15-744: Computer Networking

L-1 Intro to Computer Networks

Outline

• Administrative
• Whirlwind tour of networking

Who’s Who?

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  • Mailing List?

Short Diagnostic Quiz

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

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
  - 4 copies on reserve

Grading

- Homework assignments
  - Problem sets
  - Hands-on assignments
  - Class discussion
  - Project
  - Midterm exam
  - Final exam (not cumulative)
  - Severe late penalties

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**
  - Single link between two nodes

- **Multiple Access**
  - Multiple nodes sharing a single link

Packet Transmission Modes

- **Unicast**
  - Transmission to a single specific receiver

- **Broadcast**
  - Transmission to all network nodes

- **Multicast**
  - Transmission to a 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**
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

Packet Switching

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

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 >=10 are transmitting at the same time < 0.0017

Characteristics of Packet Switching

- Many differences between networks
  - Address formats
  - Performance – bandwidth/latency
  - Packet size
  - Loss rate/pattern/handling
  - Routing
- How to translate between various network technologies

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
Third Step: How To Find Nodes?

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

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Domain Name System

What’s the IP address for www.cmu.edu?

- It is 128.2.11.43

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?

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

Internetwork: Datagram Routing

Routers send packet to next hop point

H: Hosts
R: Routers
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 the Data gets Lost?
Problem: Lost Data
Solution: Timeout and Retransmit

What if Network is Overloaded?
Problem: Network Overload
Solution: Buffering and Congestion Control
  - Short bursts: buffer
  - What if buffer overflows?
    - Packets dropped and retransmitted
    - Sender adjusts rate until load = resources
    - Called “Congestion control”

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:

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 end2end
- 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

- Brief coverage of physical and data link layer
- 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
- Interconnect (LAN)
- Internet architecture
- Routing (IP)
- Transport (TCP)
- Queue management (FQ, RED)
- Naming (DNS)

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

Next Lecture: Links

- How to make computers talk across a wire
- How to share the wire
- How to extend to multiple segments
- Assigned reading
  - [MB76] ETHERNET: Distributed Packet Switching for Local Area Networks
  - [B+88] Measured Capacity of an Ethernet: Myths and Reality