Introduction to Linux

Linus Torvalds
Finnish college - Project 1991

operating system (software / hardware)
- Linux
- Symbol - Penguine
- GPL license - freedom to use, change, share

Linux Foundation
- Collaborative Project Event
- Context / Update & Maintenance

Developer → Patches → Senior Linux kernel developer/maintainer → Linux creator
(Developer)

Terminology

- Kernel - interact - hardware / application
- Distribution / Distros - Linux kernel + collection of program
  - Linux based OS
  - Red Hat (RHEL) - CentOS + Fedora
  - SUSE } family - OpenSUSE
  - Debian } system - Ubuntu & Linux Mint
- Boot loader - Program boot → OS
  - GRUB
  - ISO LINUX
- Service - Program run → background process — httpd, nfsd, ntpd, ftpd & named
- Filesystem - Method for storing & organizing files — ext3 FAT XFS NTFS Btrfs ext4
- X-window system - standard toolkit & protocol for Graphical User Interface (GUI)
- Desktop Environment - GNOME, KDE, Xfce & flurbox
- Command Line - Interface for typing command
- Shell - Command Line Interpreter — bash, tcsh, zsh

Boot Process - initialize system

Power - On

BIOS - Basic Input Output System (BIOS) → Software on ROM chip → Motherboard
- initialize hardware - screen, keyboard } Power on self test (POST)
- test main memory

Master Boot Record (MBR) - first sector of hard disk

Boot Loader
- Stored hard disk
  - Traditional: boot sector - BIOS/MBR systems; first sector of hard disk (MBR) (512 bytes) → examine partition table → bootable partition → boot loader → RAM
  - complicated: EFI Partition → Boot manager data (which, where) → data partition → UEFI application launch → GRUB firmware boot manager → GRUB
- 1st stage
- 2nd stage - /boot
  - choose OS - load kernel into RAM (compressed) → analyse system hardware
  - initialize any hardware device drivers
- GRUB - Grand Unified Boot Loader
- ISO LINUX - boot from removable media
- DAS U-BOOT - booting on embedded device/appliances

Linux Kernel - RAM
- initialize & configure
  - memory
  - hardware attached
    - all processor
    - IO subsystems
    - storage

Initial RAM Disk - RAM
- initramfs file system image
  - program binary files
  - mount proper root filesystem → kernel functionality
    - file system
    - device drivers
      - facility - udev
      - user devices
      - which device is present
      - locate & load driver
    - mass storage controller

mount program
- file system ready - use
- associate - mount point
- check error
- mount

OS ← initramfs - clear from RAM

/sbin/init & Services
- execute init program /sbin/init
- mounting, pivoting } final root file system

initial process → other process - to get system running
manage internal OS details / manager for non kernel process
run & shut down → system

- 1980 System V variety of UNIX - SysVinit
  - Serial process
  - sequence of run levels - scripts - start, stop
  - [parallelization, large computer - rarely shut down
- Upstart - Ubuntu 2006
- systemd - Fedora 2011

Text-Mode Login - username & password
- GUI
- Command line operation ← terminal that run command shells
  - default: bash (GNU Bourne Again Shell)
  - text prompt

Linux Filesystem Basics

File system
- method
  - storing
  - finding
  - > partition → hard disk
    - Logical partition – physical contiguous section of disk
- Types
  - Conventional
  - Flash storage
  - Database
  - Special purpose

Linux Foundation
- Standard Layout – Filesystem Hierarchy Standard (FHS)
- mount ← single filesystem – multiple < drives / partitions

Graphical Interface for filesystem

Linux Distribution
- Server
- Desktop
- Embedded

/bin/	essential user command binaries
/boot/	static files of boot loader
/dev/	device files
/etc/	host-specific system configuration
/home/	home user directories
/lib/	essential shared libraries & kernel
/media/	mount - removable media
/mnt/	mount - temp mounted filesystem
/opt/	add-on software package
/sbin/	system binaries
/srv/	data for services provided by system
/tmp/	temporary files
/usr/	user utilities & applications
/var/	variable files
/root/	home directory for root user
/proc/	virtual filesystem documenting kernel and process status as text files

GRAPHICAL INTERFACE

Interface
- Command line (CLI)
- Graphical user (GUI) – display manager – 1980s - X window system
  - recent - Wayland
  - service
    - graphical login
    - load X-server
    - display management
      - GNOME - gdm
      - Ubuntu - lightdm
      - KDE - Kdm

startx

Desktop Environment
- session manager – graphical session – start / maintain
- window manager
- other utilities

setting
- background
- Theme
- gnome-tweak-tool

Session Management
- Logging in / out
- locking screen
- Switching Users
- Suspend/sleep
- Restart/shut down

Basic Operation
- Application locate → open
- File manager utility - nautilus
  - Search Ctrl-F
  - locate Ctrl-L
  - hidden Ctrl-H (.x)
- Edit file
- Delete file
  - local /share/Trash/files
  - permanent shift+Delete

SYSTEM CONFIGURATION - GRAPHICAL INTERFACE

System - system setting panel ← GNOME desktop manager

Display
- resolution
- multiple screen – one big screen / mirror display

gnome-tweak

Date & Time
- default – internal time keeping
- Internet – Network – Network Time Protocal

Co-ordinated Universal Time (UTC)
- Greenwich Mean Time (GMT)

Network Manager – Network configuration file
- Wired
  - Dynamic Host Configuration Protocol (DHCP)
  - Static Connection ← Ethernet Media Access Control (MAC)
    - network card → Unique hexadecimal no.
- Wireless
- Mobile Broadband Network
- Virtual Private Network

Installing & Updating Software
- package – one piece of system
  - Interdependencies

utility
- low level – unpack a package → place
- high level – download & manage interdependencies apt (advanced package tool)

Debian	Red Hat Family
dpkg	RPM (Red Hat package manager)
	yum, dnf, zypper
	yellowdog updater modified

GNU Network Object Model Environment (GNOME) – Packagekit

Command line operation

dpkg
- --list
- --listfiles
- --remove

apt-cache
apt-get
- install
- remove

clear

COMMON APPLICATIONS

Internet Application
↳ global network - application
- web browser
- Email clients - message
  - Protocol: Post Office Protocol (POP), Internet Message Access Protocol (IMAP)
  - Client: Graphical - Thunderbird; Text mode - Mutt; Web browser - Gmail
- Other Internet
  - File Transfer Protocol (FTP), Secure FTP (SFTP), FTP Secure
  - Messaging Network
  - Voice Over Internet Protocol (VoIP) Network
  - Internet Relay Chat (IRC) network

Productivity & Development Applications

Office Applications/Suites
- LibreOffice
  - Word Processing - Writer
  - Spreadsheet - Calc
  - Presentations - Impress
  - Graphical Obj - Draw

Development Application
- Advanced Editor - vi, emacs
- Compiler - gcc
- Debugger - gdb, valgrid
- Complete Integrated Development Environment (IDE) - Eclipse

Multimedia Applications
- Sound Players
- Movie Players
- Movie Editor

Graphics Editors & Utilities
- GNU Image Manipulation Program (GIMP)
- Graphics Utilities

COMMAND LINE OPERATIONS - GUI makes easy tasks easier while command line interfaces makes difficult tasks possible

Command Line Mode Options

Command Line - command, options, Arguments
↑ terminal emulator program
↑ launch

User
- administrative privileges - admin
  - sudo — setup
    - su
    - /etc/sudoers.d/user - configuration file
    - chmod - change mode
- other User
  - security privileges
- root user (super user) → sudo

CTRL-ALT-Fnumkey

Virtual Terminals
- console session usages display & keyboard outside a graphical environment
- many active terminal, only one terminal remains visible

Graphical Desktop
- start
- stop
- • telinit
- • systemctl

Basic Operation

log in/out - own remote system - Secure Shell Utility (SSH)

shutdown
- shutdown -h halt → init process
- shutdown -r restart

Application
- executable - program, script — /bin, /opt, /sbin
- locate
  - which
  - whereis

Accessing Directories
- pwd present working directory
- cd change directory
- cd.. parent directory
- cd - previous directory

Path
- absolute - /
- relative - ./

Explore Filesystem
- ls list contents
- ls -a " " all
- tree tree view

Links
- hard link ln
- symbolic link ln -s

ls -li
- inode number - unique quantity for each file
  - hard link - same
  - soft link - pointer

Navigating directory history
- cd -
- pushd popd

Working with files

View: cat tac, less, head tail

touch
- create/update
- -t set
  - access time
  - change time
  - modify time

mv move/rename

rm remove
- -f forcefully
- -i interactively

cp copy

Directory
- make - mkdir
- remove
  - rmdir
  - rm -rf

Common Line Prompt
$PS1

Searching for files

Standard file streams/descriptors - always open for use

stdin	0
stdout	1
stderr	2

I/O Redirection
- < input
- > output
- 2> error file

Pipes |
output | input

Searching
- locate - database of files & directories ↑ updatedb
- find - filesystem tree, all current dir & sub-dir
  - -name: certain pattern
  - -iname " " + ignore case
  - -type: type d-directory, l-symbolic link, f-regular file
  - -exec: run command {} ';' (placeholder)
  - -ok

Wildcard & matching file names

Match
- ? any single char
- * any string of char
- [ ] any given set of char
- [!] " " " " " not negation

Time
- -ctime last change
- -atime last accessed
- -mtime last modified
- -n +n >, -n <, # of days

Size
- size
- c - bytes
- k - kilobytes
- M - megabytes
- G - Gigabytes

FINDING LINUX DOCUMENTATION

Linux Documentation Sources
- man page / Manual page — 1970 UNIX Linux man page
  - man -f all pages on topic
  - -k all pages discussed
  - -a page into/chapter
- GNU Info — GNU project's standard documentation info
- help command — --help
- Other documentation
  - Desktop help system
  - Package documentation
  - Online resources

PROCESSES

Processes & Process Attributes
- Command / Program → Operating System (OS) → Kernel → allocate → System Resources
  - memory / CPU cycles / instance / threads → Processor
- environment
  - interactive
  - background

Process Scheduling
- Kernel → Scheduler → Process
  - on/off CPU time
    - needed / granted
    - share ← priority

Processor States
- Running
- Sleep — waiting ← time slice — uninterruptible ← user/action
- Zombie

Type
- Interactive — bash, top
- Batch automatic process — updatedb
  - schedule
  - queue — FIFO
- Daemons server-continuously — httpd, sshd
- Threads — light weight — firefox
  - main processor
  - sharing memory
- Kernel — kernel task — kthreadd

Process IDs
- OS — track process — unique Process ID (PID)
- Parent Process ID (PPID)
- Thread ID (TID) - One process can have many threads

Terminate
- Kill -SIGKILL <pid>
- Kill -9 <pid>

Priorities — CPU - one task at a time
- nice value (-20 to 19)
- lower the value - higher the priority

User & Group IDs
- many users → system — user start — Real User ID (RUID)
- " determine access rights — Effective UID (EUID)
- group - RGID
- EGID

Process Metrics & Process Control
- Load Average - avg of the load number / period of time
  - actively running CPU
  - runnable but waiting for CPU
  - sleeping & waiting resource - uninterruptible sleepers

- w
- top
- uptime

Background & foreground Processes
- free shell for other tasks
- lower priority
- suffix &
- bg
- launches from terminal / shell & wait till complete
  - ctrl-z suspend
  - ctrl-C terminate
- fg
- job ← command

Managing Jobs
- command → jobs
- jobs -l

Listing Processes
- ps - information currently running processes keyed by PID
- style
  - System V style
  - BSD style - option without preceding dashes
- ps -u username
- -ef all process with full detail
- -eLf thread
- ps aux
- aox

process tree - pstree

top - interactive keys for monitoring
- live update
  - top
  - htop
  - atop
- ↓ CPU cycle
- memory

top
1. system up, # user, load average
2. processor - running, sleeping, stopped, zombie
3. %CPU time — user (us) — power priority (ni)
   - kernel (sy) — idle mode (id)
   - ^Interrupts — hardware (hi) — jobs waiting (wa)
   - software (si) — steal time (st)
     - VM
4. Memory
   - Physical
   - Swap Space — Total, Used, Free
   - hard drive
5. PID - process identification number
   USER - process owner
   PR (Priority) & nice value (NI)
   virtual (VIRT), physical (RES) & shared (SHR)
   status (S)
   %CPU & %MEM
   TIME+
   command

Starting processes in future
- at - non interactive command at a specified time
- cron - time based scheduling program
  - by system / user — crontab file ← CRON expression
  - configuration file - /etc/crontab → crontab -e
  - MIN HOUR DOM MON DOW CMD
- sleep — delay / suspend — s, m, h, d

File Operations

File System

Hierarchial file system – root /trunk
- user
- system
- devices

Many filesystem varieties
Partition – organize files
Mount points → attach ← file system

`df -Th`

mount
unmount

automatically
/etc/fstab
file system table

NFS & Network filesystem

Data – Physical System
- 1 machine
- >1 machine
  - same location
  - other location – Internet

Type NFS – Network Filesystem – Sun Microsystems
CIFS/SAMBA – – Microsoft

NFS
- server – daemons — sudo systemctl start nfs
  - restart
  - enable
  - /etc/exports – config
- client — sudo mount
  - /etc/fstab – configuration – automatically upon system boot

File Architecture

- /root /home — user /group
- /bin /usr/bin /sbin — executable binaries with essential commands
- /proc — pseudo filesystem
  - virtual
    - files / directories → mimic
      - kernel structure
      - configuration info
  - runtime system information
    - system memory
    - device mounted
    - hardware configuration
- /dev — device nodes ← pseudo file
  - not mounted – empty on disk partition
  - mounted – creates & manage device nodes
- /var — variable directory Δ – size / content as the system is running
  log, print queue, package & database file, temp file
- /etc — system configuration files, executable scripts
- /boot — files to boot the system
  Each kernel
  - vmlinux – compressed linux kernel
  - initramfs – initial ram filesystem
  - config – kernel configuration file
  - System.map – kernel symbol table
- /lib /lib64 — library to run essential program
- /run /media /mnt — removable media
- /opt — optional application software package
- /sys — virtual pseudo-filesystem
  - information – system / hardware
- /srv — site specific data
- /tmp — temporary files
- /user — multiuser application

Comparing files & filetypes

- diff — compare two files/directory
- diff3 — compare three " "
- patch — apply patch
- file — categorize file type (& extension)

Backup & Compress Data

Backup
- copy — cp
- sync — rsync – efficient & robust

Compress
- gzip, bzip2, xz – linux
- zip – across OS
- tar – group & compress large archive

Disk to disk copy — dd – copy raw disk space

Text Editors

Basic Text Editors
- nano
- gedit ← Graphical Desktop Environment

Create file without an editor
- echo
- cat << EOF

> output to file
>> append

Advanced Text Editors
- vi
  - gvim ← GNOME
  - vimtutor - tutorial
  - working
  - mode
    - command
    - insert
    - line
  - cursor position
  - search
  - external command
- emacs
  - mode
  - ctrl
  - meta (Alt, Esc) > special command

User Environment

Accounts, Users & Groups

Current User whoami, who

User Startup files - configure user environment
- /etc/profile
- ~/.bash_profile
- ~/.bash_login
- ~/.profile

~/.bashrc - alias - customized commands

Users & Groups

User - Unique User ID (UID)

Group - Group (GID)
- /etc/group
- /etc/passwd

group - shared permission
- access
- privileges
- security

Adding & Removing

User
- id
- useradd
- userdel

New group
- groups
- groupadd
- groupdel

Existing group
- usermod
- groupmod

Account Root/administrator/superuser

Elevated privileges
- su (switch/substitute user)
- sudo
  - temporary
  - specific command
  - assign

sudo configuration files
- /etc/sudoers
- /etc/sudoers.d

Environment Variables (ev)
- specific value → utilized by command shell
- default
- overwritten
- view
  - set
  - env
  - export

Setting ev
- echo $HOME
- export (~/.bashrc)

Variable
- HOME — pwd - present working directory; cd - current directory
- PATH — list of directory scanned for program or script separated by :; current directory - Null / ./
- SHELL — user's default command shell
- PS1 — prompt statement variable

Recalling Previous Command

bash - previous (command / statement) → history buffer → ~/.bash_history

Environment variable
- HISTFILE
- HISTFILESIZE
- HISTSIZE
- HISTCONTROL
- HISTIGNORE

Finding & using
- ↑ ↓
- !!
- CTRL+R - search previously used command

Keyboard Shortcut

executing
- ! starts history substitution
- !& last
- !n nth
- !string - most recent command starting with

File Permission

owner - chown
group - chgrp
other

chmod — read 4 / write 2 / execute 1

owner : group : other

Manipulating Text

Command line tools for manipulating text files
- Linux system administrator / developer / user → browse / parse / extract → text files
- file manipulation process
  - concatenate / view → cat, tac
  - display interactively → echo
- > create + add, >> append, CTRL+D
- cat > <filename> CTRL+D
- cat > <filename> <<EOF ... EOF/STOP

Working with large & compressed files
- less
- head -n
- tail -n -f
- zcat
- zless, zmore
- zgrep
- zdiff

Repeatedly edit/extract contents from a file
- sed — stream editor UNIX — input stream → working stream → output stream
  - sed -e command <filename> edit
  - sed -f scriptfile <filename> apply from script
  - sed s/pattern/replace_string/g file — substitute, global
- awk — Bell Labs
  - awk 'command' file
  - awk -f scriptfile file
  - awk -F: '{ command }' file — field separator

File manipulation Utilities
- sort
- uniq -c - count
- paste
- join
- split
- wc -word count

Regular Expression & search pattern
- character — normal, meta- . | $ ^ *
- grep - text searching tool
- strings — extract printable character strings in files; human readable content embedded in binary files

Miscellaneous Text Utilities
- translate — tr [options] set1 [set2]
- tee output → standard output, saves to file
- wc word count
- cut extract specific columns ← column based file

Network Operations

Introduction to Network
- Network - group of computer / computing devices > connected - communication channels — cable / wireless media
- uses — communicate, share devices over network, share & manage information
- Internet - the network of networks

IP Addresses
- Network - unique network address identifier → IP (Internet Protocol) address - network ← routing packets of information
- exchange information - streams of small packets
  - data buffer
  - info: source ← header, destination

IP address allocation
- network admin ← range of IP address ← Internet Service Provider (ISP)
- choose
- assign — static - manual; dynamic - Dynamic host configuration protocol

IPv4 — version 4, 32 bit = 4 x 8 bit octets
- 5 Classes
  - A, Network ID - 1, Host ID - 2,3,4
  - B - Net ID 1,2 Host ID - 3,4
  - C - Net ID 1,2,3 Host ID - 4
  - D - multicast address
  - E - reserved for future use
- limitation - # of unique address → Network Address Translation (NAT) — 1 IP shared among many locally connected computers

IPv6 - version 6, 128 bit

Name resolution
- IP address → human readable format hostname
- ← translate ← Domain Name System (DNS)

Network Configuration & Tools
- /etc
- Network manager ← Graphical system administrator

Network interface
- connection ← device, → network
- ip, ifconfig
  - addr show
  - route
- physical - Network Interface Card (NIC)
- ping — machine ⇄ (receive / send) data in network
  - host is responding

route
- source - data → nodes, multiple network → destination
- server routing tables - address of each node - network
- IP routing protocols → forwarding table
- route, ip route

traceroute — inspect route, troubleshoot network delays & errors

Networking tools - ethtool, netstat ....

Browsers, wget & curl
- Browser — Graphical / Non-Graphical
- wget - download files & information
  - large file
  - recursive file
  - password-required downloads
  - multiple file downloads
- curl - information about URL

Transferring Files
- File transfer protocol (FTP) — transfer file — network / Internet; Use — browser / stand alone client
- client-server model
  - FTP client — graphical / command line tool
    - ftp
    - sftp - uses secure shell protocol (ssh) — cryptographic network protocol
    - ncftp
    - yafc
  - 1970s — user credential — password (encrypted)
  - ↓ rsync
  - secure copy (scp)

Bash Shell and Basic Scripting

Features & Capabilities

Shell Scripting
- automate
- long & repeatitive command
- share process among user
- quick prototyping & compile
- new command & utilities

script → Interpreter → Command Shell Choice – sh, bash, tcsh, csh, ksh, zsh

Command line interpreter
↓
terminal window (user interface) – run script
- interactive (session)
- non-interactive
  - can take user input

Syntax

Basic syntax & special character

Split long commands over multiple lines – \ (concatenation operator)

Putting multiple command in a single line
- execute sequentially ;
- abort when fail &&
- proceed until success ||

Output Redirection
- write output >
- append output >>

Input Redirection – input <

comment #

Return
- exit statement
- monitor exit state of another process
- success or failure → steps in future
  - return value → 0 – success
  - $? – script
  - echo $?

Built-in Shell Commands
- compiled application – binary executable files – bin
  - rm, ls, df, vi, gzip
- Built-in bash commands – cd, pwd, echo, read..
  - help
- shell scripts – Script parameter
  - $0 – script name
  - $n – nth parameter
  - $* – all parameter
  - $# – number of argument

Command Substitution $( )

Environment Variables
- $
- env, set, printenv
- export

Functions
sub-routines – Declare – function_name() { command }
- Call

Constructs

if statement
- if condition; then statement; else statement
  - [some test]
    - -e file
    - -d
    - -f
    - -gt -ne -eq -lt -ge -le
- if ... ; then ... ; elif ...

Boolean Expression – multiple condition → proceed
- && and
- || or
- ! not

Arithmetic Expression
- expr
- $((...))
- Let

String Manipulation
- [[string1 == string2]] – compare
- ${
  - #string
  - string0n

case Statement
```
case expression in
  pattern1) execute command;;
  pattern2) execute command;;
  *)        execute default command
esac
```

Looping Constructs
- for var-name in list / while condition is true / until condition is false
  - do command done

Script Debugging

debug mode – bash -x ./script-file

bracketing parts
- set -x
- set +x

redirecting errors – file stream
- stdin – 0
- stdout – 1
- stderr – 2

Useful Techniques

Creating Temporary Files & Directory – mktemp

Discarding Output – /dev/null
- bit bucket
- black hole

Random number & data – $RANDOM

① Special hardware number generators
- noise signal
  - thermal noise
  - photoelectric effect
- transducer → electric signal → A-D converter → digital signal

② boot → event

entropy pool of
- random ← digital number
- random bits

/dev/random – quality

/dev/urandom – faster

Local Security Principles

- Understanding Linux Security
  - User account → database → User ID (UID) [useradd, userdel]
    Group ID (GID)
  - Types of account — root, system, Normal, Network
    - Set owner User ID (SUID)
  - sudo vs su
    - configuration - /etc/sudoers
    - command logging - /var/log/secure
  - last - last time each user logged in the system
  - Process Isolation ← resources
    - control groups (cgroups)
    - container
    - virtualization
  - Hardware Device Access
  - Keeping current
- Passwords
  - stored — /etc/shadow — encrypted
    - SHA-512 (Secure Hashing Algorithm 512 bits) ← US National Security Agency (NSA)
  - Practice
    - Password aging - change
    - Pluggable Authentication Modules (PAM)
    - password cracking programs
- Securing the boot process & hardware resources
  - Requiring boot loader password
  - Hardware Vulnerability
    - key logging
    - Network sniffing
    - Booting with live or rescue disk
    - Remounting & modifying disk content
  - Software Vulnerability