CS 640: Introduction to Computer Networks

Aditya Akella

Lecture 1
Introduction

Today...

• Administrivia

• Whirlwind tour of networking!

Administrative Details

• Instructors
  – Aditya Akella
    • akella@cs.wisc.edu
    • Office: #7379, 600-0122

• Teaching assistant
  – Ashutosh Shukla
    • shukla@cs.wisc.edu

• Course web page
  – http://www.cs.wisc.edu/~akella/CS640/F06/
  – News, lecture notes (morning of the lecture), readings.

• Office hours
  – Aditya: T 1:30 to 3:00PM
  – Ashutosh: F 1:30 to 3:00PM
Goals

- Understand principles and practice of networking
- Learn how network applications work; Learn to write applications that use the network
- Hands-on approach to understand network internals
- Make you ready for a career in networking!

Format

- ~25 lectures
  - Readings before lectures
- 4 paper/lab homeworks
  - Loosely tied to lecture material
- 3 programming assignments
  - Group projects (groups of two)
    - Get an early start
    - Evaluation by demos
- Midterm and final
  - Actually, two midterms
  - Roughly equal weight

Grading

- Split
  - 35% for Programming assignments
  - 20% for Homework
  - 20% for Midterm
  - 25% for Final exam
  - Roughly equal weight in assignments and exams
- Must pass both assignments and tests!
Collaboration & Late Submission

- Working together is encouraged
  - Discussion of course material, debugging issues, ...

- But final submission must be your own work!
  - Homeworks, midterm, final

- Programming assignments: Teams of two
  - Both must contribute!
  - Collaboration, group skills

- Late penalty: 10% per day
  - No more than 2 days late

---

Today...

- Administrivia

- Whirlwind tour of networking!

---

Goal of Networking

- Enable communication between network applications on different endpoints
  - End-points: computers, cell phones...
  - Applications? Web, Peer to Peer, Streaming video, IM
  - Communication? Transfer bits or information across a "network"

- Network must understand application needs/demands
  - What data rate?
  - Traffic pattern? (bursty or constant bit rate)
  - Traffic target? (multipoint or single destination, mobile or fixed)
  - App sensitivity? (to delay, "jitter", loss)
  - Difficulty: Network may not know some of these in the first place

- How does the application "use" the network?
  - Peer to peer: how to find nearest host
  - Web: how to modulate sending rate? Coexist with other users/apps?
**Defining a “Network”**

- Network = nodes + links
  - Will build on this soon

- Intentionally vague. There are several different networks:
  - The Internet
  - Wisc CS network
  - Telephone network
  - Home wireless networks

- Our focus on Internet
  - Also explore important common issues and challenges

---

**Common Principles ➔ Challenges for Networking**

- Accommodate different geographic scopes
  - The Internet vs. home network

- Enable scale
  - CS network vs. the Internet

- Seamlessly integrate different application types
  - Email vs. video conferencing

- Independent administration and Trust
  - Corporate network - owned by one entity
  - Internet owned and managed by 17,000 network providers
  - Independent, conflicting interests

---

**Network Building Block: Links**

- ‘Physical’-layer questions
  - Wired or wireless
  - Voltage (Electrical) or wavelength (optical)

- ‘Link’-layer issues: How to send data?
  - Medium access – can either side talk at once?
  - Data formats?
Basic Building Block: Links
- ... But what if we want more hosts?
- Wires for everybody?
- How many wires?
- How many additional wires per host?
- Scalability?

Key Idea: Multiplexing
- Multiplex: share network resources
  - Resources need "provisioning"
  - Grow at slower rate than number of nodes
- How to share? Switched network
  - Party "A" gets resources sometimes
  - Party "B" gets them sometimes
- Interior nodes act as "Switches"

Circuit Switching
- Source first establishes a circuit to destination
  - Switches along the way store info about connection
  - Possibly allocate resources
  - Different routes get different paths
- Source sends the data over the circuit
  - No address required since path is established beforehand
- The connection is explicitly set up and torn down
- Switches use TDM (digital) or FDM (analog) to transmit data from various circuits
Switching in the Telephone Network

Circuit Switching Discussion

- **Positives**
  - Fast and simple data transfer once the circuit has been established
  - Predictable performance since the circuit provides isolation from other users
    - E.g., guaranteed max bandwidth

- **Negatives**
  - How about bursty traffic
  - Circuit will be idle for significant periods of time
  - Also can't send more than max rate
  - Circuit set-up/tear down is expensive
  - Also, reconfiguration is slow
  - Fast becoming a non-issue

Packet Switching

- **Source sends information as self-contained packets**
  - Packets have an address
  - Source may have to break up single message in multiple packets

- **Packets travel independently to the destination host**
  - Switches use the address in the packet to determine how to forward the packets
  - *Store and forward*

- **Analogy: a letter in surface mail**
Benefits of Statistical Multiplexing

TDM: Flow gets chance in fixed time-slots
SM: Flow gets chance on demand; no need to wait for slot

Packets vs. Circuits

- Efficient
  - Can send from any input that is ready
  - No notion of waste of resources that could be used otherwise
- Contention (i.e. no isolation)
  - Congestion
    - Delay
  - Accommodates bursty traffic
    - But need packet buffers
- Address look-up and forwarding
  - Need optimization
- Packet switching predominant
  - Circuit switching used on large time-scales, low granularities

Internetwork

- A collection of interconnected networks
- Networks: Different depts, labs, etc.
- Router: node that connects distinct networks
- Host: network endpoint (computer, PDA, light switch, etc.)
- Together, an independently administered entity
  - Enterprise, ISP, etc.
Internetwork Challenges

- Many differences between networks
  - Address formats
  - Performance - bandwidth/latency
  - Packet size
  - Loss rate/pattern/handling
  - Routing
- How to translate and inter-operate?

“The Internet”

- Internet vs. internet
- The Internet: the interconnected set of networks of the Internet Service Providers (ISPs) and end-networks, providing data communications services.
  - Network of internetworks, and more
  - About 17,000 different ISP networks make up the Internet
  - Many other “end” networks
  - 100,000,000s of hosts

Challenges of the Internet

- Scale & Heterogeneity
  - 18,000+ independently administered domains
  - Thousands of different applications
  - Lots of users/hosts
  - Fast links, slow links, satellite links, cellular links, carrier pigeons
- Diversity of network technologies
  - Commercialization: different vendors, different features/formats
- Adversarial environment
  - Users/network operators could be malicious or just buggy
- All participating networks have to follow a common set of rules
  - To avoid anarchy; but rules must be minimal and not stifle growth
- Oh, and let’s make it easy to use...
  - Should support any application: minimal involvement of users...
Some Key "Internet" Design Issues

Need:
(1) naming,
(2) addressing and
(3) routing
(4) ...

Key Issues:
Naming/Addressing

What's the address for www.wisc.edu?
It is 144.92.104.243

Translates human readable names to logical endpoints

Key Issues:
Routing

Routers send packets toward destination
H: Hosts
R: Routers
Key Issues: Network Service Model

- What is the service model?
  - Defines what to expect from the network
  - Best-effort: packets can get lost, no guaranteed delivery

- What if you want more?
  - Performance guarantees (QoS)
  - Reliability
    - Corruption
    - Lost packets
    - In-order delivery for file chunks
    - 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 burst buffer
  - What if buffer overflows?
    - Packets dropped
    - Sender adjusts rate until load = resources → 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 packet is 1.5 KB
- Typical web page is 10 KB

Solution: Fragment data across packets

What if Data is Out of Order?

Problem: Out of Order

Solution: Add Sequence Numbers
Meeting Application Demands

- Sometimes network can do it
  - E.g., Quality of Service
    - Benefits of circuit switching in packet-switched net
    - Hard in the Internet, easy in restricted contexts
  - Lecture 20

- OR hosts can do it
  - E.g., end-to-end Transport protocols
    - TCP performs end-to-end retransmission of lost packets to give the illusion of a reliable underlying network.
    - Lectures 16-19

To Summarize...

Networks implement many functions
- Links
- Sharing/Multiplexing
- Routing
- Addressing/naming
- Reliability
- Flow control
- Fragmentation
- Etc...

Next Lecture

- Split of functionality
  - Across protocol layers
  - Across network nodes/entities