APPLIED SCIENCES FACULTY

APPS@UCU

Linux course

Linux File systems

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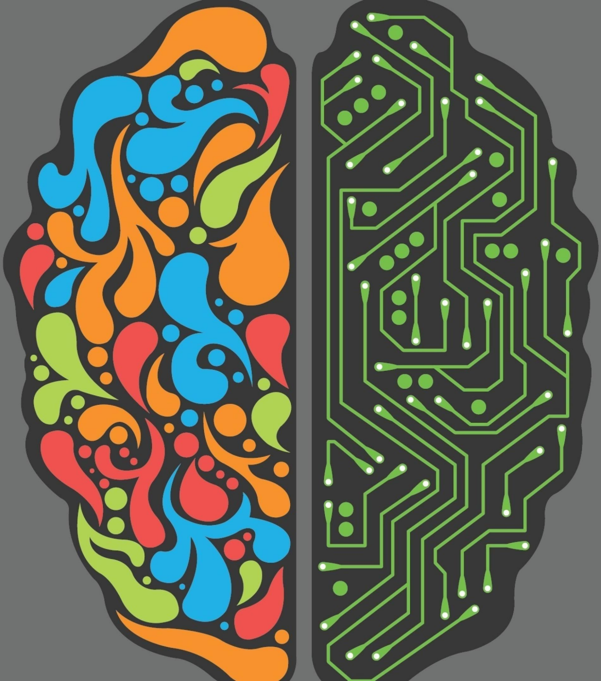
Contents

Intro

- This is not an overview of some hardware memory staff
- Neither a presentation with deep File systems implementation details
- More about that you should learn at the Operating systems course
- This is just an overview of file systems that system administrators use in their everyday life
- If you think that you are not a system administrator - think one more time, because you administrate your own system every day

Memory

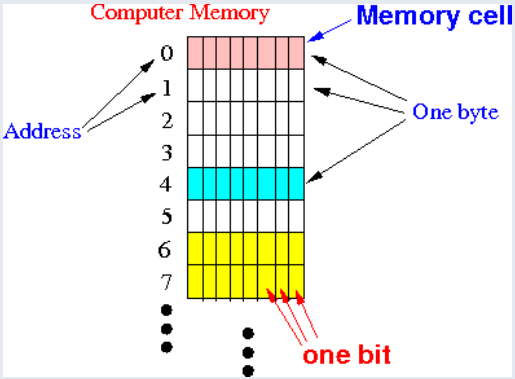


Drives

- All data stored on some physical devices
- It has different storage approaches on each device (HDD, SSD, CD, DVD, Flash, RAM, DDR memory modules)
- But now we are going to overview the memory from user point of view
- How to manage files and file systems, how to choose the most suitable

Memory storage

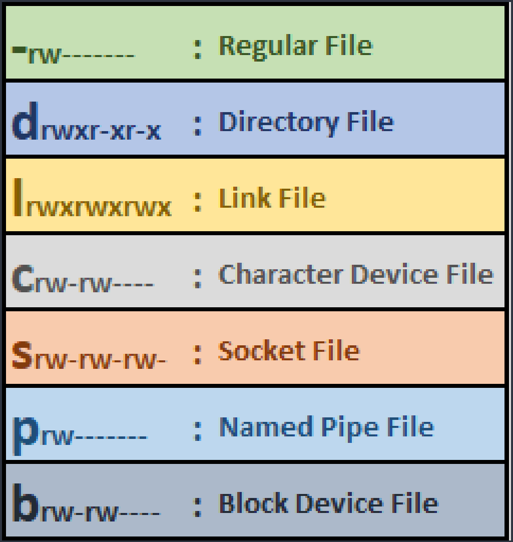
- Memory as abstraction looks like an array, where bites are stored one by one in a row
- File system - a method of data structure that the operating system uses to control how data is stored and retrieved
- A file is an ordered collection of data blocks
- In Linux system, everything is a file, and if it is not a file, it is a process
- So File systems are very important for this OS



Everything is a file

File types

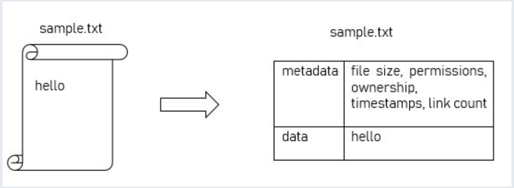
- There are a lot of file types, but the most important for us are:
- Regular Files - some files with data stored inside
- Directories - files, that allowed to group other files and keep tree filesystem structure
- Character files - for simulating character devices as terminals, keyboard, network etc
- Block files - for modelling block devices as disks, flash drives
- Links - entry points to other files
- There are pipes , sockets



-rw-------	:	Regular File
drwxr-xr-x	:	Directory File
lrwxrwxrwx	:	Link File
crw-rw----	:	Character Device File
srw-rw-rw-	:	Socket File
prw-------	:	Named Pipe File
brw-rw----	:	Block Device File

File metadata

- File also save a metadata about itself, as:
- Protection, password
- Creator, owner
- Flags (r w x)
- Size
- Creation time, last update time (timestamp)



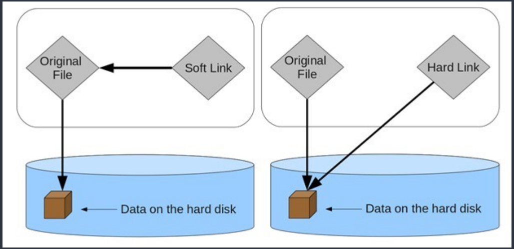
metadata	file size, permissions, ownership, timestamps, link count
data	hello

Inode

- The inode is data structure, that describes files on Unix-like OS’s
- Each inode stores disk block location, some atributes, file’s metadata
- Directory - just a file with list of inodes
- File’s inode number can be found with ls -i command
- From the inode number, the kernel’s file system driver can access the inode contents, including the location of the file, thereby allowing access to the file
- More about inodes in the Operating systems course

Links

- There are two types of links: symbolic (soft) and hard
- They are totally different types of file
- Maybe first few years you will not use
- But with experience it becomes more and more useful
- Here we will make only a brief overview and comparison



Hard vs Soft links

Hard links

- Exact replica of a file
- Share same inode with other hard links
- Can not be made across filesystems
- Changes in hl will reflect in other files
- Deleting of a hardlink wil not affect other files
- Can links to files only

Soft links

- Alias to a file
- Has another inode
- Can be established outside filesystem
- Link becomes inaccessible without original file
- Can links to both files and directories

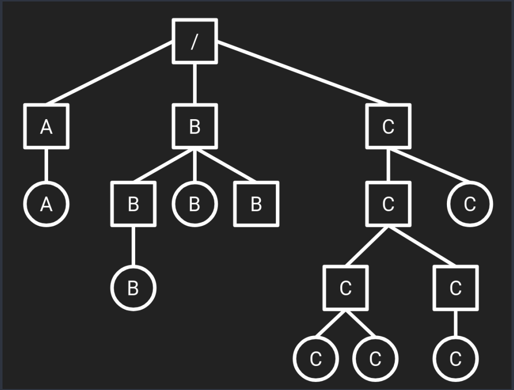
File systems

Fyle systems types overview

- There are several file systems types. Just for your information. the most important will be in orange colour
- Disk file systems for simple disks, a.e. FAT16/32, NTFS, ext2-4, brtfs etc
- Flash file systems - consider speciality of flesh memory devices
- Database file systems - another concept for file management
- Transactional file systems
- Network file systems - acts as a client for a remote file access protocol, providing access to files on a server, a.e. FTP
- Shared disk file systems - a number of machines (usually servers) all have access to the same external disk subsystem
- Flat file systems - no subdirectories, directory entries for all files are stored in a single directory

Fyle system abstraction

- We used to see a filesystem as a tree. It is really the most comfortable structure as for now
- There is a CLI tool to see your filesystem structure called tree
- Using such abstraction programmer works with files and directories, not with memory cells or some low-level staff, but with files, directories, and subdirectories



Overview of the most important filesystems

More detailes on the Operating systems course

- Remark: ext stands for extended
- ext2 - year 1993. File size can be to 2TB, file system size to 32TB
- ext3 - year 2001. Linux Kernel > 2.4.15. Max 32’000 subdirectories. Main benefit - allows different types of journalling (traking of all changes). Easy to convert ext2 -> ext3. (later) Can be mount as ext4
- ext4 - year 2008. Linux Kernel > 2.6.19. Max 64’000 subdirectories. File system size up to 1EB (10e12GB). Option of turning the journaling feature "off". Aslo some features as multiblock allocation, delayed allocation, journal checksum, fast fsck, etc was introduced
- btrfs or B-Tree filesystem - modern Copy-on-Write (CoW) filesystem. Comparison of ext4 and btrfs link. As for me, the most important features are fs snapshot and multiple devices support , built-in RAID support
- ext4 designed to be simple and stable, mostly for local-using, while btrfs to be high-performance, high-capacity and high-performance, mostly for storage servers

Overview of the most important filesystems

More detailes on the Operating systems course

- ZFS - this fs mostly used on data storages
- It has RAID support, Copy-on-write, Data integrity verification and automatic repair, Snapshots, Maximum 256 Quadrillion Zettabytes storage and Pooled storage
- It combines both fs and volume manager in one. Easy to add physical drive and extend partition size or replace physical drives, to use and maintain
- FAT - File Allocation Table fs. There are FAT16, 32, 64. Nowedays wide used on the USB flash drives. More info and work with this fs on Operating systems course
- NTFS - fs used only on windows os, so it is a proprietary journaling file system, But it can be mount to Linux OS (so you can access your win files from linux in case of dualboot)

Swap

- Swap is not a filesystem type
- It is a space on a disk, used when there is no space left in RAM, or because of some optimization processes
- Also the only possible way for hybernation
- It could be both swap partition and swap file , but first is much better
- mkswap - to make a swap partition
- swapon / swapoff - obvious

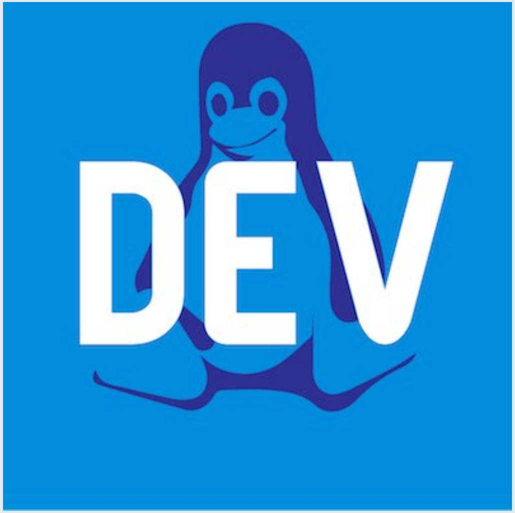
Working with file systems

Review of previous topics

- It’s part of presentation abot shell , but let’s make a brief overview
- Every proces has it’s own working directory.
- pwdx $(pgrep process_name) - show working directories for a process_name
- pwd - print working (current) directory
- ls - list what is instde the working directory
- cd - change directory
- ./ - spesial, current directory
- ../ - spesial, parrent directory (in a tree struct)
- ~/ - $HOME directory for current user
- cp <from....> <to> - copy
- mv <from....> <to> - rename (inside one fs, or move - from one to another fs)
- mkdir - make directory
- touch <filename> - update the last acces date (if no such file - create)
- rm <filename> - remove
- cat - show the file content

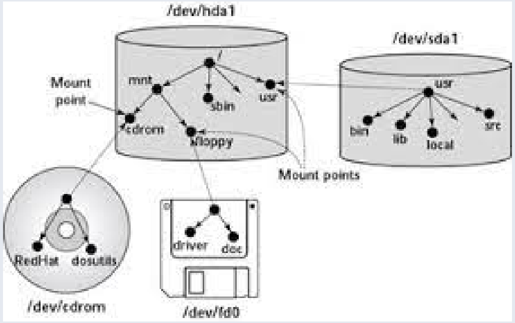
Devices

- Everything is a file , devices are not an exception
- All devices are in /dev folder
- Devices could be either secondary storages or mous, keyboard, terminals, cpu, gpu etc
- Devices can be either block or character devices
- Easy to remember:
- Block devices store or hold data
- Character devices - transmit or transfer data



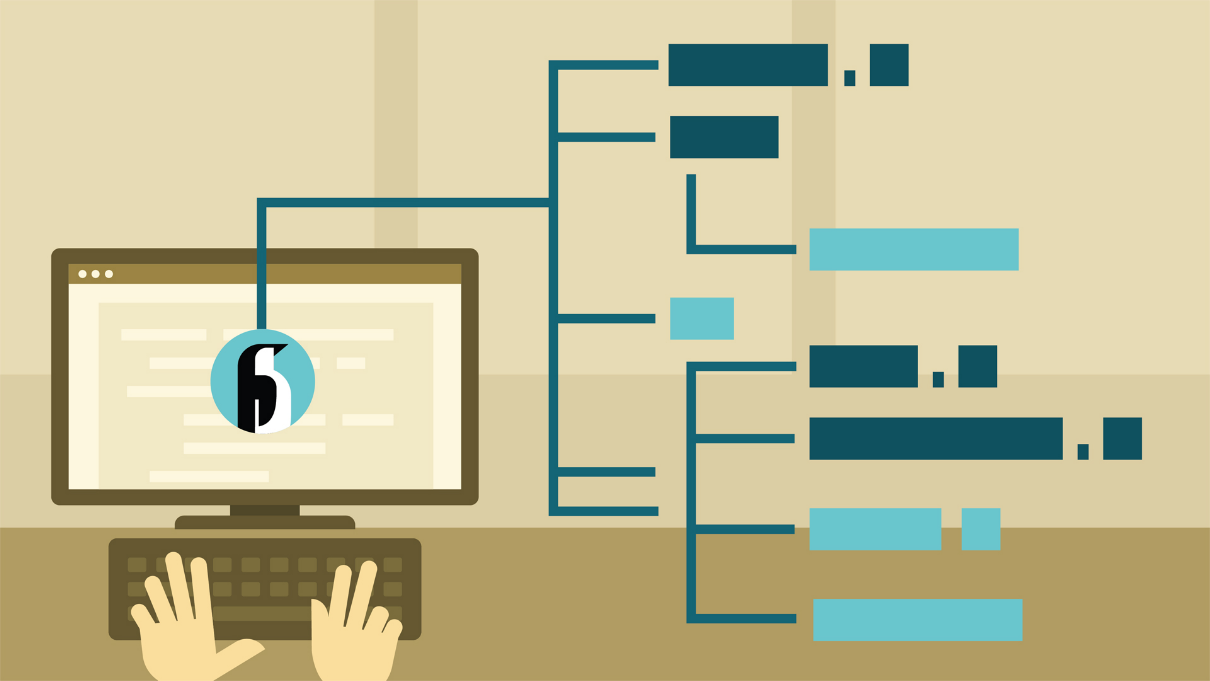
Mounting

- Mounting - attaching some additional fs to already mounted
- By default, user use only one filesystem, and it's mountpoint is /
- Then /boot is also another fs, that is not used by user directly (more about that bootloader topic)
- On one physical device there could be few filesystems (more about that partition tables topic)



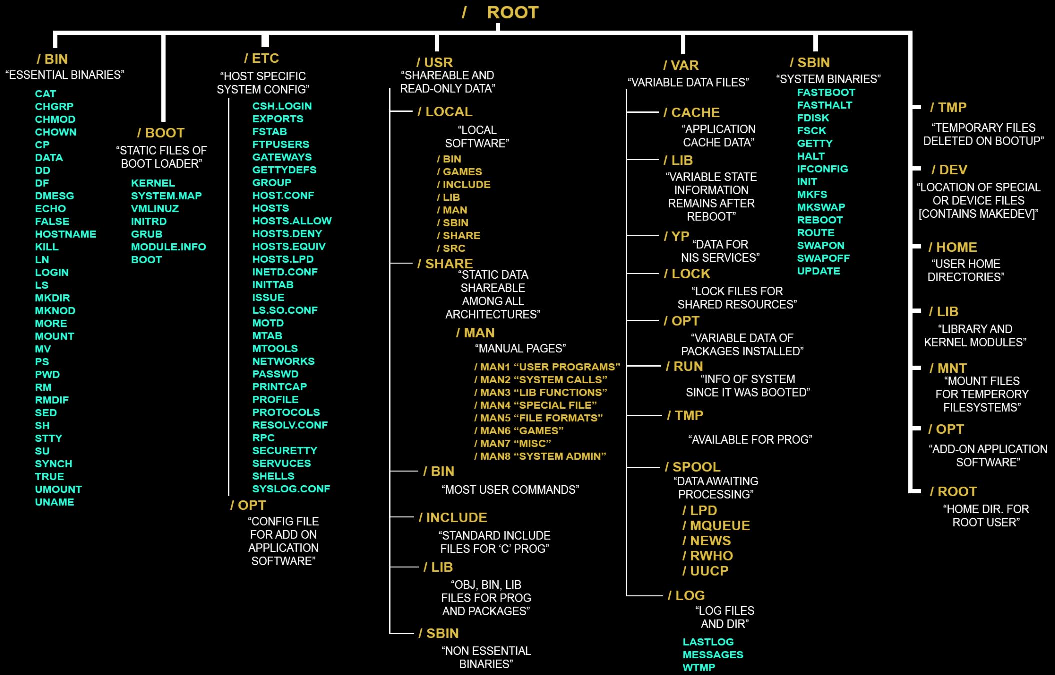
A smorgasbord of important commands and

- mkfs - make a file system on a device
- mkfs.filesystemtype /dev/X - create a filesystem on existing logical device
- fdisk -l - to see all devices available for mounting
- mount /dev/X /mnt - to mount device. mnt is used as a convension, and it is important
- /etc/fstab - file with all "default mountings" during startup. Usually has only / and boot fs’s
- UUID - Universally unique identifier - 128bit label. The probability that a UUID will be duplicated is close enough to zero to be negligible. HERE - unique device identifier
- df, du - are tools for capacity and used memory stats, but I recommend ncdu
- parted - tool for creating and editing partitions (or use GParted)



Linux Filesystems Hierarchy Standard(FHS)

- This topic is worth a separate lecture
- We will make a brief overview
- Every time while using your OS you can open this presentation
- But soon enough you will remember all this staff
- Linux Filesystem Hierarchy Standard
- Maintained by Linux Foundation
- All distros can voluntarily conform to the FHS, and most of them do
- In general, file system structure is important
- Please , Do not keep all your files in /home/username !
- There are /Downloads, /Documents, /Pictures, /Programs
- That will be much easier to move around and remember all the paths if there is some pattern


/ ROOT
/ BIN
"ESSENTIAL BINARIES"
CAT
CHGRP
CHMOD
CHOWN
CP
DATA
DD
DF
DMESG
ECHO
FALSE
HOSTNAME
KILL
LN
LOGIN
LS
MKDIR
MKNOD
MORE
MOUNT
MV
PS
PWD
RM
RMDIF
SED
SH
STTY
SU
SYNCH
TRUE
UMOUNT
UNAME
/ BOOT
"STATIC FILES OF BOOT LOADER"
KERNEL
SYSTEM.MAP
VMLINUZ
INITRD
GRUB
MODULE.INFO
BOOT
/ ETC
"HOST SPECIFIC SYSTEM CONFIG"
CSH.LOGIN
EXPORTS
FSTAB
FTPUSERS
GATEWAYS
GETTYDEFS
GROUP
HOST.CONF
HOSTS
HOSTS.ALLOW
HOSTS.DENY
HOSTS.EQUIV
HOSTS.LPD
INETD.CONF
INITTAB
ISSUE
LS.SO.CONF
MOTD
MTAB
MTOOLS
NETWORKS
PASSWD
PRINTCAP
PROFILE
PROTOCOLS
RESOLV.CONF
RPC
SECURETTY
SERVUCES
SHELLS
SYSLOG.CONF
/ OPT
"CONFIG FILE FOR ADD ON APPLICATION SOFTWARE"
/ USR
"SHAREABLE AND READ-ONLY DATA"
/ LOCAL
"LOCAL SOFTWARE"
/ BIN
/ GAMES
/ INCLUDE
/ LIB
/ MAN
/ SBIN
/ SHARE
/ SRC
/ SHARE
"STATIC DATA SHAREABLE AMONG ALL ARCHITECTURES"
/ MAN
"MANUAL PAGES"
/ MAN1 "USER PROGRAMS"
/ MAN2 "SYSTEM CALLS"
/ MAN3 "LIB FUNCTIONS"
/ MAN4 "SPECIAL FILE"
/ MAN5 "FILE FORMATS"
/ MAN6 "GAMES"
/ MAN7 "MISC"
/ MAN8 "SYSTEM ADMIN"
/ BIN
"MOST USER COMMANDS"
/ INCLUDE
"STANDARD INCLUDE FILES FOR 'C' PROG"
/ LIB
"OBJ, BIN, LIB FILES FOR PROG AND PACKAGES"
/ SBIN
"NON ESSENTIAL BINARIES"
/ VAR
"VARIABLE DATA FILES"
/ CACHE
"APPLICATION CACHE DATA"
/ LIB
"VARIABLE STATE INFORMATION REMAINS AFTER REBOOT"
/ YP
"DATA FOR NIS SERVICES"
/ LOCK
"LOCK FILES FOR SHARED RESOURCES"
/ OPT
"VARIABLE DATA OF PACKAGES INSTALLED"
/ RUN
"INFO OF SYSTEM SINCE IT WAS BOOTED"
/ TMP
"AVAILABLE FOR PROG"
/ SPOOL
"DATA AWAITING PROCESSING"
/ LPD
/ MQUEUE
/ NEWS
/ RWHO
/ UUCP
/ LOG
"LOG FILES AND DIR"
LASTLOG
MESSAGES
WTMP
/ SBIN
"SYSTEM BINARIES"
FASTBOOT
FASTHALT
FDISK
FSCK
GETTY
HALT
IFCONFIG
INIT
MKFS
MKSWAP
REBOOT
ROUTE
SWAPON
SWAPOFF
UPDATE
/ TMP
"TEMPORARY FILES DELETED ON BOOTUP"
/ DEV
"LOCATION OF SPECIAL OR DEVICE FILES [CONTAINS MAKEDEV]"
/ HOME
"USER HOME DIRECTORIES"
/ LIB
"LIBRARY AND KERNEL MODULES"
/ MNT
"MOUNT FILES FOR TEMPERORY FILESYSTEMS"
/ OPT
"ADD-ON APPLICATION SOFTWARE"
/ ROOT
"HOME DIR. FOR ROOT USER"

- / - Root directory of the entire file system hierarchy
- BUT / at the end of a path means that it is a directory, not a file
- cat /etc/fstab could show you which device is mounted to / (root) point
- /bin - NOW - symlink to /usr/bin
- /boot - boot loader files are here. There can be /boot/grub and /boot/efi folders, some other files and directories related to bootloaders
- /dev - devices (including /dev/null, /dev/random, /dev/ttyX, /dev/sdX)
- /etc - (et cetera - historically). Now - directory with all global system configurations and cpecifications. Don’t recommend to change anything here
- /home - directory that stores ALL users data (except root)
- /root - home for root
- /lib - NOW - symlink to /usr/lib
- /mnt - Eecommended as a mountpoint for mounting devices
- /opt - optional software, propriet sw, most of sw from AUR is here
- /proc - virtual filesystem providing info about kernel and all running processes. Generated and populated by OS
- /sbin - NOW - symlink to /usr/bin

- /srv - server cpecific data (a.e. to use pc as ftp or another server, all shared data is here)
- /sys - contains an information and interaction tools with kernel, devices, kernel modules
- /tmp - directory for temporary files as makepkg cache, etc. Cleared after each reboot
- /usr - Universal System Resources - all of the user data

  /usr/bin - file contains programs binaries for all users
  /usr/include - standard include files
  /usr/lib - file contains libraries for /usr/bin
  /usr/local - tertiary hierarchy for local data, specific to this host. Contains /bin, /lib, share inside
  /usr/share - architecture-independent data, a.e. fonts, icons, themes, etc
  /usr/src - source code of some programs a.e. kernel, rust, nvidia
- /var - variable files, that are permanently changing during normal work a.e. logs, cache, email files. Not cleared between reboots
- Important, must read : difference between /bin, /sbin, /usr/bin
- But it is the info from 2010. Now it is Ok to have them as symlinks to /usr/bin

Sources

Sources

- UCU Linux Club resources
- File systems Wiki
- Linux file systems
- LFSH Wiki
- Differences between hard and soft links on Unix systems
- Mounting and unmounting on Linux
- UUID Wiki
- /bin and /usr/bin differences
- Understanding the bin, sbin, usr/bin , usr/sbin split
- ext2-3-4 differences
- btrfs vs ext4
- The case for /usr merge