Class Overview

- **Course Material**
  - Class lectures, textbook readings, and handouts

- **Course Assignments**
  - Homework questions from book and handouts
    - Handed out on Tuesday due the following Tuesday
  - Potentially a small number of programming projects

- **Exams**
  - Midterm and Final
  - I will be explicit about what is covered in each
Some hints

- Come to lecture
  - Yes, I will distribute the slides online, and yes the material is in the book
  - However, lecture materials are the basis for exams

- Do the homework
  - You will have a hard time with the exams without doing the homework
  - Its 25% of your grade (easily the difference between an A and C)
Some hints (2)

- Ask questions
  - In class, via e-mail and at office hours
  - Inevitably you won’t understand something… that’s my fault, but you need to help

- Start assignments early
  - There is a statistical relationship between when you start and what grade you get.

- Sleep
Administrativa

- Web page
  http://www-cse.ucsd.edu/classes/sp02/cse123B/

- Textbook
  *Computer Networks: A Systems Approach* (2nd ed) by Peterson and Davie

- Discussion section
  - M 9:05-0:55 CENTR 109

- TA’s
  - John Paul Fryckman & Sanjeev Bansal

- Mailing list & office hours (TBA)
Course material

- The key aspects of modern computer networks and network services
  - Reliable communication
  - Congestion control
  - Routing (intradomain and interdomain)
  - Mobility, Naming
  - Address translation, Time synchronization
  - Web service, caching, load balancing, CDNs
  - Peer-to-peer networks
  - Security
  - ???
We will not cover

- Queuing theory
- Signals
- Hardware design
- Switching design
- Physical/data link layers
Overall goals

- Understand how to large scale, heterogeneous distributed networks are built
  - Fundamental problems
  - Established design principles
  - Standard Internet protocols and implementations
Large scale?

Internet Domain Survey Host Count

Source: Internet Software Consortium (www.isc.org)
Large scale? (2)
Heterogeneous?

- Homogenous network: the telephone system
  - Designed for making phone calls
  - Known call duration distribution, bandwidth, service constraints, service model

- Homogenous network: the Internet
  - Supports E-mail, web, e-commerce, audio, video, multi-player games…
  - Few underlying assumptions – a strength and a weakness
Distributed?

- Decentralized components
  - Must update/manage changes in state
- Long communication latency
  - Actions take time
- Partial failures
  - Must tolerate failures

“A distributed system is a system in which I can’t do my work because some computer has filed that I’ve never even heard of”
– Leslie Lamport
Some review

- Elementary components
- Circuit switching vs packet switching
- Basic network model/metrics
- Layering/protocols
  - Layering by example: fetching a Web page
Network components

- **Hosts**: endpoints that communicate
  - e.g. workstation, server, PDA
- **Links**: transmission medium
  - e.g. Ethernet, 802.11b, FDDI
- **Routers/Switches**: moves bits between links
  - Circuit switching: guaranteed channel for a session (Telephone system)
  - Packet switching: statistical multiplexing of independent pieces of data (Internet)
Circuit Switching

- Three phases
  1. circuit establishment (dial)
  2. data transfer (talk)
  3. circuit termination (hang up)
- If circuit not available: “Busy signal”
- Examples
  - Telephone networks
  - ISDN (Integrated Services Digital Networks)
Circuit Switching

- A node (switch) in a circuit switching network
Circuit switching: time division multiplexing

- Time divided in frames and frames divided in slots
- Relative slot position inside a frame determines which conversation the data belongs to
- Needs synchronization between sender and receiver
- In case of non-permanent conversations
  - Needs to dynamic bind a slot to a conversation
  - How to do this?
Packet Switching

- Data is sent in a bundle of bit-sequences, called a packet.
- Packets have the following structure:
  - Header and Trailer carry control information (e.g., destination address, check sum)
  - Each packet is passed through the network from node to node along some path (Routing)
  - At each node the entire packet is received, stored briefly, and then forwarded to the next node (Store-and-Forward Networks)
  - Typically no capacity is allocated for packets

Slide courtesy Ion Stoica
Packet Switching

- A node in a packet switching network
Packet Switching:
Statistical multiplexing

- Data from any conversation can be transmitted at any given time
- How to tell them apart?
  - use header to describe data

Slide courtesy Ion Stoica
Pro/cons of packet switching

- Efficiency
  - Can share network up to its capacity – no overhead for reserving bandwidth that is unused
  - Can support many different service types

- Low complexity
  - Don’t need to maintain state about each “call”

- Harder to guarantee bandwidth/delay

We will focus on packet switching in this class
Simple network model

Network is a pipe connection two computers

- Bandwidth, delay, overhead, error rate and message size

Basic Metrics
Network metrics

- **Bandwidth**
  - Data transmitted at a rate of $R$ bits/sec

- **Delay or Latency**
  - Takes $D$ seconds for bit to propagate down wire

- **Overhead**
  - Takes $O$ secs for CPU to put message on wire

- **Error rate**
  - Probability $P$ that message will not arrive intact

- **Message size**
  - Size $M$ of data being transmitted
How long to send a message?

- Transmit time \( T = \frac{M}{R} + D \)
  - 10Mbps Ethernet LAN (M=1KB)
    » \( \frac{M}{R} = 1\text{ms} \), \( D \approx 5\text{us} \)
  - 155Mbps cross country ATM (M=1KB)
    » \( \frac{M}{R} = 50\text{us} \), \( D \approx 40-100\text{ms} \)

- \( R \times D \) is the “storage” of pipe
  (also called bandwidth delay product)
Layering

- What is layering?
  - Decomposition of a complex system into an ordered series of distinct abstractions
  - The services provided by a layer depend only on the services provided by the previous, less abstract, layer

- Layering in networking
  - **Service**: what a layer does (e.g. message delivery)
  - **Interface**: how to use the service (e.g. packet format)
  - **Protocol**: how the service is implemented (e.g. TCP)
  - **Protocol stack**: collection of protocols implementing a series of layers (e.g. Ethernet/IP/TCP/Web)
The OSI layering Model

- Top four layers are end-to-end
- Lower 3 layers are peer-to-peer
What the layers are for?

- **Application**: any service (e.g. WWW, SMTP)
- **Presentation**: data format conversion (e.g. XDR)
- **Session**: connection management, synchronization (e.g. SMIL)
- **Transport**: error-control, flow-control, channel multiplexing (e.g. TCP, UDP)
- **Network**: Routing (e.g. IP)
- **Datalink**: Framing, media access (e.g. Ethernet, FDDI, SONET)
- **Physical**: Transmission/modulation (e.g. 100BaseT)
Benefits of layering

- Encapsulation
  - Functionality inside a layer is self-contained; one layer doesn’t need to reason about other layers

- Modularity
  - Can replace a layer without impacting other layers
  - Lower layers can be reused by higher layers (e.g. TCP and UDP both are layered upon IP)

- One obvious drawback
  - Information hiding can produce *inefficient implementations*
Layer encapsulation

Layer N+1 packet becomes Layer N data.

End host

Application
Presentation
Session
Transport
Network
Datalink
Physical

End host

Application
Presentation
Session
Transport
Network
Datalink
Physical

Data

Layer N+1 packet

P Data
S Data
T Data
N Data
D Data
Ph Data

Data

P Data
S Data
T Data
N Data
D Data
Ph Data

April 9, 2002
CSE 123b -- Lecture 1 -- Introduction and Review
Layer Encapsulation (2)

- Typical Web packet

- Notice that layers add overhead
  - Space (headers), effective bandwidth
  - Time (processing headers, peeling the onion), latency
The Internet layering model

- So-called “hourglass” model
  - One network layer protocol
  - Significant diversity at other layers

- No presentation or session layers

- Implementations more important than interfaces
Layering by example...

- **ROUGHLY**, what happens when I click on a Web page from UCSD?

My computer  www.yahoo.com

Internet
Application layer (HTTP)

- Turn click into HTTP request

GET http://www.yahoo.com/r/mp HTTP/1.1
Host: www.yahoo.com
Connection: keep-alive
...
Application layer?
Name resolution (DNS)

- Where is www.yahoo.com?

My computer (132.239.9.64)

What’s the address for www.yahoo.com

Oh, you can find it at 64.58.76.177

Local DNS server (132.239.51.18)
Transport layer (TCP)

- Break message into packets (TCP segments)
- Should be delivered reliably & in-order

GET http://www.yahoo.com/r/mp HTTP/1.1
Host: www.yahoo.com
Connection:keep-alive

“and let me know when they got there”
Network layer: IP Addressing

- Address each packet so it can traverse network and arrive at host

My computer
(132.239.9.64)

www.yahoo.com
(64.58.76.177)

<table>
<thead>
<tr>
<th>Destination</th>
<th>Source</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>64.58.76.177</td>
<td>132.239.9.64</td>
<td>GET htt</td>
</tr>
</tbody>
</table>
Network layer: IP Routing

- Each router forwards packet towards destination

UCSD - Sprint - UUNet - Qwest - AT&T

www.yahoo.com
(64.58.76.177)
Datalink layer (Ethernet)

- Too boring for a picture (sorry)
- Break message into frames
- Media Access Control (MAC)
- Send frame
Physical layer

- 2.4Ghz Radio
  DS/FH Radio
  (1-11Mbps)

- 802.11b Wireless Access Point

- Cat5 Cable (4 wires)
  100Base TX Ethernet
  100Mbps

- Ethernet switch/router

- To campus backbone

- 62.5/125um 850nm MMF
  1000BaseSX Ethernet
  1000Mbps
Summary

- Packets switching is an efficient and simple architecture for data communications
  - Gives up guarantees on service
- Layering is a technique for managing complexity in systems
  - Encapsulate related functionality in a layer and provide an interface to upper and lower layers
  - A model: implementations do not necessarily respect layers
For Next Time...

- Review Patterson&Davie Chap1
- Read Chap 4.1 - 4.1.4