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Complete Linux

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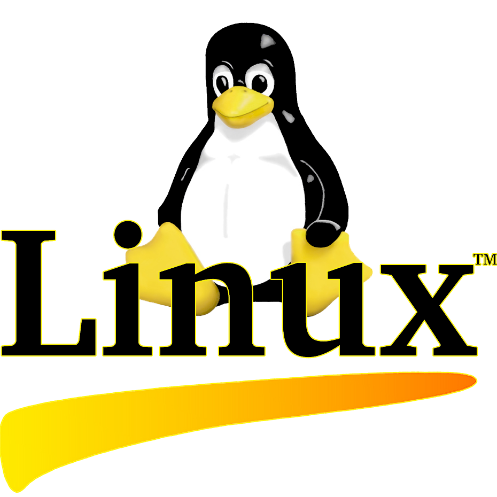
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# 1. Linux

In 1969, Ken Thompson and Dennis Ritchie of Bell Laboratories developed the UNIX operating system which was later rewritten in C.

A decade or so later, Richard Stallman started working on the GNU (GNU is Not UNIX) project, the GNU kernel called Hurd, which unfortunately never came to completion.

During this time other efforts such as BSD, MINIX, etc. were developed to be UNIX like-systems. However, one thing that all these UNIX like-systems had in common was the lack of a unified kernel.

Then in 1991, Linus Torvalds started developing what we now know today as the Linux kernel.

# 2. Linux Distributions (Distros)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Debian**  https://raw.githubusercontent.com/EgoistDeveloper/operating-system-logos/master/src/48x48/DEB.png | **Ubuntu**  https://raw.githubusercontent.com/EgoistDeveloper/operating-system-logos/master/src/48x48/UBT.png | **openSUSE**  https://raw.githubusercontent.com/EgoistDeveloper/operating-system-logos/master/src/48x48/SSE.png | **Fedora** | **RHEL** | **Arch** | **Gentoo** |
| **Maintainer** | Debian Project | Canonical Ltd. | openSUSE + SUSE | Fedora Project | Red Hat (IBM) | Arch Community | Gentoo Community |
| **Release Model** | Stable, Testing, Unstable | Regular + LTS | Tumbleweed (rolling), Leap (stable) | Regular (~6 months) | Long-Term Support (10+ yrs) | Rolling | Rolling (source-based) |
| **Package Manager** | APT (.deb) | APT (.deb) + Snap | Zypper (.rpm) | DNF (.rpm) | YUM/DNF (.rpm) | Pacman | Portage |
| **Default File System** | ext4 | ext4 | Btrfs (Leap), ext4 (Tumbleweed) | ext4 | XFS | ext4 | ext4 |
| **Stability** | Very High | High | High (Leap), Medium (Tumble) | Moderate | Enterprise-grade | Moderate | Depends on user |
| **Target Users** | Advanced users, servers | Beginners, desktops, cloud | Developers, sysadmins | Developers, enthusiasts | Enterprises | Power users, enthusiasts | Experts, tinkerers |
| **Pros** | Very stable, open-source focused | User-friendly, strong hardware support | YaST tool, flexible models | Cutting-edge tech, GNOME default | Paid support, long lifecycle | Bleeding-edge, highly customizable | Full control, optimized for performance |
| **Cons** | Older packages, less beginner-friendly | Snap criticisms, heavier | Less software availability, slower Leap updates | Short support cycle, upgrade demands | Paid, closed-source elements | DIY install, fragile if misused | Very steep learning curve, time-intensive |

# 3. Linux Boot Process

There are 6 high level stages of a typical Linux Boot Process.



## BIOS / UEFI Initialization

|  |  |
| --- | --- |
| **BIOS** | **UEFI** |
| * BIOS stands for Basic Input/Output System * Performs some system integrity checks * Searches, loads, and executes the boot loader program. * It looks for boot loader in floppy, cd-rom, or hard drive. You can press the BIOS key during the BIOS startup to change the boot sequence. * Once the boot loader program is detected and loaded into the memory, BIOS gives the control to it. * So, in simple terms BIOS loads and executes the MBR or GPT boot loader. | * UEFI stands for Unified Extensible Firmware Interface. * Runs in 32-bit or 64-bit protected mode for faster and more secure booting. * Provides features like secure boot and graphical setup menus. * Has become the standard firmware on most modern Linux systems. * Many systems still support legacy BIOS mode for compatibility. * Enabling UEFI with secure boot is recommended to protect against boot-level |

## MBR / GPT

|  |  |
| --- | --- |
| **MBR** | **GPT** |
| * MBR stands for Master Boot Record. * Located in the first sector (LBA 0) of the bootable disk (e.g., /dev/sda). * Exactly 512 bytes:   + 446 bytes: Primary bootloader code   + 64 bytes: Partition table (up to 4 entries)   + 2 bytes: Boot signature (0x55AA) * BIOS loads and executes the MBR to initiate the Stage 1 bootloader (e.g., GRUB or LILO). * Supports disks up to 2 TB and allows up to 4 primary partitions. | * GPT stands for GUID Partition Table. * Used with UEFI firmware, it supports drives up to 9.4 ZB. * GPT stores partition data in LBA 1, with a backup header at the end of the disk. * Includes a protective MBR for legacy system compatibility. * Supports a dedicated EFI System Partition (ESP) to store bootloader files. * Offers better redundancy and structure compared to MBR. |

## GRUB

* GRUB stands for Grand Unified Bootloader.
* If you have multiple kernel images installed on your system, you can choose which one to be executed.
* GRUB displays a splash screen, waits for few seconds, if you don’t enter anything, it loads the default kernel image as specified in the grub configuration file.
* GRUB has the knowledge of the filesystem (the older Linux loader LILO didn’t understand filesystem).
* Grub configuration file is /boot/grub/grub.conf (/etc/grub.conf is a link to this).
* It contains kernel and initrd image.
* So, in simple terms GRUB just loads and executes Kernel and initrd images.

## Kernel

* Mounts the root file system as specified in the “root=” in grub.conf
* Kernel executes the /sbin/init program
* Since init was the 1st program to be executed by Linux Kernel, it has the process id (PID) of 1.
* initrd stands for Initial RAM Disk.
* initrd is used by kernel as temporary root file system until kernel is booted and the real root file system is mounted.
* It also contains necessary drivers compiled inside, which helps it to access the hard drive partitions, and other hardware.

## init / systemd

|  |  |
| --- | --- |
| **init** | **systemd** |
| * Looks at the /etc/inittab file to decide the Linux run level. * Following are the available run levels   + 0 – halt   + 1 – Single user mode   + 2 – Multiuser, without NFS   + 3 – Full multiuser mode   + 4 – unused   + 5 – X11   + 6 – reboot * Init identifies the default initlevel from /etc/inittab and uses that to load all appropriate program. * Identify the default run level: `grep initdefault /etc/inittab` * You can set the default run level from 0 to 6 but it is advised to set it to either 3 or 5. | * systemd manages Linux startup by tracking service dependencies via unit files. * Enables parallel and ordered service initialization for faster boots. * Uses boot targets (like graphical.target) similar to traditional runlevels. * Parses unit files (e.g., /etc/systemd/system/\*.service) to build a dependency graph. * The [Install] section links services to boot targets. * systemd improves boot speed and management but requires adapting to new init concepts. |

## Runlevel Programs

* During boot, runlevel programs execute from directories based on the runlevel:
  + Runlevel 0: /etc/rc.d/rc0.d/
  + Runlevel 1: /etc/rc.d/rc1.d/
  + … up to Runlevel 6: /etc/rc.d/rc6.d/
* Symbolic links like /etc/rc0.d point to /etc/rc.d/rc0.d/ for convenience.
* Programs in these directories start with **S** (startup) or **K** (kill/shutdown).
* Numbers following S/K indicate execution order (sequence number).
* Example: S12syslog starts syslog before S80sendmail starts sendmail.

# 4. Standard File System Hierarchy

|  |  |  |
| --- | --- | --- |
| **Directory Type** | **Directory** | **Purpose** |
| Top level Directory | / | Root directory — top of the filesystem tree |
| Essential System Directories | /bin | Essential user binaries (commands needed in single-user mode) |
| /boot | Boot loader files, kernel, initrd |
| /dev | Device files (hardware devices like disks, terminals) |
| /etc | Host-specific system configuration files |
| /lib | Essential shared libraries and kernel modules |
| /sbin | System binaries (commands for system administration) |
| User Directories | /root | Home directory for the root user |
| /home | User home directories |
| /media | Mount points for removable media (USB, CD-ROM) |
| /mnt | Temporary mount point for mounting filesystems |
| Virtual or Temporary File Systems | /proc | Virtual filesystem providing process and kernel info |
| /sys | Virtual filesystem for kernel device and system info |
| /run | Runtime variable data, information about running system |
| /tmp | Temporary files (cleared on reboot) |
| Optional or Variable Components | /opt | Optional application software packages |
| /srv | Data for services provided by the system |
| /usr | Secondary hierarchy for read-only user data; contains binaries, libraries, documentation |
| /var | Variable files like logs, spool files, mail, cache |

# 5. Linux Commands

|  |  |
| --- | --- |
| **Category** | **Key Linux Commands / Utilities** |
| **Basic Commands** | echo, pwd, date, whoami, hostname, uptime |
| **File and Directory Management** | ls, cd, pwd, mkdir, rmdir, rm, cp, mv, find, stat, file |
| **Text Processing** | cat, tac, head, tail, grep, sed, awk, cut, sort, uniq, tr, wc |
| **Process Management** | ps, top, htop, kill, killall, nice, renice, jobs, fg, bg |
| **User Management and Permissions** | useradd, usermod, userdel, passwd, groups, id, chmod, chown, chgrp, sudo |
| **Networking** | ping, traceroute, ifconfig (deprecated), ip, netstat, ss, scp, ssh, wget, curl, dig |
| **Disk and Filesystem Management** | df, du, mount, umount, fsck, blkid, lsblk, parted, fdisk, tune2fs |
| **Package Management** | apt, dpkg (Debian/Ubuntu), yum, dnf (Fedora/RHEL), pacman (Arch), zypper (openSUSE), rpm |
| **Shell and Scripting** | bash, sh, zsh, dash, source, alias, export, env, cron, at |
| **System Information and Monitoring** | uname, top, vmstat, iostat, free, uptime, dmesg, lscpu, lsusb, lspci |
| **Job Scheduling and Automation** | cron, crontab, at, batch, systemd timers |
| **Security and Encryption** | iptables, firewalld, ufw, openssl, gpg, ssh-keygen, fail2ban, selinux |
| **Archiving and Compression** | tar, gzip, gunzip, bzip2, xz, zip, unzip, 7z |
| **System Services and Daemon Management** | systemctl, service, chkconfig, init, journalctl |
| **Hardware Information and Configuration** | lshw, lsusb, lspci, hwinfo, dmidecode, modprobe |
| **Development Tools (compilers, debuggers)** | gcc, make, gdb, strace, valgrind, ld, objdump |
| **Virtualization and Containers** | docker, podman, kubectl, virsh, qemu, vboxmanage |
| **Backup and Recovery** | rsync, tar, dd, dump, restore, timeshift |
| **Logging and Auditing** | journalctl, logger, auditctl, ausearch, syslog, rsyslog |
| **Localization and Internationalization** | locale, localectl, timedatectl, gettext |

## Basic Commands

|  |  |  |
| --- | --- | --- |
| **Command** | **Description** | **Basic Syntax** |
| echo | Display a line of text | echo "Hello World" |
| pwd | Print current working directory | pwd |
| date | Show or set system date/time | date |
| whoami | Show current user | whoami |
| clear | Clear terminal screen | clear |
| man | Display manual pages | man ls |

## File and Directory Commands

|  |  |  |
| --- | --- | --- |
| **Command** | **Description** | **Basic Syntax** |
| ls | List directory contents | ls -l /home |
| cd | Change directory | cd /path/to/dir |
| mkdir | Create new directories | mkdir new\_folder |
| rmdir | Remove empty directories | rmdir empty\_folder |
| rm | Remove files/directories | rm file.txt |
| touch | Create empty file / update timestamp | touch file.txt |
| cp | Copy files/directories | cp file1 file2 |
| mv | Move or rename files/directories | mv oldname newname |
| stat | Show file/directory status | stat file.txt |

## Text Processing Commands

|  |  |  |
| --- | --- | --- |
| **Command** | **Description** | **Basic Syntax** |
| cat | Concatenate and display files | cat file.txt |
| head | Display first lines of a file | head -n 10 file.txt |
| tail | Display last lines of a file | tail -n 10 file.txt |
| grep | Search text with patterns | grep "pattern" file.txt |
| sed | Stream editor for filtering text | sed 's/old/new/g' file.txt |
| awk | Pattern scanning and processing | awk '{print $1}' file.txt |
| sort | Sort lines of text files | sort file.txt |
| cut | Extract sections of lines | cut -d',' -f1 file.txt |
| wc | Count lines, words, bytes | wc -l file.txt |
| uniq | Remove duplicate lines | uniq filename |

## User and Group Management

|  |  |  |
| --- | --- | --- |
| **Command** | **Description** | **Basic Syntax** |
| who | Show logged-in users | who |
| id | Show user and group IDs | id username |
| useradd | Add a new user | useradd username |
| userdel | Delete a user | userdel username |
| usermod | Modify user account | usermod -aG group username |
| groupadd | Add new group | groupadd groupname |
| passwd | Change user password | passwd username |
| groups | Show groups user belongs to | groups username |

## Process Management

|  |  |  |
| --- | --- | --- |
| **Command** | **Description** | **Basic Syntax** |
| ps | Show current processes | ps aux |
| top | Real-time process monitoring | top |
| htop | Interactive process viewer | htop |
| kill | Send signal to terminate process | kill PID |
| killall | Kill processes by name | killall process\_name |
| nice | Start process with modified priority | nice -n 10 command |
| renice | Change priority of running process | renice 5 -p PID |
| pgrep | Find process IDs by name | pgrep process\_name |

## Disk and File System Management

|  |  |  |
| --- | --- | --- |
| **Command** | **Description** | **Basic Syntax** |
| df | Show disk space usage | df -h |
| du | Estimate file/directory space usage | du -sh /path |
| mount | Mount a filesystem | mount /dev/sda1 /mnt |
| umount | Unmount a filesystem | umount /mnt |
| fsck | Filesystem consistency check | fsck /dev/sda1 |
| blkid | Display block device attributes | blkid |
| Fidk | Disk partitioning tool for MBR | Fdisk /dev/sda |
| parted | Disk partitioning tool for GPT | parted /dev/sda print |
| lsblk | List information about block devices | lsblk |
| mkfs | Create filesystem | mkfs.ext4 /dev/sda1 |

## Networking Commands

|  |  |  |
| --- | --- | --- |
| **Command** | **Description** | **Basic Syntax** |
| ifconfig | Configure network interfaces (deprecated) | ifconfig eth0 up |
| ip | Modern network configuration tool | ip addr show |
| ping | Send ICMP echo requests | ping google.com |
| traceroute | Trace network route | traceroute google.com |
| netstat | Network connections, routing tables (deprecated) | netstat -tulnp |
| ss | Display socket statistics | ss -tuln |
| wget | Download files from the web | wget http://example.com/file |
| curl | Transfer data from or to a server | curl http://example.com |
| nslookup | DNS query tool | nslookup google.com |

## Package Management

|  |  |  |
| --- | --- | --- |
| **Command** | **Description** | **Basic Syntax** |
| apt | Debian/Ubuntu package manager | apt install package |
| dpkg | Debian package manager tool | dpkg -i package.deb |
| yum | RHEL/CentOS package manager (deprecated) | yum install package |
| dnf | Fedora/RHEL/CentOS package manager | dnf install package |
| zypper | openSUSE package manager | zypper install package |
| pacman | Arch Linux package manager | pacman -S package |
| portage | Gentoo package manager | emerge package |

## Process Management

|  |  |  |
| --- | --- | --- |
| **Command** | **Description** | **Basic Syntax** |
| ps | Show current processes | ps aux |
| kill | Send signals to processes | kill PID |
| killall | Kill processes by name | killall processname |
| nice | Run process with a specific priority | nice -n 10 command |
| renice | Change priority of a running process | renice 10 -p PID |
| pgrep | Find process IDs by name | pgrep processname |

## Compression and Archiving

|  |  |  |
| --- | --- | --- |
| **Command** | **Description** | **Basic Syntax** |
| tar | Archive files | tar -cvf archive.tar files |
| gzip | Compress files | gzip file |
| gunzip | Decompress gzip files | gunzip file.gz |
| bzip2 | Compress files | bzip2 file |
| bunzip2 | Decompress bzip2 files | bunzip2 file.bz2 |
| xz | Compress files | xz file |
| unxz | Decompress xz files | unxz file.xz |
| zip | Create zip archives | zip archive.zip files |
| unzip | Extract zip archives | unzip archive.zip |

## System Monitoring

|  |  |  |
| --- | --- | --- |
| **Command** | **Description** | **Basic Syntax** |
| top | Real-time system monitor | top |
| htop | Interactive system monitor | htop |
| vmstat | Virtual memory stats | vmstat 1 |
| iostat | CPU and I/O stats | iostat |
| free | Memory usage | free -h |
| sar | System activity report | sar -u 1 3 |
| uptime | System uptime and load average | uptime |
| pidstat | Process statistics | pidstat 1 |