The Internet: Fundamentals

Announcements

- Tonight:
  - Lab 11
- Tomorrow:
  - Exam
  - Lab 12
- Monday: Lab Exam 2

Overview

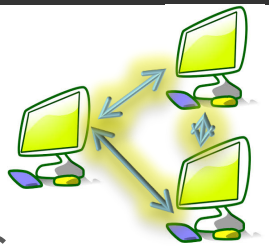
- Protocols
- Some history
- Addressing
- Packet switching
- End-to-end principle
- Net neutrality

protocols

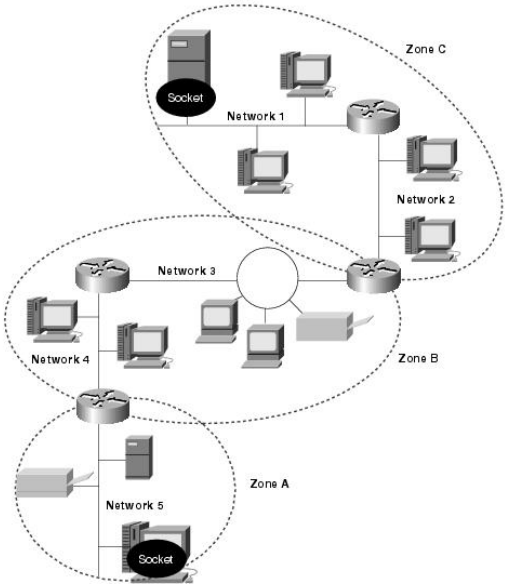
agreeing to communicate

Computer Networks

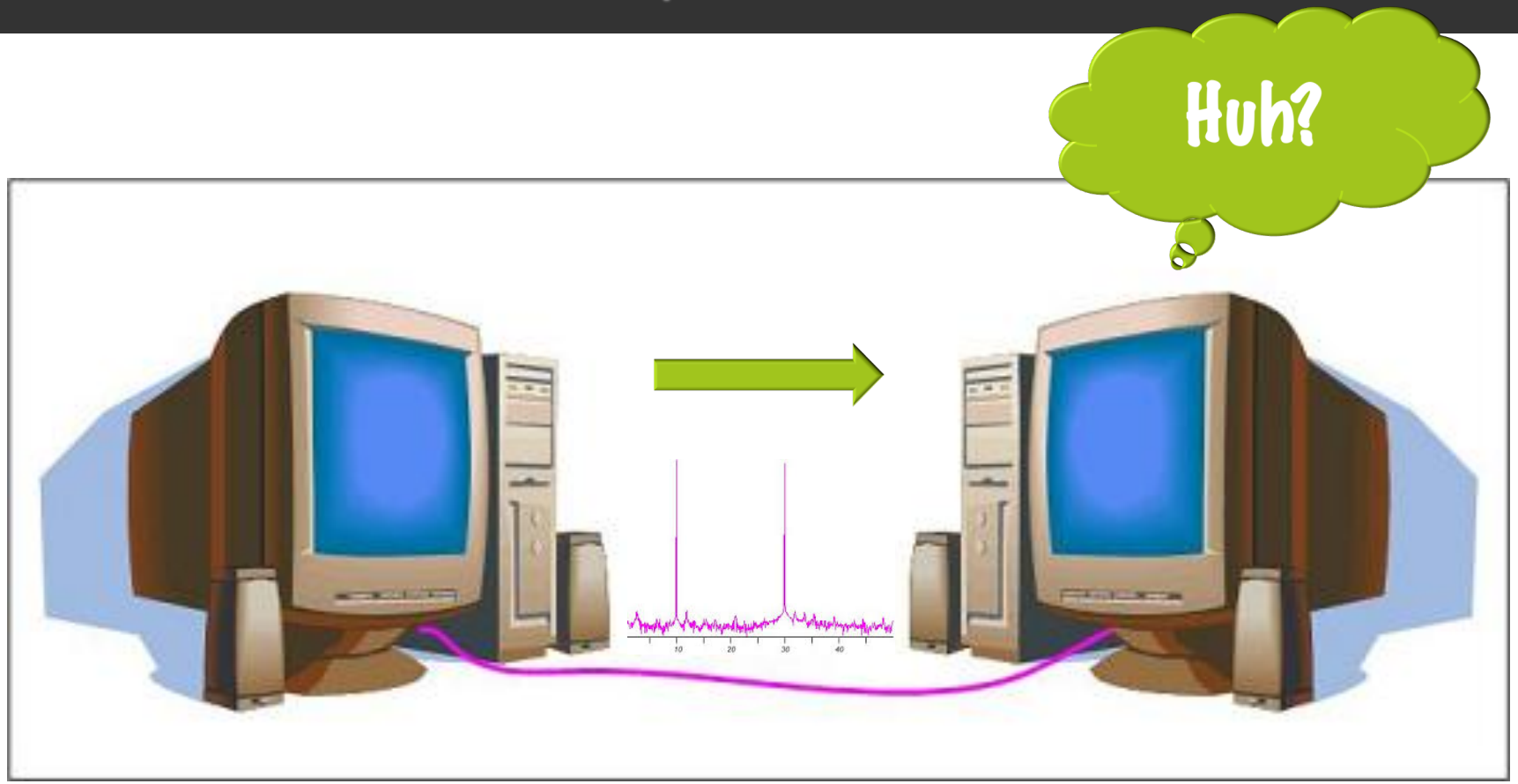
- A computer network is a set of independent computer systems connected by telecommunication links.



- The Internet is *the* network of networks



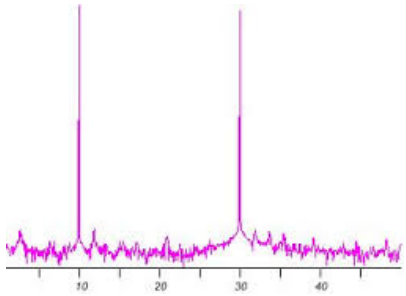
The need for protocols



Protocols and network connections

- "Data links" are the physical connections
- Signals propagate through data links
  - could be voltages, photons, radio waves
- **Question:** how does a sequence of voltage changes become *data* (bits)?

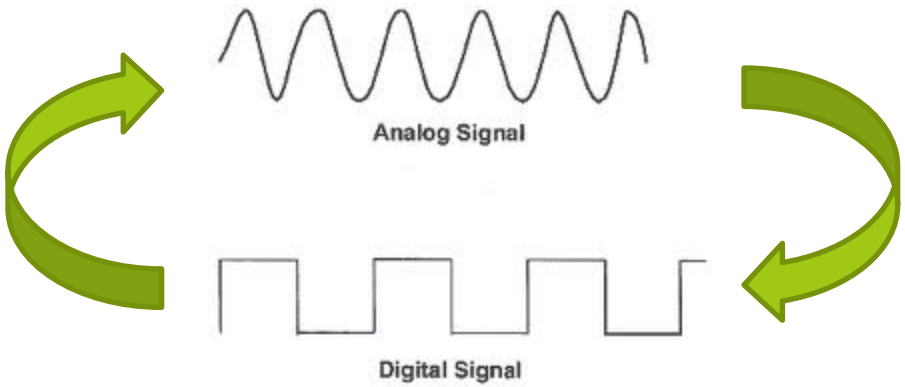
Answer: Physical Network Protocols

- From  to 0100100

- *Protocols* are agreements on a technical standard

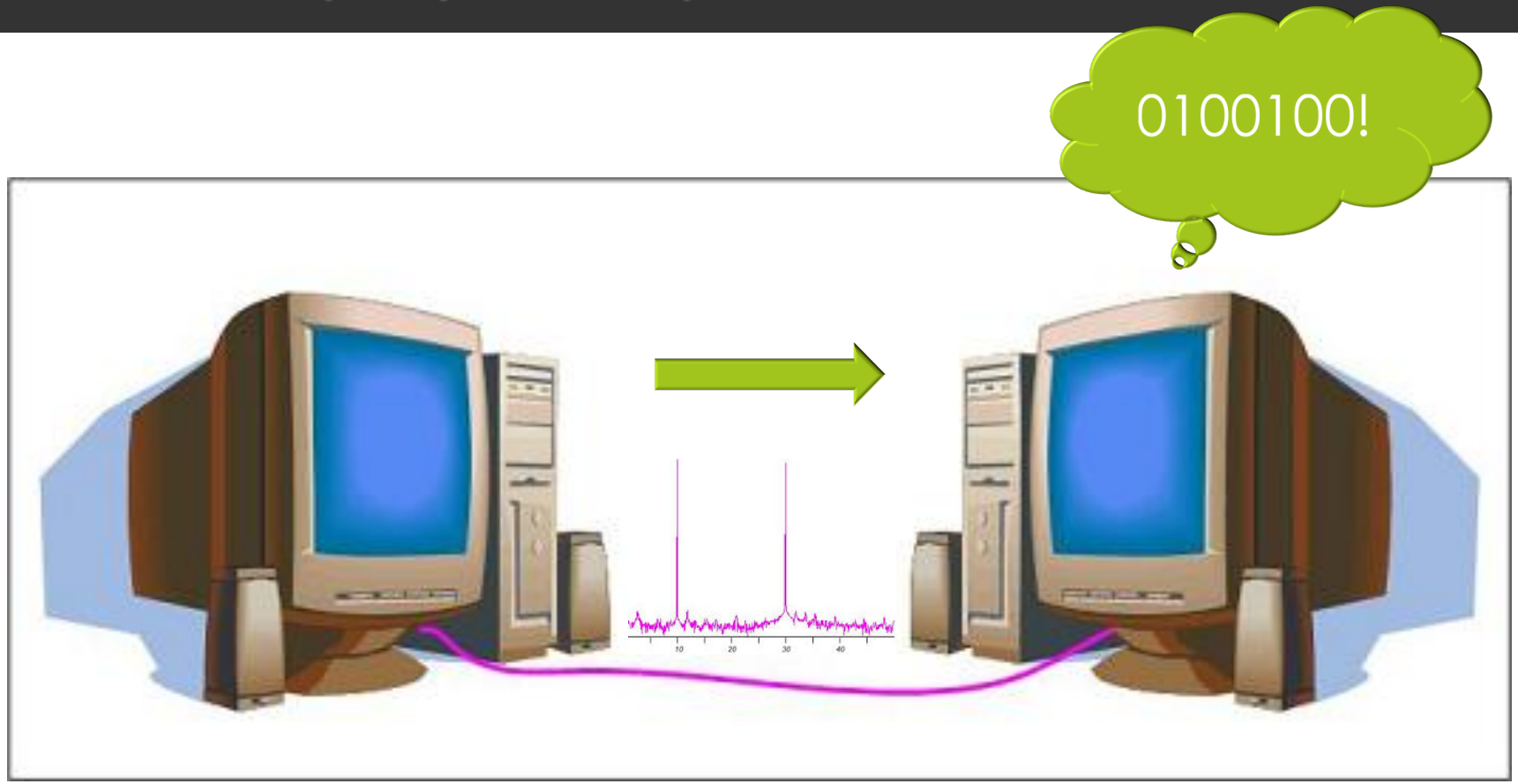
- *Devices* (hardware/software) obey or *implement* protocols

A modem implements a physical protocol



Modem (modulator - demodulator) transforms between **physical states** (analog) and **bits** (digital)

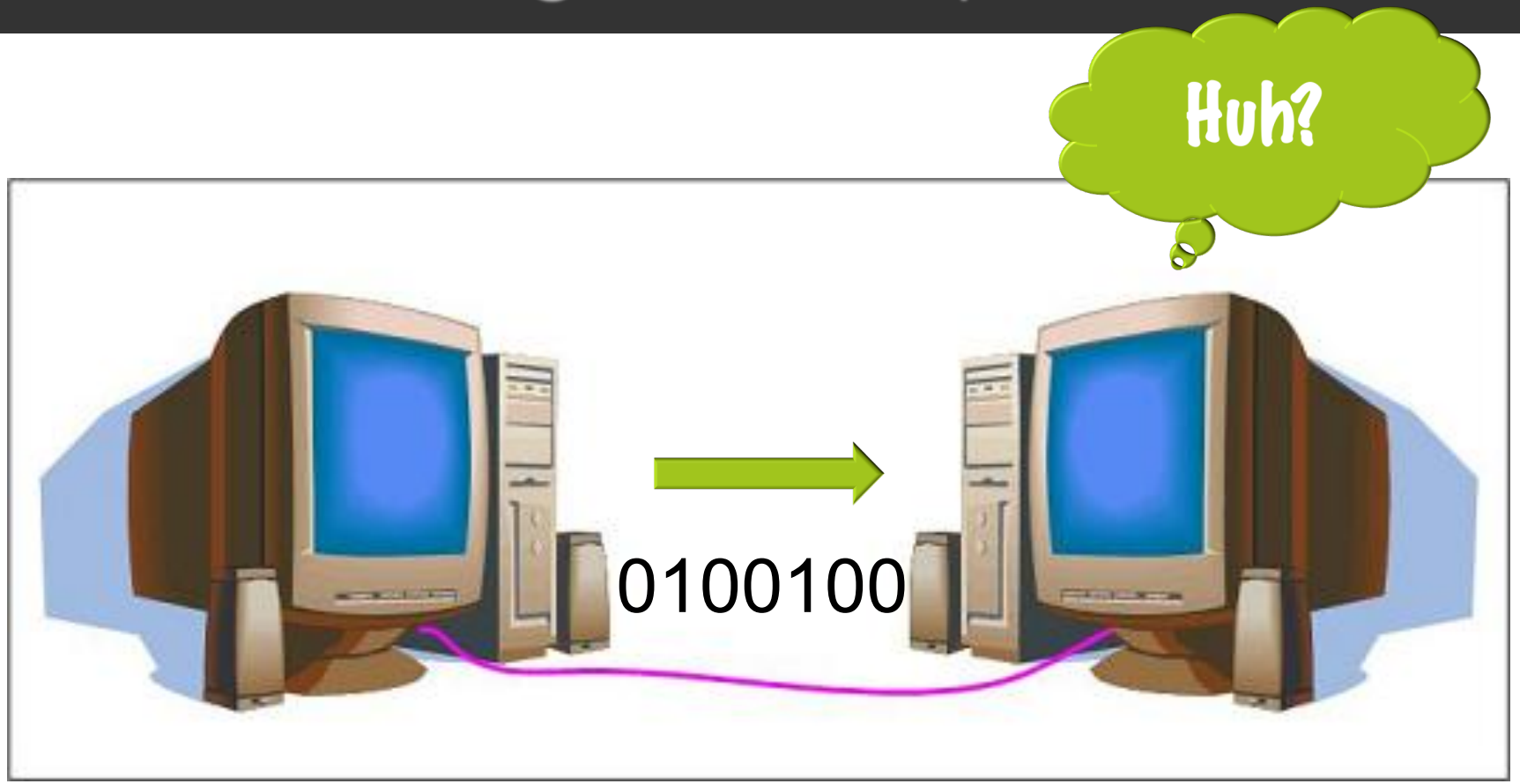
With physical protocols



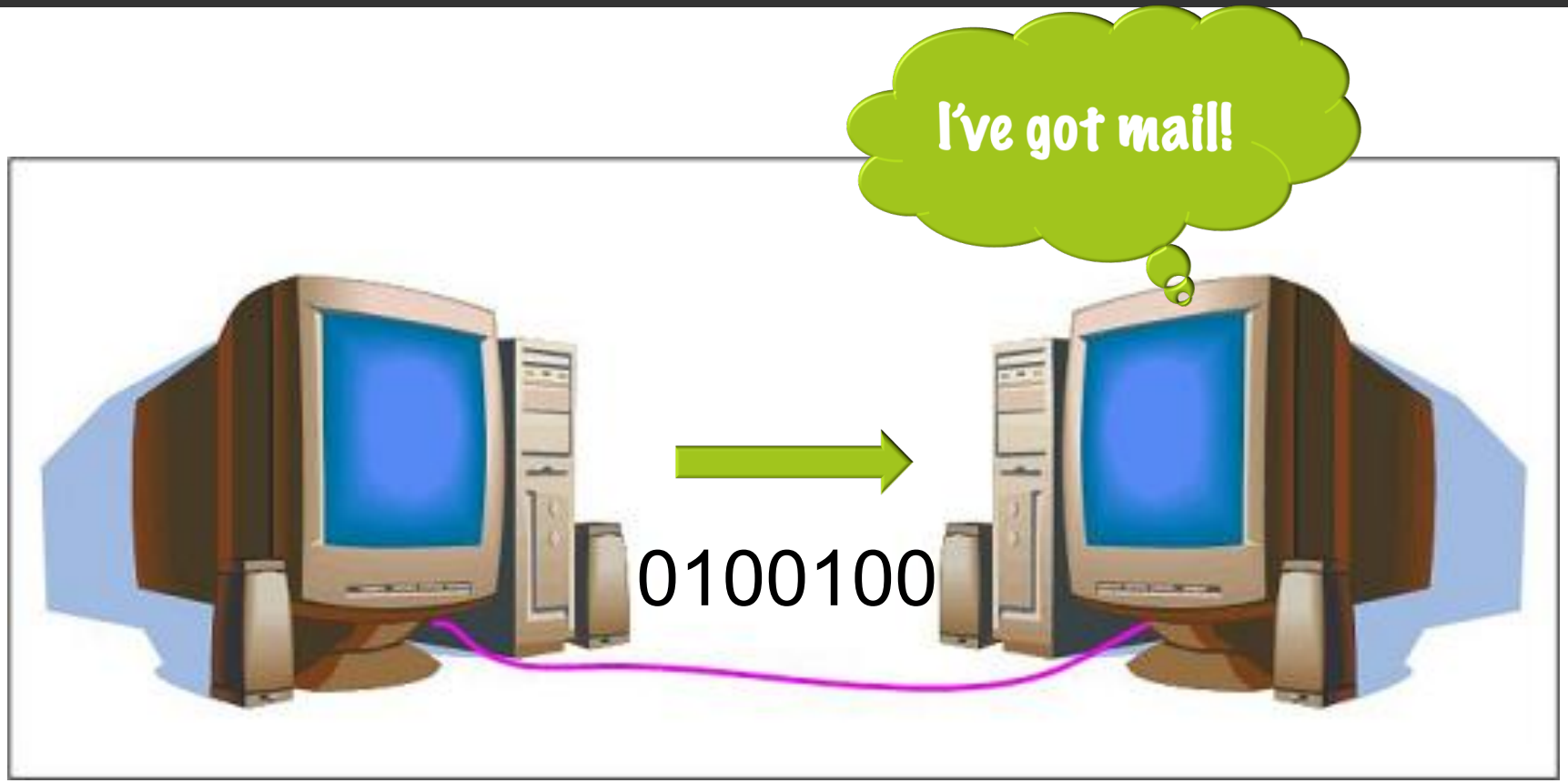
Higher-level protocols

- *Question:* how does a sequence of bits become a message that makes sense to a person?
  - *encodings* (we already saw this)
  - and *protocols* (agreements on when to send what information)
- *Example:* our use of file *extensions* is a protocol. A file `kitty.jpg` is interpreted as a jpeg-compressed file.

Without higher-level protocols



With higher-level protocols



What is the Internet?

- It's our world!
- But to a techie **the** Internet is *a collection of protocols*
  - Implemented in software and hardware
  - Designed to interconnect all types of networks (cell phones, Ethernet, wifi, …)
- No one entity controls/owns the Internet
  - But to connect to it, you need a machine that obeys the protocols

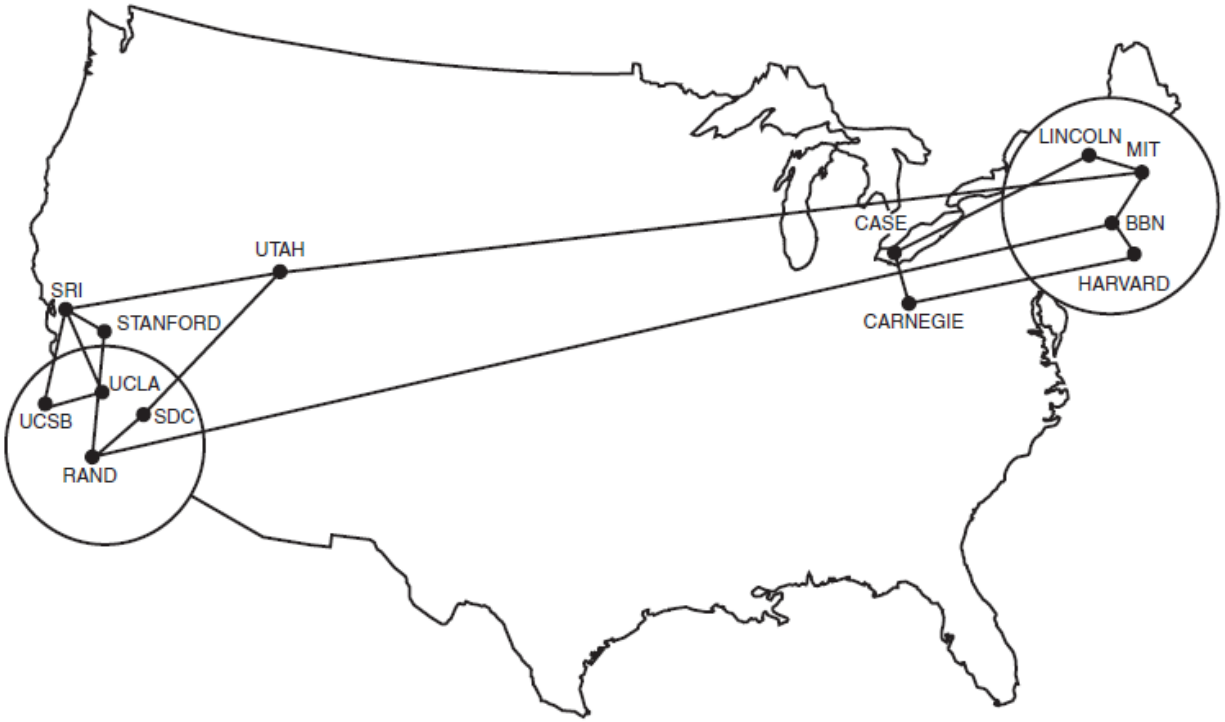
history

From Arpanet to Internet

Some Internet History

- Why history? It reveals some reasons for the way things are now:
  - Security vulnerabilities
  - Political stances
  - Governance structures

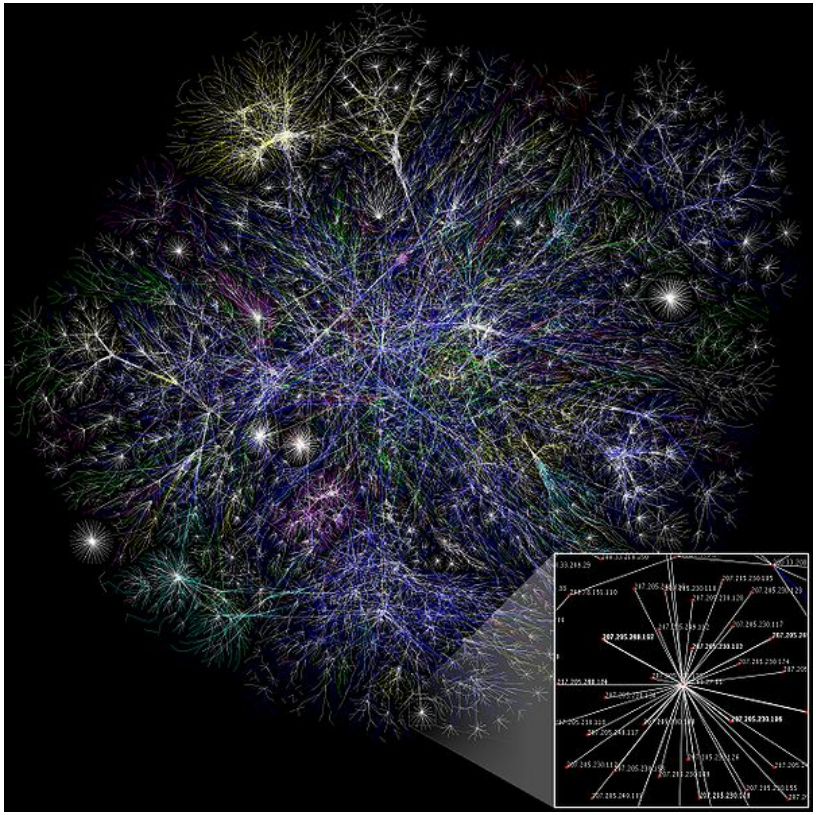
ARPANET to Internet



Source: Heart, F., McKenzie, A., McQuillian, J., and Walden, D., ARPANET Completion Report, Bolt, Beranek and Newman, Burlington, MA, January 4, 1978.

Dec. 1970
Arpanet

ARPANET to Internet



2000's
Internet Map
(small section)

ARPANET Design Goals

- Connect geographically separated computers
  - Universities
  - Research institutes, e.g. SRI
- Be robust to loss of parts of network
  - Remaining parts continue functioning
- **Not a goal: security—**all connected systems were *trusted*
- This worked until the *Morris worm* incident

ARPANET Innovations

- Packet switching
- TCP/IP: the foundational Internet protocols
- Applications
  - remote logins
  - email
  - electronic bulletin boards

ARPANET to Internet

- Originally ARPANET was a *wide-area network* – not an internet (all the links were the same type)
- TCP/IP made it *an* internet: connected disparate network types (early 80s)
- Commercial ISPs made it public: *the* Internet (late 80s to early 90s)

Internet Design Goals

In order of priority:

1. Continue despite loss of networks or gateways
2. Support multiple types of communication service
3. Accommodate a variety of networks
4. Permit distributed management of Internet resources
5. Cost effective
6. Host attachment should be easy
7. Resource accountability

internet addressing

getting from here to there: where is “here”? where is “there”?

IP Addresses

IP stands for "Internet Protocol"

- Each computer on the Internet is assigned an IP Address consisting of four numbers between 0 and 255 inclusive

  ____ . ____ . ____ . ____

  Example: 128. 2. 13. 163

Data sent on the Internet must always be sent *to some IP address*

- How many bits per address? How many computers can be on the Internet at the same time?

Where do IP addresses come from?

- An IP address **isn't part of** a computer!
- Groups of addresses are allotted to various organizations by IANA (Internet Assigned Numbers Authority)

  These organizations assign addresses to computers.
- *Static* versus *dynamic* assignments
  - static for important *server* machines
  - dynamic for others

What does an IP address "say"

- Identifies a particular machine *at a particular time*
- Identifies (somewhat vague) geographic location based on organization that "owns" it
- What it doesn't say
  - who is using the machine to do what
  - what kind of machine it is

packet switching

getting from here to there: basic transportation mechanism

The path from "here" to "there"

- For now, think of sending a message (group of bits) from one machine to another through the Internet
- We attach the source and destination IP addresses to the message
- "The Internet" gets it from source to destination
  - **but how? using packet switching**

Design Decisions

- No limit on message size
- Flexible and robust delivery mechanism

Circuit Switching
the road not taken

- Two network nodes (e.g. phones) establish a **dedicated connection** via one or more switching stations.

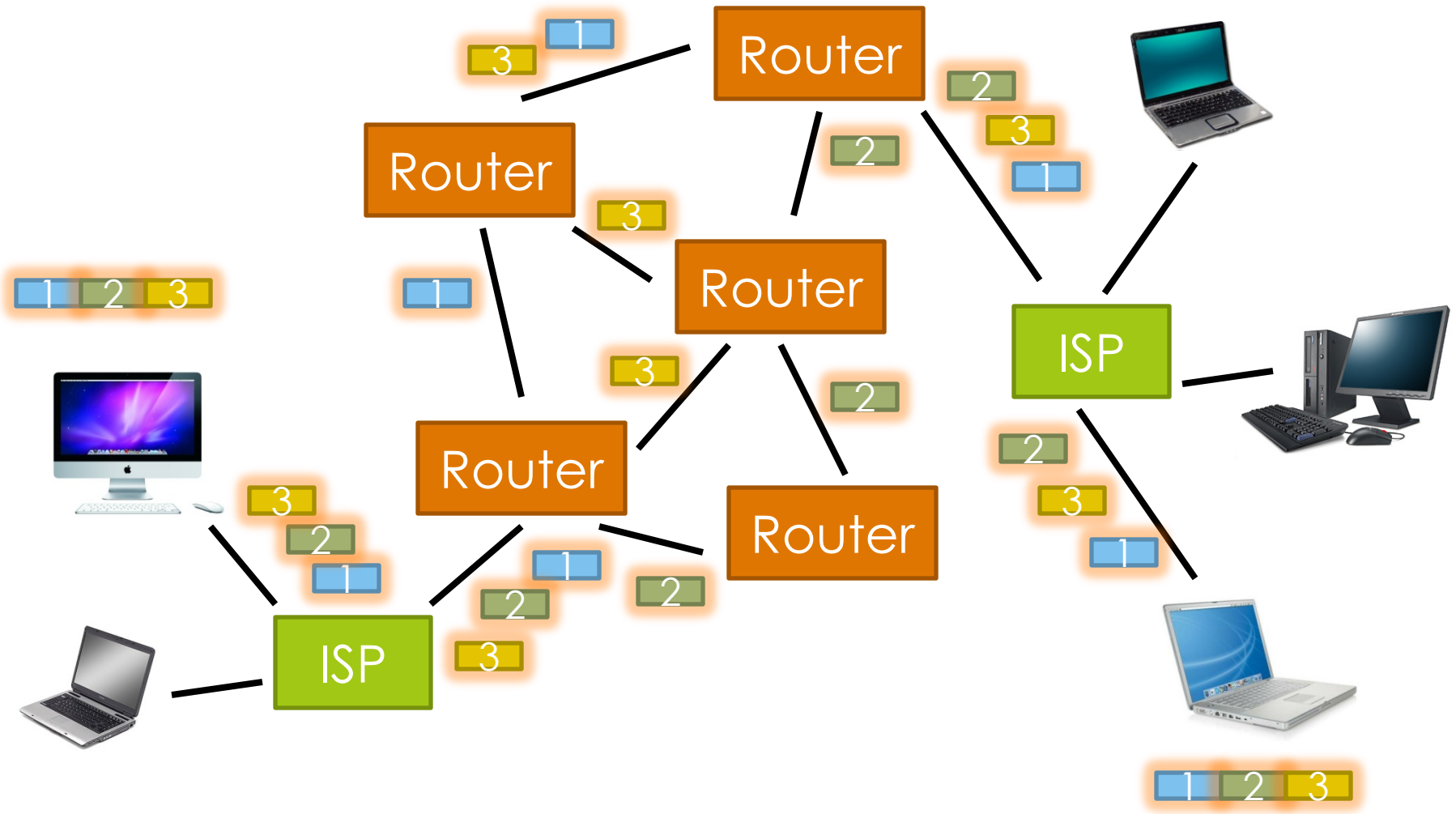
Circuit switching

- Advantages
  - reliable
  - uninterruptible
  - simple to understand
- Disadvantages
  - costly
  - inflexible
  - wasteful
  - hard to expand

Packet Switching

- Two network nodes (e.g. computers) communicate by **breaking the message up into small packets**
  - each packet sent separately
  - with a serial number and a destination address.
- *Routers* forward packets toward destination
  - table stored in router tells it which neighbor to send packet to, based on IP address of destination
- Packets may be received at the destination in any order
  - may get lost (and retransmitted)
  - serial numbers used to put packets back into order at the destination

Packet Switching



Routing and Internet structure

- Core provides transport services to edges
  - routers and gateways forward packets
  - Internet Service Providers (ISPs) provide data transmission media (fiber optic etc.)
  - domain name servers (DNS) provide directory of *host* names (more on this next time)
- Edges provide the services we humans use
  - individual users, "hosts"
  - private networks (corporate, educational, government…)
  - business, government, nonprofit services

end-to-end principle

Internet article of faith

Core architectural guideline

- Idea: *routers should stick to getting data quickly from its source to its destination!*
  - they can be fast and stupid
- Everything else is responsibility of edges, *e.g.*
  - error detection and recovery
  - confidentiality via encryption
  - …

Benefits of End-to-end

- Speed and flexibility
- Support for innovation: routers need know nothing about apps using their services
- Equality of uses: routers can't discriminate based on type of communication (*net neutrality*)

Controversies

- End-to-end principle under pressure
  - because of technical developments
    - video streaming requires high-quality delivery service
  - because of social and economic developments
    - lack of **trust** because of bad actors on the Internet
    - profit opportunities for ISPs
    - corporate and government monitoring of communications

Governing the Internet

- Internet Society: a range of partners from non-profit agencies, local and global NGOs, academia, technologists, local councils, federal policy and decision makers, business (www.isoc.org)

- Internet Service Providers (ISPs) regulated in the USA by the Federal Communications Commission (FCC)

network neutrality

current issue

Net neutrality principle

- All communications are treated equally
  - regardless of source, destination, or type

Where is there net neutrality?

- In principle, most places
- But some governments already censor or otherwise control the Internet within their borders

Net neutrality and the FCC
(grossly oversimplified)

- Historically the FCC prohibited ISPs from violating net neutrality
  - 2014: Federal court ruled FCC had no authority for their then-current regulations because ISPs were not "common carriers".
- Recently
  - February 2015: FCC voted (on party lines) to enforce net neutrality based on a different legal authority.
  - Verizon, Comcast, etc. *unhappy*
  - Facebook, Netflix, Google, etc. *happy*

Next time: the Internet for humans

- From packet switching to reliable transport
- From IP addresses to names
- From the Internet to the web

image: Aleksei Bitskoff, bitskoff.blogspot.com