

# Linux Essentials for Application Developers

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License on page 2

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# Contents

- Introduction
- Linux
- Unix
- The console
- Text tools
- File and directories
- Memory and processes
- bash
- Networking
- System administration
- Software development tools

# Introduction

[back to Contents](#)

# Introduction

- The purpose of this document is to provide sufficient information for an experienced programmer to become proficient in a Linux environment
- Notation:
  - commands that are entered at a shell (command-line) prompt are in **fixed-width font**
  - command arguments are *italicized*
  - ... indicates an argument that can appear any number of times
  - examples are indented:  
**echo 'text to display'**
- Exercises have the answer on the following slide

# Linux

[back to Contents](#)

# What is Linux?

- Free and open source multiuser operating system
  - Free: anyone is free to do whatever they would like with the code, subject to license agreement
  - Open source: the source code is publicly available for anyone to study and modify
  - Operating system: the executing code (program) that manages all system resources, including hardware and software
  - Multiuser: supports simultaneous use by multiple users
- Some refer to GNU/Linux when referring to the entire operating system, including GNU tools and the Linux kernel

# Where is Linux?

- Linux is a free and open source operating system
- Linux runs on everything from embedded IoT devices to supercomputers
- The Android cellphone operating system is based on the Linux kernel
- So Linux is running on billions of devices worldwide



# Linux distribution families

- A Linux distribution typically includes the Linux kernel, a suite of programs, and a package distribution system
- Most currently supported Linux distributions derive from one of these distributions, first released in 1993 (except Android):
  - Slackware/SuSE
  - Debian
  - Red Hat
    - most of the distribution-specific examples in this deck will be based on Red Hat
  - Android, first released in 2005
- A. Lundqvist and D. Rodic have prepared a fascinating GNU/Linux Distribution Timeline, at

[https://upload.wikimedia.org/wikipedia/commons/5/58/Linux\\_Distribution\\_Timeline\\_with\\_Android.svg](https://upload.wikimedia.org/wikipedia/commons/5/58/Linux_Distribution_Timeline_with_Android.svg)

# Can I emulate Linux on Mac or Windows?

- On Mac, open the terminal app. Most of the commands in this deck will work on it. Though some, such as find, are slightly different
  - Mac OS X and later are based on Mach, a Unix variant
- On Windows, Cygwin provides the feel of Linux. To install, download and run [https://www.cygwin.com/setup-x86\\_64.exe](https://www.cygwin.com/setup-x86_64.exe)
  - its package management is different but intuitive
- Alternatively, Linux virtual machines can be run on Mac, Windows, or any other platform that supports them

[back to Contents](#)

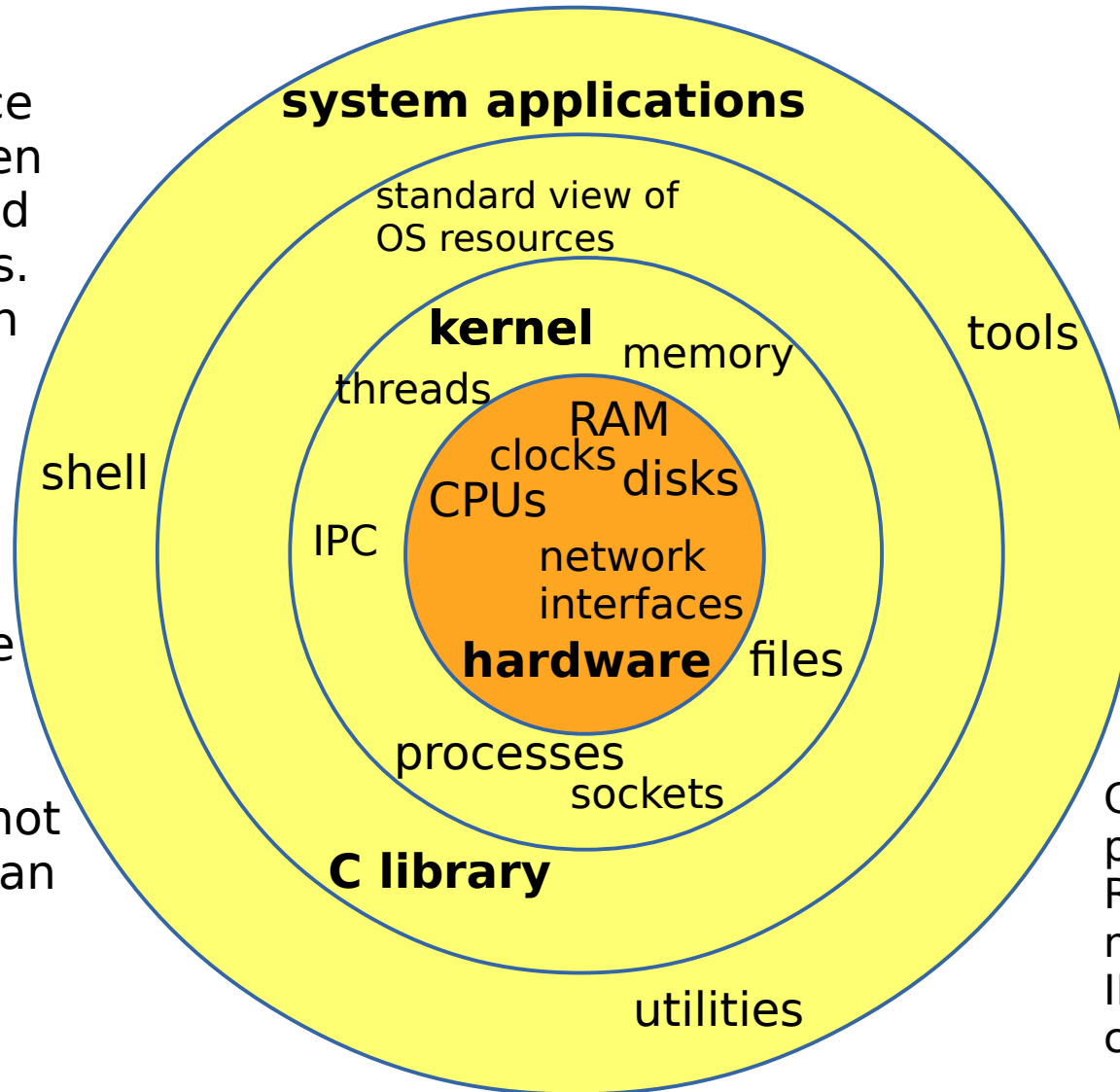
# Where did Linux come from?

- MIT, Bell Labs, and GE developed Multics in mid-1960s
  - Multiplexed Information and Computer Services
- AT&T Bell Labs developed Unix in the early 1970s for internal use
  - Uniplexed Information and Computer Service
  - stylized as Unix, trademarked as UNIX®
- Unix licensed to others starting in 1983 as AT&T System V
  - University of California, Berkeley developed UCB version
  - POSIX (Portable Operating System Interface) standardizes user and programmer interfaces
- Linus Torvalds developed Linux in 1991 in response to restrictive licensing of Unix

# What is an operating system?

An OS is a software resource manager between the hardware and user applications. Each OS layer (in yellow here) provides resources to layers above through a well-defined interface

User applications (not shown here) can access OS facilities and resources



CPU = central processing unit  
RAM = random access memory  
IPC = interprocess communication

# The Unix philosophy

- As summarized by Doug McIlroy in 1978:
  1. Each program (application) should do one thing, and do it well
  2. The output of one program can be the input to another
    - Loose coupling, i.e., not dependent on particular formats
  3. Design and build software to be tried early
    - Rapid prototyping, agile
  4. Build and use tools, even for one use

# Command basics

- Commands have a name, any number of options, and any number of arguments
  - options are also called flags or switches, and may themselves take arguments
    - all are separated by whitespace: one or more space or tab characters
  - options are indicated with a leading single or double dash
    - single-dash options are usually single letter
    - double-dash options are usually more descriptive, and preferred in scripts and documentation
  - arguments usually don't start with a dash
  - some commands use a double-dash, with no other characters, to separate the command options and arguments

# Commands and programs

- A command executes either a built-in shell command or external program
  - built-in shell commands, documented in the shell man page
  - an external program is contained in an executable disk file
    - execute permission is required for the user to execute the program
  - an external program may either be a shell script or binary
    - shell scripts should start with line of the form:  
`#!/bin/bash`  
and can contain any commands for that shell
    - binary files contain executable code, or code in and intermediate form that is executed by another program such as a Java virtual machine



# Help

- Every command should have a man page
  - view with `man(1p)` command, e.g.,  
**`man less`**
  - shows man pages related to a topic  
**`man -k topic`**
  - `man` can be run directly on a man page  
**`man /usr/share/man/man1/ls.1.gz`**
- Most commands have a `--help`, `-h`, or `-?` help option

# Reference manual sections

- Manual pages are arranged in sections, see those with  
`man man`
- To specify a specific section when using `man`, precede the topic with the section number, e.g.,  
`man 3 sleep`
  - Without the section, `man` would show the documentation for the `sleep(1p)` command

# Reference conventions

- Commands, system calls, file formats, and other Unix entities are often referred to with their manual section in parentheses the first time the command is mentioned, e.g.,
  - `less(1)` is the `less` command, described in section 1 of the reference manual
  - `regex(7)` documents POSIX regular expressions in section 7 of the reference manual
- In this document, POSIX standard commands are shown with a section 1p reference, e.g, `more(1p)`. The corresponding section 1 man page shows any non-POSIX features of the command
  - Section 3p man pages correspond to Section 2 pages
- Non-POSIX commands are shown with a section 1 reference, e.g, `less(1)`

# The console

[back to Contents](#)

# Keyboard: prompt shortcuts

- These are the default (emacs mode) bindings. vi bindings can be selected by entering `set -o vi`
  - Ctrl-a/Ctrl-e: beginning/end of line
  - Ctrl-b/Ctrl-f: backward/forward one character
    - or left/right arrows
  - Ctrl-p/Ctrl-n: previous/next command in history
    - or up/down arrows
  - Ctrl-r: search back through command history
  - Ctrl-u: erase input
    - Can be used at password prompt
  - Ctrl-d: end of input
- The `reset(1)` command fixes a “messed up” terminal

# Keyboard: tab completion

- bash and other shells offer tab completion
- After entering the first few characters of a command, hitting the Tab key will complete if unique
  - If there isn't a unique completion, nothing happens
  - Then, hitting the Tab key a second time shows all possible completions
    - Enter more characters until the completion is unique
- Tab completion also works for filenames
- Tab completion may also be supported for command arguments

# Keyboard: job control shortcuts

- Ctrl-z: put job in background
- Ctrl-s/Ctrl-q: stop/resume foreground job
- Ctrl-c: terminates foreground process by sending it the keyboard interrupt signal
- Ctrl-\  
terminates foreground process by sending it the quit signal
  - Only try if Ctrl-c doesn't terminate the process

# Keyboard: virtual consoles

- Ctrl-Alt-F1 through Ctrl-Alt-F6 (typically): go to the specified virtual console.
  - X windows runs on one of them, usually the first
- If your X windows environment enters an unusable state, you might be able to switch to another virtual console, login, and try to kill an errant process
  - Example:
    1. Run a process, such as `xlock(1)`, in a window
    2. Switch to another virtual console using Ctrl-Alt-F2
    3. Login
    4. Kill the process started in step one using the `kill(1p)` command
    5. Logout
    6. Switch back to X windows using Ctrl-Alt-F1 (usually)



# The X Window System™

- The X Window System™ provides the basis for the graphical user interface (GUI) of most Linux distributions, except Android
  - The X Window System is a trademark of The Open Group
  - The latest version is X11R6.4
  - Also called X11, X windows, or X
- Client-server based
  - The X server renders and manages displays, including pointer and audio
  - Graphical applications are clients
- X.Org provides the server, Xorg(1), implementation for many distributions

# Using X

- Start using `startx(1)` or `xinit(1)`
  - usually done for the user on login
- The `DISPLAY` environment variable controls where windows are displayed
  - Default value is something like `:0`
  - Must be set manually if unset, e.g., after `su`  
`export DISPLAY=:0.0`

# Window managers

- With an X server running the user can start a *window manager*
  - Again, this is usually done for users in a system that has been configured with graphical interfaces
  - Sometimes run user's `~/.xinitrc` script, which should end by starting a window manager
  - Or, the `startx` program may start a particular window manager
- The window manager supports root (on the display background) menus, manages physical displays, manages application windows, and manages events such as keyboard and pointer (mouse) input, and audio output
- Example window managers include `mwm`, `twm`, and `xfce`

# xterm(1)

- xterm(1) is a terminal emulator for X
- Each invocation opens a new window with a terminal (command) prompt
  - Runs the user's shell, as set in /etc/passwd
  - A user can change their shell with chsh(1)
- Appearance can be customized in ~/.Xresources file
  - Usually read by xrdb(1)
  - Contains settings for other X clients, not just xterm

# Desktop environments

- Desktop environments such as GNOME and KDE provide a higher level abstraction
- Include a GUI server such as X
- Include a window manager
- Include applications for various user-level tasks

# Text tools

[back to Contents](#)

# Text tools

- View: `cat(1p)`, `less(1)`, `od(1p)` or `hexdump(1)`, `wc(1p)`
  - `more(1p)` is a predecessor of `less` that allows only forward movement
  - `od` and `hexdump` show the content as bytes
- Search: `grep(1p)`, `strings(1p)`, `cut(1p)`, `join(1p)`
  - `fgrep` (`grep -F`) and `egrep` (`grep -E`) are variants that disable and enhance the `grep` regular expressions
- Compare: `diff(1p)`, `cmp(1p)`
- Modify/transform: `python(1)`, `sed(1p)`, `tr(1p)`
  - `perl(1)` and `awk(1p)` are older tools that are sometimes useful

# less customization

- Options to less can be stored in the LESS environment variable. That can be set your shell profile such as `~/.bash_profile`, e.g.,  
**`export LESS=eMqRsX`**
  - e removes the need to use “q” to terminate less
  - M causes less to prompt verbosely
  - q suppresses alerts when trying to view before the beginning or past the end of the file
  - R interpret ANSI color escape sequences, so that text colors are retained
  - s squeezes multiple blank lines into one
  - X disables clearing the screen on termination



# grep

- grep searches for text matching a regular expression pattern

**grep** [*options*] *pattern* [*file...*]

- -i case insensitive
- -c just returns count
- -h suppresses filename in output, with multiple files (not POSIX)
- -E (or egrep): extended regular expression pattern
- -F (or fgrep): literal pattern

# grep regular expressions

- This is just a general introduction, please see the `grep(1p)` and `regex(7)` man pages for details
- An item can be a single character, a character class, or a parenthesized group of items
- A period, `.`, matches any single character
- Some special characters (except with `-F` or `fgrep`) specify the quantity of the preceding item
  - `*` matches any number of the item
  - `+` matches one or more of the item
  - `?` matches zero or one of the item

# grep regular expressions, cont'd

- Some special characters (except with -F or fgrep) restrict the match
  - ^ matches at the beginning of a line
  - \$ matches at the end of a line
- [] indicates a character class, such as [A-Za-z0-9] or [:alpha:]

# grep examples

- Count occurrences of “error” or “warning” in log files

```
grep -cEi 'error|warning' files
```

- Set exit status to zero if “error” or “warning” occurs in log files

```
grep -Eiq 'error|warning' files
```

```
echo $?
```

- Show all processes that match pattern, except grep itself, e.g.,

```
ps -ef | grep '[p]ython'
```

- without the brackets in the pattern, the output would include “grep python”, which probably is not of interest

# List of dictionary words

- `/usr/share/dict/words` contains a list of English words
  - if the words package is installed
  - `/usr/share/docs/words/readme.txt` describes the contents
- Can be useful, though it is not authoritative

# Dictionary word exercise 1

- List all 6-letter words, excluding proper names, that start with 'a' and end with 'x'

solve exercise before proceeding

# Dictionary word exercise 1

- List all 6-letter words, excluding proper names, that start with 'a' and end with 'x'

```
grep '^a....x$' /usr/share/dict/words
```

adieux

afflux

amplex

anatox

approx

auspex

# Dictionary word exercise 2

- List all 6-letter words, including proper names, that start with 'a' and end with 'x'

solve exercise before proceeding



# Dictionary word exercise 2

- List all 6-letter words, including proper names, that start with 'a' and end with 'x'

```
grep '^[Aa].....x$' /usr/share/dict/words
```

or

```
grep -i '^a.....x$' /usr/share/dict/words
```

Adds the following to the output of the previous exercise:

**Astrix**

**Atarax**

# Files and directories

[back to Contents](#)

# File and directory names

- File and directory names can contain any character except /
  - Though it's best to avoid non-printable characters in names
- Names are case sensitive
  - For example, foo and Foo refer to two distinct files and/or directories
- File and directory names are just entries in tables
  - Removing a file does not remove its contents from disk
  - Though in practice, recovering the contents of a removed file is difficult, or impossible if the contents were overwritten for use by another file

# File types

- The most common file types are:
  - Plain file, containing bytes
  - Symbolic link, which points to another file
    - created with **ln -s**
  - Directory, which is an entry in a directory's list of contained files
  - Special files, often used as the OS interface to a hardware device
- The `file(1p)` command shows the type of a file
- Plain files are in turn categorized based on their content
  - `/etc/mime.types` lists many types
- In general, filename extensions are not authoritative

# File management commands

- `cp(1p)`: copies one or more files, `-p` preserves ownership, permissions, and timestamps

```
cp [-p] foo bar
```

- `rm(1p)`: removes (deletes) a file

```
rm [-i] foo[...]
```

- `mv(1p)`: move (rename) a file

```
mv foo bar
```

- `touch(1p)`: create new file or update last modification time on existing one
- `file(1p)`: show the type of a file
- `stat(1)`: show ownership, permissions, and timestamps

# Directory management commands

- `mkdir(1p)`: makes one more more new directories
  - The `-p` option allows creation of multiple levels
- `rmdir(1p)`: removes one or more empty directories
  - So does `rm -r`
- `ls(1p)`: lists contents of one or more directories
- `cd(1p)`: changes current directory
- `pushd/popd`: shell built-ins to change current directory, pushing/popping to/from a stack
  - `dirs` displays the contents of the stack

# File and directory permissions

- Permissions restrict actions on a file or directory
  - The actions are read, write, and execute
    - A file can only be executed if it allows execute permission
  - Separate permissions for owner, group, and all others
- `ls -l` and `stat(1)` show permissions
- `chmod(1p)` allows owner, and root, to change permissions

# rm

- The `rm(1p)` command removes files and directories
- The `-i` option causes `rm` to request confirmation from the user of each removal
  - Many people add a shell alias to their profile to always enable `-i`. This can be overridden by adding `-f` when executing the command, or bypassing the alias with `\rm`
- The `-r` option is required to remove a directory
  - all of the files and directories are removed first, recursively
- Removal does not actually remove the data in the file
  - removal just unlinks the file name from its directory
  - the space for the data can be reused by the operating system



# rsync

- rsync(1) is a handy and efficient tool for copying files and directories to a remote machine, or on the local machine
  - synchronizes files or directories
- The general format is:  

```
rsync [options] src... dest
```
- The source(s) and destination can be local or remote files or directories. Remote files and directories are indicated with a leading *[user@]host*:
- There is one subtlety: source directories should always include a trailing /
- Usually use -a (--archive) option with directories
- Other common options: -v for verbose, --delete to delete, --exclude to exclude specified files/directories

# rsync examples

- Copy directory on local machine

```
rsync -av /path1/dir/ /path2/dir
```

- Copy remote directory to local machine

```
rsync -av remote:path1/dir/ path2/dir
```

- Can use absolute or relative paths in either of the above examples

- Copy, excluding .o files

```
rsync -av --exclude '*.o' remote:/path1/dir/ path2/dir
```

- Test if contents of two directories are identical

```
rsync -nav --delete dir1/ dir2
```

# File compression

- Compression can drastically reduce the size of a large text file
- Compression effectiveness on a binary file depends on its content; it can even increase the size

| Compression | File extension | Introduced in |
|-------------|----------------|---------------|
| compress    | .Z             | 1983          |
| gzip        | .gz            | 1992          |
| bzip2       | .bz2           | 1996          |
| lzma        | .lzma          | 1999          |
| xz          | .xz            | 2009          |

## Common compression formats

- Each compression format has a corresponding program of the same name, see man pages for usage info

# File compression examples

- decompress a gzip file

```
gzip -d foo.gz
```

or

```
gunzip foo.gz
```

- detect type of contents of gzip file

```
gzip -cd foo.gz | file -
```

or

```
zcat foo.gz | file -
```

- compress file using bzip2

```
bzip2 foo
```

# File archives

- Archives are used for packaging a collection of files

| Archive format | File extension | Compressed |
|----------------|----------------|------------|
| ar             | .a             | no         |
| ZIP            | .zip           | yes        |
| tar            | .tar           | no         |
| gzipped tar    | .tgz           | yes        |
| cpio           | .cpio          | no         |
| gzipped cpio   | .cgz           | yes        |
| 7-Zip          | .7z            | yes        |

## Common archive formats

- See man pages for usage info

# File archive examples

- view contents of ar archive

```
ar t foo.a
```

- extract contents of gzipped tar archive

```
tar xvpf foo.tgz
```

- extract contents of gzipped cpio archive

```
zcat foo.cgz | cpio -imdv
```

or

```
gzip -cd foo.gz | file -
```

- create compressed tar archive

```
tar cvzf foo.tgz files.. directories..
```

# Disk management

- Disks are divided into *partitions*, e.g.,

| Device    | Boot | Start     | End       | Sectors   | Size  | Id | Type            |
|-----------|------|-----------|-----------|-----------|-------|----|-----------------|
| /dev/sda1 | *    | 2048      | 163842047 | 163840000 | 78.1G | 7  | HPFS/NTFS/exFAT |
| /dev/sda2 |      | 163842048 | 348162047 | 184320000 | 87.9G | 83 | Linux           |
| /dev/sda3 |      | 348162048 | 409602047 | 61440000  | 29.3G | 83 | Linux           |
| /dev/sda4 |      | 409602048 | 488397167 | 78795120  | 37.6G | 5  | Extended        |
| /dev/sda5 |      | 409606144 | 411703295 | 2097152   | 1G    | 83 | Linux           |
| /dev/sda6 |      | 411705344 | 473151487 | 61446144  | 29.3G | 83 | Linux           |
| /dev/sda7 |      | 473153536 | 488396799 | 15243264  | 7.3G  | 82 | Linux swap      |

- fdisk(1) can view and modify local disks
- df(1p) reports partition space usage

# Filesystems

- Each partition contains a *filesystem* e.g.,

| Filesystem | 1K-blocks | Used     | Available | Use% | Mounted on    |
|------------|-----------|----------|-----------|------|---------------|
| /dev/sda2  | 90581112  | 79042092 | 6914636   | 92%  | /home         |
| /dev/sda3  | 30106488  | 14921476 | 13632628  | 53%  | /mnt/Fedora28 |
| /dev/sda5  | 999320    | 505968   | 424540    | 55%  | /boot         |
| /dev/sda6  | 30109560  | 15885504 | 12671520  | 56%  | /             |

- mkfs(1) creates a filesystem on a partition



# Devices: /dev/null

- /dev/ contains special files and directories, e.g., to easily access hardware
  - Documented by name, e.g., null in manual section 4
- /dev/null: reads nothing, like reading an empty file; discards data written to it
  - POSIX grep does not have --quiet, so:  
`grep foo file >/dev/null && echo file contains foo`
  - Can be used to discard unexpected error messages, though will also discard unexpected error messages  
`grep foo * 2>/dev/null`

# Devices: /dev/zero, RNGs

- /dev/zero: reads endless stream of 0 (null) bytes

```
head --bytes 10 /dev/zero | od -x
```

- /dev/full: always full device, useful for testing behavior of programs that write to full disk

```
ls >/dev/full
```

- /dev/urandom: returns random bytes, non-blocking so relies on pseudorandom number generator
- /dev/random: random number generator (RNG) that blocks to achieve sufficient entropy

# Devices: hardware

- `/dev/cdrom`, `/dev/cdrw`, `/dev/dvd`, or similar: CD or DVD drive(s)
- `/dev/sd*`: disk drives, starting with `/dev/sda`
  - Partitions are numbered following the drive letter, starting with `/dev/sda1`
  - `sd` refers to Small System Computer Interface (SCSI), which might be emulated by the disk driver
- `/dev/hd*`: non-SCSI hard disk drives
- `/dev/fd*`: floppy disk drives

# Devices: terminals

- `/dev/tty*`: terminals (consoles)
  - You can write to, and read from, terminal `/dev/tty`
- `/dev/pts/*`: pseudoterminals
  - Used for windows: each window is associated with a different pseudoterminal
  - You can write to, and read from, your own pseudoterminals:  

```
echo 'guess who!' >/dev/pts/0
```
  - The `w(1)` command shows all terminals and pseudoterminals in use
- `/dev/ttyS*`: serial terminals
  - Used for connection to serial devices such as networking equipment and embedded computers

# Devices: I/O

- `/dev/stdin`, `/dev/stdout`, `/dev/stderr`: input and output (I/O) devices
  - Correspond to the 3 standard streams associated with every Unix program
  - Within the program, each stream is associated with a *file descriptor (fd)*
    - An fd is an integer handle to the open file
    - 0 for stdin, 1 for stdout, 2 for stderr
- stdin (standard input) is for console (keyboard) input
- stdout (standard output) is for normal program output
- stderr (standard error) is for error messages or other unusual output

# Devices exercises

- Write a simple, non-blocking shell command to display 10 random bytes

solve exercise before proceeding

# Devices exercises

- Write a simple, non-blocking shell command to display 10 random bytes

```
head --bytes 10 /dev/urandom | od -x
```

or

```
head -c 10 /dev/urandom | od -x
```

- Write a dd(1p) command to zero out a file. You'll need to limit it to the length of the file.

solve exercise before proceeding

# Devices exercises

- Write a simple, non-blocking shell command to display 10 random bytes

```
head --bytes 10 /dev/urandom | od -x
```

or

```
head -c 10 /dev/urandom | od -x
```

- Write a dd(1p) command to zero out a file. You'll need to limit it to the length of the file.

```
dd if=/dev/zero of=file bs=1 count=len
```

or

```
dd if=/dev/zero of=file bs=1 count=$(cat file | wc -c)
```



# Reading CDs and DVDs

- Mount a CD or DVD using `mount(1)`:

```
mount /dev/cdrw /mnt/tmp
```

- The device might be something else, such as `cdrom` or `dvd`. The mount point can be any directory and must already exist. It usually should be empty, because its contents won't be visible after the mount.
  - This must be done by root unless it's listed in `/etc/fstab`.
- The mount point, `/mnt/tmp/`, can then be used like any other directory. Though it is read-only by default, so it can't be modified.
  - The `-w` option mounts the filesystem read-write. Though that's not valid with non-writeable CDs and DVDs.
- Unmount the filesystem using `umount(1)`:

```
umount /mnt/tmp
```

# Writing CDs and DVDs

- CDs and DVDs usually contain ISO9660 filesystems
- Copy a directory hierarchy to a so-called iso image:  
`mkisofs -DRU -max-iso9660-filenames -o image.iso directory`
- Mount an iso image so its contents can be viewed:  
`mount -o loop image.iso /mnt/tmp`
  - On Macs, the command is:  
`hdiutil attach image.iso`  
umount as usual with umount (hdiutil detach on Macs)
- Burn an iso image to a CD:  
`cdrecord -v dev=/dev/cdrw -data image.iso`
- Burn an iso image to a DVD:  
`growisofs -dvd-compatible -Z /dev/dvd=image.iso`

# Image files

- The ImageMagick package has useful utilities for viewing and manipulating image files
- View with `display(1)`
  - left click to access modifications menus
  - right click to manage files
- Convert to different format with `convert(1)`  
`convert foo.jpg foo.png`
- List all formats supported by `convert`  
`convert -list format`
- For more complex image manipulation, try `gimp`
- The `ffmpeg` package has useful utilities for viewing and manipulating video files

# PDF files

- View PDF files with `xpdf(1)`
- Adobe has an old version of acrobat reader available at [http://ardownload.adobe.com/pub/adobe/reader/unix/9.x/9.5.5/enu/AdbeRdr9.5.5-1\\_i486linux\\_enu.rpm](http://ardownload.adobe.com/pub/adobe/reader/unix/9.x/9.5.5/enu/AdbeRdr9.5.5-1_i486linux_enu.rpm)
  - It's 32-bit, so might require many the installation of many library packages
- The `poppler-utils` package contains tools for manipulating PDF files, including:
  - `pdftotext(1)`
  - `pdfinfo(1)`
  - `pdfseparate(1)`
  - `pdfunite(1)`
  - `pdftotext(1)`
- `unoconv(1)` can convert documents to and from pdf

# PostScript files

- Before PDF, PostScript was a widely used electronic document format
  - Both PostScript and PDF were created by Adobe
- Still used by printers
- And used as an intermediate format when converting text to PDF, e.g.,

```
enscript -Bp- foo.txt | ps2pdf - foo.pdf
```

- enscript(1) isn't always installed on modern systems

# Unix and DOS files

- Unix files use ASCII LF (line feed, newline), hex 0A, to indicate the end of a text line
- Microsoft products use a two-character line end sequence: ASCII CR (carriage return), hex 0D followed by LF
- Mac OS X and later use LF, prior used just CR
- dos2unix(1) and unix2dos(1) convert files between the formats

```
dos2unix -n dos_file.txt unix_file.txt
```

```
unix2dos <unix_file.txt >dos_file.txt
```

- The ascii(7) man page lists the 128 ASCII characters and their hex values

# Memory and processes

[back to Contents](#)

# Memory management

- `top(1)` shows current usage and uses of CPU and memory
- `free(1)` reports current memory usage, e.g,

```
$ free -h
```

|       | total | used  | free  | shared | buff/cache | available |
|-------|-------|-------|-------|--------|------------|-----------|
| Mem:  | 7.5Gi | 670Mi | 4.6Gi | 82Mi   | 2.3Gi      | 6.5Gi     |
| Swap: | 0B    | 0B    | 0B    |        |            |           |

- `vmstat(1)` reports virtual memory statistics

```
$ vmstat -a
```

| procs |   | -----memory----- |         |        |         |    | ---swap-- |    | -----io---- |     | -system-- |    | -----cpu----- |    |    |    |
|-------|---|------------------|---------|--------|---------|----|-----------|----|-------------|-----|-----------|----|---------------|----|----|----|
| r     | b | swpd             | free    | inact  | active  | si | so        | bi | bo          | in  | cs        | us | sy            | id | wa | st |
| 1     | 0 | 0                | 5112720 | 804120 | 1537052 | 0  | 0         | 55 | 42          | 158 | 346       | 3  | 1             | 95 | 0  | 0  |

Those are averages since boot. Can also invoke with delay time, which results in periodic sampling.



# Process management

- `top(1)` lists processes as well as CPU and memory utilization
- `ps(1p)` lists processes
  - `ps -efj | less`
    - To see all of your own processes: `ps x`
    - Options preceded with `-` are different than options not preceded with dash (BSD options)
- `pgrep(1)` searches for processes by name
- `kill(1p)` sends a signal to a process, see next slide
- `pkill(1)` kills processes by name

# Process termination

- Ctrl-C or Ctrl-\ usually terminate the foreground process
- Background processes can be usually be terminated by looking up its pid and sending one of these signals:

```
kill -INT pid
```

```
kill -QUIT pid
```

```
kill -TERM pid
```

```
kill -KILL pid
```

- -KILL (or -9) should only be used as last resort, because it does not allow the process to perform any cleanup operations
- Some programs can also be killed with -HUP, but some other programs use -HUP to cause reload of a configuration file

# Date and time

- UNIX times start (are 0) at midnight of January 1, 1970, the *epoch*
- The `date(1p)` command gets and sets the current system date and time
- A service, `ntpd`, is often used to synchronize the system date and time with known sources
  - `ntpq -p` can be used to query the status of `ntpd`

# Timing a command

- The `time(1p)` command (also a built-in bash command) shows how long it takes to run another command
  - `time -p` provides a familiar output on many different systems
    - real (elapsed), user (CPU time spent executing the user program), and system (CPU time spent executing system processes on behalf of the user for the program)
- Example:

```
time -p sleep 2
```

produces

```
real 2.00
```

```
user 0.00
```

```
sys 0.00
```

# bash

[back to Contents](#)

# The shell

- The shell provides a so-called command line
  - it waits for a user to enter a command, then executes the command
- You can do just about anything from the command line
- Most modern Linux installations default to the bash shell
  - Bourne-again shell
- Other shells include Bourne shell (/bin/sh), csh, tcsh, and Korn shell (ksh)
  - Shells are listed in /etc/shells, but it usually contains other programs that aren't useful for interactive, i.e., command line, use

# Shell basics

- A shell provides the following capabilities:
  - a command prompt, where command are entered
    - \$ by default, but can be set to anything
  - ability to redirect input to and output from commands
    - < and > to redirect standard input and output, respectively, from a file
    - | to pipe the standard output of one command to the standard input of another
  - job control
  - parameter substitution
  - a language with conditional and iteration constructs

# Types of commands

- Internal (built-in) command
  - When entered at the command prompt, the shell performs the command without loading it from a file
  - Includes control flow such as conditionals and iteration
  - Varies by shell, but often includes **echo** and **test**
- External command
  - Contained in a file, so must be loaded each time it is run
- Alias
  - An alias is just another name for a command
- Function
  - A function can be defined, that when run performs a sequence of specified commands



# PATH search

- External commands are found on the user's PATH
  - PATH is an environment variable
  - PATH contains a colon-separated list of directories
  - When the file containing an external command must be found, the shell looks for it in each directory, in order, of the PATH
    - Not used if the file *absolute* or *relative* path
      - An absolute paths starts with /
      - A relative path contains at least one / but does not start with a /
        - Subdirectory, e.g., *foo/program*
        - Sibling directory, e.g., *../dir/program*
        - Current directory, *./program*
- To prevent an attack by a malicious program in current directory, do not include . in PATH

# Job control

- Appending & to a command starts it in the background
  - If the command's standard input and error are redirected to /dev/null, it can be detached from the terminal, e.g.,  
`command >/dev/null 2>&1 &`
  - 2>&1 redirects standard error to the standard output stream
- Ctrl-z followed by bg(1p) can be used to move the foreground job to background
- fg(1p) brings a background job to foreground

# Command history

- bash stores the history of commands
  - View using the history built-in command
  - Saved in file named by \$HISTFILE
    - Defaults to ~/.bash\_history
    - Disabled by unsetting HISTFILE
- Can be navigated at command prompt using Ctrl-p, Ctrl-n, Ctrl-r, Ctrl-s, etc.

# Shell variables

- Shell variables are assigned with =, without any spaces, e.g.,

```
myvar=foo
```

- Be sure to quote values with special characters

```
myvar='foo bar'
```

- The value of a shell variable is accessed by preceding the name with \$

```
echo $myvar
```

- Brace expressions can provide a default or alternate value, see Parameter Expansion in the bash(1) man page

```
echo ${myvar:+replacement value}
```

# Environment variables

- Every program execution has an *environment*, which includes *environment variables*, each of which is a unique name and a (possibly null) value
- Shell variables can be designed to be in the environment

```
export MY_PORT=1000
```

  - bash allows combined assignment and export, Bourne shell separates them
- A program cannot modify its parent's environment
- A parent's environment is passed to its children
  - At the time the child is forked: subsequently changing the parent's environment does not alter the environment of the child process

# Environment control

- The source (or `.`) built-in command can update the current environment from commands in a file

```
echo ${X:-X not set}
```

```
cat >/tmp/X <<<X=x
```

```
. /tmp/X
```

```
echo ${X:-X not set}
```

- The `-i` option to `env(1p)` suppresses the environment transfer from parent to child

```
env -i program
```

and add specific settings

```
env -i FOO=bar program
```

# Shell variable exercise

- What is the output from the first and last of this sequence of commands?

```
echo ${X:-X not set}
```

solve exercise before proceeding

```
echo X=x >/tmp/X
```

```
. /tmp/X
```

```
echo ${X:-X not set}
```

solve exercise before proceeding

# Shell variable exercise

- What is the output from the first and last of this sequence of commands?

```
echo ${X:-X not set}
```

```
    X not set
```

```
echo X=x >/tmp/X
```

```
. /tmp/X
```

```
echo ${X:-X not set}
```

```
    x
```



# Shell aliases

- Shell aliases are typically defined in an initialization file so that they are always available
- A common alias is 'rm -i' for rm(1p), so that it prompts for every removal

```
alias rm='rm -i'
```

- Can an alias be bypassed? How do I remove many files at once without responding to the prompt for each?
  - Prepending a backslash to the command bypasses its alias:  

```
\rm -fr foo
```
  - Alternatively, the full path to an external command can be used to bypass the alias:

```
/bin/rm -fr foo
```

- An alias can be removed with unalias

# bash initialization files

- Per user:
  - `~/.bash_profile` is sourced for the user's login shells
  - `~/.bashrc` is also sourced by each new interactive shell
- System wide:
  - `/etc/profile` is sourced for login shells
  - Other files, such as `/etc/bashrc` and the files in `/etc/profile.d/`, may be sources as well
- Cleanup files can also be created, see the FILES section of the `bash(1)` man page

# Shell command prompt

- Default command prompt is \$ for Bourne shell and derivatives
  - Except it is # for superuser
  - Can be changed by setting PS1 through PS4 parameters (variables)
- The bash function on the next slide can be used to customize the primary bash command prompt
  - To always enable it, add the function to your ~/.bash\_profile
  - To try it once, put it in a file and **source** the file
  - See PROMPT\_COMMAND shell variable description in the bash(1) man page for more information

# bash function to customize prompt

```
if [ "$PS1" ]; then
    export PROMPT_COMMAND=prompt_command
    function prompt_command() {
        local exit_status=$?
        local reset='\[\e[0m\]'
        local red='\[\e[1;31m\]'
        local yellow='\[\e[0;33m\]'
        local blue='\[\e[0;34m\]'

        if [ $exit_status = 0 ]; then
            #### hostname in blue, directory in yellow
            PS1="${blue}\h ${yellow}\W${reset}$ "
        else
            #### plus exit status of previous command, all in red
            PS1="${red}[exit ${exit_status}] \h \W${reset}$ "
        fi
    }
fi
```

# bash tidbits

- `~` expands to the user's home directory when encountered by the shell in appropriate context
  - Bourne shell does not have this expansion
- `{x..y}` is the sequence of numbers from `x` to `y`
- `$((expr))` evaluates an integer math expression
  - For floating point, use `bc(1p)`, `bc -lq`
- `(command)` executes `command` in a *subshell*
  - To run in a different environment, employ complex output redirection, and other obscure purposes
- The bash man page has nearly 6,000 lines of useful information

# bash exercises

- Write a one-line command sequence to print “done” after 30 seconds

solve exercise before proceeding

- How do you execute a program named **xyz** in your current directory (assuming no . in your PATH)?

# bash exercises

- Write a one-line command sequence to print “done” after 30 seconds

```
sleep 30 && echo done
```

or less concise

```
if sleep 30; then echo done; fi
```

- How do you execute a program named **xyz** in your current directory (assuming no . in your PATH)?

solve exercise before proceeding

# bash exercises

- Write a one-line command sequence to print “done” after 30 seconds

```
sleep 30 && echo done
```

or less concise

```
if sleep 30; then echo done; fi
```

- How do you execute a program named **xyz** in your current directory (assuming no . in your PATH)?

```
./xyz
```



# Shell scripts

- If you're going to perform a sequence of commands more than once, put them in a file, called a shell script
- Check each command for success
  - In bash and other Bourne shell derivatives, can exit execution of the immediately on any failure by setting `-e` shell variable in (near the top of) the shell script

```
set -e
```
- `true(1p)` and `false(1p)` for avoiding or forcing their respective exit status
  - E.g., to proceed if no errors in a log file:

```
grep -iq error logfile || true
```

# Shell (script) facilities

- Conditionals (if, &&, ||), iteration (for, while, until)
  - && and || allow concise conditional execution, e.g.,  
`grep -q foo file && echo found || echo not found`
- Input (<) and output (>, >>) redirection, pipes (|)
  - > overwrites output file, >> appends to it
- *Here documents* and *bash here strings* allow in-line provision of text input, e.g.,

```
cat >file <<-EOF
```

```
    this text input will be redirected to the file  
EOF
```

# Basic output

- `echo(1p)` outputs its argument
  - Most shells contain a built-in version, which may be slightly different
  - Examples:  

```
echo $LESS
```

```
echo $((6*7))
```
- `printf(1p)` outputs using C-style formatting
  - bash contains built-in version
  - Example, to print hex value of a decimal number:  

```
printf '%x\n' 255
```

# Output redirection

- bash supports redirection of output in every imaginable way, and then some. Some very simple examples:
  - redirect stdout to file: `command >file`
  - redirect stderr to file: `command 2>file`
  - redirect stdout and stderr to same file: `command &>file`  
or: `command >file 2>&1`
    - stdout is buffered but stderr is not, so they may be interleaved messily
  - redirect stderr through pipe: `command1 |& command2`  
or: `command1 2>&1 | command2`
  - redirect stdout to stderr: `command 1>&2`

# Command substitution

- Command substitution executes a command and provides its output
  - Bourne shell provides backticks, ``
  - bash also provides `$()`, which can be embedded
- Examples

```
start_dir=`pwd`
```

```
myid=$(id -u)
```

# find(1p) and xargs(1p)

- find(1p) searches for files meeting specified criteria
  - The criteria can include properties such as filename, permissions, type, owner, group, size, and time of creation, last update, or last access
- xargs(1p) applies an operation to the arguments fed to its standard input
- Together, find and xargs provide a powerful tool to search files for specified content
  - Example, find all .txt files under my home directory that contain the string *Foo*  

```
find ~ -name '*.txt' -print0 | xargs -0 egrep -l Foo
```
  - The print0 option to find and -0 option to xargs allow proper handling of filenames with special characters

# Living on the command line

- `bc(1p)` calculator

`bc -lq`

- `cal(1p)` calender

`cal -3`

- `date(1p)` shows the current date and time

- And components can be selected with the `+` format option
- To show seconds since epoch:

`date +%s`

# Command-line word lookup

- Here is a bash function to provide command-line access to online dictionary:

```
function dict() {  
    # First parameter is word to look up. Can be optionally be  
    # appended with :database.  
    # Second, optional, parameter is either d (define), m (match),  
    # or show (for first arguments of db or strat).  
    curl dict://dict.org/${2:-d}:$1  
}
```

- To set up, add that function to your `~/.bash_profile` and source it

```
. ~/.bash_profile
```

- To use:

```
dict word
```



# Networking

[back to Contents](#)

# Networking: hosts

- Every node (machine) on an Internet network has an address
  - IPv4: 32 bit address, e.g., 10.0.0.1
  - IPv6: 128 bit address, e.g.,  
2601:018f:0902:7700:0000:0000:0000:0004
- Names are more convenient than numbers, so they are mapped to addresses using host tables and domain name service (DNS)
  - The host table is stored in file `/etc/hosts` and/or is available from DNS servers
  - DNS servers are listed in `/etc/resolv.conf`(5)
  - View with `getent hosts` or `host(1)`
- Local host is 127.0.0.1 (IPv4) and `::1` (IPv6)

# Networking: ports

- Each host can offer services on ports, numbered 1 through 65535
- Names are more convenient than numbers, so they are mapped to services using a services file and network resources
  - The services table is stored in file `/etc/services` and/or is available from network servers
  - View with `getent services`
- Examples of ports include:
  - 22 for ssh
  - 80 for http
  - 443 for https

# Networking: protocols

- A protocol is a standardized arrangement for data
- Internet Protocol (IP) forms the foundation for the Internet by supporting addressing and routing
- Transmission Control Protocol (TCP) provides reliable connection-oriented message communication using IP
- User Datagram Protocol provides datagram communication using IP
  - connectionless, unreliable
  - A datagram includes a header and payload (data)

# Web file retrieval

- curl(1) and wget(1) retrieve web content

```
curl -O url
```

```
wget url
```

- w3m(1) and lynx(1) can be useful for quick viewing of a web page or html file

# ssh

- ssh runs a shell on a remote machine using an encrypted connection
- ssh is safest to use with public-private key pair
  - ssh-keygen(1) can generate the key pair
  - Some installations disable use of passwords
  - Some installations disable remote logins by root
- Two options are useful, but only use on trusted networks:
  - -X option forwards X11 session, allowing remote windows
  - -A option forwards authentication agent (ssh-agent) connection
- scp can copy files and directories to/from remote machines; it is useful when rsync is not installed

# ssh-keygen

- Example usage:

```
ssh-keygen -t rsa [-f keyfile]
```

- Keys are stored in `~/.ssh` directory, which should not be accessible by others

```
chmod go-rwx ~/.ssh
```

- it's good practice to create a separate key pair for each group of remote hosts that you use
- Never allow anyone else to access any of your private keys
- Public keys may be provided to others. If added to the `~/.ssh/authorized_keys` file on a remote machine, you will be able to access the account on that machine without a password

# Networking tools, basic

- ping(1) can tell you if you can reach a host
  - Unless the host has disabled ping responses
- traceroute(1) can show you the path to a host
- tcpdump(1) captures network packets
  - Should specify the network interface or **any**
  - Has many options to, e.g., write or read captures to a file, filter packets by host or protocol, display numbers instead of names, display the packet contents. A simple example is:  
`tcpdump -i any -s0 -w all_traffic.pcap not arp`



# Networking tools, for testing

- telnet(1) attempts to open a TCP connection to a host
  - To see if sshd is running on a specific host:  
`telnet 10.0.0.2 22`
- nc(1)/ncat(1)/netcat(1) create a trivial TCP or UDP client or server
  - Input/output can be redirected from/to a file
  - Example UDP server/client pair, in separate windows or on separate machines:  
`nc -lu 5500`  
`nc -u localhost 5500`
  - To terminate, Ctrl-d in client and Ctrl-c n server

# Networking tools, command line

- bash supports redirection to a special network device that specifies the host name or address, and port
- These work (assuming listener on the ports)!

```
echo hello >/dev/tcp/localhost/1234
```

```
cat <file >/dev/udp/127.0.0.1/5678
```

- For both input and output, can open a new file descriptor[1]

```
exec 3<> /dev/tcp/checkip.amazonaws.com/80
```

```
printf "GET / HTTP/1.1\r\nHost: checkip.amazonaws.com\r\nConnection: close\r\n\r\n" >&3
```

```
tail -n1 <&3
```

[1] <https://www.anmolsarma.in/post/bash-net-redirections/>

# Networking configuration

- ifconfig(1) lists all (active) network interfaces
  - -a option adds inactive interfaces
- To list all Internet addresses of the host:

```
ifconfig | egrep 'inet '
```

- To bring an interface up:

```
ifup ifname
```

- To bring an interface down:

```
ifdown ifname
```

- To list all routes from the host:

```
route
```

or

```
netstat -rn
```

# System administration

[back to Contents](#)

# User accounts

- Every account has a name, sometimes called a *login*
- The `/etc/passwd` file, and/or a directory service, maintains the accounts on a system
  - `getent(1)` shows account information  
`getent passwd [name ...]`
- Each account can be a member of any number of groups
  - `getent(1)` shows the members of a group  
`getent group [groupname ...]`
- Internally, accounts and groups are represented by numbers
- `id(1p)` shows the numbers, and group memberships of any account

# The superuser and su command

- Unix and Linux systems have a privileged user account
  - referred to as the superuser
  - login (account) name is **root**
  - can perform any operation on the system
    - strictly minimize use, and use carefully
- The su command allows a user to substitute as another user, including the superuser.
  - requires the user, other than the superuser, to know the password of the substitute user account
  - superuser can substitute as any other user without knowing their password
  - su discouraged in favor of sudo

# sudo command

- The sudo (**s**uperuser **d**o) command is the preferred mechanism to execute a command as another user, including the superuser.
  - does not require password of substitute user account
  - does require setup
  - tracks usage in, typically, /var/log/secure
  - To run a command as superuser, just prepend with sudo, e.g.,  
**sudo less /var/log/secure**
- Setup is via files added to /etc/sudoers.d
  - edit them using sudoedit, for safety

# RPM package management: rpm

- Red Hat-based systems use rpm and dnf for package management. rpm can refer to:
  1. the rpm (RPM package manager) system
  2. the rpm program
  3. an actual package file
- All software on the system is packaged into package files, which have a .rpm extension.
  - rpm files are stored in cpio format, if low-level manipulation is needed
  - a software package may comprise multiple rpms, e.g.,
    - bzip2-1.0.6-28.fc29.x86\_64
    - bzip2-devel-1.0.6-28.fc29.x86\_64
    - bzip2-libs-1.0.6-28.fc29.x86\_64
    - bzip2-static-1.0.6-28.fc29.x86\_64



# RPM package management: rpm

- The rpm program can be used to install, remove, or upgrade packages on a system. It can also be used to query installed packages and to query an rpm file. E.g.,

```
rpm -ivh rpm-file
```

```
rpm -e package
```

```
rpm -q package
```

- rpms are built from source rpm packages
  - the rpm-build program can be used for the build
  - source rpm files have .srpm file extensions
- The rpm program should usually not be used directly
  - instead, use dnf

# rpm examples

- show the info of an rpm

```
rpm -qip foo.rpm
```

- list the files that would be installed by an rpm

```
rpm -qlp foo.rpm
```

- list the dependencies of an rpm

```
rpm -qp -R foo.rpm
```

- For each of the above, remove the `p` to query an installed package

- list the actual contents of an rpm

```
rpm2cpio foo.rpm | cpio -it
```

- extract `/etc/bar.cnf` from an rpm

```
rpm2cpio foo.rpm | cpio -imdv ./etc/bar.cnf
```

# rpm exercises

- List all of the rpms installed on a system  
**solve exercise before proceeding**
- List the information about, and files contained in, the installed **words** rpm
- List the information about the package that contains the **w** command

# rpm exercises

- List all of the rpms installed on a system

`rpm -qa`

- List the information about, and files contained in, the installed **words** rpm

solve exercise before proceeding

- List the information about the package that contains the **w** command

# rpm exercises

- List all of the rpms installed on a system

```
rpm -qa
```

- List the information about, and files contained in, the installed **words** rpm

```
rpm -qil words
```

- List the information about the package that contains the **w** command

solve exercise before proceeding

# rpm exercises

- List all of the rpms installed on a system

```
rpm -qa
```

- List the information about, and files contained in, the installed **words** rpm

```
rpm -qil words
```

- List the information about the package that contains the **w** command

```
rpm -qif $(type -p w)
```

# RPM package management: dnf

- To address deficiencies of rpm, especially with package dependencies, yum (Yellowdog Updater, Modified) was developed
- dnf (dandified yum) has replaced yum, with the same subcommands

```
dnf install package
```

```
dnf localinstall rpm-file
```

```
dnf upgrade package
```

```
dnf remove package
```

```
dnf whatprovides glob
```

# dnf exercises

- What does this command do?

```
dnf whatprovides *bin/valgrind
```

solve exercise before proceeding



# dnf exercises

- What does this command do?

```
dnf whatprovides *bin/valgrind
```

It lists all of the packages that provide a valgrind program, e.g.,

valgrind-1:3.14.0-7.fc29.x86\_64 : Tool for finding memory management bugs in programs

Repo : updates

Matched from:

Other : \*bin/valgrind

# Service control with service(1)

- System V-based systems, including RedHat 6 and earlier, use System V init scripts to control system services
  - Scripts in `/etc/rc.d/` subdirectories are used to start, stop, and check the status of each service
- Init scripts are run at system startup to start services in proper order
- After startup, an init script can be used at any time, e.g.,  

```
/etc/rc.d/init.d/network status
```

```
/etc/rc.d/init.d/network restart
```
- The service command is the preferred way to run init scripts  

```
service network status
```

```
service network restart
```
- `chkconfig(1)` can be used to manage the scripts
  - add, del, on, off, etc.

# Service control with systemctl(1)

- RedHat 7 and later use systemctl(1) to manage services
  - systemd(1) manages the services
  - systemd is the first running process, so it has pid 1
- systemctl controls systemd, e.g.,
  - `systemctl status network.target`
  - `systemctl restart network.target`
- To list all services:
  - `systemctl list-units`
- systemd logs events to a journal, which can be queried using journalctl(1)

# systemd

- The first process launched after boot is systemd(1)
  - All other *units* are *activated* by systemd
  - See systemctl(1), including its list-units command
- systemd replaces the System V init(1) command
  - init uses the concept of runlevels, which can vary but typically include:
    - 0: power off
    - 1: single user, without network
    - 2: multi-user without network
    - 3: multi-user
    - 5: multi-user with display manager, such as using X server
    - 6: reboot
  - telinit(1) changes runlevel

# fork and exec

- All programs are launched using the fork and execve system calls
- fork(3p) creates a new *child* process that is an exact copy of the *parent* process, but with a different process ID (pid)
- execve(3p) executes a program
  - The C library contains wrappers such as exec(3), execl(3), and execv(3)
    - support different arrangements of program arguments
    - support PATH searching
    - support provision environment
- pstree(1), ps -eH, and ps axf show how all user processes descend from systemd

# Name service configuration

- `/etc/nsswitch.conf(5)` configures each name service
- For example, this entry directs `passwd` information to be provided by `sss` (System Security Services Daemon) and `files` (`/etc/passwd`), in that order:  

```
passwd: sss files
```
- Another example is this entry, which provides host information from `files` (`/etc/hosts`) and `DNS`, in that order:  

```
hosts: files dns
```
- `getent(1)` obeys `nsswitch.conf`, providing quick access to the information provided by each name service

# Name service exercises

- How can you view the passwd information of your own login?

solve exercise before proceeding

- How can you view all (both IPv4 and IPv6) of the information about your local host?

# Name service exercises

- How can you view the passwd information of your own login?

```
getent passwd $(id -u)
```

- How can you view all (both IPv4 and IPv6) of the information about your local host?

solve exercise before proceeding



# Name service exercises

- How can you view the passwd information of your own login?

```
getent passwd $(id -u)
```

- How can you view all (both IPv4 and IPv6) of the information about your local host?

```
getent hosts | grep localhost
```

or

```
getent hosts localhost ::1
```

# Shutdown

- For systems with `poweroff(1)` and `reboot(1)`, they can be used from the command line to turn off or reboot, respectively
- Through the GUI, there should be shutdown and reboot selections
- The GUI may have a power button
  - red
  - with a 0/1 indication
- Older systems use the `shutdown(1)` command  
`shutdown -h now`

# Software development tools

[back to Contents](#)

# Software build

- A traditional software build process includes configure, build, test, install
  - configure can be used to customize install directories, compile and link options, etc.
  - make runs the compile and link
  - make *targets* are typically used to test, install, clean up, etc.
- On one line:  
`./configure && make && make test && make install`

# Software analysis tools

- For dynamic (run-time) testing of native binaries, valgrind is indispensable
  - just prepend the invocation with valgrind
  - valgrind can significantly slow down execution, so it's not suitable for real-time programs
- Run-time profiling can help isolate performance bottlenecks
  1. Compile and link with -pg
  2. After execution, analysis with gprof
- <http://brendangregg.com/linuxperf.html>

# Debugging symbols

- Programs must be compiled with an option, such as `-g`, to include debugging symbols in the linked file
- `strip(1p)` removes the debugging symbols, if desired at a later time
- `size(1)` shows the size of the program, excluding debugging symbols
- A debugger such as `gdb(1)` can run the program under precise control
  - breakpoints, to stop execution at specified points such as functions or source code locations
  - watchpoints, to stop execution on specified conditions such as variable values

# Execution tracing

- `strace(1)` shows the system calls executed by a process
  - For example, to show all `openat(3p)` calls executed by `ls(1p)`:  
`strace -e trace=openat ls`
- `ltrace(1)` shows the library calls executed by a process
- Both put their output on the standard error stream

# Symbols

- nm(1p) shows the symbols in a binary object file
  - An object file is compiled code
    - Includes linked objects, which results in an executable binary file
      - excludes shell scripts
  - Symbols include names of data and functions
    - These names may be *mangled*, i.e., decorated with additional information such as function parameter types
      - Functions were originally named without any of their arguments, preventing overloading



# Source code (version) control

- Source code control systems manage all **versions** of files and, with some systems, directories
  - support retrieval of any version at any time
  - support comparison of versions of text files
- Useful for more than code, such as documents, spreadsheets, and any other files that change
- Some support simultaneous updates by multiple users
- Usually view version history as a tree with multiple branches
  - merge changes from one branch to another
  - typically one branch has designation such as main or master

# git

- Developed in 2005 by Linus Torvalds in response to restrictive licensing of existing systems
- Pros: popular, powerful, free and open source, geared to multiuser environments, supports off-line use
- Cons: steep learning curve
- Githubs are commonly used for software distribution
  - e.g., <https://www.github.com/>

# Basic git commands

- git init
  - one-time setup of local git repository
- git add
  - stage files/directories for commit to local repository into an *index*
- git commit
  - commit the index
- git pull/push
  - synchronize local repository with remote repository
- git status
  - view state of index
- git log/whatchanged
  - view history of local repository
- git diff
  - view changes, such as uncommitted changes in workspace

# git bisect

- Bisect is an invaluable capability
  - Narrows down change in behavior (bug) to single commit
- Usage: initialize, then repeatedly checkout and test a version between known good and bad points

```
git bisect init
```

```
git bisect good
```

or

```
git bisect bad
```

- Can streamline with git run if a test program is provided
- To finish:

```
git bisect reset
```

# User versus kernel space

- Memory regions that are in use by the kernel is referred to as *kernel space*
- Memory regions that have been allocated to a user program are referred to as *user space*
  - By default, memory allocated to one program cannot be accessed by other programs
  - Memory can optionally be *shared* with other programs

# How do applications access the OS?

- The OS interface is accessed through *system calls*
  - Applications invoke a system call just like any other function call
  - Each system call is documented in a man page, in section 2 of the system manual
  - Example: the unlink system call removes a (file or directory) name from a filesystem
    - Its signature is `int unlink (const char *)`
    - Its one argument is the name and it returns a integer status
    - If the name has no more links and doesn't refer to a file that is opened by a running process, the file is removed

# System call return values

- System calls often return an integer
  - Called a return value or status
- 0 indicates success
  - If a request was made, then it was performed successfully
- Non-0 indicates failure
  - The man page describes possible values and their meanings
  - The global variable `errno` is often set to provide further information on the failure
    - The man page for the particular system call lists the possible values
    - The `errno.h(0p)` man page lists the usual meanings for each value

# Program memory layout

memory managed by  
compiler: used for  
each function call

memory managed  
explicitly by  
application (new/  
delete)

global data: object  
locations are fixed,  
but their values  
can be modified

code: read-only

**Stack**

**Heap**

**Global Data  
Segment**

**Code (text)  
Segment**

function params,  
local objects

dynamically  
allocated  
objects

global objects

function definitions