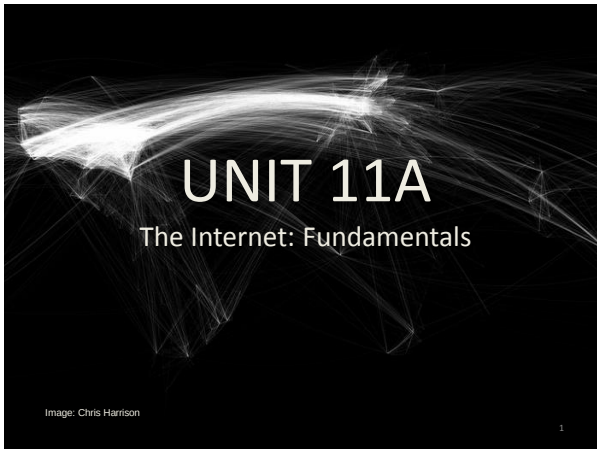


Overview

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

2

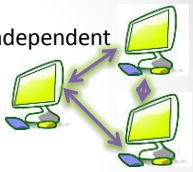
protocols

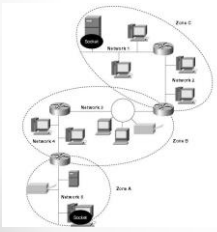
agreeing to communicate

3

Computer Networks

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

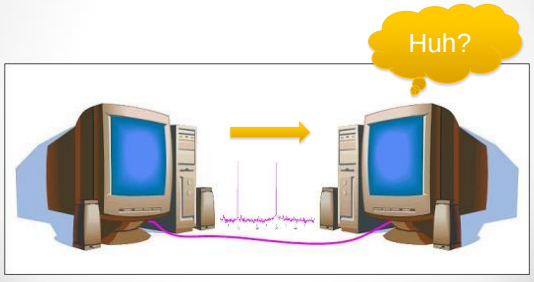




- The Internet is *the* network of networks

4

The need for protocols



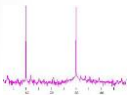
5

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)?

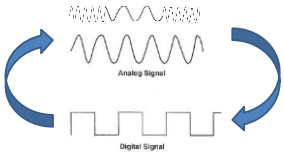
6

Answer: Physical Network Protocols

- From  to 0100100
- ***Protocols*** are agreements on a technical standard
- *Devices* (hardware/software) obey or *implement* protocols

7

A modem implements a physical protocol



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

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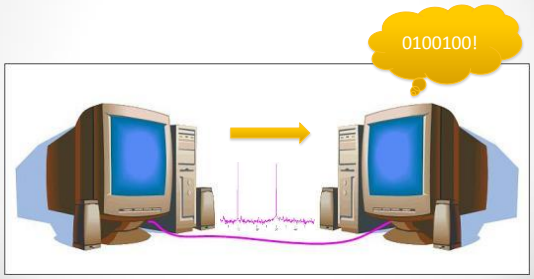
With physical protocols



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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.

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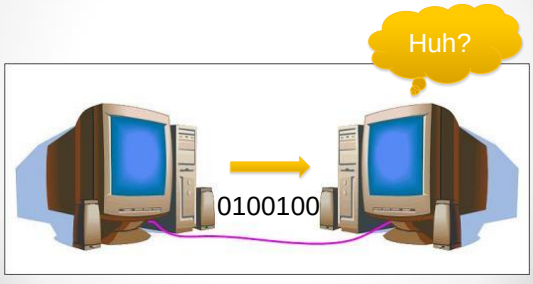
Without higher-level protocols



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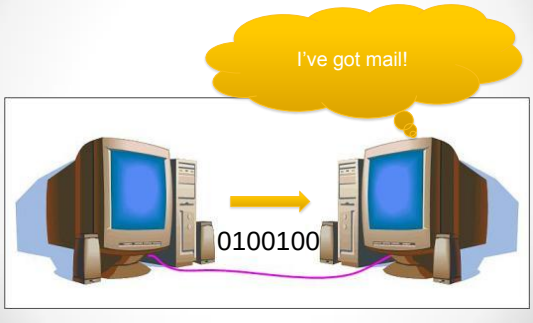
With higher-level protocols



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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

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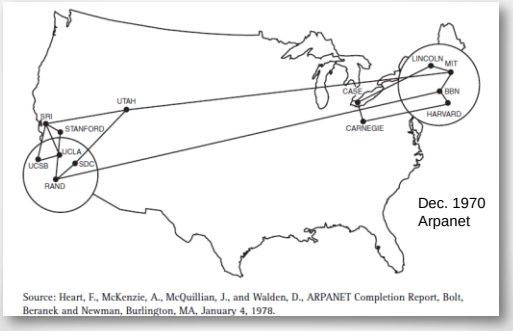
history

From Arpanet to Internet

14

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.

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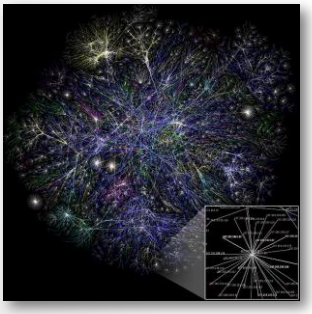
ARPANET to Internet



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
  - https://en.wikipedia.org/wiki/Morris_worm

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 addressing

getting from here to there: where is "here"? where is "there"?

IP stands for "Internet Protocol"

IP Addresses (IPv4)

- 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?

New IP (IPv6)

- IPv6 uses 128-bit addresses
  → supports 2^{128} unique computer addresses
  → = 3.4 X 10^{38}
- Allows for many more devices (cell phones, video game machines, appliances, automobiles, etc.)
- Designed to deal with the approaching use of all available addresses in IPv4.

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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

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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

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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**

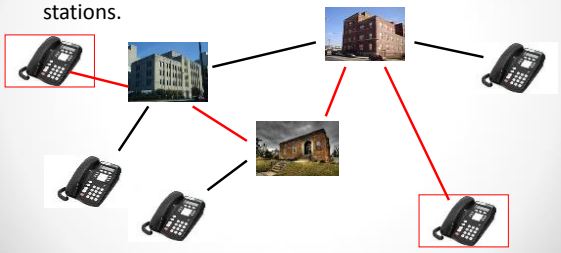
Design Decisions

- 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.



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Circuit switching

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

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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

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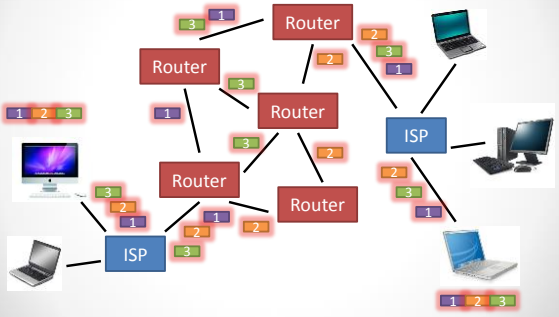
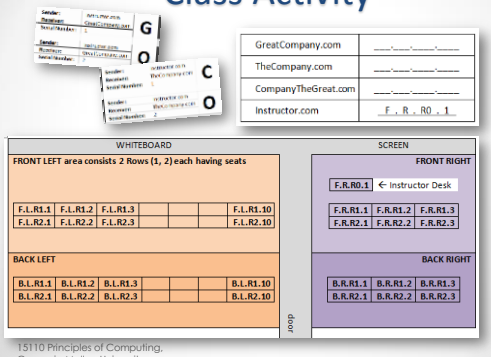
Packet Switching



Class Activity



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

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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)

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network neutrality

current issue

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Net neutrality principle

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

"Net neutrality means simply that all like Internet content must be treated alike and move at the same speed over the network. The owners of the Internet's wires cannot discriminate."

– Lawrence Lessig and Robert W. McChesney (Washington Post, June 8, 2006)

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Where is there net neutrality?

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

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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

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