main operating system for the computer.**
- **The bootloader may be multistage**
- **In Desktop Computers, the boot process involve running of system BIOS followed by the second stage bootloader like GRUB, BOOTMGR, LILO or NTLDR which is located in the boot sector of the boot device or the hard disk.**

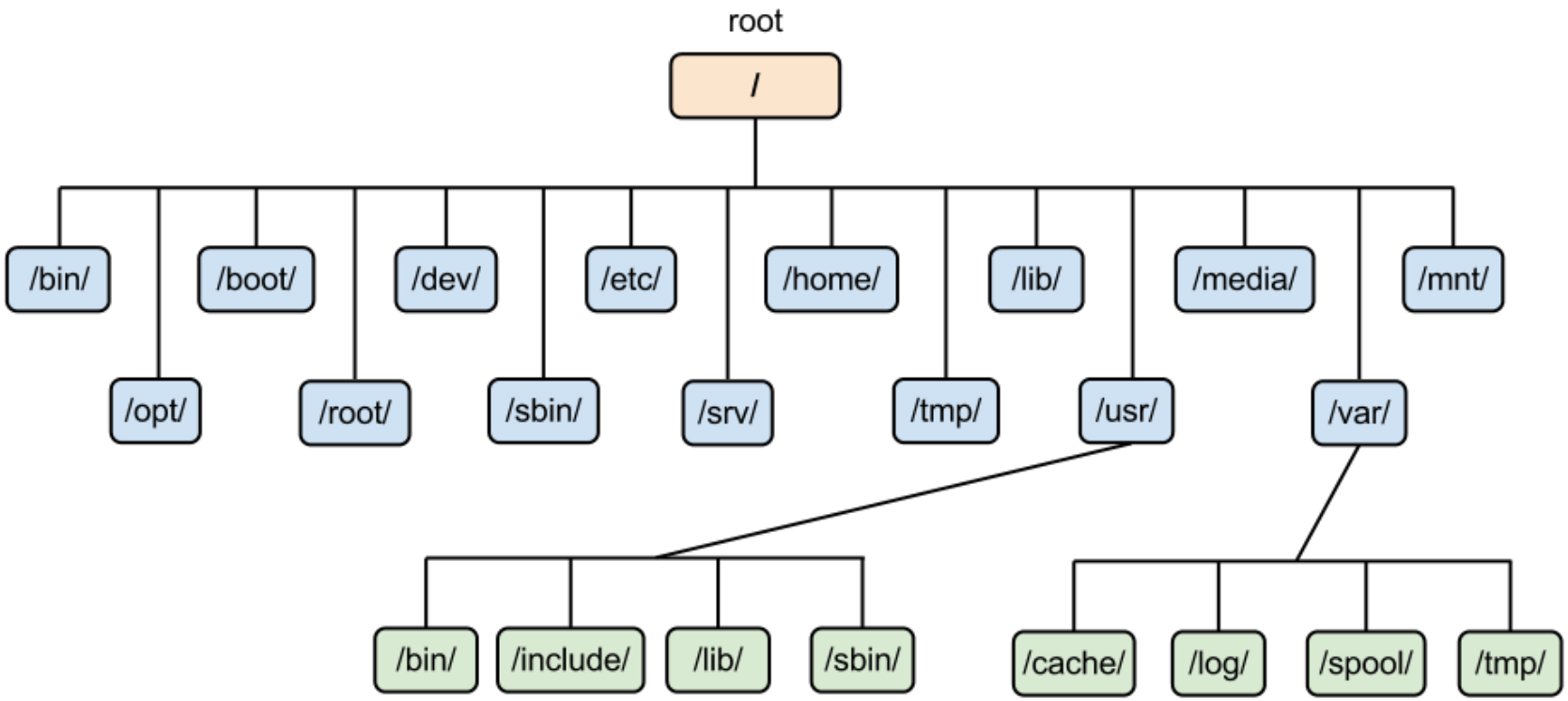
Grub 2


GNU GRUB version 2.02~beta2-9ubuntu1.3
*Ubuntu
Advanced options for Ubuntu
Memory test (memtest86+)
Memory test (memtest86+, serial console 115200)
Fedora release 20 (Heisenbug) (on /dev/sda10)
Advanced options for Fedora release 20 (Heisenbug) (on /dev/sda10)
CentOS release 6.6 (Final) (on /dev/sda11)
Advanced options for CentOS release 6.6 (Final) (on /dev/sda11)
Fedora release 22 (Twenty Two) (on /dev/sda5)
Advanced options for Fedora release 22 (Twenty Two) (on /dev/sda5)
Slackware Linux (Slackware 13.37.0) (on /dev/sda6)
Advanced options for Slackware Linux (Slackware 13.37.0) (on /dev/sda6)
Fedora release 18 (Spherical Cow) (on /dev/sda7)
Advanced options for Fedora release 18 (Spherical Cow) (on /dev/sda7)
openSUSE 11.4 (x86_64) (on /dev/sda8)
Use the ↑ and ↓ keys to select which entry is highlighted.
Press enter to boot the selected OS, `e' to edit the commands
before booting or `c' for a command-line. ESC to return previous
menu.
The highlighted entry will be executed automatically in 52s.

Lilo


OS Selection
Slackware
CentOS-vm
CentOS-6
GRUB-Legacy
slackware
01 00 00 00
Select an OS to boot, or hit <Tab> for a LILO prompt:

HIERARCHICAL FILESYSTEM



Hierarchical FileSystem

- Files are kept in directories
- Directories can hold other directories.
- FHS – Filesystem Hierarchy Standard defines the rules for where certain files will always be kept.
- The “root” of the Linux FS is always ‘/’
- Files & directories can be owned by users to enforce security privileges.

Partitions

```
[root@master ~]# df -h
Filesystem      Size  Used Avail Use% Mounted on
/dev/sda5        76G  3.1G   73G   4% /
devtmpfs        899M     0  899M   0% /dev
tmpfs           913M  144K  913M   1% /dev/shm
tmpfs           913M  9.0M  904M   1% /run
tmpfs           913M     0  913M   0% /sys/fs/cgroup
/dev/sda2        20G   33M   20G   1% /home
/dev/sda1       197M  139M   59M  71% /boot
tmpfs           183M   16K  183M   1% /run/user/0
/dev/sr0        3.8G  3.8G     0 100% /run/media/root/RHEL-7.2 Server.x86_64
[root@master ~]#
```

Linux file system types

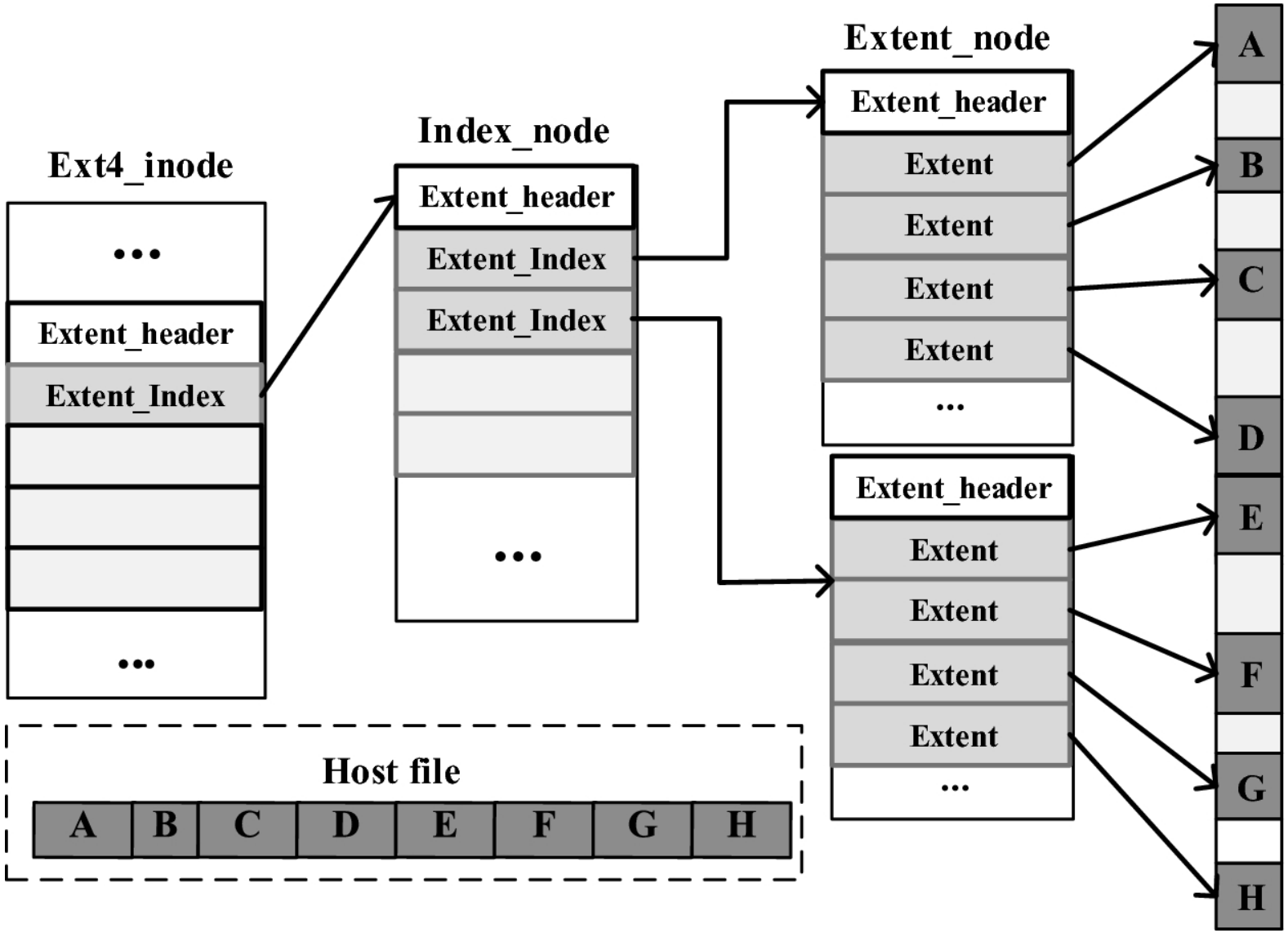
- (ext2, ext3 and ext4)
- XFS, JFS, and btrfs
- a flash translation layer(FTL)
- Memory Technology Device (MTD)
- UBIFS, JFFS2 and YAFFS
- SquashFS is a common compressed read-only file system.

Ext4(**extended file system**) Features

- **Large file system The** ext4 filesystem can support volumes with sizes up to 1 (EB) and single files with sizes up to 16 (TB) with the standard 4 KB block size.
- The maximum file, directory, and filesystem size limits grow at least proportionately with the filesystem block size up to the maximum 64 KB block size .
- Extents replace the traditional block mapping scheme used by ext2 and ext3. An extent is a range of contiguous physical blocks, improving large file performance and reducing fragmentation. A single extent in ext4 can map up to 128 MB of contiguous space with a 4 KB block size. There can be four extents stored directly in the inode. When there are more than four extents to a file, the rest of the extents are indexed in a tree.

Ext4(**extended file system**) Features cont.

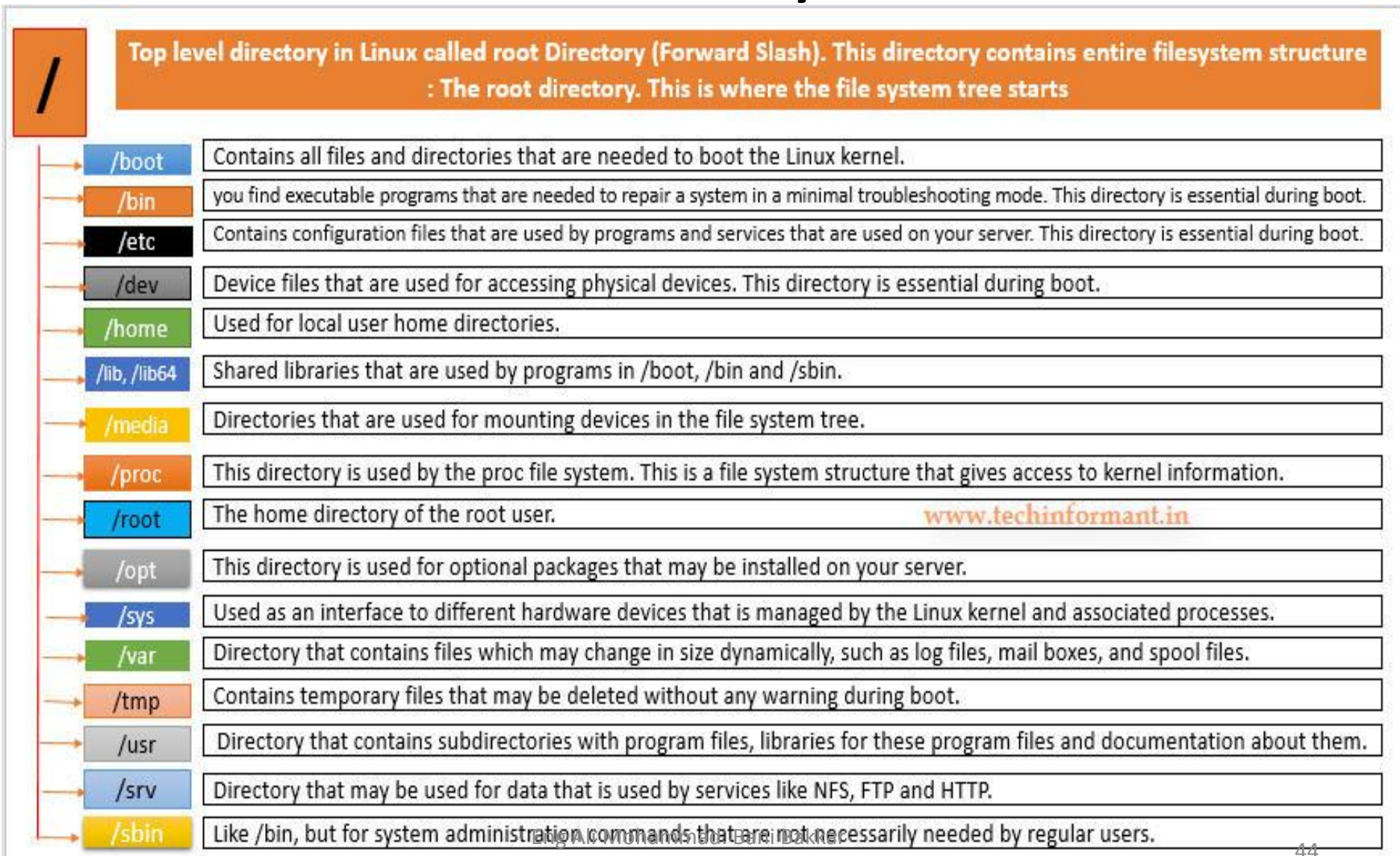
- **Backward compatibility**
- **Persistent pre-allocation**
- **Delayed allocation**
- **Unlimited number of subdirectories(**In Linux 4.12 and later the largedir feature enabled a 3-level HTree and directory sizes over 2 GB, allowing approximately 6 billion entries in a single directory.)
- **Journal checksumming**
- **Metadata checksumming**
- **Faster file system checking**
- **Multiblock allocator**
- **Improved timestamps (nano seconds)**
- **Project Quotas (**The project ID of a file is a 32-bit number stored on each file, and is inherited by all files and subdirectories created beneath a parent directory with an assigned project ID**)**
- **Transparent encryption**


Ext4_inode
Extent_header
Extent_Index
Index_node
Extent_header
Extent_Index
Extent_Index
Extent_node
Extent_header
Extent
Extent
Extent
Extent
Extent_header
Extent
Extent
Extent
Extent
Host file
A
B
C
D
E
F
G
H

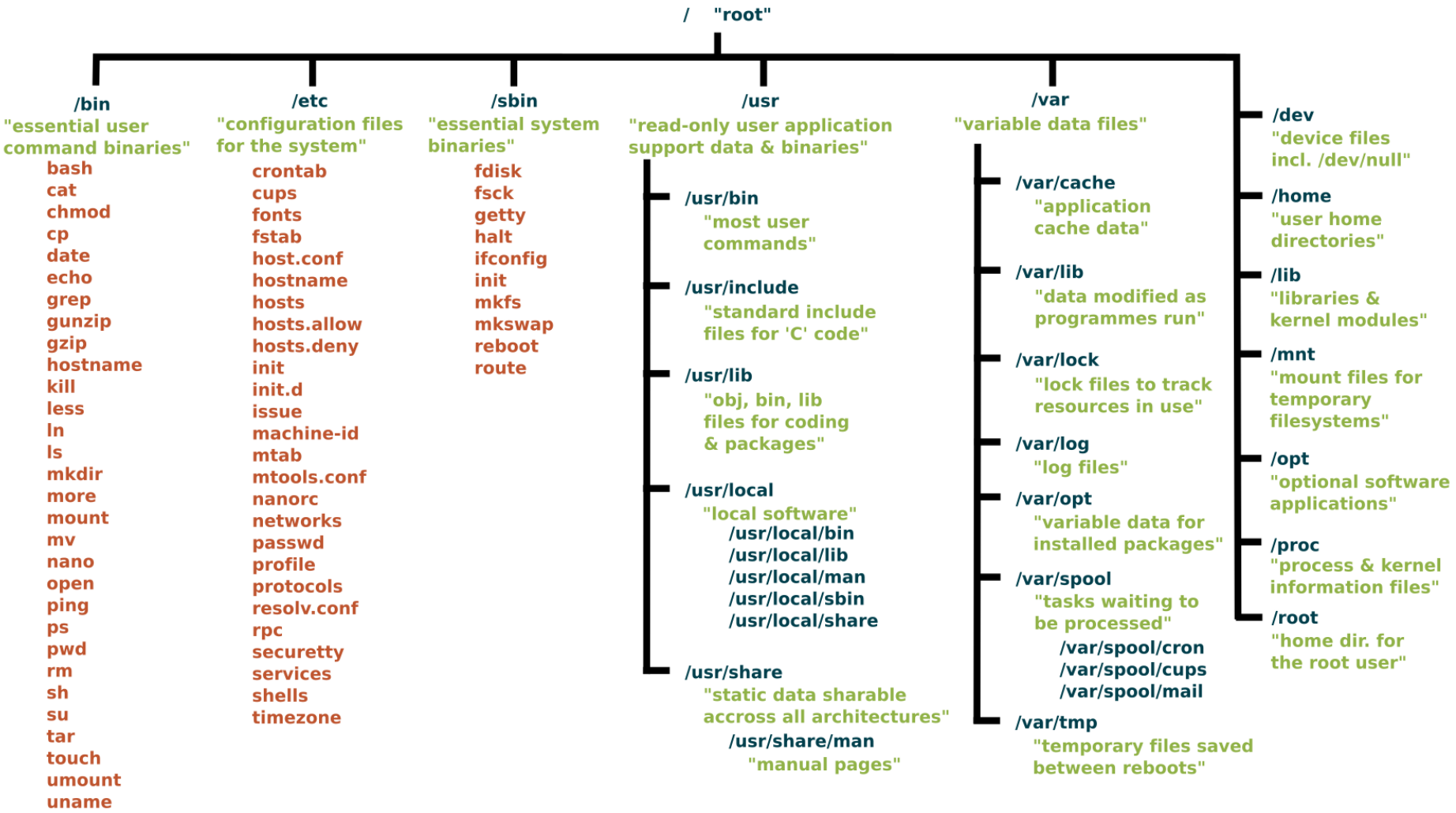
Allocate-on-flush

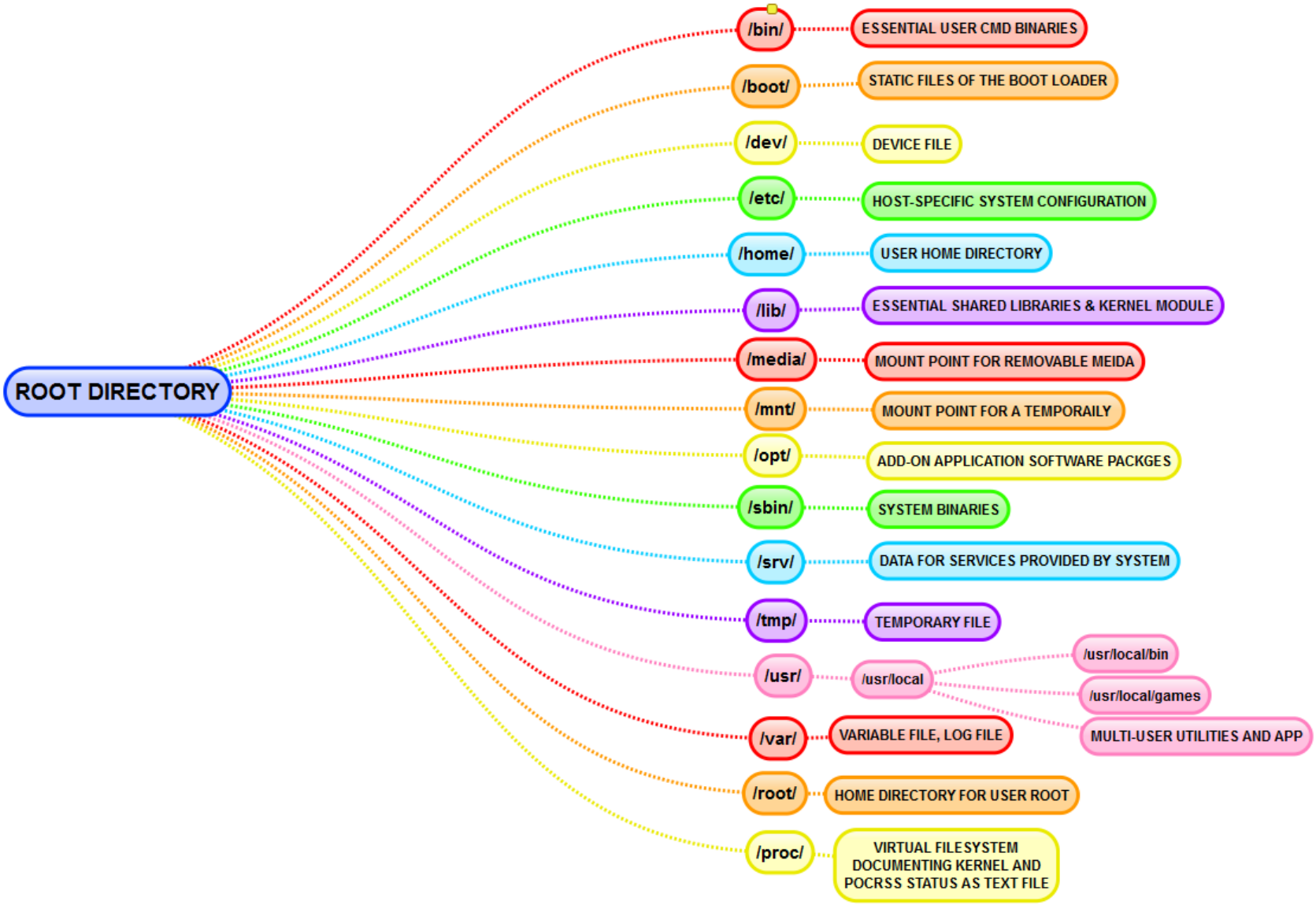
- (also called **delayed allocation**) is a file system feature implemented in HFS+, XFS, Reiser4, ZFS, Btrfs, and ext4. The feature also closely resembles an older technique that Berkeley's UFS called "block reallocation".
- When blocks must be allocated to hold pending writes, disk space for the appended data is subtracted from the free-space counter, but not actually allocated in the free-space bitmap. Instead, the appended data are held in memory until they must be flushed to storage due to memory pressure, when the kernel decides to flush dirty buffers, or when the application performs the Unix "sync" system call.

Linux File System

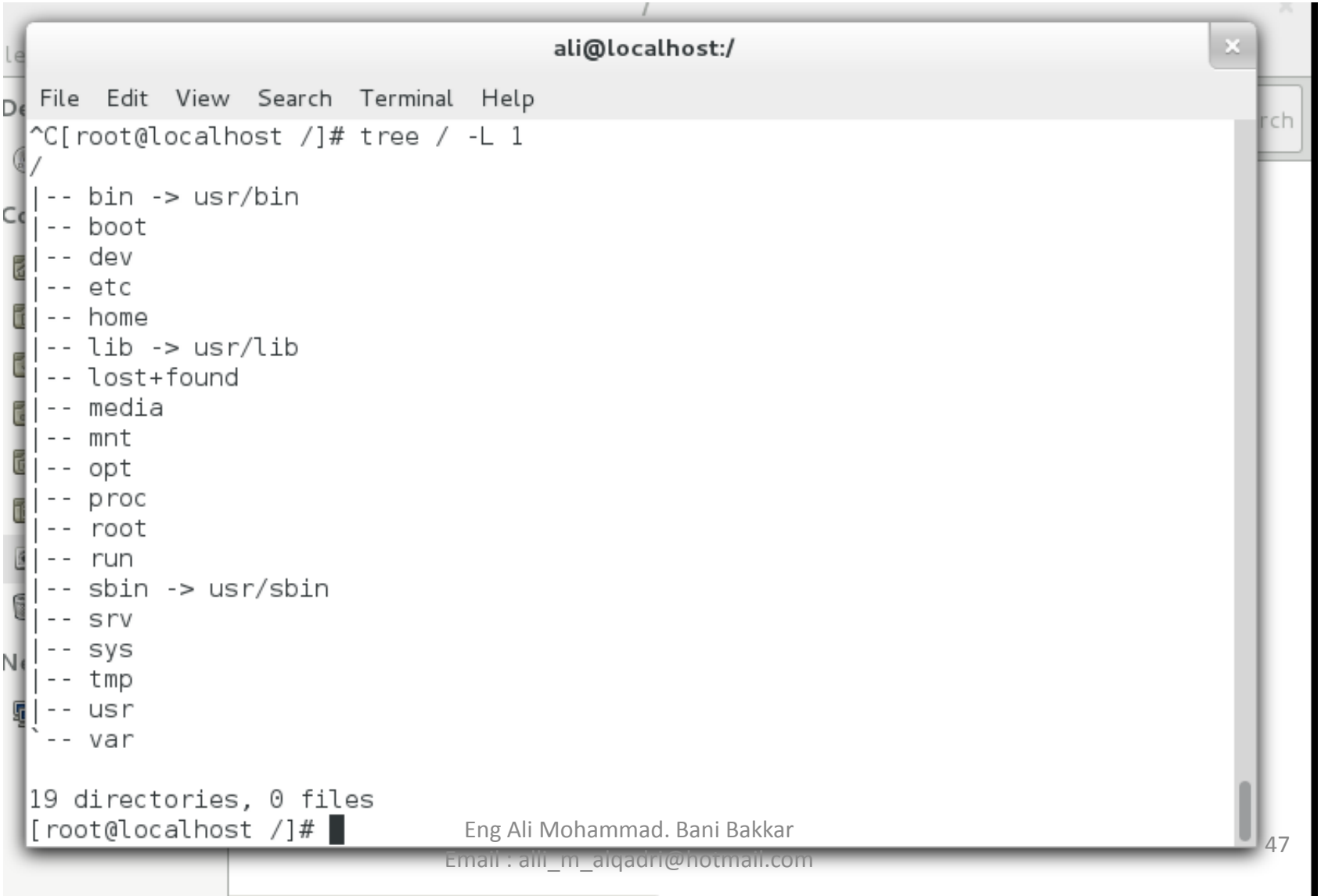


Linux File System(cont.)




ROOT DIRECTORY
/bin/
ESSENTIAL USER CMD BINARIES
/boot/
STATIC FILES OF THE BOOT LOADER
/dev/
DEVICE FILE
/etc/
HOST-SPECIFIC SYSTEM CONFIGURATION
/home/
USER HOME DIRECTORY
/lib/
ESSENTIAL SHARED LIBRARIES & KERNEL MODULE
/media/
MOUNT POINT FOR REMOVABLE MEIDA
/mnt/
MOUNT POINT FOR A TEMPORAILY
/opt/
ADD-ON APPLICATION SOFTWARE PACKGES
/sbin/
SYSTEM BINARIES
/srv/
DATA FOR SERVICES PROVIDED BY SYSTEM
/tmp/
TEMPORARY FILE
/usr/
/usr/local
/usr/local/bin
/usr/local/games
MULTI-USER UTILITIES AND APP
/var/
VARIABLE FILE, LOG FILE
/root/
HOME DIRECTORY FOR USER ROOT
/proc/
VIRTUAL FILESYSTEM DOCUMENTING KERNEL AND POCRSS STATUS AS TEXT FILE

Linux File System Example



root Definition

- *root* is the user name or account that by default has access to all commands and files on a Linux or other Unix-like operating system. It is also referred to as the *root account*, *root user* and the *superuser*.
- One of these is the *root directory*, which is the *top level directory* on a system. That is, it is the directory in which all other directories, including their subdirectories, and files reside. The root directory is designated by a forward slash (/).
- Another is */root* (pronounced *slash root*), which is the root user's *home directory*. A home directory is the primary repository of a user's files, including that user's configuration files, and it is usually the directory in which a user finds itself when it logs into a system.