13 – Networking and Package Management

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

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Table of Contents

As always: Everybody! ssh to wash.cs.cornell.edu

- Quiz time! Everybody! run `quiz-02-20-19`
- You can just explain a concept from last class, doesn't have to be a command this time.

THE INTERNET

How do computers communicate?

- Send data back and forth
- Data takes the form of *packets*

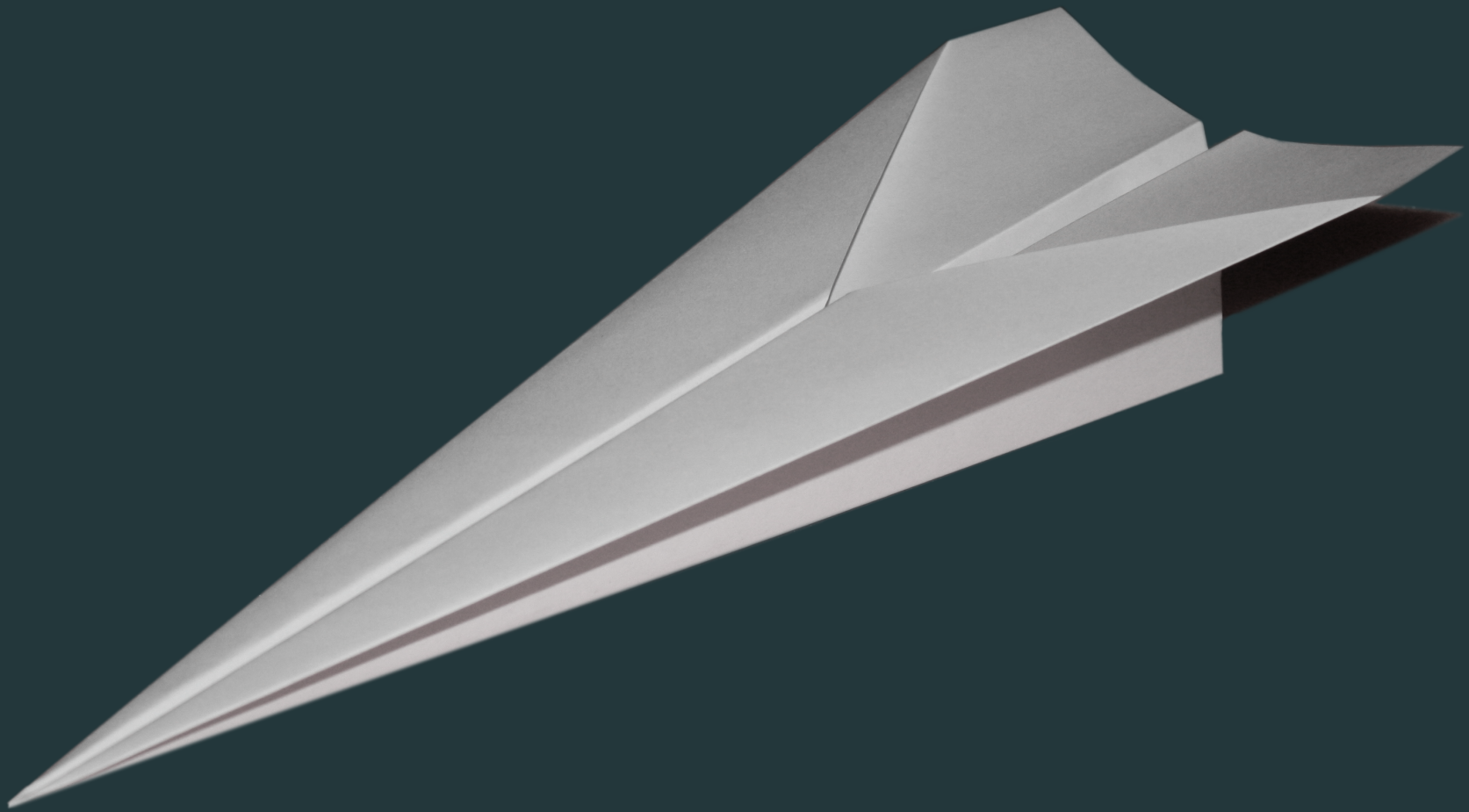


Figure 1: Paper airplane

Throwing paper airplanes blind???

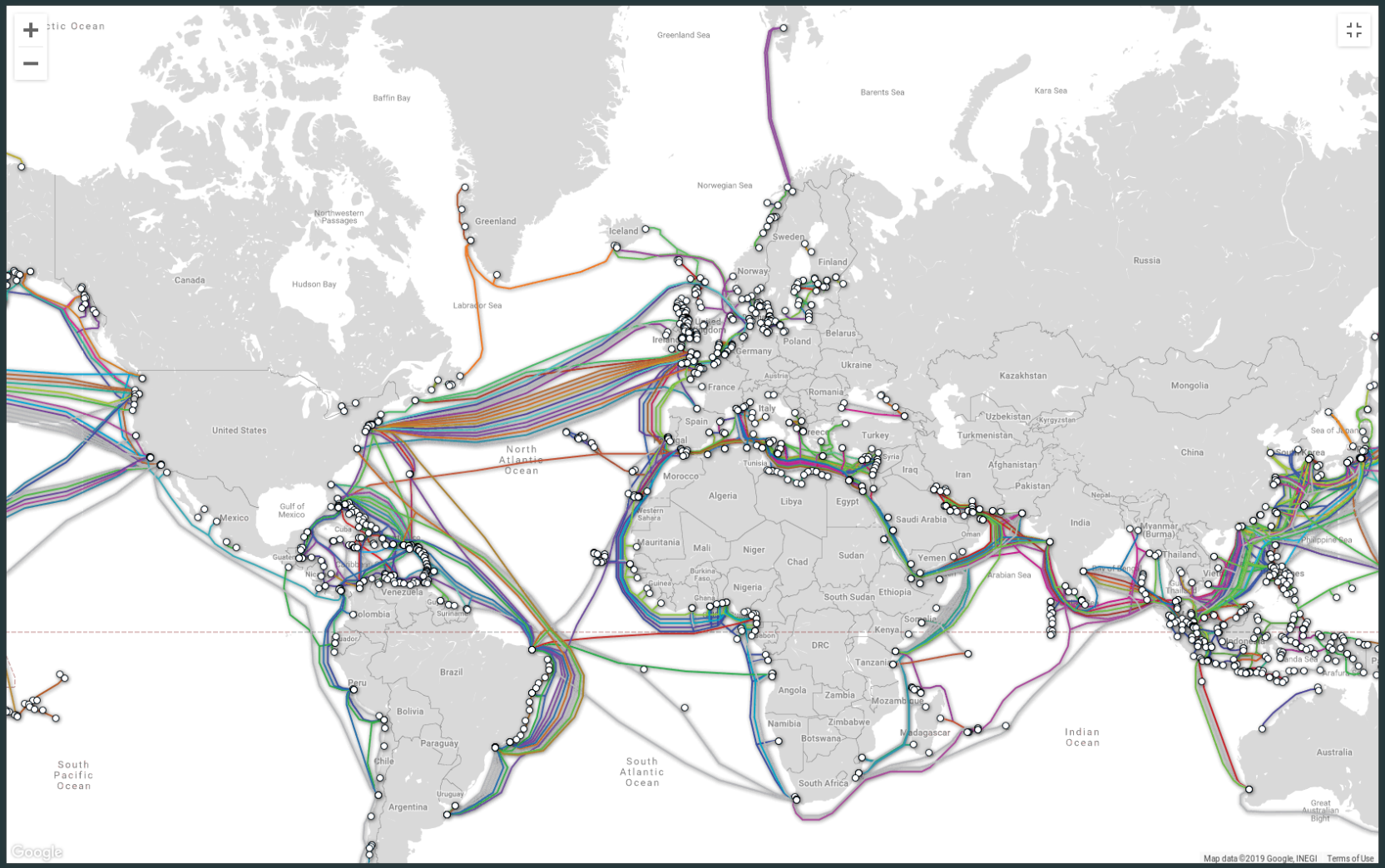
- Surprisingly accurate metaphor.
- You might miss! Need to acknowledge receipt
- You might throw at different speeds! Need sequence numbers
- these things (and more!) handled by the TCP protocol

Ok, but what's really going on?

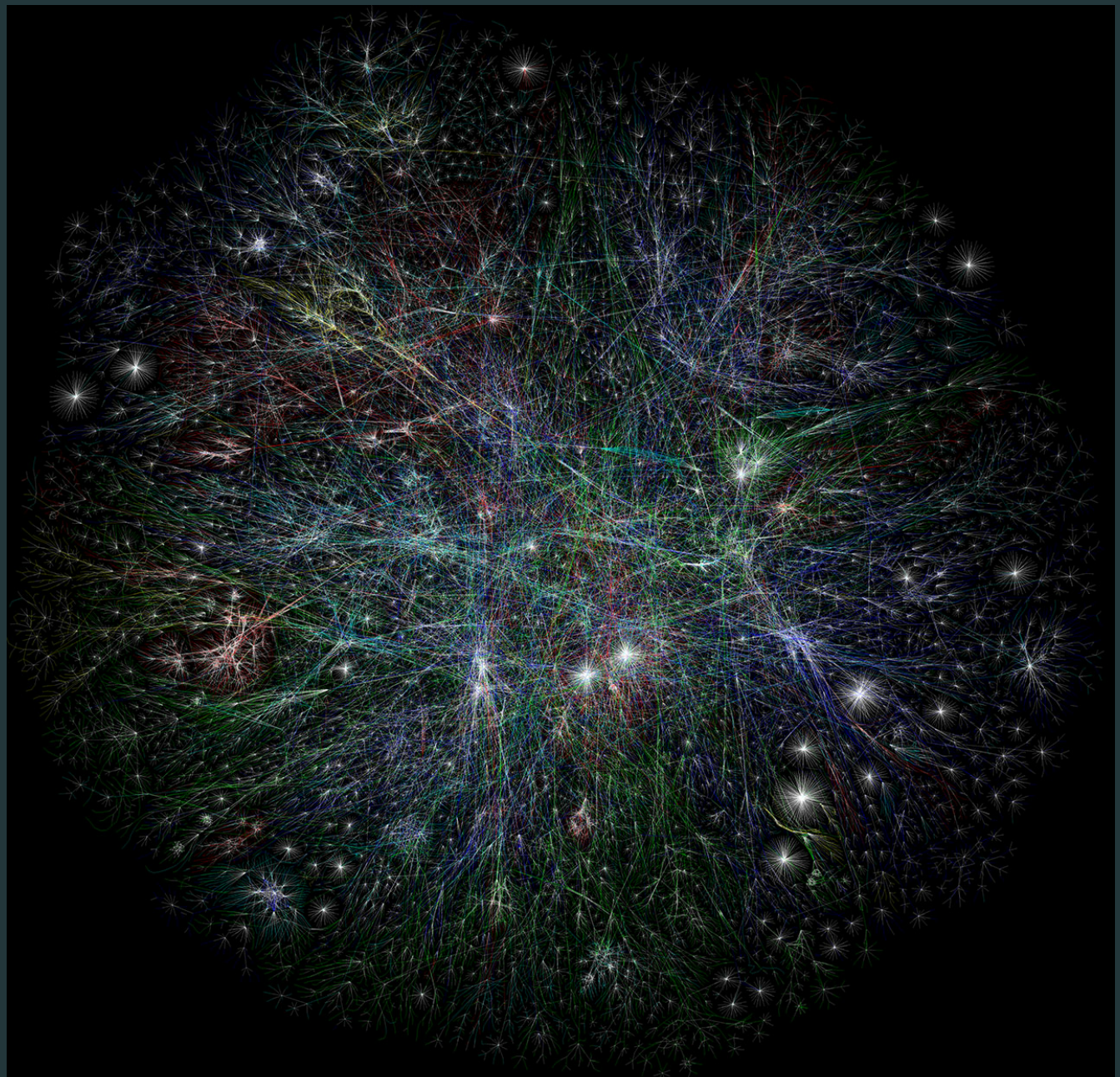
- Network cards convert local communication to network communication
- Limited memory and processing power
- Packet is small, "safe" size
    - will always fit in network hardware memory
    - is very fast to transfer; can't easily "split" a packet
- once a packet arrives, networking hardware moves it as "data" to your application
- gives the illusion of a stream of packets
    - or an unending torrent of paper airplanes...

WHAT IS... THE INTERNET

- interconnected networks of computers



WHAT IS... THE INTERNET



Ok, smaller scale

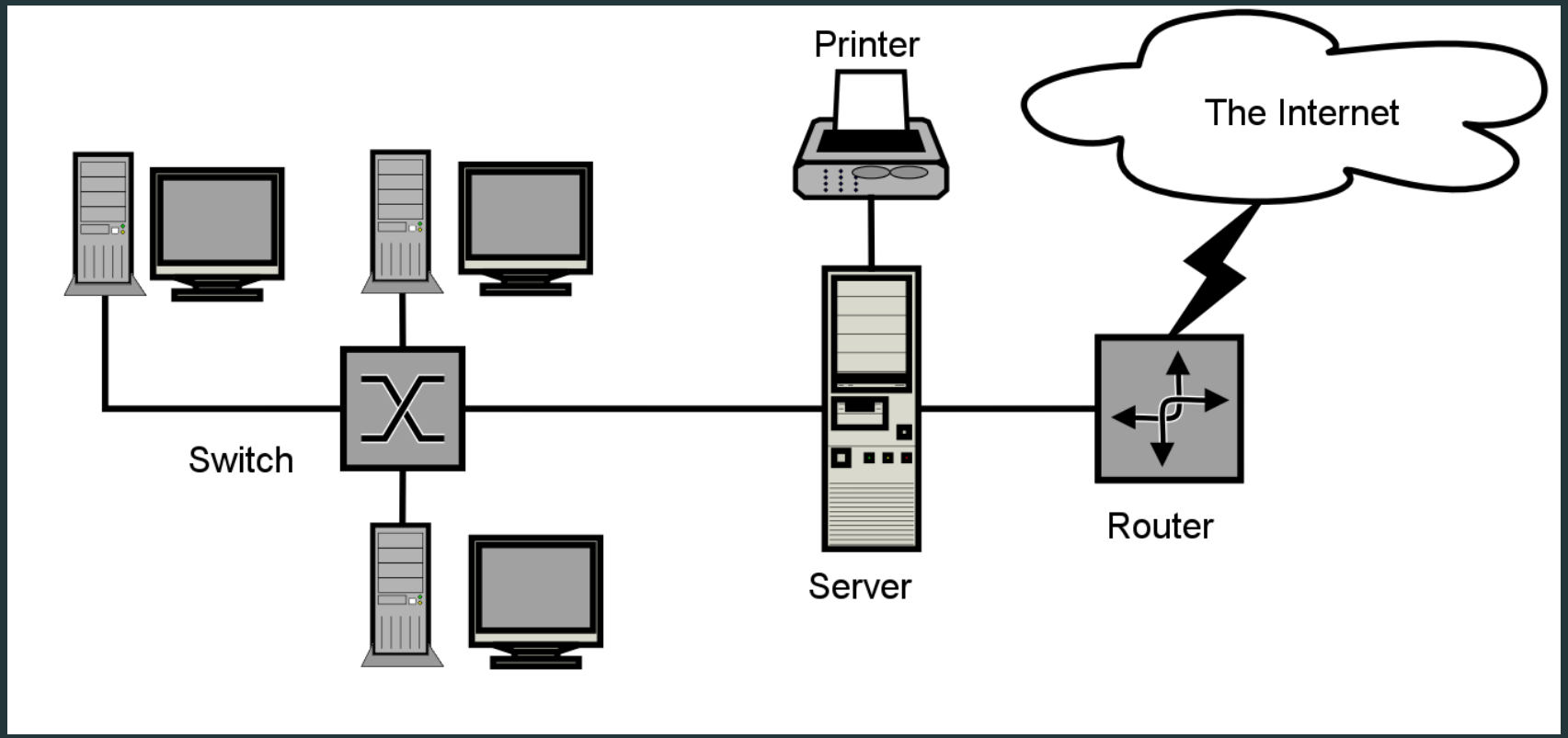


Figure 4: Small network

Finding your target

- You are *directly* connected to a switch
  - you send all your traffic there
  - the *switch* needs to know where to forward it
- Need an *address*: a destination the switch can understand
- We use IP addresses
  - just a sequence of numbers
- Can also *broadcast*
  - everyone gets it
  - usually blocked by firewalls outside of your local network

IPv4 Addresses:

- Usually displayed as `XXX.XXX.XXX.XXX`
  - example: `192.168.1.101`
  - example: `128.84.216.194`
- GLOBALLY routable: (most) IP addresses globally unique!
  - a few small exceptions: `192.168.*`, `10.*`
  - You can use these locally, but nobody can reach them from the wider internet.
  - think of them like private roads in the address system.
- How do we know they're globally unique?
  - Convention! The ICANN tells you what your number is, gets angry when you use the wrong one

Getting an IP address

- IP addresses change based on your network
- Each internet connection has its own “slice” of the IP space
  - computers attached to that network use its “slice”
- Can just give yourself an IP address
  - things break if you go outside the slice
- Can ask for help via DHCP
  - some server will give you an address
  - it probably knows which addresses are valid
  - it can tell when they’re used.
- ever see a `169.254.XX.YY` address? That’s your computer wildly guessing!

MAC Addresses:

- based on your actual exact hardware
- does not change based on network
- only used for *local* forwarding
    - within the same route
    - we'll talk about that later
- How switches actually connect to your device
- use the ARP protocol to map IP to MAC
    - Literally broadcast "who has `192.168.1.1`? Tell `192.168.1.5`"

Command break: ifconfig

configure your internet devices

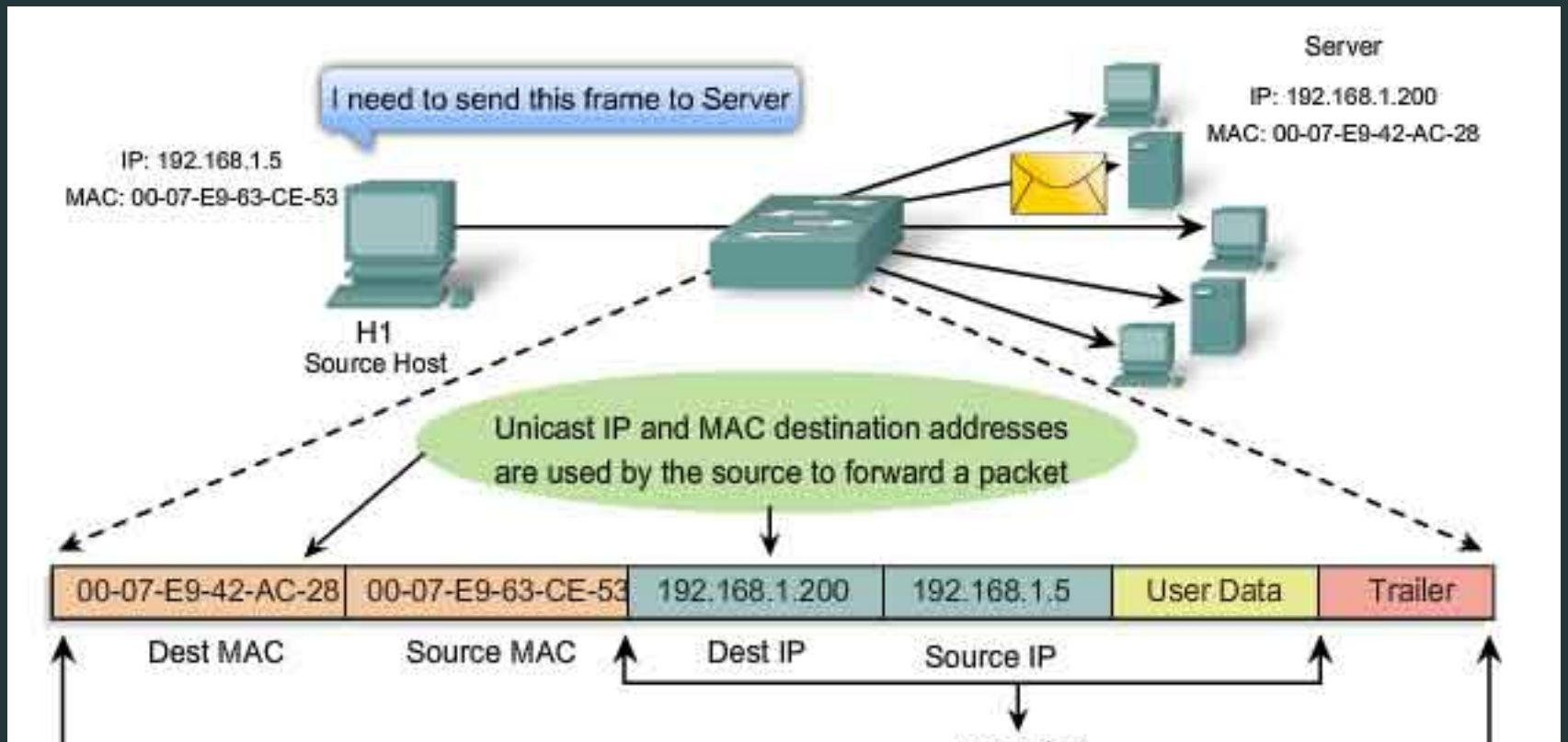
```
ifconfig [Options...]
```

```
lo: flags=73<UP,LOOPBACK,RUNNING>  mtu 65536
        inet 127.0.0.1  netmask 255.0.0.0
        inet6 ::1  prefixlen 128  scopeid 0x10<host>
        loop  txqueuelen 1000  (Local Loopback)
        RX packets 40  bytes 2357 (2.3 KiB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 40  bytes 2357 (2.3 KiB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

wlp3s0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        inet 10.132.6.227  netmask 255.255.128.0  broadcast 10.132.127.255
        inet6 fe80::4141:aa4f:3c83:5a88  prefixlen 64  scopeid 0x20<link>
        ether 00:23:15:f0:91:41  txqueuelen 1000  (Ethernet)
        RX packets 97595  bytes 34824177 (33.2 MiB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 69065  bytes 34033683 (32.4 MiB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0
```

Making packets

- Ethernet “frames” and IP “packets” are not exactly the same thing
- Like putting smaller envelopes in bigger ones
- “Wrap” Ethernet information around IP information



Routing packets

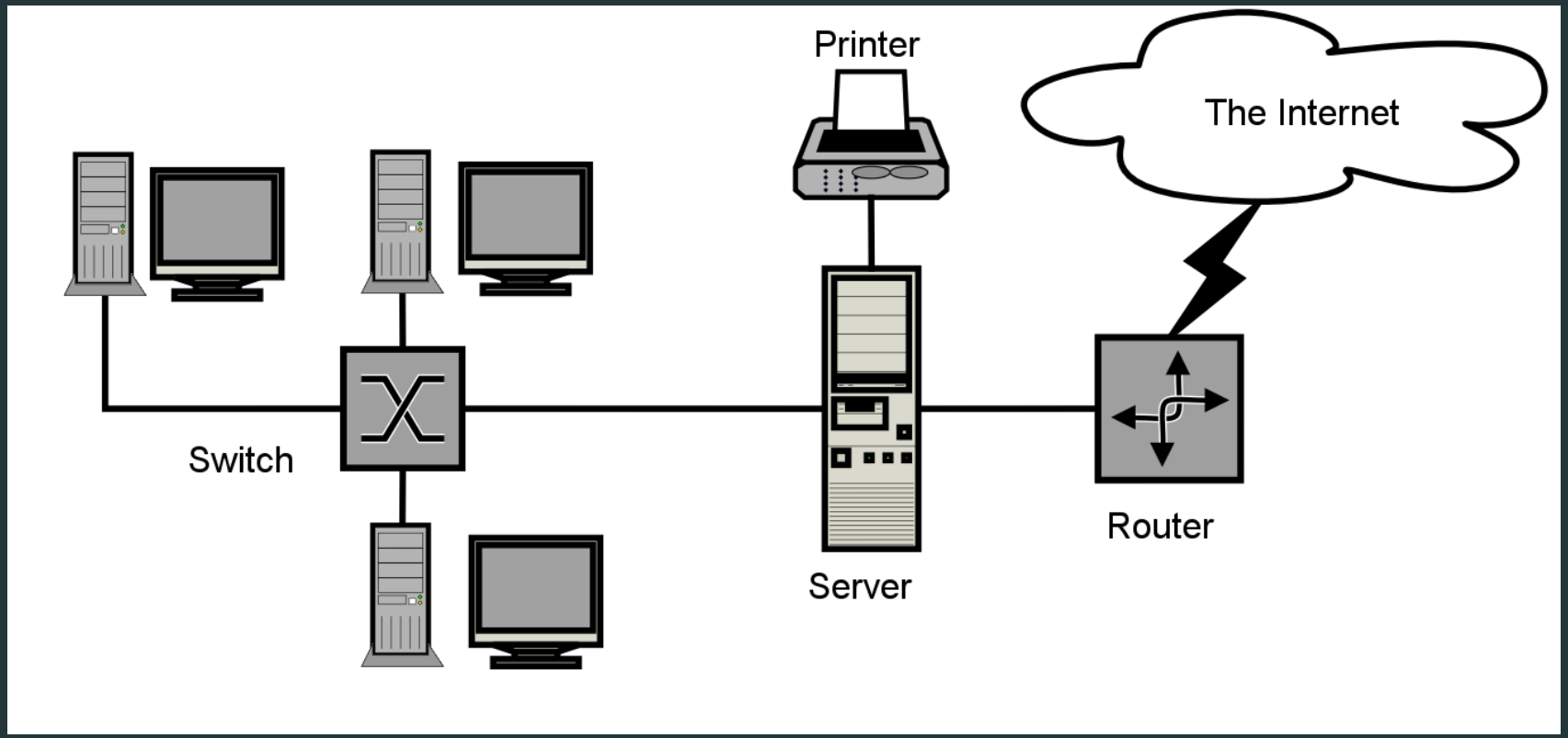


Figure 6: Small network

Routing packets

- *Routers* jump across network boundaries
- Limit of MAC protocol; MAC routes locally, IP routes globally
- Your *netmask* defines local IP addresses
  - Example: My IP is `192.168.1.100` and my netmask is `255.255.255.0`
  - Everything that starts with `192.168.1` is *local*; everything else needs *routing*
- Your *gateway* handles routing
  - Example: My IP is `192.168.1.100` and my gateway is `192.168.1.1`
  - Gateways have lots of IP addresses; they're connected to lots of networks!
  - Like this one Island in Canada...

Routing packets

- All IP addresses outside of local network use Router as initial destination
- Router re-packages packet for new network, acts as sender in that network
    - it will eventually hit a new network, and do that again

trace the route your packet takes

```
traceroute <dest_addr>
```

- lists each routing hop between you and destination
- displays *DNS name* or IP address

Traceroute example

Example:

```
 $ traceroute google.com
traceroute to google.com (172.217.12.174), 30 hops max, 60 byte packets
 1  rhodes1-ex-vl1245.net.cornell.edu (128.84.216.1)  1.372 ms  1.334 ms  1.355 ms
 2  core1-mx-xe-11-0-4.net.cornell.edu (128.253.222.161)  0.720 ms  0.706 ms core2-mx-xe-11-0
 3  wan2-mx-et-0-0-0.net.cornell.edu (128.253.222.58)  0.570 ms  0.568 ms  0.564 ms
 4  199.109.109.25 (199.109.109.25)  3.089 ms  3.019 ms  3.021 ms
 5  199.109.107.162 (199.109.107.162)  8.076 ms  8.042 ms  8.064 ms
 6  72.14.202.166 (72.14.202.166)  8.007 ms  8.083 ms  8.054 ms
 7  108.170.248.1 (108.170.248.1)  10.017 ms  10.052 ms  9.915 ms
 8  108.170.226.201 (108.170.226.201)  9.055 ms 108.170.226.199 (108.170.226.199)  9.017 ms 1
 9  lga25s62-in-f14.1e100.net (172.217.12.174)  8.996 ms  8.992 ms  8.961 ms
```

DNS names

- A big dictionary in the sky
- translates english *domain* names (like `google.com`) into IP addresses
- Also managed by ICANN

domain information groper

`dig [@`*DNS server*`] [`*domain name*`]`

- gives you a lot of information behind the domain name
- includes IP address, owner, owner's e-mail address, and more

dig example

```
 $ dig @1.1.1.1 google.com

; <<>> DiG 9.12.2-P2 <<>> @1.1.1.1 google.com
; (1 server found)
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 22816
;; flags: qr rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 0, ADDITIONAL: 1

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags:; udp: 1452
;; QUESTION SECTION:
;google.com.                    IN      A

;; ANSWER SECTION:
google.com.             215     IN      A       216.58.219.206

;; Query time: 10 msec
;; SERVER: 1.1.1.1#53(1.1.1.1)
;; WHEN: Wed Feb 20 10:51:56 EST 2019
;; MSG SIZE  rcvd: 55
```

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.