15-744: Computer Networking

L-1 Intro to Computer Networks

Outline

• Administrivia
• Whirlwind tour of networking

Who’s Who?

• Professor: Srinivasan Seshan
  • http://www.cs.cmu.edu/~srini
  • srini@cmu.edu
  • Office hours: Wed 1:30-2:30pm
• TA: Amit Manjhi
  • manjhi@cs.cmu.edu
  • Office hours: Mon 3:00-4:00pm
• Course info
  • http://www.cs.cmu.edu/~srini/15-744/F02/

Objectives

• Understand the state-of-the-art in network protocols, architectures and applications
• Understand how networking research is done
  • Teach the typical constraints and thought process for networked systems
• 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
  - Kurose & Ross (preferably 2nd edition)
    - I have some spare (1st ed) that I can lend out

Grading
- Homework assignments
  - Problem sets & hands-on assignments (15%)
  - Hand-ins for readings (10%)
- Class participation (5%)
- 2 person project (30%)
- Midterm exam (20%)
- Final (2nd Midterm) exam (not cumulative) (20%)

Waitlist & HW 0
- HW 0 – due next Thursday in class
- If you are trying to add class
  - HW 0 is due on Tuesday in class
  - I will email enrollment decisions by next Friday
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

What are Switched Networks?

- 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)

- 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 is $< 0.0017$.

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**Characteristics of Packet Switching**

- Store and forward
  - Packets are self contained units
  - Can use alternate paths – reordering
- Contention
  - Congestion
  - Delay

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**Second Step: Internet[work]**

- A collection of interconnected networks.
- Host: network endpoints (computer, PDA, light switch, ...)
- Router: node that connects networks
- Internet vs. internet

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

Internetwork: Datagram Routing

- 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
- On Ethernet, max IP packet is 1.5kbytes
- Typical web page is 10kbytes

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:

  Application
  Application-to-application channels
  Host-to-host connectivity
  Link hardware

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

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 end2end
- Session: how to tie flows together
- Presentation: byte ordering, security
- Application: everything else

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
  - [Cla88] Design Philosophy of the DARPA Internet Protocols
  - [SRC84] End-to-end Arguments in System Design
  - [Cla02] Tussle in Cyberspace: Defining Tomorrow's Internet