# 15 – Networking and Package Management

## CS 2043: Unix Tools and Scripting, Spring 2019 [1]

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# welcome back to THE INTERNET

# Command we forgot from last time

## ping a packet off a remote host

`ping [flags...] <host>`

- Simple echo back-and-forth
- tests connections
- uses **ICMP** protocol – same as `traceroute`
- runs forever by default

```
$ ping -c 4 google.com
PING google.com (172.217.9.238) 56(84) bytes of data.
64 bytes from lga34s11-in-f14.1e100.net (172.217.9.238): icmp_seq=1 ttl=55 time=8.24 ms
64 bytes from lga34s11-in-f14.1e100.net (172.217.9.238): icmp_seq=2 ttl=55 time=8.51 ms
64 bytes from lga34s11-in-f14.1e100.net (172.217.9.238): icmp_seq=3 ttl=55 time=8.56 ms
64 bytes from lga34s11-in-f14.1e100.net (172.217.9.238): icmp_seq=4 ttl=55 time=8.56 ms

--- google.com ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 8ms
rtt min/avg/max/mdev = 8.237/8.468/8.563/0.163 ms
```

# Last time

- Computers communicate by sending **packet**s through the network
- Packets are addressed to a local **MAC** and a potentially-remote **IP**
- **Switches** connect computers into a *local network* and forward packets by **MAC**
- **Routers** connect local networks into an *intranet* and forward packets by **IP**

# Protocols from last time

- The **DHCP** protocol gives computers an IP address
- The **ARP** protocol associates an IP address with a MAC address
- The **DNS** protocol associates a domain name (google.com) with a MAC address

# What is a protocol?

- an agreement on what sort of packets to exchange to achieve a particular goal
- Can be multi-step
- we distinguish between *transport layer* and *application layer*

# More about protocols: transport layer

- *transport-layer* protocols correspond to different “kinds” of packets
    - examples: ARP, ICMP
- Operating system sees the different packets, handles them accordingly
- **operating system’s job** to handle transport-layer packets

# More about protocols: application layer

- *application-layer* protocols use the *same* kind of packet
  - examples: DHCP, DNS, HTTPS, SSH, most others you know
- Operating system passes them to applications
- How do applications find their packets?

# Introducing: TCP and UDP

- *transport-layer* protocols for communicating with applications
- differentiate applications with “ports”
    - just a 16-bit integer
    - like apartment numbers
- applications listen at a specific port
    - registers with the OS
    - OS only forwards port-destined traffic
- contains “return addresses” for easy reply to client

# TCP

- Most popular transport protocol
  - examples: HTTP, SSH
- *connection-oriented* protocol
  - “connect” to a port on a remote stream
  - receive a private channel on which to keep communicating
  - like a phone call … or SSH session
- Hides common failures
  - ensures packets are reasonably ordered
  - retransmits packets if they get lost
  - cool algorithm to avoid congestion

# UDP

- Second-most popular transport protcol
  - examples: DHCP, DNS, VoIP, Steam (as in video games), internet radio
  - **not** netflix
- **only gives you the port**
  - no connection: works like physical mail.
- All common failures exposed to application
  - packet order may vary
  - packets may not arrive
  - no indication whether transmitted packet got there
- Mostly used in either very-old, high-assurance or real-time applications
- more resilient to DOS attacks than TCP

# Application protocols

- Still defines pattern of communication
- specific messages expected at specific times
- messages sent via (usually) TCP/UDP
- Example: HTTP, SSH, etc.

# Exploring application protocols: netcat

## netcat : so much more than cat over the network

```
nc [flags] [host]
nc -l -p <port>
nc <host> <port>
```

- Raw TCP protocol tool
- sends `stdin` over the network
- receives `stdout` from the network
- `nc -l` “listens”, behaves like a server
- `nc <host>` “connects”, behaves like a client

# HTTP: a protocol to explore

- HTTP messages are raw text!
- Strings sent via TCP to port 80
- GET request: access a page

```
GET /people/mpmilano/ HTTP/1.1
Host: cs.brown.edu
```

- Let's send this via `netcat`! (demo)
- Can explore more protocols this way; try it!

# Some common ports

- HTTP: TCP/80
- SSH: TCP/22
- FTP: TCP/20 and TCP/21
- HTTPS: TCP/443
- SMTP (mail): TCP/25

# Firewalls

- In a perfect world, we wouldn't need a firewall.
- Lives in the network, or in the kernel
- inspects traffic *before* it reaches its destination
- Two primary uses: filter legitimate services, block unwanted ones

# Firewalls: the good uses

- Legit: *Filters* certain ports to prevent regions of the internet from accessing them
    - Cornell firewall drops all traffic destined to on-campus servers originating from off-campus IPs
    - `wash` firewall does the same
    - mail relay firewall would only allow known senders to connect
- prevents server from being overloaded by random external griefers
- prevents aggressive server scans from the darkweb
    - which, by the way, exists. ask me later.

# Firewalls: the lazy uses.

- Block insecure / old apps
- cover up for weird/bad OS/system design
    - Example: print server on a mac at port 631
    - Example: just a lot of windows
- Block **all** uninvited remote connections
    - if your laptop isn't a server, shouldn't have exposed ports
    - if it does have exposed ports, some application is doing a bad.
- Fundamentally lazy: right answer is to secure the applications, not hide them.
- lots of legacy apps (that we're stuck with) can't be fixed, so also fundamentally necessary

# Package Management

# Package Management Overview

- If I had to give *only one reason* why Unix systems are superior to Windows: Package Management.
- Can install almost anything with ease of from your terminal.
- Update to the latest version with one command.
  - No more download the latest installer nonsense!
- Various tools can be installed by installing a *package*.
  - A package contains the files and other instructions to setup a piece of software.
  - Many packages depend on each other.
  - High-level package managers download packages, figure out the dependencies for you, and deal with groups of packages.
  - Low-level managers unpack individual packages, run scripts, and get the software installed correctly.
- In general, these are “pre-compiled binaries”: no compilation necessary. It’s already packaged nice and neat just for you!

# Package Managers in the Wild

- GNU/Linux:
  - Low-level: two general families of *packages* exist: `deb`, and `rpm`.
  - High-level package managers you are likely to encounter:
    - Debian/Ubuntu: `apt-get`.
    - Some claim that `aptitude` is superior, but I will only cover `apt-get`. They are roughly interchangeable.
    - SUSE/OpenSUSE: `zypper`.
    - Fedora: `dnf` (Fedora 22+).
    - `zypper` and `dnf` use `SAT`-based dependency solvers, which many argue is fundamentally superior. The dependency resolution phase is usually not the slowest part though...installing the packages is. See [3] for more info.
    - RHEL/CentOS: `yum` (until they adopt `dnf`).
- Mac OSX:
  - Others exist, but the only one you should ever use is `brew`.
  - Don't user others (e.g. `port`), they are outdated / EOSL.

# Using Package Managers

- Though the syntax for each package manager is different, the concepts are all the same.
  - This lecture will focus on `apt-get`, `dnf`, and `brew`.
  - The `dnf` commands are almost entirely interchangeable with `yum`, by design.
  - Note that `brew` is a "special snowflake", more on this later.
- What does your package manager give you? The ability to
  - `install` new packages you do not have.
  - `remove` packages you have installed.
  - `update` installed packages.
  - update the lists to search for files / updates from.
  - view `dependencies` of a given package.
  - a whole lot more!!!

# A Note on **`update`**

- The **`update`** command has importantly different meanings in different package managers.
- Some **do**, and some do **not** default to system (read linux kernel) updates.
  - Ubuntu: default is *no*.
  - Fedora: default is *yes*.
  - RHEL: default is *no*.
- It depends on your operating system, and package manager.
  - Know your operating system, and look up what the default behavior is.
- If your program needs a specific version of the linux kernel, you need to be very careful!

# A Note on Names and their Meanings

- You may see packages of the form:
  - `<package>.i[3456]86` (e.g. `.i386` or `.i686`):
    - These are the `32-bit` packages.
  - `<package>.x86_64`: these are the `64-bit` packages.
  - `<package>.noarch`: these are independent of the architecture.
- Development tools can have as many as three packages:
  - The header files are usually called something like:
    - `deb`: usually `<package>-dev`
    - `rpm`: usually `<package>-devel`
  - The library you will need to link against:
    - If applicable, `lib<package>` or something similar.
  - The binaries (executables), often provided by just `<package>`.
  - Most relevant for `C` and `C++`, but also `Python` and others.
  - Use the `search` functionality of your package manager.

# Example Development Tool Installation

- If I needed to compile and link against `Xrandr` (X.Org X11 libXrandr runtime library) pn Fedora, I would have to install
  - `libXrandr`: the library.
  - `libXrandr-devel`: the header files.
  - Not including `.x86_64` is OK / encouraged, your package manager knows which one to install.
  - Though in certain special cases you may need to get the `32-bit` library as well.
    - In this case, if I were compiling a program that links against `libXrandr`, but I want to release a pre-compiled *32bit* library, it must be installed in order for me to link against it.
- The `deb` versions should be similarly named, but just use the `search` functionality of find the right names.
- This concept has no meaning for `brew`, since it compiles everything.

# System Specific Package Managers

# Debian / Ubuntu Package Management (`apt-get`)

- Installing and uninstalling:
  - Install a package:
    `apt-get install <pkg1> <pkg2> ... <pkgN>`
  - Remove a package:
    `apt-get remove <pkg1> <pkg2> ... <pkgN>`
  - Only one `pkg` required, but can specify many.
  - "Group" packages are available, but still the same command.
- Updating components:
  - Update lists of packages available: `apt-get update`.
    - No arguments, it updates the whole list (even if you give args).
  - Updating currently installed packages: `apt-get upgrade`.
    - Specify a `package` name to only update / upgrade that package.
  - Update core (incl. kernel): `apt-get dist-upgrade`.
- Searching for packages:
  - Different command: `apt-cache search <pkg>`

# RHEL / Fedora Package Managers (**yum** and **dnf**)

- Installing and uninstalling:
  - Install a package:
    `dnf install <pkg1> <pkg2> ... <pkgN>`
  - Remove a package:
    `dnf remove <pkg1> <pkg2> ... <pkgN>`
  - Only one **pkg** required, but can specify many.
  - "Group" packages are available, but different command:
    - `dnf groupinstall 'Package Group Name'`
- Updating components:
  - Update EVERYTHING: `dnf upgrade`.
  - `update` exists, but is essentially `upgrade`.
    - Specify a `package` name to only upgrade that package.
  - Updating repository lists: `dnf check-update`
- Searching for packages:
  - Same command: `dnf search <pkg>`
- `yum` and `dnf` (`Dandified Yum`) nearly interchangeable: [3].

# `dnf`: Cautionary Tales

- **WARNING**: if you install package Y, which installs X as a dependency, and later `remove Y`
  - By default, X will be removed!
  - Refer to [2] for workarounds.
  - Generally, won't know you needed to `mark` until it is too late.
- Solution?
  - Basically, **pay attention to your package manager**.
  - It gets removed because nothing *explicitly* depends on it.
  - So one day you may realize "OH NO! I'm missing package X"...
  - ...so just `dnf install X`.
    - So while `mark` is available, personally I don't use it.
  - Sad face, I know. Just the way of the world.

# OSX Package Management: Install `brew` on your own

- Sitting in class right now with a Mac?
- **DON'T DO THIS IN CLASS**. You will want to make sure you do not have to interrupt the process.
  - Make sure you have the "Command Line Tools" installed.
    - Instructions are on the First Things First Config Page
  - Visit `http://brew.sh/`
  - Copy-paste the given instructions in the terminal *as a regular user (not* `root`*:)*.
- **VERY IMPORTANT**: READ WHAT THE OUTPUT IS!!!! It will tell you to do things, and you *have* to do them. Specifically

```
You should run 'brew doctor' BEFORE you install anything.
```

# OSX Package Management (`brew`)

- Installing and uninstalling:
  - Install a *formula*:
    `brew install <fmla1> <fmla2> ... <fmla2>`
  - Remove a formula:
    `brew uninstall <fmla1> <fmla2> ... <fmlaN>`
  - Only one `fmla` required, but can specify many.
  - "Group" packages have no meaning in `brew`.
- Updating components:
  - Update `brew`, all *taps*, and installed formulae listings. This does not update the actual software you have installed with `brew`, just the definitions: `brew update`.
  - Update just installed formulae: `brew upgrade`.
    - Specify a `formula` name to only upgrade that formula.
- Searching for packages:
  - Same command: `brew search <formula>`

# OSX: One of These Kids is Not Like the Others (Part I)

- Safe: confines itself (by default) in `/usr/local/Cellar`:
  - No `sudo`, plays nicely with OSX (e.g. Applications, `python3`).
  - Non-linking by default. If a conflict is detected, it will tell you.
  - **Really important to read what `brew` tells you!!!**
- `brew` is modular. Additional repositories ("*taps*") available:
  - Essentially what a `.rpm` or `.deb` would give you in linux.
  - These are 3rd party repos, not officially sanctioned by `brew`.
- Common taps people use:
  - `brew tap homebrew/science`
    - Various "scientific computing" tools, e.g. `opencv`.
  - `brew tap caskroom/cask`
    - Install `.app` applications! Safe: installs in the "Cellar", symlinks to `~/Applications`, but *now these update with brew all on their own* when you `brew update`!
    - E.g. `brew cask install vlc`

# OSX: One of These Kids is Not Like the Others (Part II)

- `brew` installs *formulas*.
  - A `ruby` script that provides rules for where to download something from / how to compile it.
- Sometimes the packager creates a "Bottle":
  - If a bottle for your version of OSX exists, you don't have to compile locally.
  - The bottle just gets *downloaded* and then "*poured*".
- Otherwise, `brew` downloads the source and compiles locally.
- Though more time consuming, can be quite convenient!
  - `brew options opencv`
  - `brew install --with-cuda --c++11 opencv`
  - It really really really is magical. No need to understand the `opencv` build flags, because the authors of the `brew` formula are kind and wonderful people.
  - `brew reinstall --with-missed-option formula`

# OSX: One of These Kids is Not Like the Others (Part III)

- Reiteration: **pay attention to `brew` and what it says**. Seriously.
- Example: after installing `opencv`, it tells me:

```
==> Caveats
Python modules have been installed and Homebrews site-packages
is not in your Python sys.path, so you will not be able to
import the modules this formula installed. If you plan to
develop with these modules, please run:

mkdir -p /Users/sven/.local/lib/python2.7/site-packages
echo 'import site; site.addsitedir(                    \
    "/usr/local/lib/python2.7/site-packages")' >> \
    /Users/sven/.local/lib/python2.7/site-packages/homebrew.pth
```

- `brew` gives copy-paste format, above is just so you can read.
- I want to use `opencv` in `Python`, so I do what `brew` tells me.

# Less Common Package Management Operations

- Sometimes when dependencies are installed behind the scenes, and you no longer need them, you will want to get rid of them.
  - `apt-get autoremove`
  - `dnf autoremove`
  - `brew doctor`
- View the list of repositories being checked:
  - `apt-cache policy` (well, sort of...`apt` doesn't have it)
  - `dnf repolist [enabled|disabled|all]`
    - Some repositories for `dnf` are *disabled* by default (with good reason). Usually you want to just
      `dnf --enablerepo=<name> install <thing>`
      e.g. if you have `rawhide` (development branch for fedora).
  - `brew tap`

# Other Managers

# Like What?

- There are so many package managers out there for different things, too many to list them all!
- Ruby: `gem`
- Anaconda Python: `conda`
- Python: `pip`
- Python: `easy_install` (but really, just use `pip`)
- Python3: `pip3`
- LaTeX: `tlmgr` (uses the CTAN database)
    - Must install TeX from source to get `tlmgr`
- Perl: `cpan`
- Sublime Text: `Package Control`
- Many many others...

# Like How?

- Some notes and warnings about Python package management.
- Notes:
  - If you want `X` in Python 2 **and** 3:
    - `pip install X` *and* `pip3 install X`
  - OSX Specifically: advise only using `brew` or Anaconda Python. The system Python can get really damaged if you modify it, you are better off leaving it alone.
  - So even if you want to use `python2` on Mac, I strongly encourage you to install it with `brew`.
- Warnings:
  - Don't mix `easy_install` and `pip`. Choose one, stick with it.
    - But the internet told me if I want `pip` on Mac, I should `easy_install pip`
    - NO! Because this `pip` will modify your **system** python, **USE BREW**.
  - Don't mix `pip` with `conda`. If you have Anaconda python, just stick to using `conda`.

# References


[1] Stephen McDowell, Bruno Abrahao, Hussam Abu-Libdeh, Nicolas Savva, David Slater, and others over the years. “Previous Cornell CS 2043 Course Slides”.

[2] Reddit.com. *DNF Remove Package, keep dependencies??* 2016. URL: https://www.reddit.com/r/Fedora/comments/3pqrv9/dnf_remove_package_keep_dependencies/.

[3] Jack Wallen. *What You Need to Know About Fedora’s Switch From Yum to DNF*. 2015. URL: https://www.linux.com/learn/tutorials/838176-what-you-need-to-know-about-fedoras-switch-from-yum-to-dnf.