13 – Networking

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

Matthew Milano

February 20, 2019

Cornell University

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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???

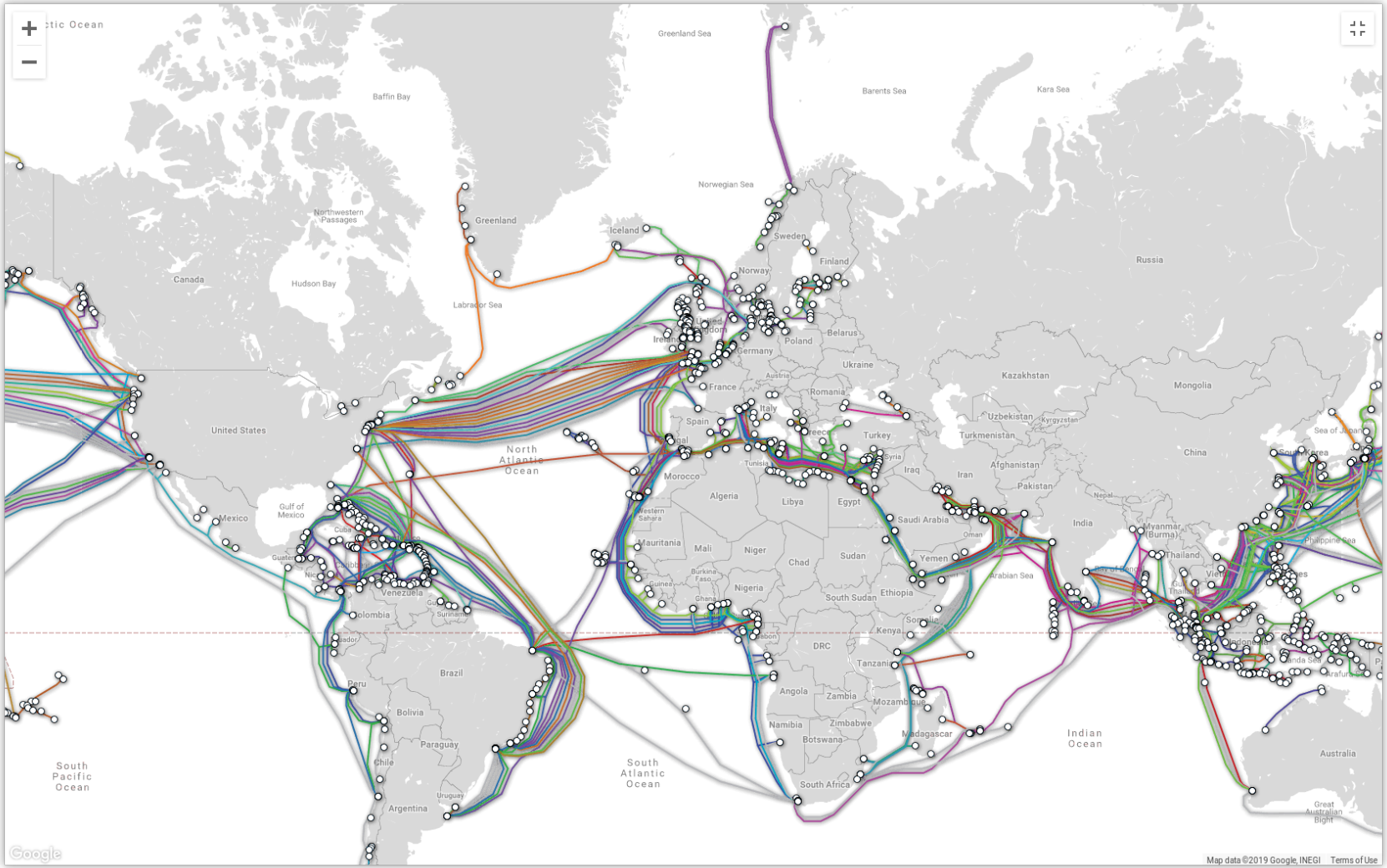
- Surprisingly accurate metaphor.
- You might miss! Need to acknowledge receipt
- You might throw at different speeds! Need sequence numbers
- these things (and more!) handled by the TCP protocol

Ok, but what's really going on?

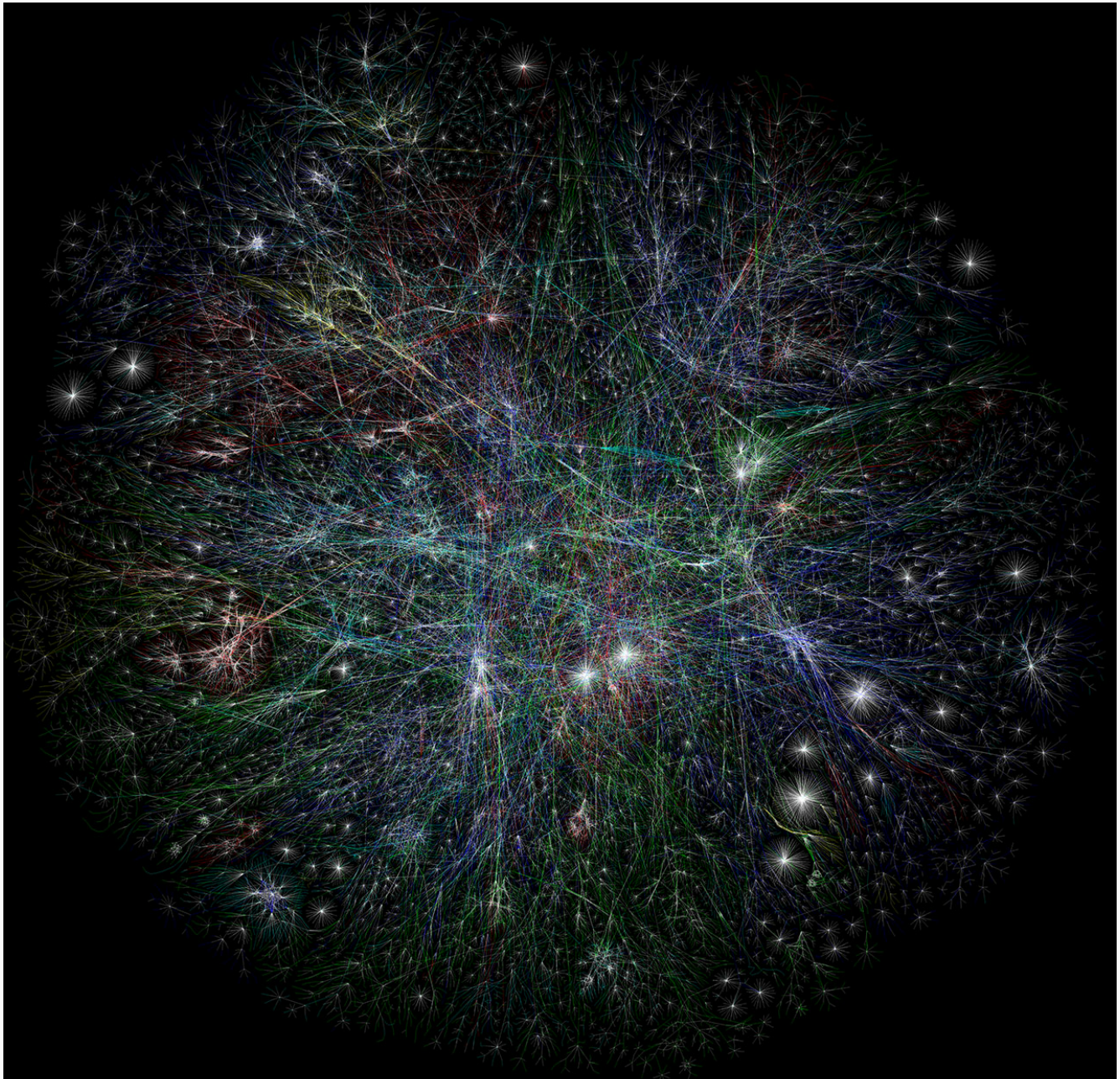
- Network cards convert local communication to network communication
- Limited memory and processing power
- Packet is small, "safe" size
    - will always fit in network hardware memory
    - is very fast to transfer; can't easily "split" a packet
- once a packet arrives, networking hardware moves it 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

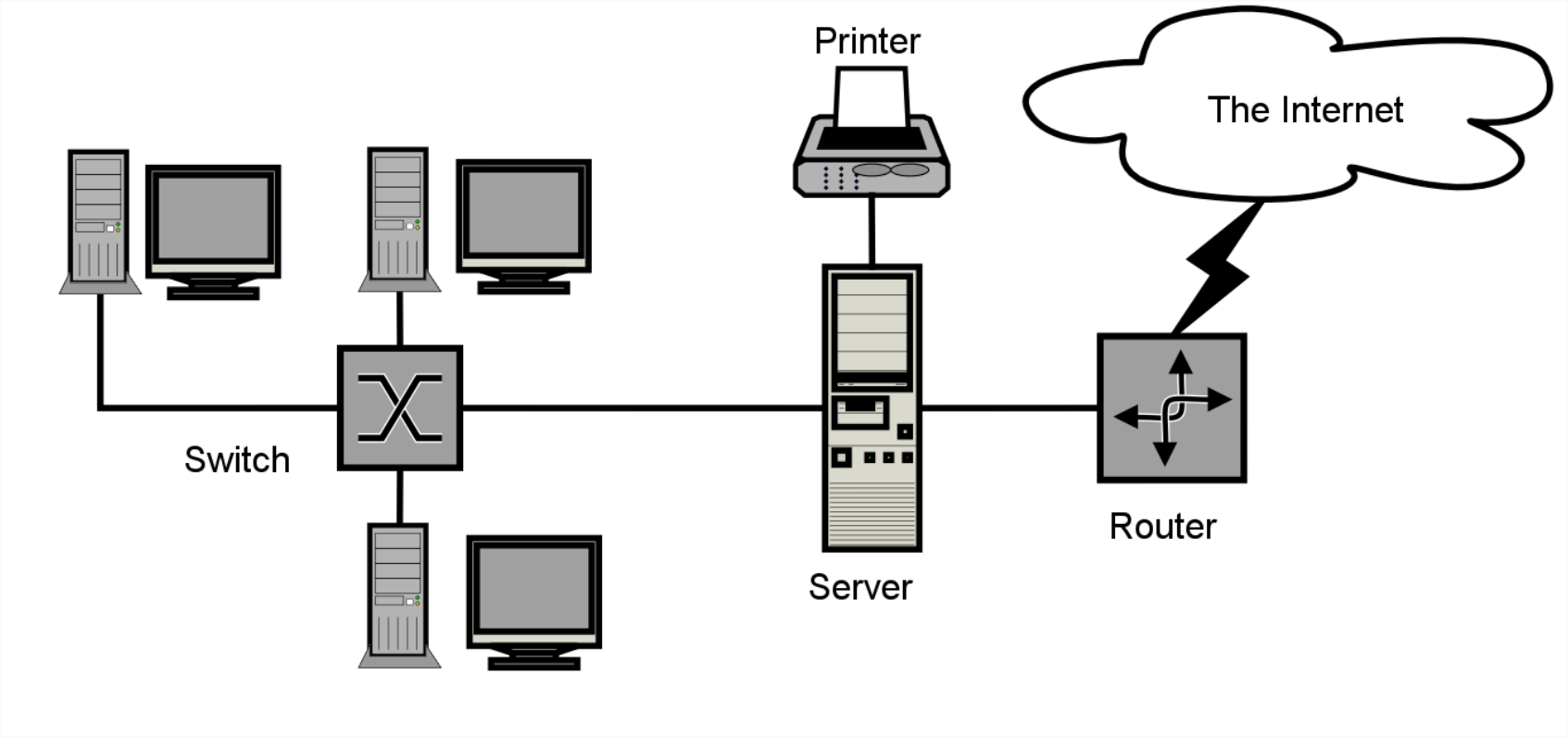


Figure 4: Small network

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

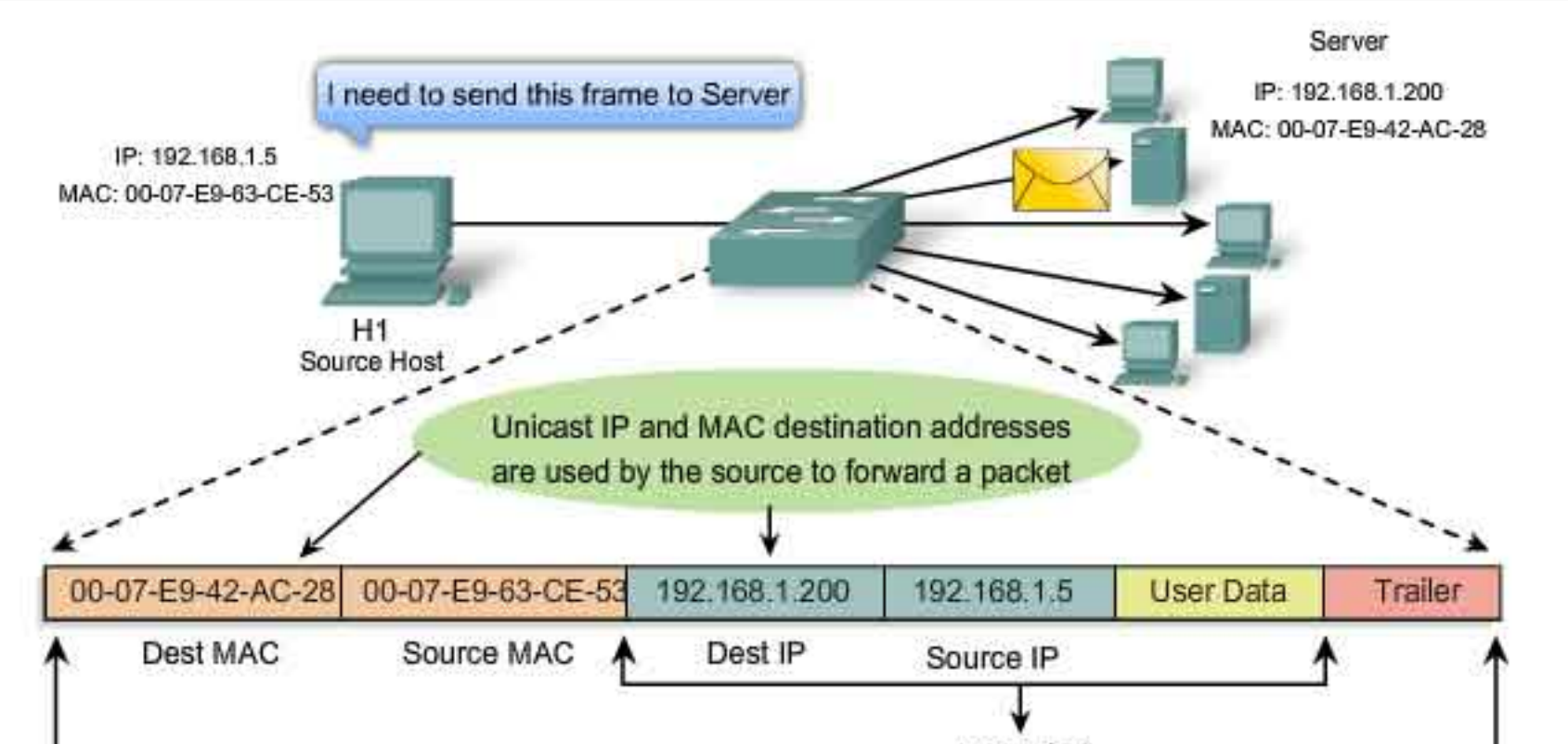
```
ifconfig [Options...]
```

```
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

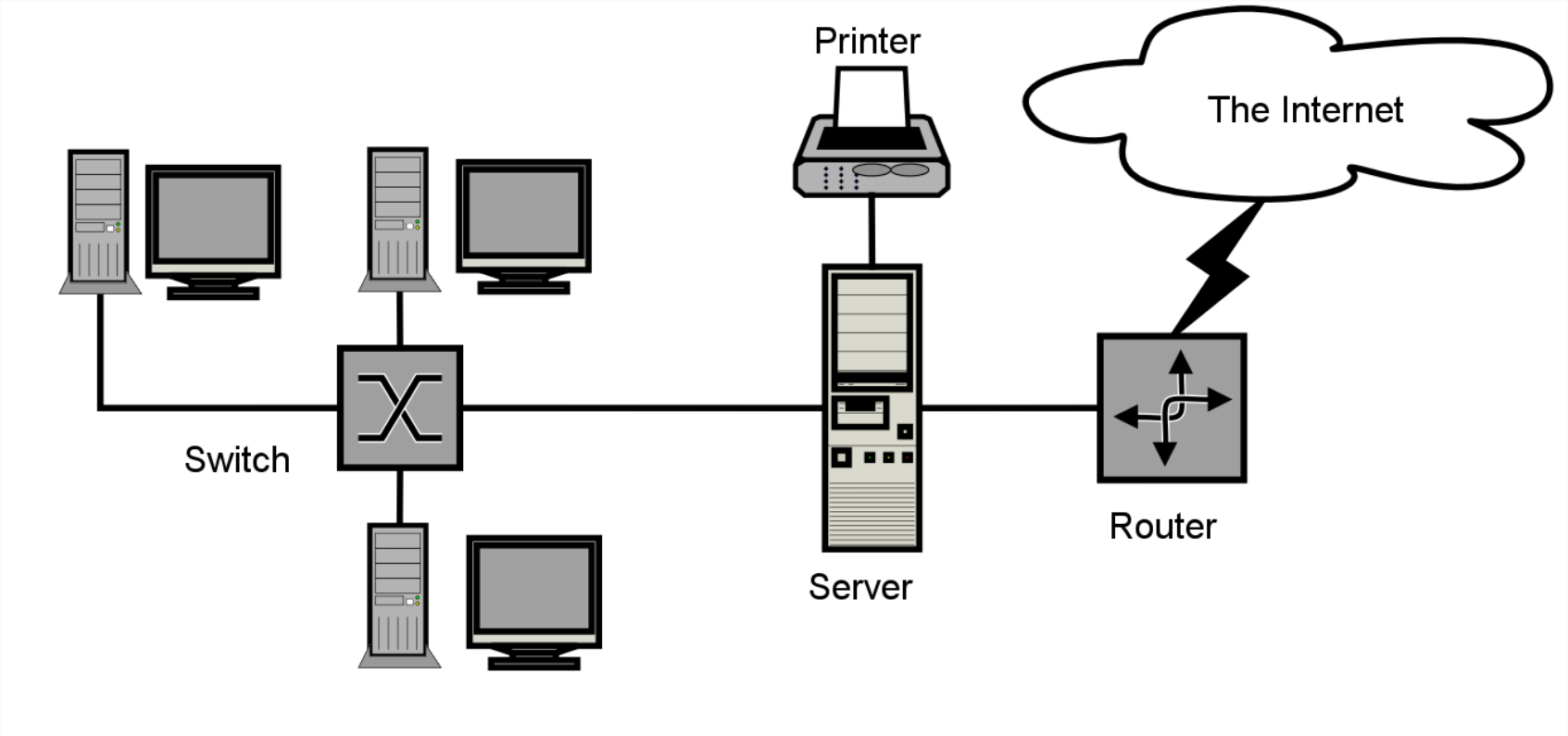


Figure 6: Small network

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
```

References

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