15-744: Computer Networking

Intro to Computer Networks
Outline

• Administrivia

• Layering
Who’s Who?

• Professor: Srinivasan Seshan
  • http://www.cs.cmu.edu/~srini
  • srini@cs.cmu.edu
  • Office hours: by appt.

• TAs:
  • Devdeep Ray
    • http://www.cs.cmu.edu/~devdeepsr
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  • Vamshi Konagari
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• Course info
  • http://www.cs.cmu.edu/~15744/
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 processes used in networking research

• 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
Discussion Site

• On Piazza
  • Please signup at http://piazza.com/cmu/spring2018/15744
Discussion Site

• For each lecture, post a brief comment about each paper:
  • Since I would like to read the reviews before the lecture, you should have this done by 5pm the day before the lecture.
  • Learn to critique and appreciate systems papers

• Each student will present on the lecture topic once this semester
  • 10 min presentation
  • Choose a relevant but uncovered paper
  • HW0 for signup
How to read a paper (3-pass approach)

1. Skim abstract/intro + section headings + references (5-10min)
   • Make rough assessment of paper
   • Many people will read your paper at this level

2. Read but ignore details (e.g. proofs) (1hr)
   • Good general understanding of techniques
   • Identify related work you need to look at

3. “Virtual re-implementation” (1-3hrs)
   • Identify hidden assumptions
   • Identify issues with techniques used
How to read a paper

• Learn to be critical
  • Many papers are part “marketing” – trying to show their design in the best possible light
  • Some papers may be “old”

• Learn to be positive
  • Very easy to become overly critical especially once you know topic area
  • Focus on what you learned from the paper

• Why or why not keep this paper in syllabus?
• What issues are left open for future research?
• What are the important implications of the work?
• What would you have done differently or differently now?
Course Materials

• Research papers
  • Links to ps or pdf on Web page
  • Combination of classic and recent work
  • ~40 papers
  • Optional readings

• Recommended textbooks
  • For students not familiar with networking
  • Peterson & Davie, Kurose & Ross, Tanenbaum & Wetherall
Grading

- Homework assignments (15%)
  - 4 Problem sets & hands-on assignments
- Class + discussion site participation (10%)
- Midterm exam + final exam (40%)
  - Closed book, in-class
- 2 or 3 person project (35%)
  - Main focus of class work
  - Make project productive for you!
Class Coverage

• Little coverage of physical and data link layer
• Little coverage of undergraduate material
  • Students expected to know this or learn this along the way
• 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

• Data centers
• Mobility/wireless
• Security
• Content delivery
• SDN
• P2P systems
• Privacy

+ some TBD slots
Homework 0

• Fill Google Form
  • 4 lecture choices for presentation
  • 1 sentence version of project interest areas & list of project partner
    • E.g., I want to apply game theory to network routing
  • 1 request for TBD lecture slot
Outline

• Administrivia

• Layering
This/Monday 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

• Optional Reading
  • [CT90] Architectural Considerations for a New Generation of Protocols
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
Back in the Old Days…
Packet Switching (Internet)
Packet Switching

**Positives**

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

**Challenges**

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

- A collection of interconnected networks
- Host: network endpoints (computer, PDA, light switch, …)
Internet[work]

• A collection of interconnected networks
• Host: network endpoints (computer, PDA, light switch, …)
• Router: node that connects networks
Challenge

• Many differences between networks
  • Address formats
  • Performance – bandwidth/latency
  • Packet size
  • Loss rate/pattern/handling
  • Routing
• How to translate between various network technologies?
Challenge 1: Address Formats

• Map one address format to another?
  • Bad idea → many translations needed

• Provide one common format
  • Map lower level addresses to common format
Challenge 2: Different Packet Sizes

- Define a maximum packet size over all networks?
  - Either inefficient or high threshold to support
- Implement fragmentation/re-assembly
  - Who is doing fragmentation?
  - Who is doing re-assembly?
Gateway Alternatives

• Translation
  • Difficulty in dealing with different features supported by networks
  • Scales poorly with number of network types (N^2 conversions)

• Standardization
  • “IP over everything” (Design Principle 1)
  • Minimal assumptions about network
IP Standardization

- Minimum set of assumptions for underlying net
  - Minimum packet size
  - Reasonable delivery odds, but not 100%
  - Some form of addressing unless point to point

- Important non-assumptions:
  - Perfect reliability
  - Broadcast, multicast
  - Priority handling of traffic
  - Internal knowledge of delays, speeds, failures, etc
How To Find Nodes?

Computer 1

Internet

Computer 2

Need naming and routing
Naming

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

It is 128.2.11.43

Computer 1

Local DNS Server

Translates human readable names to logical endpoints
Routing

Routers send packet towards destination

H: Hosts
R: Routers
Meeting Application Demands

- Reliability
  - Corruption
  - Lost packets
- Flow and congestion control
- Fragmentation
- In-order delivery
- Etc…
What if the Data gets Corrupted?

Problem: Data Corruption

Internet

GET index.html

GET windex.html

Solution: Add a checksum

0, 9, 9 → 6, 7, 8, 21 → 4, 5, 7 → 1, 2, 3, 6
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 → “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

GET index.html
What if the Data is Out of Order?

Problem: Out of Order

Solution: Add Sequence Numbers
Lots of Functions Needed

- 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>----------------</td>
</tr>
<tr>
<td>Host-to-host connectivity</td>
</tr>
<tr>
<td>----------------</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: technique to simplify complex systems
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

Application
Presentation
Session
Transport
Network
Data Link
Physical

Host
Switch
Router
Host
IP Layering (Principle 2)

- Relatively simple
- Sometimes taken too far
IP Hourglass

- Need to interconnect many existing networks
- Hide underlying technology from applications
- Decisions:
  - Network provides minimal functionality
  - “Narrow waist”

**Tradeoff:** No assumptions, no guarantees.
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
Friday Lecture: Recitation on Routing

- Background material from 15-441/641
- Basics of routing on the Internet
  - Link-state
  - Distance-vector
  - Forwarding
  - Address allocation
  - IP basics
Monday Lecture: Design Considerations

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Homework 0

• (by Friday) Fill Google Form
  • 4 lecture choices for critique/public review
    • Note that lecture dates may shift
  • 1 topic choice for first TBD lecture
  • 1 sentence version of project interest & list of project partner(s)
    • E.g., I want to apply game theory to network routing.

• We will be posting some questions on Piazza to answer about the two papers for Monday’s lecture (post response by 5pm on Sunday)
Layer Encapsulation

User A

- Get index.html
- Connection ID
- Source/Destination
- Link Address

User B

Connections between entities:
- User A
- User B
Protocol Demultiplexing

- Multiple choices at each layer

![Diagram showing multiple network protocol choices at each layer.](image-url)