Lecture 1: Introduction

COMP 332, Fall 2018

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Acknowledgements: materials adapted from Computer Networking: A Top Down Approach 7th edition: ©1996-2016, J.F Kurose and K.W. Ross, All Rights Reserved as well as from slides by Abraham Matta at Boston University and some material from Computer Networks by Tannenbaum and Wetherall.

Today

1. Announcements
   - Homework 1 out Wed., Sept. 5, due Wed. Sept. 12

2. Administrivia

3. Computer networks
   - overview

4. Building a network
   - how to connect devices
   - how to connect processes on devices
   - how to share resources

Administrivia

Course webpage

Everything posted here

- http://vumanfredi.web.wesleyan.edu/comp332-f18/

Please sign up for piazza

- https://piazza.com/wesleyan/spring2018/comp332

Grade breakdown

- 40%: 2 exams
- 60%: 10 homework assignments, no scores dropped
  - mix of written and (multi-assignment) programming projects

Late days

- 4 free days, use at most 2 for any assignment
- Once used, you will lose 15% of grade for each 24 hours late

Getting started

Python3

- we'll review as needed, see class resources webpage
  - please check you have python3 installed!
    - type python3 at terminal prompt
  - tutorials and other resources posted on course website

Python help available

- at SCIC on 1st floor of Exley

vim and python

- create a .vimrc file in your home directory
- put lines in block in .vimrc and save it
- open new terminal and use vim
  - should see color, line numbers, etc.

```
syntax on
filetype indent plugin on
set modeline
set number
autocmd BufWritePre * %s/\s\+$//ei
au BufNewFile,BufRead *.py
\ set tabstop=4
\ set softtabstop=4
\ set shiftwidth=4
\ set textwidth=79
\ set expandtab
\ set autoindent
\ set fileformat=unix
```

Homework

1st homework out Wednesday

- warm-up homework: implement tic-tac-toe in python
- 2nd homework is to implement distributed tic-tac-toe using sockets

Submissions

- https://wesfiles.wesleyan.edu/home/vumanfredi/web/comp332-f18/submissions/hw#/USERNAME/
- substitute your wesleyan username for USERNAME

Important!

- put your name inside every file!
- file formats: only .py, pdf, .txt so my printing script works
  - if I can’t print it, I can’t grade it :-)
- filename should match what is specified

Looking forward

1st few weeks

- high-level overview of components of network
- familiarity with terminology
- covers a lot of material!

Rest of course

- digging into details of what we talked about in 1st few weeks
- will talk about each layer and component in much greater depth
- having had high-level should help give context for details

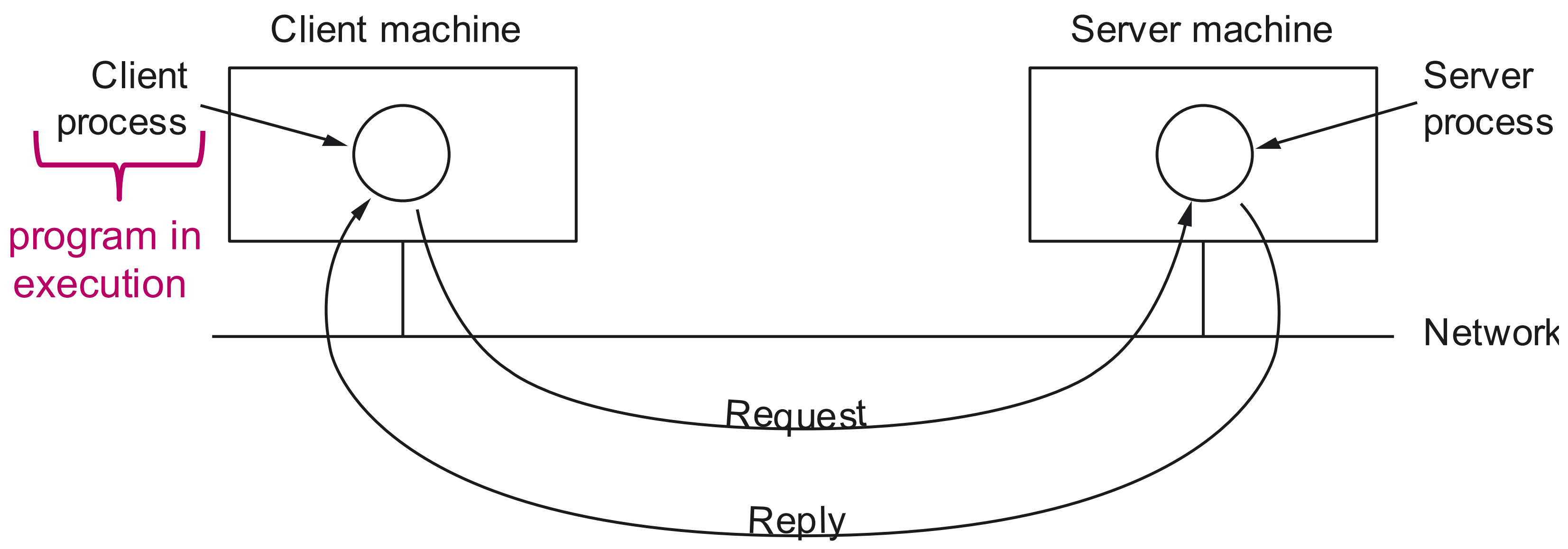
If you have questions or concerns please come talk to me

Computer Networks

OVERVIEW

What's a computer network?

2 or more computing devices able to exchange data



Necessary network functionality

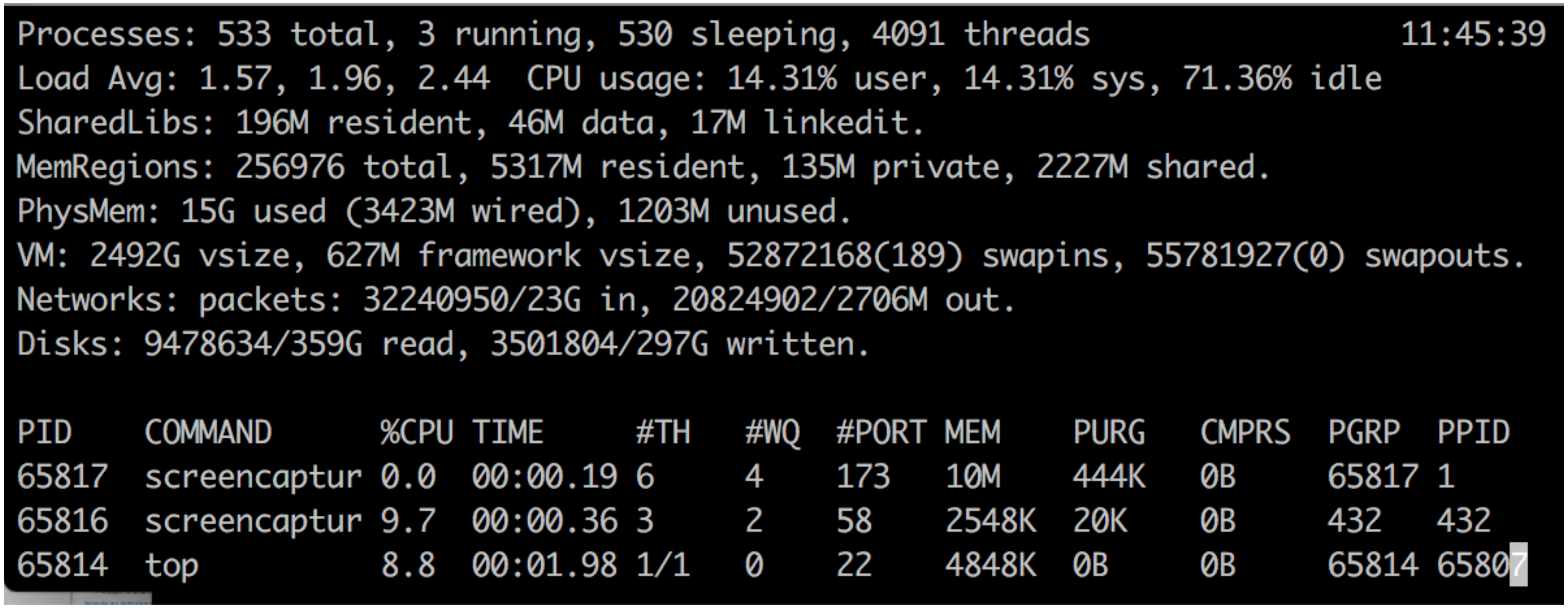
1. Specify remote machine
2. Connect to it (possibly some handshaking)
3. Transfer data
4. Close connection

More on processes

Process: program in execution

- your machine has many processes running on it

"top" command (or type "ps auxwww" in terminal)



```
Processes: 533 total, 3 running, 530 sleeping, 4091 threads                   11:45:39
Load Avg: 1.57, 1.96, 2.44  CPU usage: 14.31% user, 14.31% sys, 71.36% idle
SharedLibs: 196M resident, 46M data, 17M linkedit.
MemRegions: 256976 total, 5317M resident, 135M private, 2227M shared.
PhysMem: 15G used (3423M wired), 1203M unused.
VM: 2492G vsize, 627M framework vsize, 52872168(189) swapins, 55781927(0) swapouts.
Networks: packets: 32240950/23G in, 20824902/2706M out.
Disks: 9478634/359G read, 3501804/297G written.

PID    COMMAND      %CPU TIME     #TH    #WQ   #PORT MEM    PURG   CMPRS  PGRP  PPID
65817  screencaptur 0.0  00:00.19 6      4     173   10M    444K   0B     65817 1
65816  screencaptur 9.7  00:00.36 3      2     58    2548K  20K    0B     432   432
65814  top          8.8  00:01.98 1/1    0     22    4848K  0B     0B     65814 65807
```

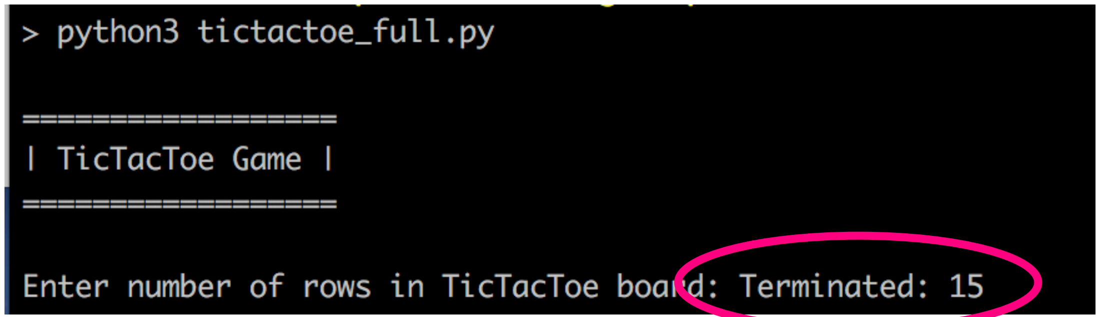
Killing processes

Use “ps” to get process id

- type ps auxwww | grep NAME

Use “kill” to terminate process

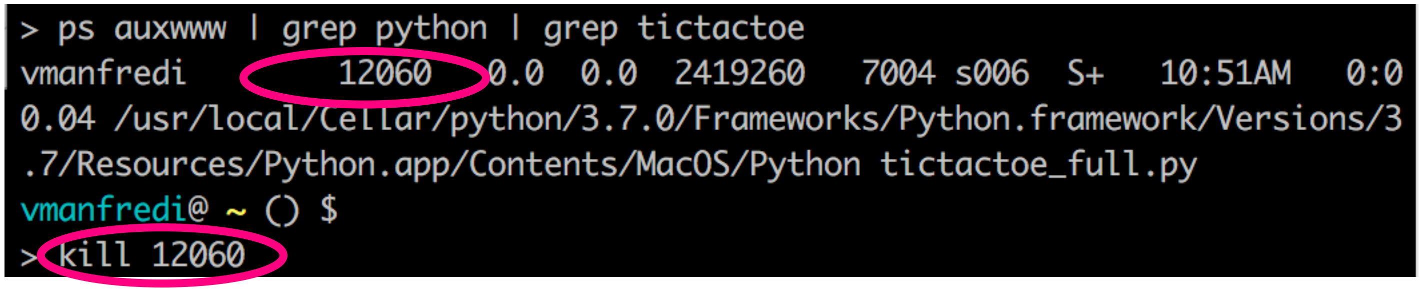
- kill processid
- kill -9 processid   // nuclear option: don’t let process clean up



```
> python3 tictactoe_full.py

===================
| TicTacToe Game |
===================

Enter number of rows in TicTacToe board: Terminated: 15
```



```
> ps auxwww | grep python | grep tictactoe
vmanfredi         12060   0.0  0.0  2419260   7004 s006  S+    10:51AM   0:0
0.04 /usr/local/Cellar/python/3.7.0/Frameworks/Python.framework/Versions/3
.7/Resources/Python.app/Contents/MacOS/Python tictactoe_full.py
vmanfredi@ ~ () $
> kill 12060
```

Distributed system vs. computer network

Distributed system

- software system built on top of computer network

Example

- $\underbrace{\text{World Wide Web}}_{\text{Distributed system}}$ is built on top of $\underbrace{\text{Internet}}_{\text{Computer network}}$

Why build a computer network?

User view

- sharing resources
  - hardware: printers, compute servers, cloud computing
  - software: word, Matlab
  - data: customer records, inventory, financials, p2p file sharing
  - information: web-browsing, Wikipedia, search
- communication
  - email, text, voIP, screen share, video conference, social network
- electronic commerce
  - online shopping, banking, business
- entertainment
  - multi-user network games, video streaming

Why build a computer network?

Programmer view

- to support distributed applications
  - e.g., web, ftp, …
- most functionality in software
  - many applications, easy to create
- general-purpose, increasingly faster computers
  - can manage many processes
- new functionality easily added ``inside'' network
  - e.g., Content Distribution Net

Why should you care?

Networks of processes are ubiquitous

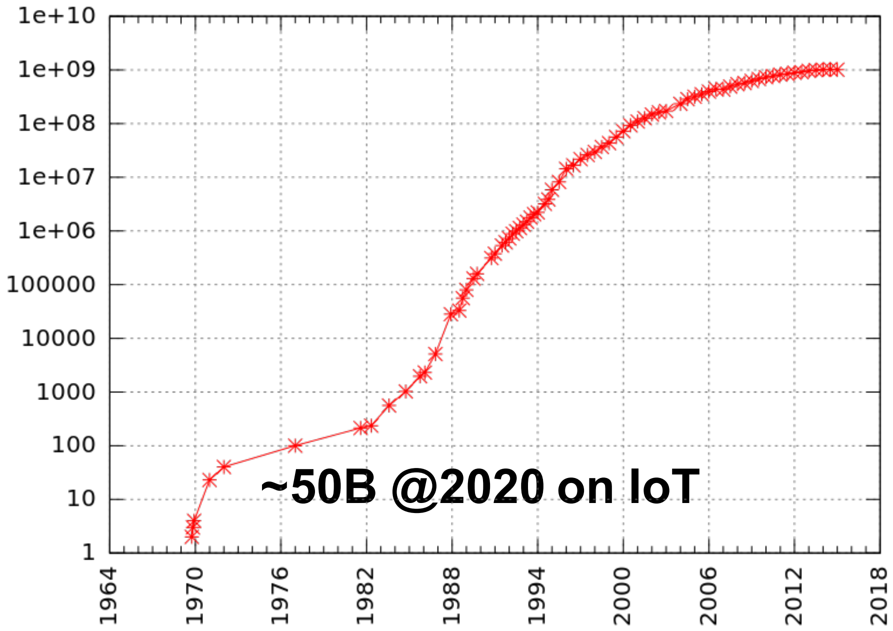
– to support a myriad of distributed applications

Networks are getting larger and more complex

– need experts in leveraging & managing them

YOU'RE STILL BURYING YOUR BONES? I STORE MINE IN THE CLOUD NOW.
CARTOONSTOCK .com
Search ID: jcen2000

Number of hosts on Internet



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Many "networking" firsts originated not too far away

First optical (light) "one-if-by-land-and-two-if-by-sea" signals

- used to signal that the British are coming in 1775

First telegraph (Morse code)

- used by Boston Fire Alarm Telegraph System for reporting fires in 1852

First transatlantic radio message

- from Nova Scotia to England in 1902

First switches and email message

- at BBN in 1967-1972

Paul Revere

Guglielmo Marconi

How to build a computer network?

1. Need way to connect devices
2. Need way to connect processes on devices
3. Need way to share-resources efficiently

We'll overview general networks today. But in future our focus will primarily be Internet

Building a Network

HOW TO CONNECT DEVICES

Building blocks

Nodes: laptop, server, router, switch, cell phone, UAV, IoT devices, …

Links: copper wire, coaxial cable, optical fiber, radio, …

Telephone lines

Ethernet, up to 10 Gbps

Cable TV infrastructure

Shared/broadcast medium, more people using simultaneously, less bandwidth each gets

10's of Mbps

Glass fiber carrying light pulses (bits)

Forms Internet core: carries lots of traffic. Low bit error rate since unaffected by electromagnetic. noise

up to 100s of Gbps

Kbps = 10^3 bits per second
Mbps = 10^6 bits per second

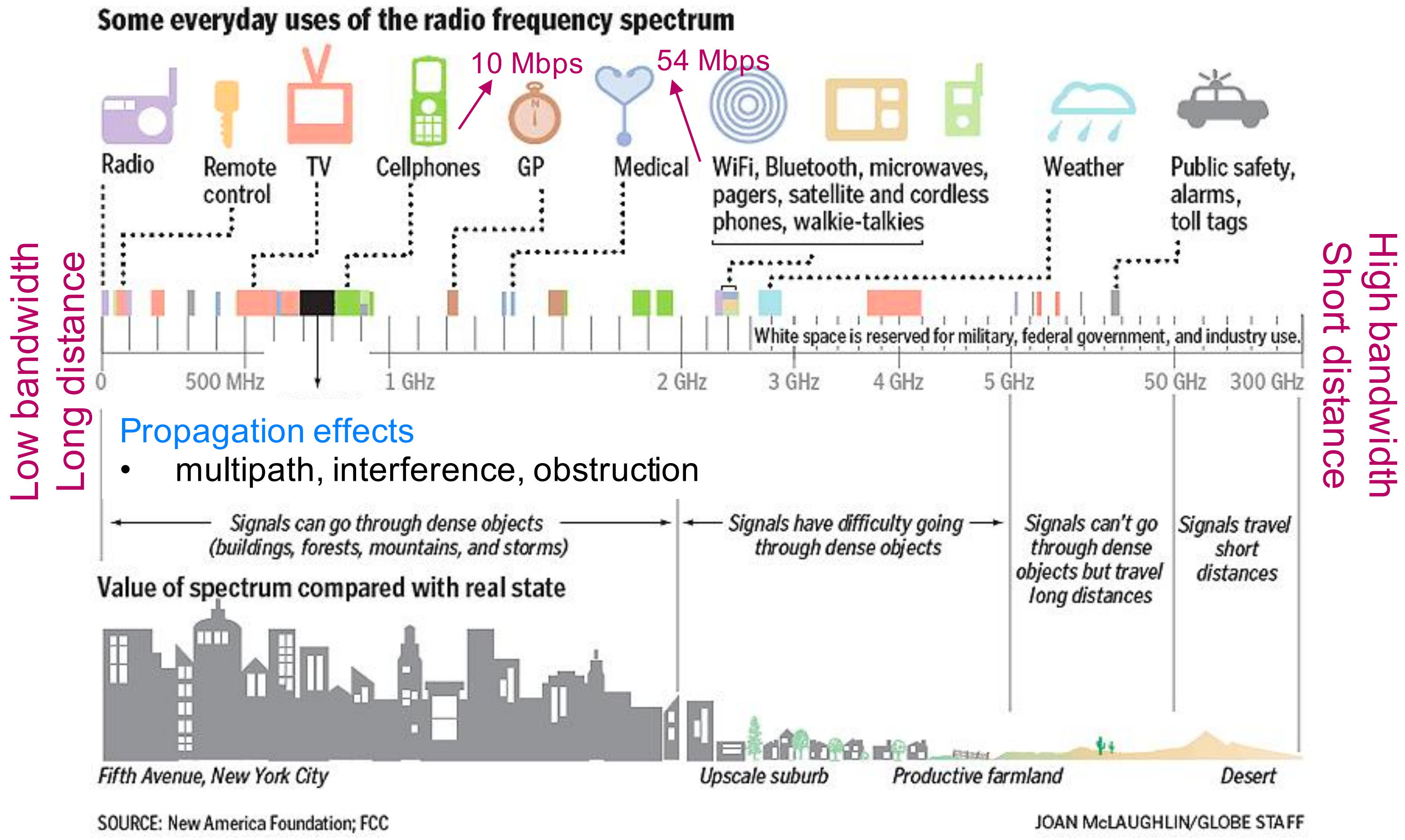
→ **Wired link media**

Building blocks

Nodes: laptop, server, router, switch, cell phone, UAV, IoT device…

Links: copper wire, coaxial cable, optical fiber, radio, ➡ **Wireless**

Signal carried in electromagnetic spectrum } Shared, typically broadcast, medium



Some everyday uses of the radio frequency spectrum
10 Mbps
54 Mbps
Radio
Remote control
TV
Cellphones
GP
Medical
WiFi, Bluetooth, microwaves, pagers, satellite and cordless phones, walkie-talkies
Weather
Public safety, alarms, toll tags
White space is reserved for military, federal government, and industry use.
0
500 MHz
1 GHz
2 GHz
3 GHz
4 GHz
5 GHz
50 GHz
300 GHz
Low bandwidth
Long distance
High bandwidth
Short distance
Signals can go through dense objects (buildings, forests, mountains, and storms)
Signals have difficulty going through dense objects
Signals can't go through dense objects but travel long distances
Signals travel short distances
Value of spectrum compared with real state
Fifth Avenue, New York City
Upscale suburb
Productive farmland
Desert
SOURCE: New America Foundation; FCC
JOAN McLAUGHLIN/GLOBE STAFF

Propagation effects

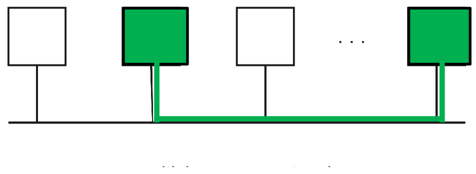
- multipath, interference, obstruction

Connecting devices with direct links

Point-to-point

E.g., dial-up, Digital Subscriber Line (DSL))

Multiple access

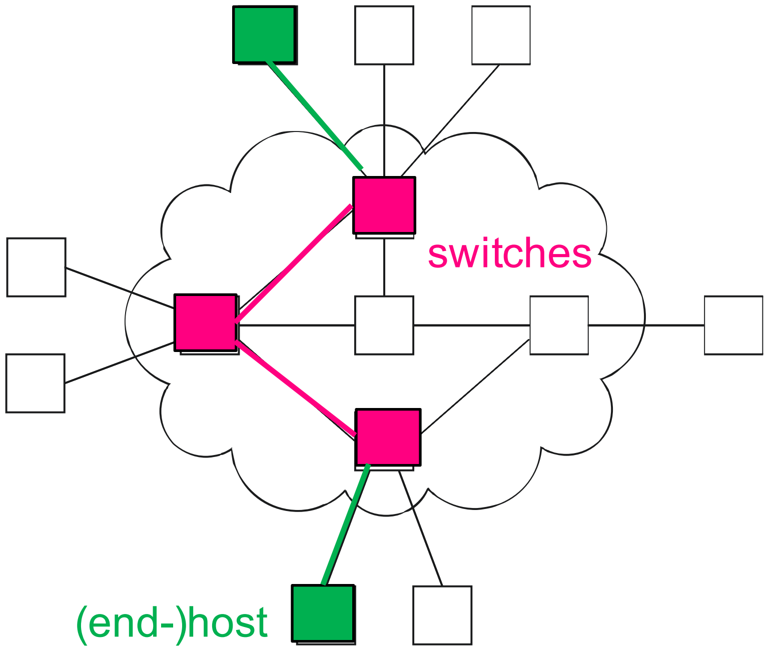


LAN environment

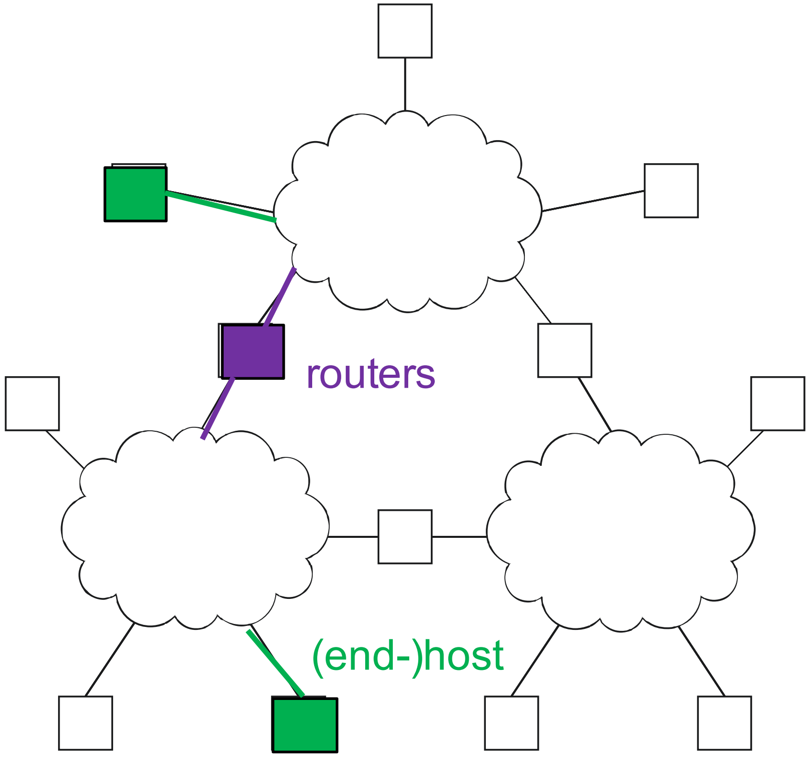
Need MAC (Medium Access Control) protocol
to control access to shared medium. E.g., shared Ethernet, Hybrid Fiber Coaxial (HFC) upstream channel, wireless

Connecting devices with switches and routers

- Indirect connectivity
  - switched network



- Internetwork
  - routers: connect networks



- A network can be defined recursively
  - 2 or more devices connected by a physical link
  - 2 or more networks connected by 2 or more devices

How do devices identify and find each other?

Addressing

- address is byte-string that identifies device; usually unique

Routing

- algorithm determining how routers forward messages toward destination device based on address

Types of addresses

- unicast: device-specific
- broadcast: all devices on network
- multicast: some subset of device on network

Internet addresses example

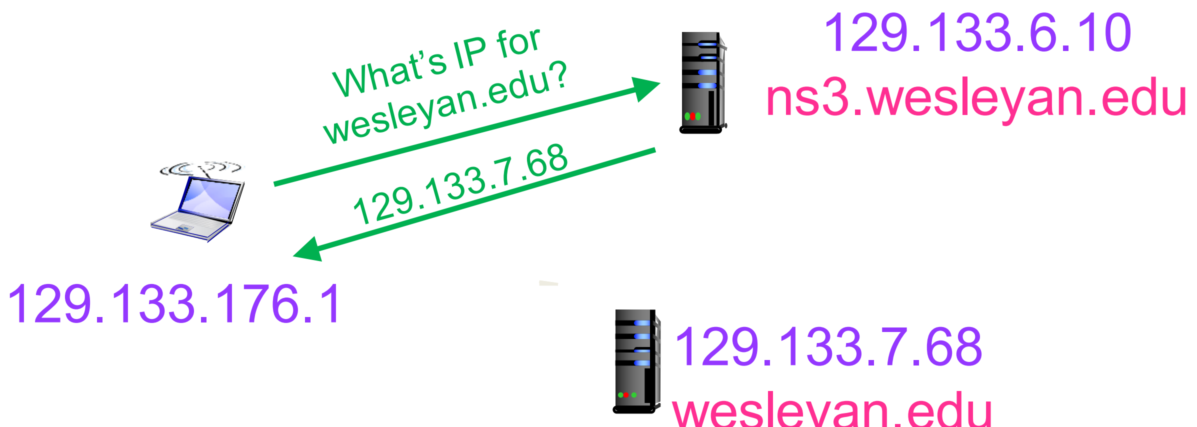
Every device on Internet has Internet Protocol (IP) address

- string of #s interpretable by computer
- assigned when host joins network connected to Internet

129.133.176.1

Some IP addresses are associated with a domain name

- use equivalent of phone book to do mapping

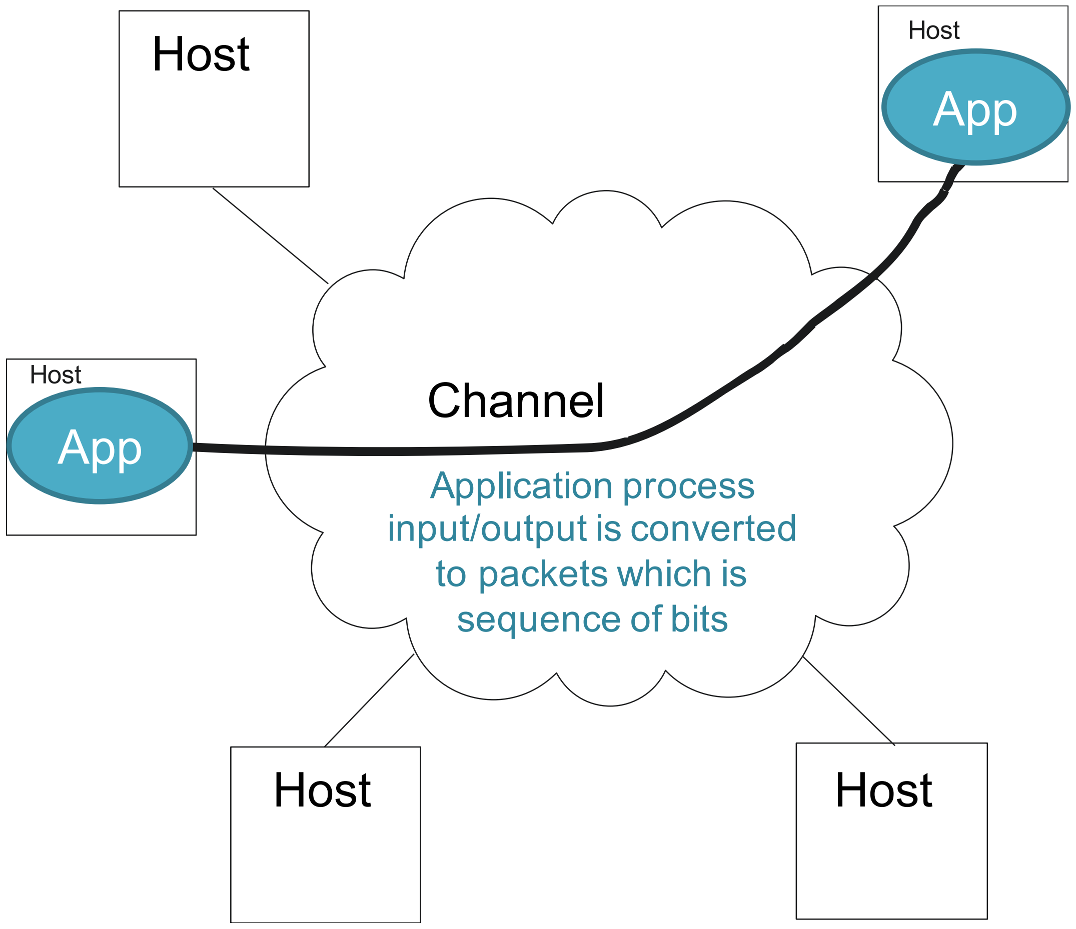


Building a Network

HOW TO CONNECT PROCESSES ON DEVICES

Processes, not devices, are communicating

How do processes running on different devices communicate?


Host
Host
App
Host
App
Channel
Application process input/output is converted to packets which is sequence of bits
Host
Host

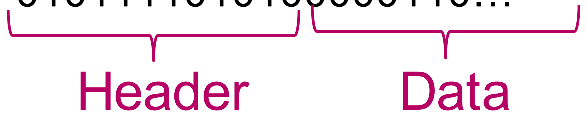
Bit

– propagates over links between src/dest

Packet

– sequence of bits

– 01011110101000000110…



Typical goals for communication channels

Reliable

- no loss, no errors, no duplication, in-order
- for file access and digital libraries

Secure

- privacy, authentication, message integrity

Delay-bounded

- for real-time voice and video

What goes wrong in network?

All sorts of things …

- bit-level errors (electrical interference)
- packet-level errors (bit errors, congestion)
- link and node failures
- packets are delayed
- packets are delivered out-of-order
- third parties eavesdrop

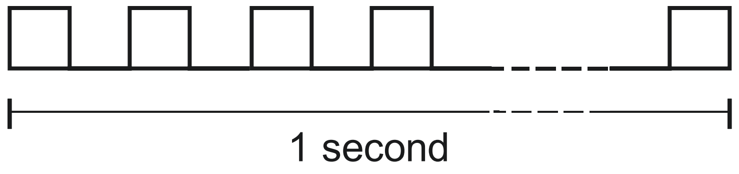
Channel needs to work even when things go wrong

- key problem
  - fill in gap between what applications expect and what underlying technology provides

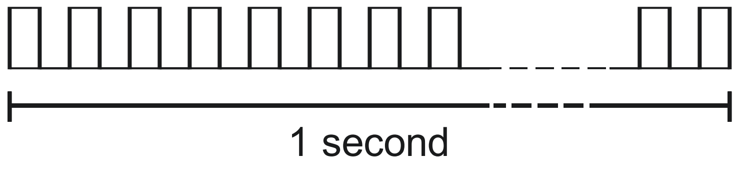
Quantifying channel performance

Bit Rate (aka throughput aka capacity)

- amount of data that can be transmitted per unit time
  - link versus end-to-end
- measurement units
  - Kbps = 10^3 bits per second
  - Mbps = 10^6 bits per second
  - Gbps = 10^9 bits per second



1Mbps
(each bit 1 microseconds wide)



2 Mbps
(each bit 0.5 microseconds wide)

Quantifying channel performance

Delay

- time to send packet from host A to host B
  - example: 24 milliseconds (ms)
  - sometimes interested in round-trip time (RTT)
    - include time to get reply back from host B

- components
  - Total Delay = **Processing** + **Propagation** + **Transmission** + **Queue**
  - **Propagation** Delay = Distance / SpeedOfLight
  - **Transmission** Delay = Packet length / Bit Rate

- speed of light
  - 3.0×10^8 meters/second in a vacuum
  - 2.3×10^8 meters/second in a cable
  - 2.0×10^8 meters/second in a fiber

Building a Network

HOW TO SHARE RESOURCES

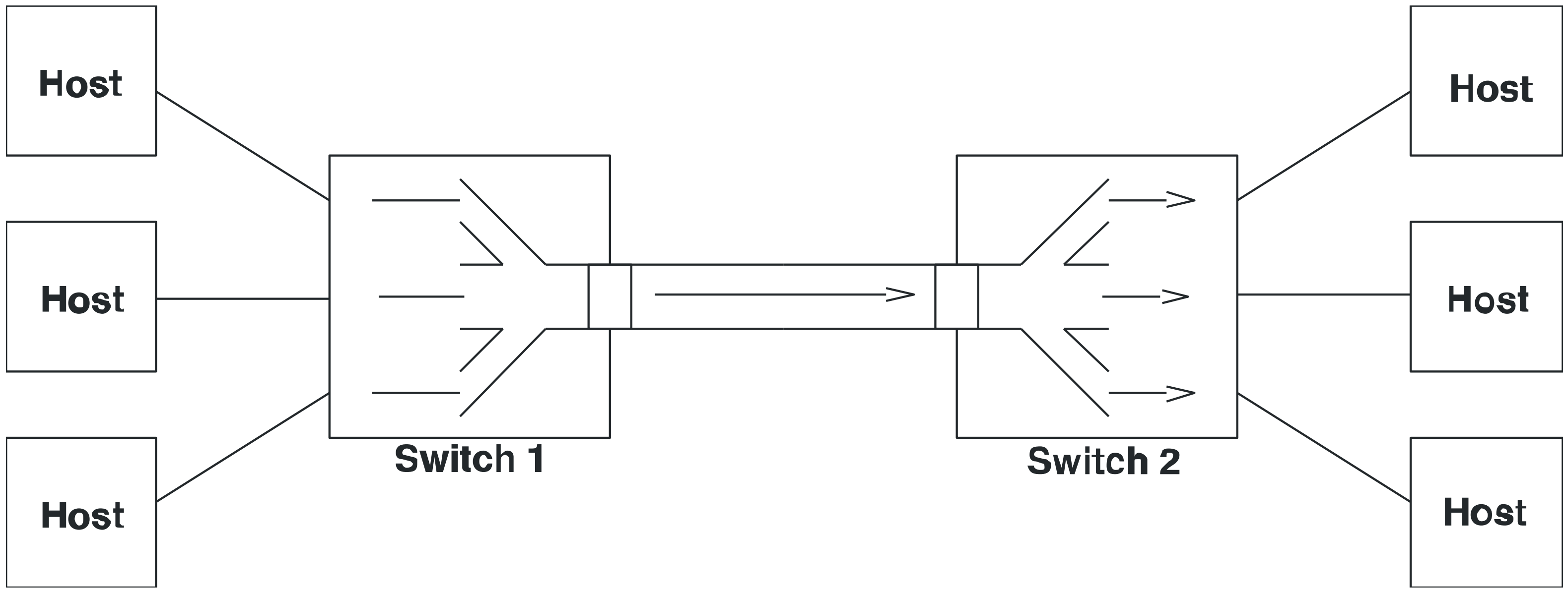
Sharing network resources

Devices and links

- must be shared (multiplexed) among multiple users

Common Multiplexing Strategies

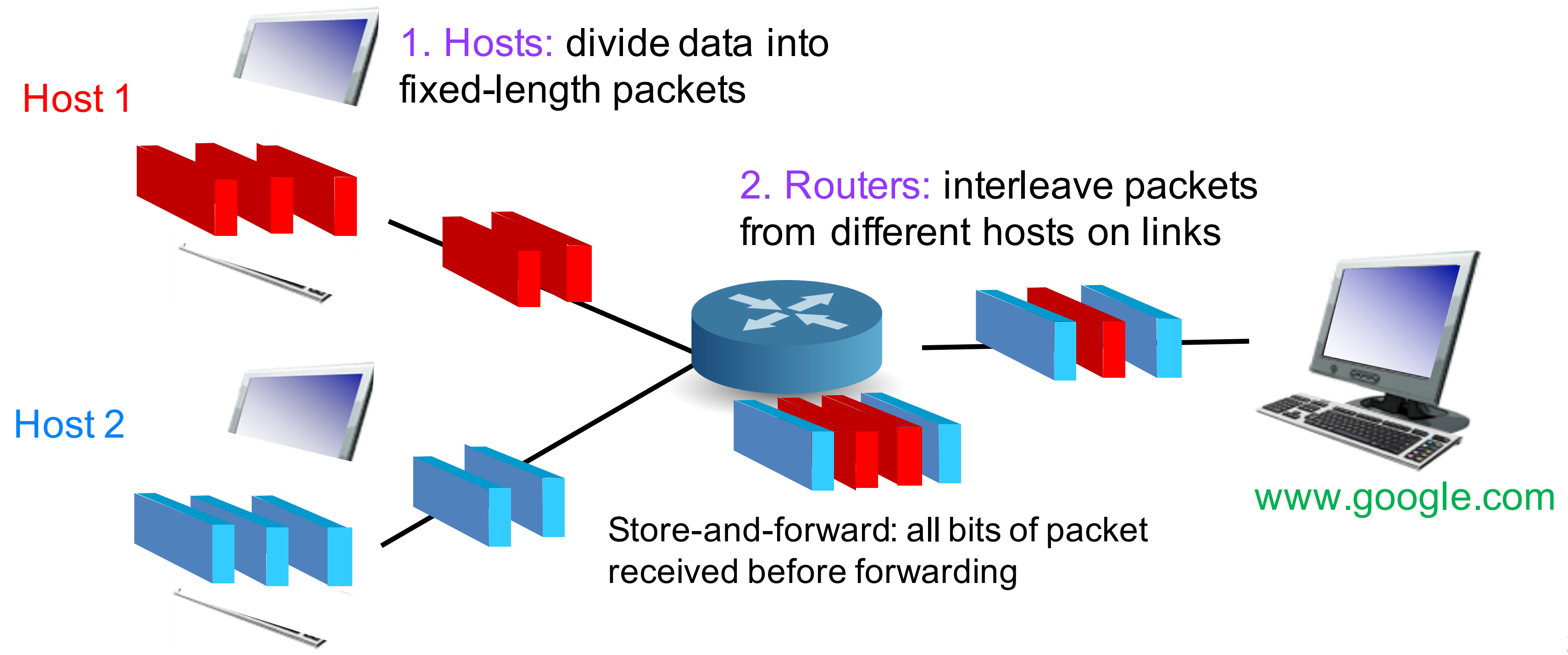
- Frequency-Division Multiplexing (FDM): pre-assign frequencies
- Time-Division Multiplexing (TDM): pre-assign time slots



Multiplexing strategy used on Internet

Statistical Multiplexing

- time-division, but on demand rather than fixed (no waste)
  - reschedule link on per-packet basis
  - packets from different sources interleaved on link
- buffer overflow causing packet drops (loss), is called congestion


Host 1
1. Hosts: divide data into fixed-length packets
2. Routers: interleave packets from different hosts on links
Host 2
Store-and-forward: all bits of packet received before forwarding
www.google.com