The Internet
CSE 120 Spring 2017

Instructor: **Teaching Assistants:**

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Alphabet will track health data of 10,000 volunteers to 'create a map of human health'

Verily is launching today a four-year study called Project Baseline to find out why people transition from being generally healthy to getting sick.

Most doctors will treat symptoms as they arise, but have little indication into how the patient was faring in the years leading up to the illness. The Baseline researchers are hoping to find early warning signs for disease from all the data it is collecting, including on sleep, activity, heart rate, genomics and more, which might translate into new lifestyle or therapeutic interventions.

- http://www.cnbc.com/2017/04/18/alphabet-verily-project-baseline-longitudinal-health-study.html

Administrivia

❖ Assignments:
  ▪ Binary Practice (4/21)
  ▪ Creativity Assignment (4/24)

❖ Midterm in class on Wednesday, 4/26
  ▪ 1 sheet of notes (2-sided, letter, handwritten)
  ▪ Fill-in-the-blank(s), short answer questions, maybe simple drawing
    • Questions will cover lectures, assignments, and readings
  ▪ Midterm Review sheet covered in lab next week (4/25)

Outline

- ❖ **Networks**

- ❖ Growth of the Internet

- ❖ Sending Information

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Communication Channels

❖ We often transmit sequences of bits between computers – why? *duplicate/store information, get information you don't have*

  ▪ Only capability we need because of binary encoding!
  ▪ Via wire: Ethernet
  ▪ Via wireless: WiFi, 3G/4G, Bluetooth ← *different technologies, similar idea*

❖ A network is a group of computing devices connected together, either by wire or wirelessly
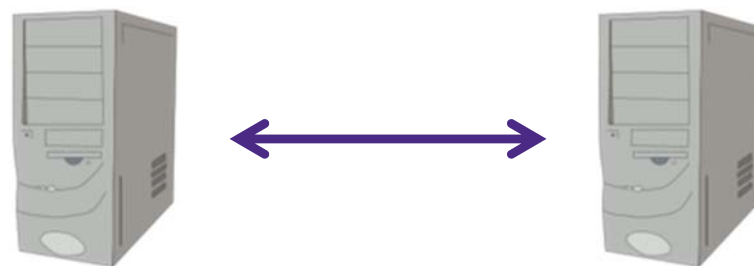
A Simple Model for Networks

❖ One way to represent computer networks is as a graph

   ▪ Each node represents one machine on the network
   ▪ Each edge represents a connection between two machines

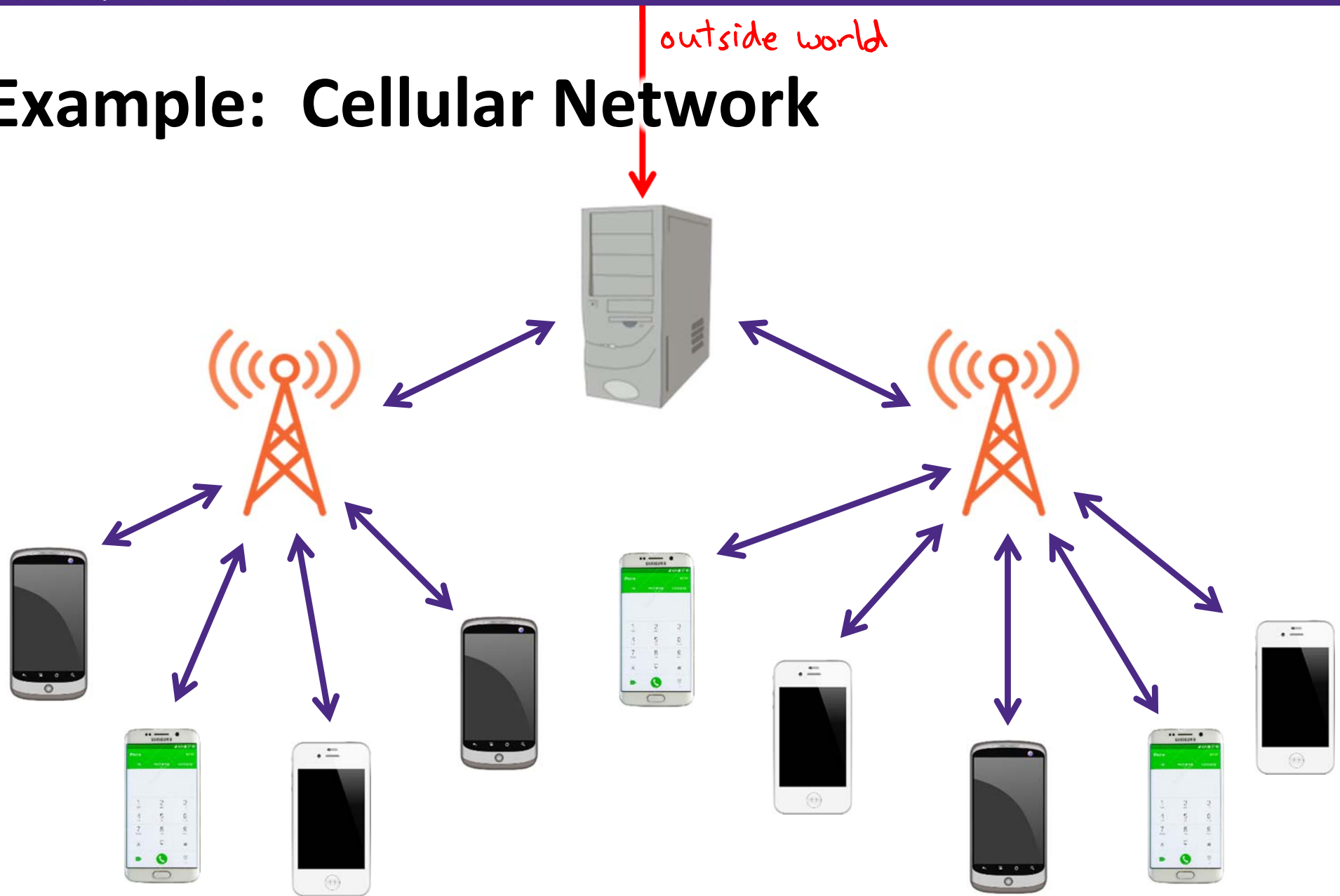❖ Below is a network of just two computers:

   ▪ 2 nodes and 1 edge

Node   Node
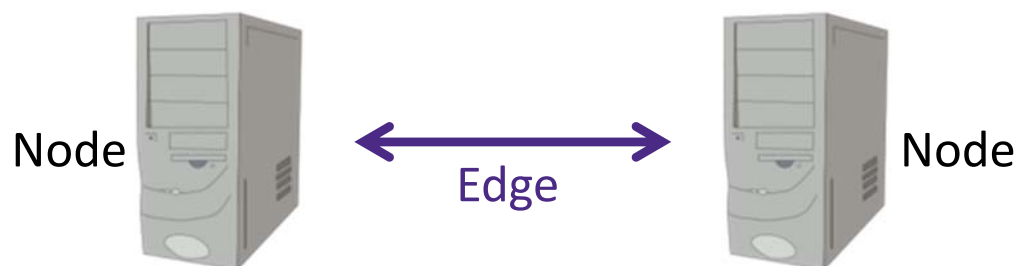
Edge

Example: Home Network

❖ The network at my house: 7 nodes, 6 edges
  ▪ Not counting the outside world

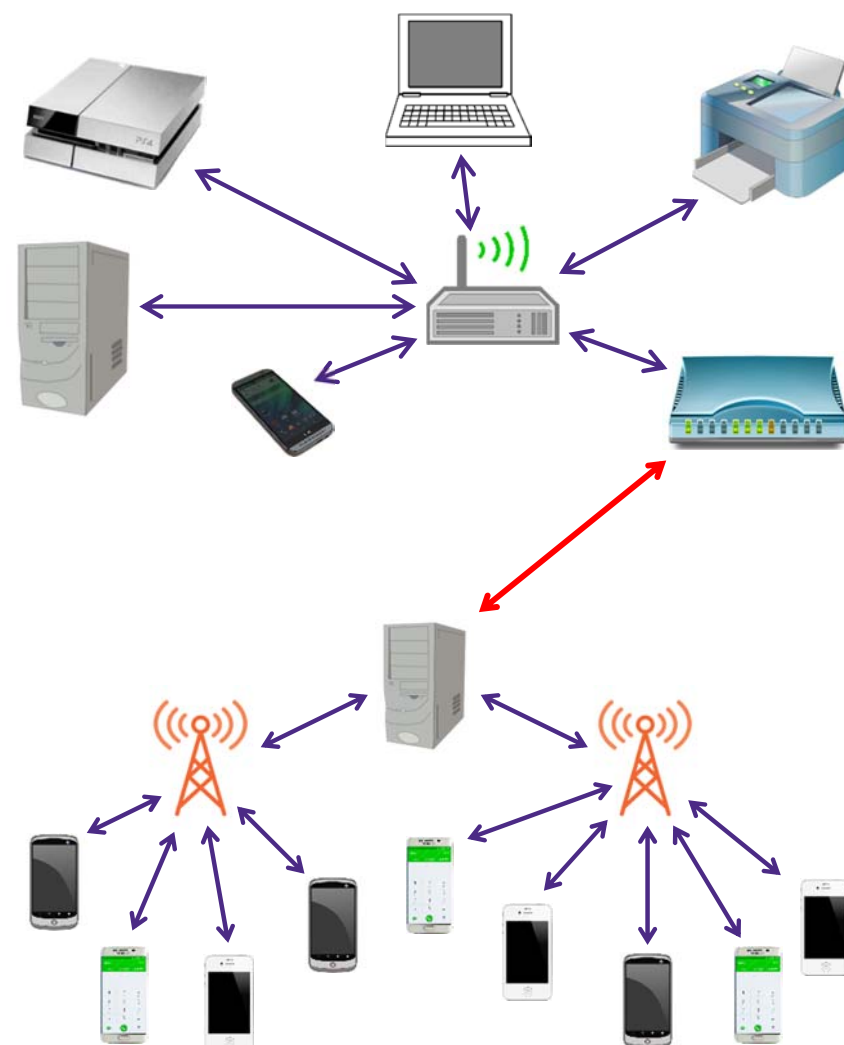
router is the "hub"

outside world
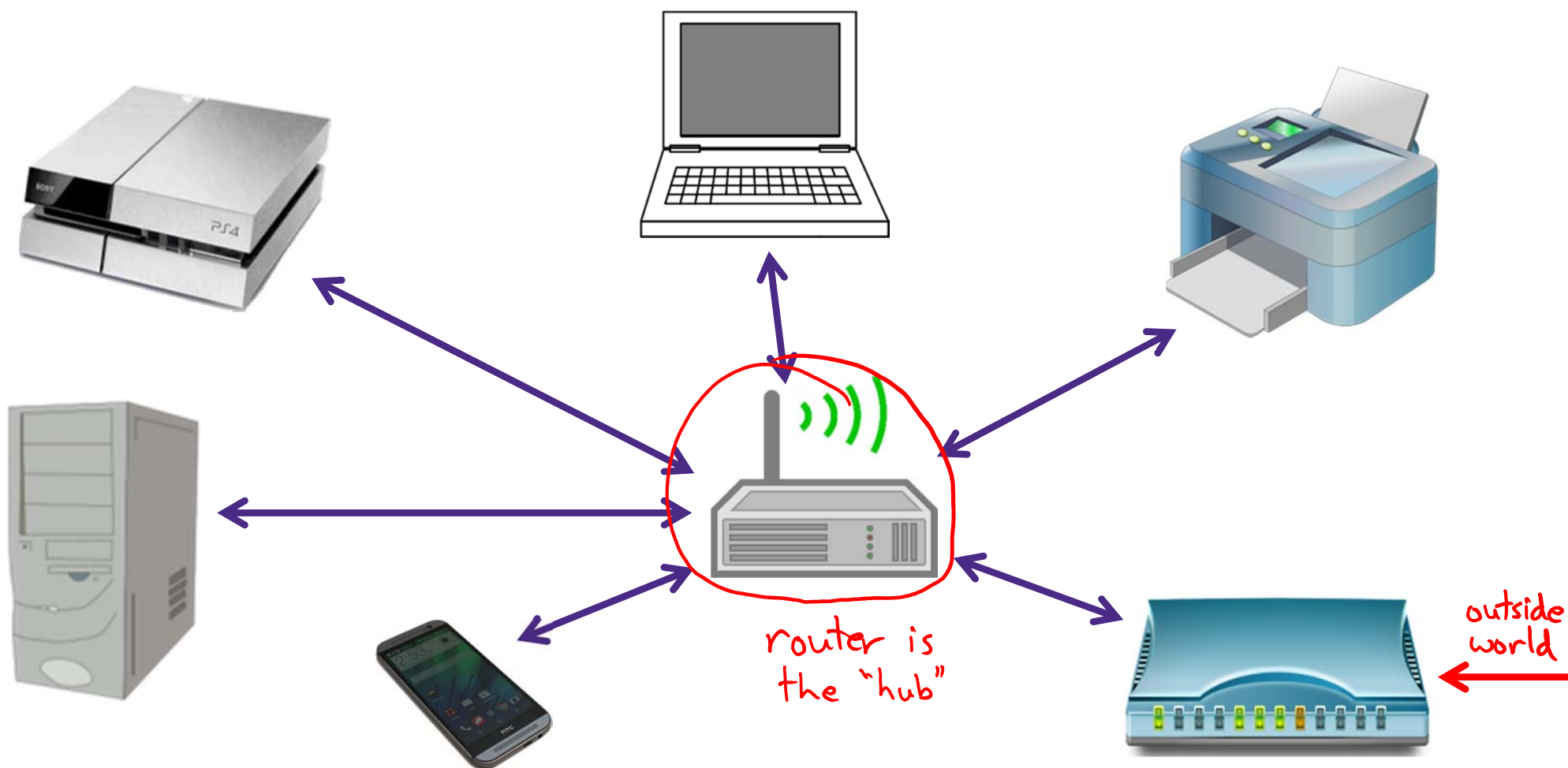
Example: Cellular Network

outside world

Internetworking

- ❖ If you connect two networks, you still have a network
  - ▪ Sometimes called an "internetwork"

- ❖ The largest network of networks on the planet is usually called "The Internet"

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Network Scales

❖ Table from an old UW Networking MOOC:

Scale	Type	Example
Vicinity	PAN (Personal Area Network)	Bluetooth (*e.g.* headset)
Building	LAN (Local Area Network)	WiFi, Ethernet
City	MAN (Metropolitan Area Network)	Cable, DSL
Country	WAN (Wide Area Network)	Large ISP
Planet	The Internet (network of all networks)	The Internet

The Interwebs?

- ❖ The Internet vs. The World Wide Web (WWW)
  - ▪ Is there a difference?

today's lecture

- ❖ The Internet: All of the *hardware* and *data* associated with the network of all networks (wires, fibers, switches, routers, servers, files, etc.)

- ❖ The World Wide Web: The system used to *access* the Internet (data transmission via browsers, web servers, web services, etc.)

Internet Accessibility

- ❖ Can now get Internet almost anywhere:
  - On a bus
  - On a plane
  - On a mountain
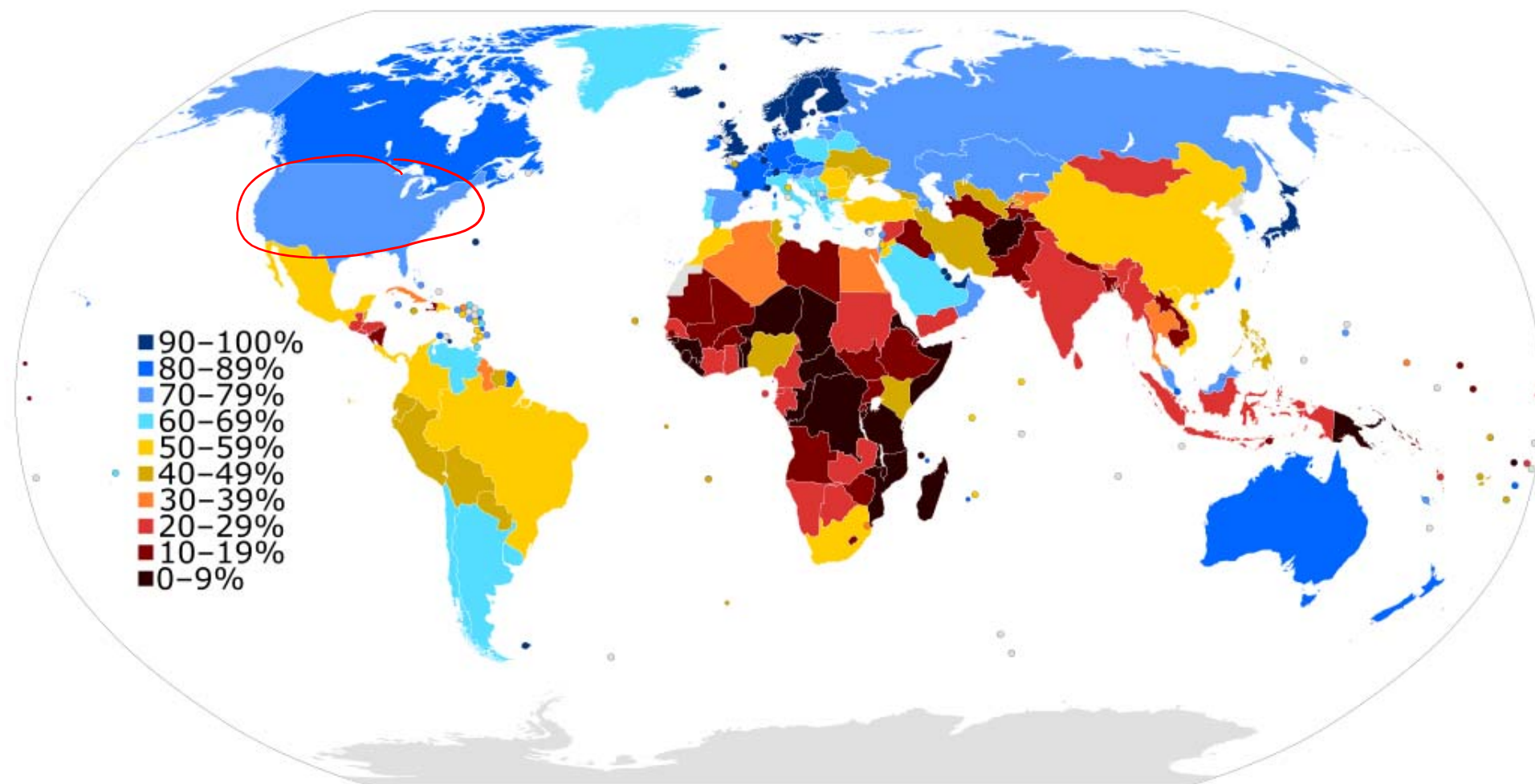 - In outer space

StarTribune

united.com

Slash Gear

NASA

The Internet Today

Internet Usage as a Percentage of Population (2015)

By Jeff Ogden (W163) - Own work, based on figures from the Wikipedia:List of countries by number of Internet users article in the English Wikipedia, which is in turn based on figures from the International Telecommunications Union (ITU) for 2010 (updated to use figures for 2012 on 28 June 2013).iThe source code of this SVG is valid.This vector image was created with a text editor.This vector image includes elements that have been taken or adapted from this: BlankMap-World6.svg., CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=19202338

Question

❖ In the last two years, what's the longest stretch of time you've gone without internet?

- Vote at http://PollEv.com/justinh

A. **Several Hours**

B. **1-2 days**

C. **More than 2 days**

D. **Several weeks**

E. **More than several weeks**

Audience Responses

❖ Why no Internet?
- Schoolwork (still used Internet)
- Vacation in the wild
- Rural area
- Assignment to go without Internet (roadtrip)
- Ran out of data
- Layover without free airport internet

Outline

- ❖ Networks
- ❖ **Growth of the Internet**
- ❖ Sending Information

The DoD and Computer Networks

❖ The Department of Defense (DoD) observed that central offices made communication network vulnerable to attack

- 1950s – The Cold War

- Can we build a more robust, decentralized system?

*town
city
community*

*terrible if this
goes down!*

*multiple paths
from point 1 → point 2*

Figure from [Computer Networks by Tanenbaum and Wetherall]

(a)   (b)
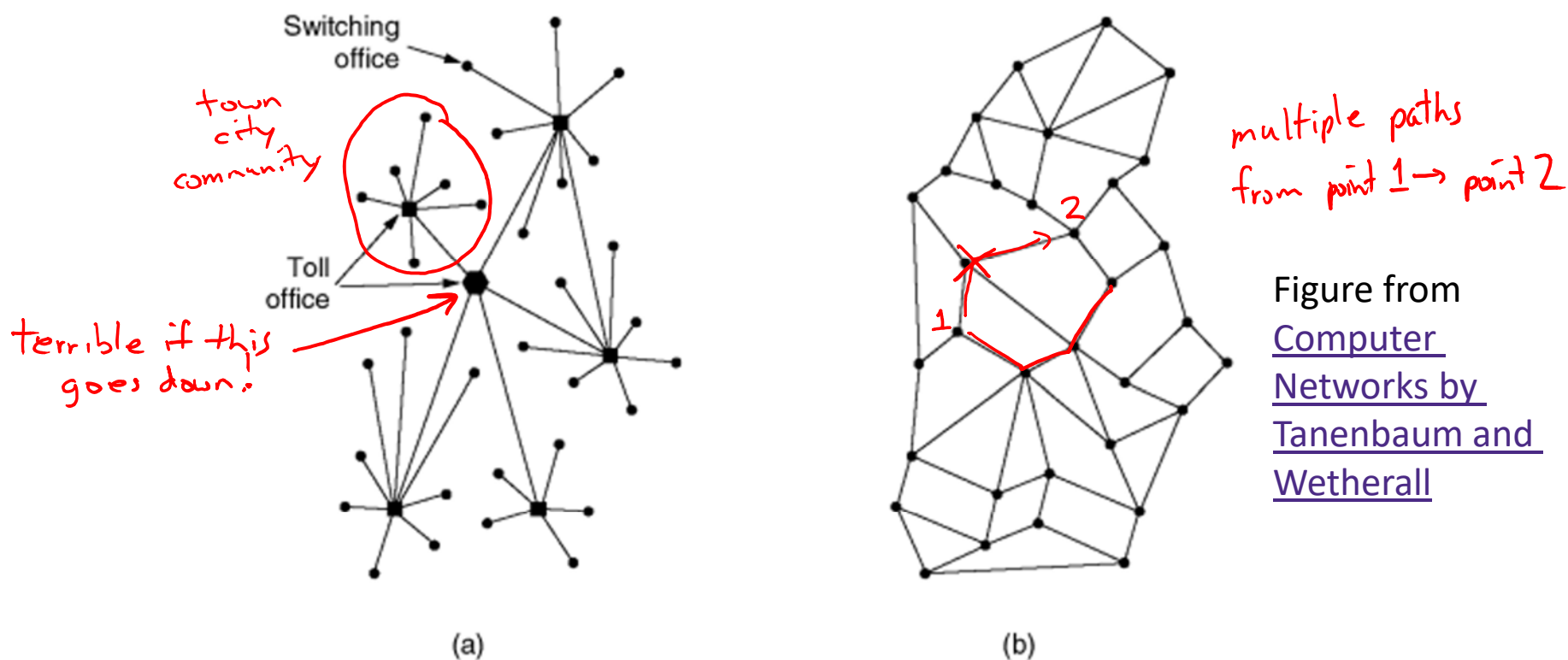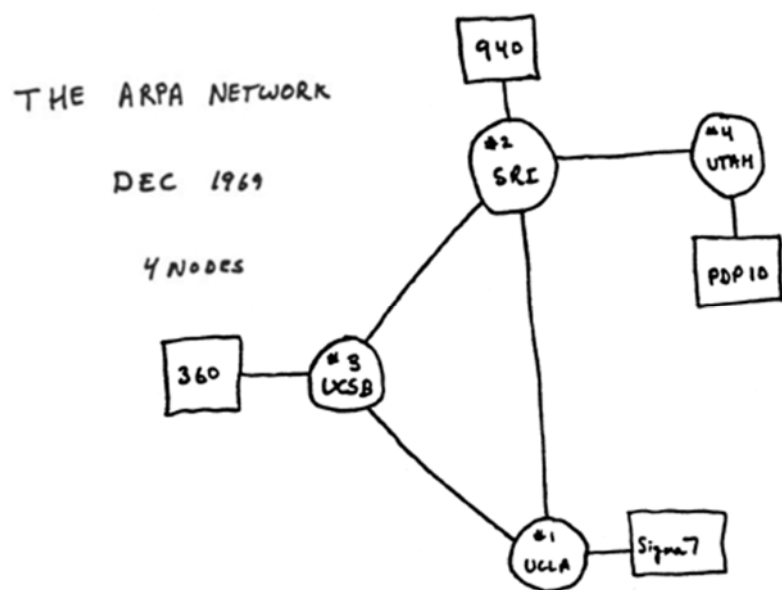
Figure 1-25. (a) Structure of the telephone system. (b) Baran's proposed distributed switching system.

ARPANET

- ❖ First 4 nodes of <u>ARPANET</u> connected in 1969
  - Stanford, UC Los Angeles, UC Santa Barbara, Utah
- ❖ By Sept. 1971, there were 18 nodes across the US
  - Grew exponentially from there for a long, long time
  - ARPANET superseded by <u>NSFNET</u> in '86, Internet in '91

Growth of the Internet

❖ The major point in building networks is *agreement*
- The only way to get seamless integration

❖ Open standards/protocols enabled rapid growth
- Internet Engineering Task Force (IETF)
  - Request for Comments (RFC)
- World Wide Web Consortium (W3C)
  - HTML
- International Standards Organization (ISO)
  - JPEG, MPEG
- Institute of Electrical and Electronics Engineers (IEEE)
  - WiFi

Outline

❖ Networks

❖ Growth of the Internet

❖ **Sending Information**

Analogy: Mailing a Letter

❖ Want to send a letter to my parents
  1) Write their unique address on the envelope
  2) Stamp it
  3) Drop it in a mailbox

❖ I rely on the *abstraction* that the US Postal Service will magically deliver the letter to the specified address

What Information?

❖ **Remember that all digital information is sent as bits**
- In order to make sense of anything, must follow communication *protocols*

❖ **Example protocols:**
- Ethernet
  - For physical connection in a LAN
- TCP/IP
  - Transmission control protocol and internet protocol
- HTTP
  - Hypertext transfer protocol for web pages

Internet Communication

1) Break the information into lots of tiny pieces called packets, about 1500 bytes long each

2) Packets are sent through the network (passing through many different machines) to their destination

3) The packets are reassembled on the other side

❖ Packets must contain:
  ▪ Destination address
  ▪ Sequence/piece number
  ▪ Content/data

addr	#	data

Internet Communication

1) Break the information into lots of tiny pieces called packets, about 1500 bytes long each

2) Packets are sent through the network (passing through many different machines) to their destination

3) The packets are reassembled on the other side

❖ **Advantages:**

■ Packets can take separate routes
  • Can even originate from different locations

■ If packet is lost, only have to resend small amount of info

Internet Communication

1) Break the information into lots of tiny pieces called packets, about 1500 bytes long each

2) Packets are sent through the network (passing through many different machines) to their destination

3) The packets are reassembled on the other side

❖ **Disadvantages:**

- Extra transmission data
  - *e.g.* same destination address for many packets
- Every computer along a packet's path sees the content of the packet   *Security/privacy issue!*

IP Addresses

Image:
Archeologia Informatica

❖ In 1974, Vint Cerf and Bob Kahn completed the specifications for the Internet Protocol (IP)

  ▪ Every device given a unique 32-bit address (IP address)

    • Large entities (e.g. companies, universities) can keep an IP address forever and allocate to physical machines as desired

    • For home machines, IP address is typically not permanent

  ▪ Address is used to get information to the right computer on a network
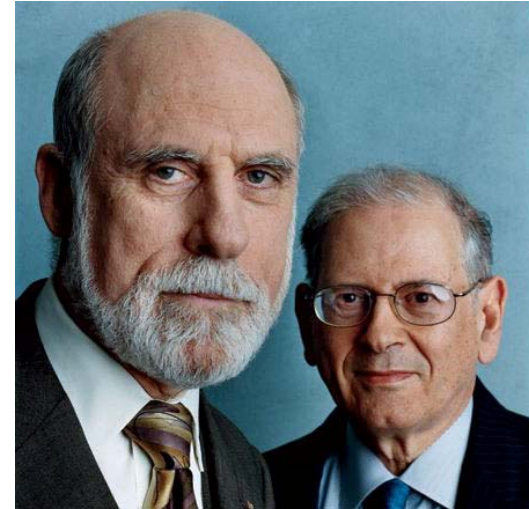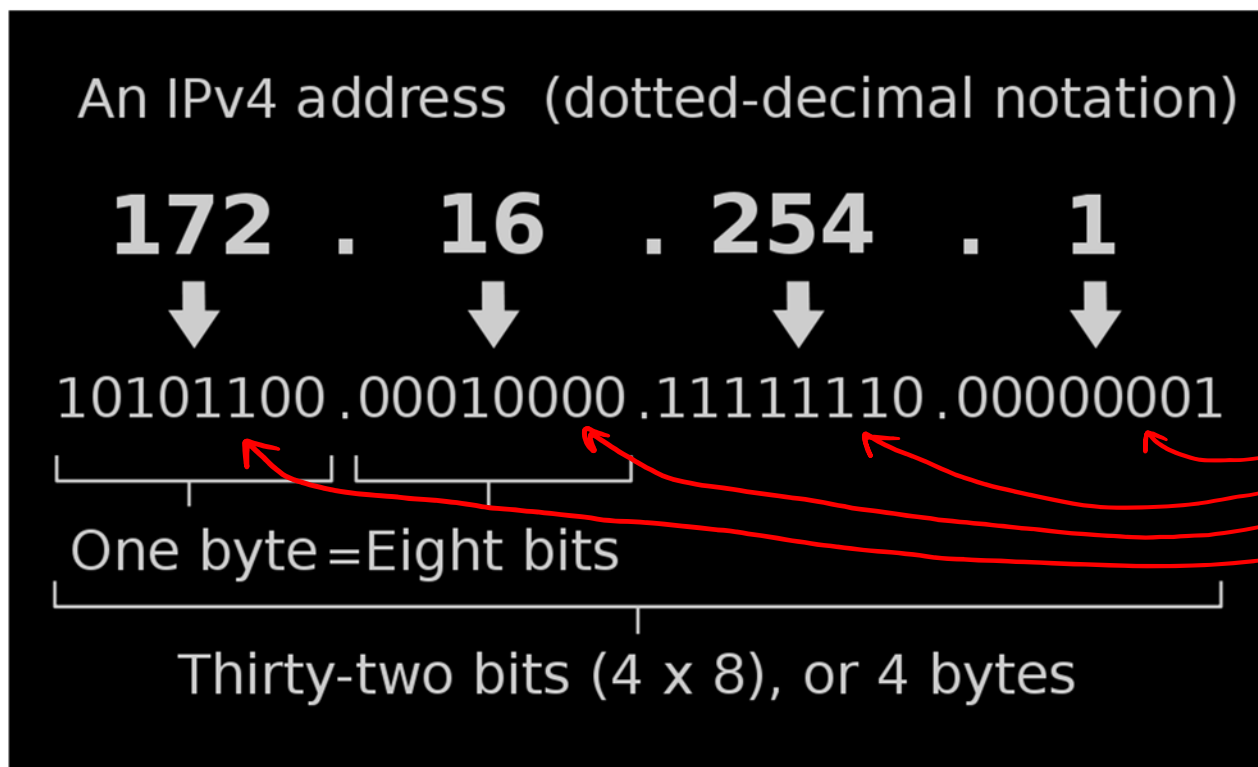
IPv4 Addresses

with n bits, can represent 2^n things

$2^8 = 256$

❖ Broken into four 8-bit chunks, and specified in "dotted-decimal notation"

An IPv4 address (dotted-decimal notation)

172 . 16 . 254 . 1

⬇ ⬇ ⬇ ⬇

10101100 . 00010000 . 11111110 . 00000001

One byte = Eight bits

Thirty-two bits (4 x 8), or 4 bytes

1 byte = 8 bits

can represent 0 – 255

- Split by network and computer: 172.16.254.1
- Unlike a phone number, no "area code"

Question

- ❖ How many internet-capable devices do you own?
  - ▪ Vote at http://PollEv.com/justinh

  A. 0

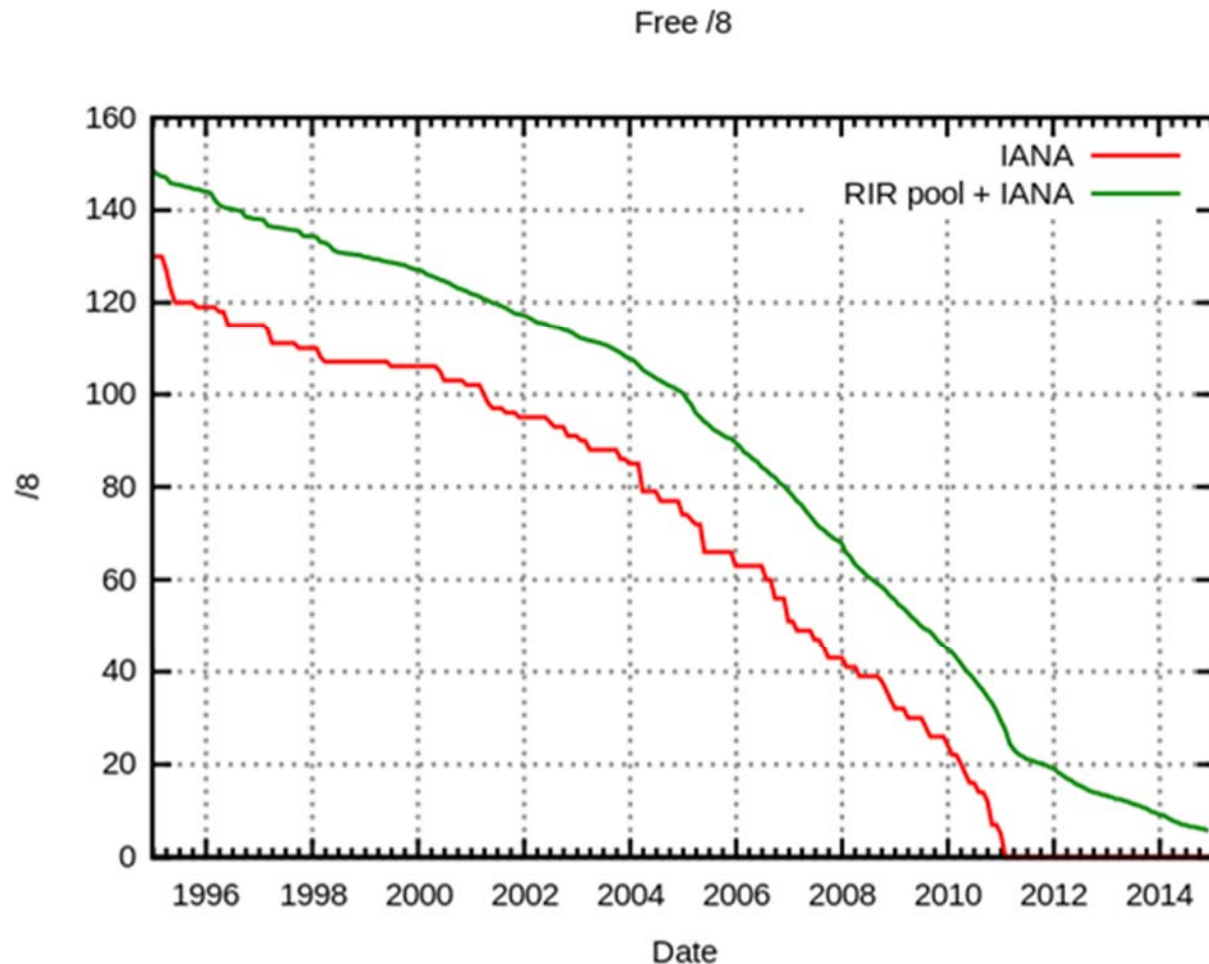 B. 1

  C. 2-5

  D. 6-9

  E. 10+

Image: dreamstime.com

- ❖ How many people are there in the world? ~7.5 billion as of Apr. 2017

- ❖ How many IPv4 addresses are there (32 bits)? $2^{32} \approx 4.3$ billion

# IPv4 Address Exhaustion

Free /8

Source: [Wikimedia Commons](#)

❖ Neat video of allocation through the years:

   ▪ https://www.youtube.com/watch?v=y8WqJum_Gfg

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IPv6

An IPv6 address   (in hexadecimal)

2001:0DB8:AC10:FE01:0000:0000:0000:0000

⬇   ⬇   ⬇   ⬇

2001:0DB8:AC10:FE01::   Zeroes can be omitted

Source:
Wikimedia
Commons

0010000000000001:0000110110111000:1010110000010000:1111111000000001:

0000000000000000:0000000000000000:0000000000000000:0000000000000000
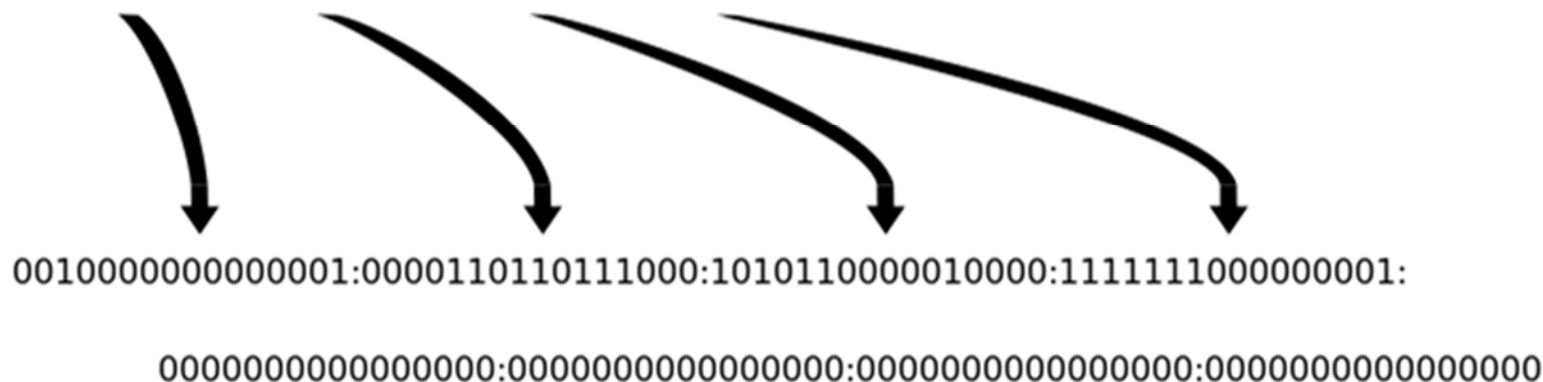
IPv4: 32 bits → 2^{32} addresses ⎤ 4x bits used

❖ 2^{128} unique addresses   IPv6: 128 bits → 2^{128} addresses ⎰ 2^{96}x addresses can be represented!!!

❖ Issue: adoption still in progress

   ▪ Which are you? https://www.whatismyip.com

Domain Name System

❖ Remembering IP addresses would be brutal for humans

- Instead we use domain names, which are human-readable and more flexible
  - *e.g.* `cs.washington.edu` instead of 128.208.3.88

❖ Computers find IP address for a domain name from the domain name system (DNS)

- Another computer that acts as an IP address book
  - Your computer *does* need to know the IP address of the DNS server
- DNS is an automatic directory search – it's huge!

Logical vs. Physical

❖ <u>Humans</u> see the Internet as a logical network: an hierarchy of domains

❖ <u>Computers</u> see the Internet as a physical network: IP addresses that map to computers

❖ The DNS relates the logical network to the physical network by translating domain names to IP addresses

  ▪ Requesting a web page from the same domain name may get "served" to you from a different IP address each time!

  ▪ For improved performance, most web content is stored in multiple locations

Discussion (If Time)

❖ The Internet was supposed to bring the world "closer together"

❖ Do you think it has? Why or why not?

- closer: easier to reach people or access information that is far away

- changed our modes of communication; less in-person (physically close) communication

- filter bubbles: seeking out only validating opinions leads to more divergent opinions and more disagreement

Summary

❖ A network is a group of computing devices connected together, either by wire or wirelessly

- From very small to very big
- The Internet is the largest network of networks

❖ The Internet grew rapidly and has become increasingly omnipresent

- Highly fault-tolerant due to decentralization
- Growth aided by open standards

❖ Data is passed between computing devices in small pieces called packets

- The domain name system translates from domain names to IP addresses in order to reach a specific device