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
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
“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)?
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

0100100!
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

0100100
With higher-level protocols

I’ve got mail!

0100100
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

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

- 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
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

ISP
Router
Router
Router
Router
ISP
ISP
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