Class Administration Issues
Administrative Info

- Communication:
  - E-mail preferred.
  - Send e-mail to instructor AND TAs.
Introduction

Fundamental concepts, terminology
(Chapter 1)
Chapter 1: roadmap

1.1 what is the Internet?
1.2 network edge
   - end systems, access networks, links
1.3 network core
   - packet switching, circuit switching, network structure
1.4 delay, loss, throughput in networks
1.5 protocol layers, service models
1.6 networks under attack: security
What is a network?
What is a network?

- Definition: “A group or system of interconnected people or things”. [Google]
- Many types of networks. Examples?
Many types of networks
What is a computer network?

From Webopedia:
“A compute network is a group of two or more computer systems linked together.”
What are the components of a computer (communication) network?
What are the components of a computer (communication) network?
What are the components of a computer (communication) network?

- Links, nodes, and "terminals".
- What's the difference between "nodes" and "terminals"?
Nodes and Terminals

Source: K. Salah Module 3.4
Nodes and Terminals

Terminals = Hosts, End-User Devices
The Internet

- The Internet versus an internet?
- “internet” is an abbreviation of “internetwork”.
  - Collection of interconnected networks, with no central administration or management.
  - A “network” has a single administrative authority.
- Intranetwork.
What made the Internet so popular?

What was the killer application ("killer app") of the Internet?
2nd killer application?
And more?
Internet Evolution

1: Connecting (few) computers: e-mail, file transfer, remote login.
2: Connecting larger number of computers: sharing information (WWW).
3: Connecting wireless and mobile devices.
4: Connecting people: social networks.
5: Connecting objects: Information-Centric Networks (ICNs), Internet of Things (IoT), Context-Aware Networking.
Internets of the future: a vision

What does the future hold?

“Sorry it’s taking so long to load. I’m still on dial-up.”
Internets of the future: a vision

Smart home

Interplanetary networks

Vehicular networks

Wireless mesh network

Mobile ad-hoc networks

Smart grid

Sensor networks

Smart office
“The Internet of Everything”

- IP picture frame
  [Link](http://www.ceiva.com/)

- Web-enabled toaster + weather forecaster

- World’s smallest web server
  [Link](http://www-ccs.cs.umass.edu/~shri/iPic.html)

- Internet phones
Challenges

- Scalability
  - As of early 2013, ~1.5 billion connected PCs and ~1 billion Internet-enabled mobile phones.
  - By 2020, ~50-100 billion Internet-connected devices.

- Heterogeneity
  - Devices
  - Networks
  - Services

- Autonomy and administrative decentralization
What’s the Internet?
What's the Internet: "Nuts and Bolts" View

PC

server

wireless

laptop

cellular

handheld

Access

points

wired

links

router

Millions of connected computing devices:

hosts = end systems

- Running network apps

Connection links

Fiber, copper, radio, satellite

Routers:

Forward packets (chunks of data)
What's the Internet: “Nuts and Bolts” View

- Internet: “network of networks”
  - hierarchical

Diagram:
- Mobile network
- Global ISP
- Regional ISP
- Institutional network
- Home network
What's the Internet: “Service” View

- Communication Infrastructure enables distributed applications:
  - Web, VoIP, email, games, e-commerce, file sharing

- Communication services provided to apps:
  - reliable data delivery from source to destination
  - “best effort” (unreliable) data delivery
What’s a protocol?

**Human protocols:**
- “What’s the time?”
- “I have a question”
- Introductions.

... specific messages sent
... specific actions taken when messages received, or other events
What's a protocol?

Human protocols:
- “What’s the time?”
- “I have a question”
- Introductions.

... specific messages sent
... specific actions taken
when messages received, or other events

Network protocols:
- Machines rather than humans
- All communication activity in Internet governed by protocols

Protocols define format, order of messages sent and received among network entities, and actions taken on message transmission and receipt.
What’s a protocol?

Human protocol and network protocol:

Protocols control sending, receiving of messages e.g., TCP, IP, HTTP, Skype, Ethernet
A closer look at network structure:

- **network edge:**
  - hosts: clients and servers
  - servers often in data centers

- **access networks, physical media:** wired, wireless communication links

- **network core:**
  - interconnected routers
  - network of networks
Chapter 1: roadmap

1.1 what is the Internet?

1.2 network edge
   - end systems, access networks, links

1.3 network core
   - packet switching, circuit switching, network structure

1.4 delay, loss, throughput in networks

1.5 protocol layers, service models

1.6 networks under attack: security
The Network Edge

- **End systems (hosts):**
  - run application programs
  - e.g. Web, email
  - at “edge of network”
Q: How to connect end systems to edge router?

- residential access nets
- institutional access networks (school, company)
- mobile access networks

*keep in mind:*

- bandwidth (bits per second) of access network?
- shared or dedicated?
- Bandwidth cap
Access net: home network

- wireless devices
- often combined in single box
- wireless access point (54 Mbps)
- to/from headend or central office
- cable or DSL modem
- router, firewall, NAT
- wired Ethernet (100 Mbps)
Enterprise access networks (Ethernet)

- typically used in companies, universities, etc
- 10 Mbps, 100Mbps, 1Gbps, 10Gbps transmission rates
- today, end systems typically connect into Ethernet switch
Wireless access networks

- shared *wireless* access network connects end system to router
  - via base station aka “access point”

*wireless LANs:*
- within building (100 ft)
- 802.11b/g (WiFi): 11, 54 Mbps transmission rate

*wide-area wireless access:*
- provided by telco (cellular) operator, 10’ s km
- between 1 and 10 Mbps
- 3G, 4G: LTE
Host: sends packets of data

host sending function:

- takes application message
- breaks into smaller chunks, known as packets, of length $L$ bits
- transmits packet into access network at transmission rate $R$
  - link transmission rate, aka link capacity, aka link bandwidth

\[
\text{packet transmission delay} = \frac{L \text{ (bits)}}{R \text{ (bits/sec)}}
\]
Chapter 1: roadmap

1.1 what is the Internet?

1.2 network edge
   ▪ end systems, access networks, links

1.3 network core
   ▪ packet switching, circuit switching, network structure

1.4 delay, loss, throughput in networks

1.5 protocol layers, service models

1.6 networks under attack: security
The network core

- mesh of interconnected routers
- [https://www.youtube.com/watch?v=yU9oMOCRsuE](https://www.youtube.com/watch?v=yU9oMOCRsuE)
- packet-switching: hosts break application-layer messages into packets
  - forward packets from one router to the next, across links on path from source to destination
  - each packet transmitted at full link capacity
Packet-switching: store-and-forward

- Takes $L/R$ seconds to transmit (push out) $L$-bit packet into link at $R$ bps
- **Store and forward**: entire packet must arrive at router before it can be transmitted on next link
- End-end delay = $2L/R$ (assuming zero propagation delay)

**One-hop numerical example:**
- $L = 7.5$ Mbits
- $R = 1.5$ Mbps
- One-hop transmission delay = 5 sec

More on delay shortly …
Packet Switching: queueing delay, loss

queueing and loss:
- If arrival rate (in bits) to link exceeds transmission rate of link for a period of time:
  - packets will queue, wait to be transmitted on link
  - packets can be dropped (lost) if memory (buffer) fills up
Mathematical background

Queuing theory:

Whenever $V(I) > 0$, then the system is said to be busy, and only when $V(I) = 0$ is the system said to be idle. The duration and location of these busy and idle periods are also quantities of interest.

![Queueing Systems](image)

Figure 2.1 A general queueing system.

* The notation $\Delta$ is to be read as "equals by definition."
Next class

- Please read Chapter 1.4-1.7 of your textbook BEFORE Class