Short Diagnostic Quiz

- **Problem**
  - Different undergraduate backgrounds
- **Objective**
  - Gauge relative skill level
- **Time**
  - 15 minutes

Outline

- **Administrivia**
- Whirlwind tour of networking

Who’s Who?

- **Professor: Srinivasan Seshan**
  - [http://www.cs.cmu.edu/~srini](http://www.cs.cmu.edu/~srini)
  - srini@cmu.edu
  - Office hours: Wed 11:00-12:00 (for now…)
- **TA: Bianca Schroeder**
  - bianca@cs.cmu.edu
  - Office hours: Mon 12:00-1:00
- **Course info**

Objectives

- Understand the state-of-the-art in network protocols, architectures and applications
- Understand how networking research is done
- How is class different from undergraduate networking (15-441)
  - Training network programmers vs. training network researchers

Web Page

- Check regularly!!
- Course schedule
- Reading list
- Lecture notes
- Announcements
- Assignments
- Project ideas
- Exams
- Student list
Course Materials
- Research papers
  - Links to ps or pdf on Web page
  - Combination of classic and recent work
  - ~40 papers
  - Optional readings
- Recommended textbook
  - For students not familiar with networking
  - Peterson & Davie 2nd edition
  - 2 copies on reserve

Grading
- Homework assignments (20%)
  - Problem sets
  - Hands-on assignments
- Class participation (10%)
  - Pop quizzes
- 2 person project (30%)
- Midterm exam (20%)
- Final exam (not cumulative) (20%)

Outline
- Administrivia
- Whirlwind tour of networking

What is the Objective of Networking?
- Communication between applications on different computers
- Must understand application needs/demands
  - Traffic data rate
  - Traffic pattern (bursty or constant bit rate)
  - Traffic target (multipoint or single destination, mobile or fixed)
  - Delay sensitivity
  - Loss sensitivity

Four Steps to Networking
- Communicating across a link
- Connecting together multiple links (internetworking)
- Finding and routing data to nodes on internetwork
- Matching application requirements

A First Step
- Creating a link between nodes
- Link: path followed by bits
  - Wired or wireless
  - Broadcast or point-to-point (or both)
- Node: any device connected to a link
Types of Links

- Point-to-Point
- Multiple Access

Packet Transmission Modes

- Unicast
  - Transmission to single specific receiver
- Broadcast
  - Transmission to all network nodes
- Multicast
  - Transmission to specific subset of nodes
- Anycast
  - Transmission to one of a specific subset of nodes

Switched Network

- Switch: moves bits between links
  - Packet switching
  - Circuit switching

Back in the Old Days...

Then Came TDM...

- Synchronous time division multiplexing

TDM Logical Network View
Packet Switching (Internet)

Packet Switching
- Interleave packets from different sources
- Efficient: resources used on demand
  - Statistical multiplexing
- General
  - Multiple types of applications
  - Accommodates bursty traffic
  - Addition of queues

Statistical Multiplexing Gain
- 1 Mbps link; users require 0.1 Mbps when transmitting; users active only 10% of the time
- Circuit switching: can support 10 users
- Packet switching: with 35 users, probability that \( \geq 10 \) are transmitting at the same time < 0.0017

Characteristics of Packet Switching
- Store and forward
  - Packets are self contained units
  - Can use alternate paths - reordering
- Contention
  - Congestion
  - Delay

Second Step: Internet\[work\]
- A collection of interconnected networks
- Host: network endpoints (computer, PDA, light switch, …)
- Router: node that connects networks
- Internet vs. internet

Challenge
- Many differences between networks
  - Address formats
  - Performance – bandwidth/latency
  - Packet size
  - Loss rate/pattern/handling
  - Routing
- How to translate between various network technologies
### Third Step: How To Find Nodes?

**internet**

Computer 1  Computer 2

### Naming

- Humans use readable host names
- E.g., **www.cmu.edu**
- Globally unique (can correspond to multiple hosts)
- Naming system translates to physical address
  - E.g., DNS translates name to IP Address (e.g. 128.2.11.43)
  - Address reflects location in network

### Domain Name System

**What's the IP address for www.cmu.edu?**

**It is 128.2.11.43**

Computer 1  Local DNS Server

DNS server address manually configured into OS

### Packet Routing/Delivery

- Each network technology has different local delivery methods
- Address resolution provides delivery information within network
  - E.g., ARP maps IP addresses to Ethernet addresses
  - Local, works only on a particular network
- Routing protocol provides path through an internetwork

### Network: Address Resolution Protocol

**Broadcast: who knows the Ethernet address for 128.2.11.43?**

**Broadcast: Yes, it is 08-00-2c-19-dc-45**

### Internetwork: Datagram Routing

R: Routers

H: Hosts

Routers send packet to next closest point
Routing

• Forwarding tables at each router populated by routing protocols.
• Original Internet: manually updated
• Routing protocols update tables based on “cost”
  • Exchange tables with neighbors or everyone
  • Use neighbor leading to shortest path

Fourth Step: Application Demands

• Reliability
  • Corruption
  • Lost packets
• Flow and congestion control
• Fragmentation
• In-order delivery
• Etc…

What if the Data gets Corrupted?

Problem: Data Corruption

Solution: Add a checksum

What if Network is Overloaded?

Problem: Network Overload

Solution: Buffering and Congestion Control
  • Short bursts: buffer
  • What if buffer overflows?
  • Packets dropped
  • Sender adjusts rate until load = resources
  • Called “congestion control”

What if the Data gets Lost?

Problem: Lost Data

Solution: Timeout and Retransmit

What if the Data Doesn’t Fit?

Problem: Packet size

Solution: Fragment data across packets
What if the Data is Out of Order?

Problem: Out of Order

Solution: Add Sequence Numbers

Network Functionality Summary

- Link
- Multiplexing
- Routing
- Addressing/naming (locating peers)
- Reliability
- Flow control
- Fragmentation
- Etc….

What is Layering?

- Modular approach to network functionality
- Example:

<table>
<thead>
<tr>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application-to-application channels</td>
</tr>
<tr>
<td>Host-to-host connectivity</td>
</tr>
<tr>
<td>Link hardware</td>
</tr>
</tbody>
</table>

Protocols

- Module in layered structure
- Set of rules governing communication between network elements (applications, hosts, routers)
- Protocols define:
  - Interface to higher layers (API)
  - Interface to peer
    - Format and order of messages
    - Actions taken on receipt of a message

Layering Characteristics

- Each layer relies on services from layer below and exports services to layer above
- Interface defines interaction
- Hides implementation - layers can change without disturbing other layers (black box)

Layering

Layering: technique to simplify complex systems
Layer Encapsulation

Protocol Demultiplexing
- Multiple choices at each layer

E.g.: OSI Model: 7 Protocol Layers
- Physical: how to transmit bits
- Data link: how to transmit frames
- Network: how to route packets
- Transport: how to send packets end-to-end
- Session: how to tie flows together
- Presentation: byte ordering, security
- Application: everything else

OSI Layers and Locations

Example: Transport Layer
- First end-to-end layer
- End-to-end state
- May provide reliability, flow and congestion control

Example: Network Layer
- Point-to-point communication
- Network and host addressing
- Routing
Is Layering Harmful?

- Sometimes..
  - Layer N may duplicate lower level functionality (e.g., error recovery)
  - Layers may need same info (timestamp, MTU)
  - Strict adherence to layering may hurt performance

Class Coverage

- No coverage of physical and data link layer
  - Students expected to know this
- Focus on network to application layer
  - We will deal with:
    - Protocol rules and algorithms
    - Investigate protocol trade-offs
    - Why this way and not another?

Lecture Topics

**Traditional**
- Layering
- Internet architecture
- Routing (IP)
- Transport (TCP)
- Queue management (FQ, RED)
- Naming (DNS)

**Recent Topics**
- Multicast
- Mobility
- Active networks
- QOS
- Security
- Network measurement
- Overlay networks
- P2P applications

Next Lecture: Design Considerations

- How to determine split of functionality
  - Across protocol layers
  - Across network nodes
- Assigned Reading
  - [SRC84] End-to-end Arguments in System Design
  - [Cla88] Design Philosophy of the DARPA Internet Protocols