Today’s Lecture

• Administrivia

• Why are networks important?
  • What is a network?
  • What is the Internet
  • Internet design

• A whirlwind tour of the course
Teaching Staff

• Instructors:
  • Peter Steenkiste

• Teaching assistants:
  • Serhat Kiyak
  • Harshad Shirwadkar

• staff-441@cs.cmu.edu \(\rightarrow\) course staff
  • Please use this instead of emailing just one of us!
  • Office hours and contact information on the web site.

Course Goals

• Become familiar with the principles and practice of data networking
  • Routing, transport protocols, naming, ...
  • Design of networks and services

• Learn how to write applications that use the network
  • A web server
  • Optimizing application performance

• Get some understanding about network internals in a hands-on way
  • TCP-style reliable congestion control
Course Format

• ~28 lectures
  • Cover the “principles and practice”
  • Complete readings before lecture
• 4 homework assignments
  • “Paper”: Do you understand and can you apply the material?
  • “Lab”: Illustrate networking concepts
  • Teach networking concepts/tools
  • Preparation for midterm and final
• 3 programming projects
  • How to use and build networks / networked applications
  • Application-layer programming; include key ideas from kernel
  • Larger, open-ended group projects. Start early!
• Midterm and final
  • Emphasis on understanding of course material

Recitation Sections

• Key 441 objective: system programming - C
• Different from what you’ve done before!
  • Networks and services designed to run indefinitely
  • Must handle all errors! Must be secure
  • Interfaces specified by documented protocols
  • Concurrency involved (inter and intra-machine)
  • Must have good test methods
• Recitations address this
  • “A system hackers’ view of software engineering”
  • Help develop practical skills needed in the projects (and beyond)
Course has 3 Projects

- Web server: example of a widely used service accessed using a standard protocol
  - Implement GET, PUT, HTTPS, and cgi
- Bit torrent: exposure to network internals
  - Implement transport level functions
- Video streaming: end-to-end infrastructure for delivering high quality video
  - Uses load sensitive QoE optimization, content delivery networks, DNS redirect, ...

Project Logistics

- First project is solo – others are in teams of 2
- We will use piazza for communication
- You must use version control – git
  - We are flexible about where you keep the repository
- We use autolab for grading
  - But: Autolab is a terrible debugging tool
  - You will have to write your own test scripts
  - We will provide some example scripts but grading will use a more extensive set of tests
- See web page and course handouts for details
Sounds Great! How Do I Get In?

- We currently still have a waiting list
  - If you are not taking the course, please drop it ASAP
- 15-213/18-213/15-513 is a prerequisite
  - If you have not taken this course you will have to argue that you have an equivalent background
  - Please respond to my e-mail if you want to get in
- You can only enroll if you have enough credits!
  - If you are maxed out on courses, please drop one so we can move you
- Historically, all students who persist by attending class get into the course

Administrative Stuff

- Watch the course web page
  - Handouts, readings, ..
  - Always check here first

- Office hours posted on web page
  - Make an appointment if you have a conflict

- Course secretary
  - TBD – new admin starting later in September
  - Pick up graded assignments, …
Grading

- Roughly equal weight in projects and testing
  - 45% for Projects I, II and III
  - 18% for Midterm exam
  - 27% for Final exam
  - 10% for Homework
- You **MUST** demonstrate competence in both projects and tests to pass the course
  - Fail either and you fail the class!

Policy on Collaboration

- Working together is important
  - Discuss course material in general terms
  - Work together on program debugging, ..
  - Final submission must be your own work
    - Homeworks, midterm, final

- Projects: Solo (P1) + Teams of two (P2,P3)
  - Collaboration, group project skills
  - Both students should understand the entire project

- Web page has details, e.g., university policy, etc.

- Things we don't want to have to say: We run projects through cheat-checkers against all previously and concurrently handed in versions…
Late Work and Regrading

- Late work will receive a 15% penalty/day
  - No assignment can be more than 2 days late
  - Only exceptions are documented illness and family emergencies

- Requests for regrading must be submitted in writing to course secretary within 2 weeks.
  - Do not contact us by e-mail
  - Office hours are fine for discussion but not for regrading
  - Regrading of assignment will be done by original grader

- No assignments with a “short fuse”
  - Homeworks: ~1-2 weeks - Projects: ~4 weeks
  - Start on time!
  - Every year some students discover that a 4 week project cannot be completed in a week

The Slides

- The slides are a resource that is shared by the many instructors of 15-441
  - Also some sharing with 18-345

- They include contributions from Peter Steenkiste, Srini Seshan, Dave Andersen, Hui Zhang, Eric Anderson, and others
Today’s Lecture

- Administrivia

- Why are networks important?
  - What is a network?
  - What is the Internet
  - Internet design

- A whirlwind tour of the course

What is a Network?

- An infrastructure that allows (distributed) “users” to communicate with each other
  - People, devices, …
  - By means of voice, video, text, …
  - We focus on electrical/optical/RF/.. (not trucks)
- It is assumed that the infrastructure is shared by many users
  - Point to point link is not very interesting
  - Value increases with the number of users!
Basic Building Block: Links

- Simplest example: 2 nodes
  - Sender changes voltage, frequency, …
  - Or maybe it is optical or wireless?
- But receiver must “understand” sender – protocols
  - More on this later
- Okay… what about more nodes?
- How about a million?

Scaling the Network

(N^2) Wires for everybody!

Or one wire

Or how about …
Telegraphs & Long-Distance Message Communications

- Courier: physical transport of the message
  - Messenger pigeons, pony express, FedEx
- Telegraph: message is transmitted across a network using signals – much faster!
  - Drums, beacons, mirrors, smoke, flags.
  - Light, electricity

Electric Telegraph Networks

- Electric telegraph networks exploded
  - Message switching & Store-and-Forward operation
  - Key elements: Addressing, Routing, Forwarding
- Optical telegraph networks disappeared
Bell’s Telephone

- Alexander Graham Bell (1875) working on harmonic telegraph to multiplex telegraph signals
- Discovered voice signals can be transmitted directly
  - Microphone converts voice pressure variation (sound) into analog electrical signal
  - Loudspeaker converts electrical signal back into sound
- Telephone patent granted in 1876
- Bell Telephone Company founded in 1877

Signal for “ae” as in cat

Links and Switches in Early Telephone Networks
Three Phases of a Connection

1. Pick up phone
2. Dial tone.
3. Dial number
4. Network selects route; Sets up connection; Called party alerted
5. Exchange voice signals
6. Hang up.

Circuit Switching

- Source first establishes a connection (circuit) to the destination
  - Each switch along the way stores info about connection (and possibly allocates resources)
- Source sends the data over the circuit
  - No need to include the destination address with the data since the switches know the path
- The connection is explicitly torn down
- Example: telephone network (analog)
Circuit Switching Discussion

• Circuits have some very attractive properties.
  • Fast and simple data transfer, once the circuit has been established
  • Predictable performance since the circuit provides isolation from other users
  • E.g. guaranteed bandwidth

• But it also has some shortcomings.
  • How about bursty traffic
    • Do you need a permanent circuit to Facebook?
    • Circuit will be idle for significant periods of time
  • How about users with different bandwidth needs

Contrast this with Packet Switching (our emphasis)

• Source sends information as self-contained messages that have an address.
  • Source may have to break up single message in multiple packets

• Each packet travels 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.
And Some More Examples …

- Television network
  - Over the air
  - Cable TV
  - Satellite
- Radio broadcast
- Various private networks
  - E.g., for first responders, military, ..

Today’s Lecture

- Administrivia

- Why are networks important?
  - What is a network?
  - What is the Internet
  - Internet design

- A whirlwind tour of the course
What about the Internet

• An inter-net: a network of networks.
  • Networks are connected using routers and other devices, e.g., for security, accounting, …
  • Networks can use diverse technologies
  • Typically managed by different organizations

• The Internet: the interconnected set of networks of the Internet Service Providers (ISPs)
  • About ~23,000 “transit” ISPs make up the Internet
  • Many more “edge” networks

What is the Objective of the Internet?

• Enable communication between diverse applications on diverse devices (“computers”)
  • Web, peer-to-peer, video streaming, distributed processing, video and audio conferencing, …
  • Over very diverse infrastructures
  • The “Internet”, WiFi and cellular, data center networks, corporate networks, dedicated private networks, …

• In contrast: previous networks were special purpose and fairly homogeneous in terms of technology

• Must understand application needs/demands (Thursday)
  • Traffic data rate and loss sensitivity
  • Traffic pattern (bursty or constant bit rate)
  • Traffic target (multipoint or single destination, mobile or fixed)
Packet Switching – Statistical Multiplexing

- Switches arbitrate between inputs
- Can send from any input that’s ready
  - Links are never idle when there is traffic to send
  - (Efficiency!)

Multiplexing

- Need to share network resources

- How? Switched network
  - Party “A” gets resources sometimes
  - Party “B” gets them sometimes
  - Interior nodes act as “Switches”

- Many challenges: fairness, efficiency, …
Internet Design

- In order to inter-operate, all participating networks must follow a common set of rules
- Example: requirements for packets:
  - Address format, header information, packet size limit, ...
- But also: routing, error reporting, billing, …
- Also: what is the “service model”, i.e., the commitment made to applications
  - Internet: *best-effort* – packets can get lost, etc.
  - But some applications need reliable data delivery, a minimal bandwidth guarantee, low latency, …

Networks Juggle Many Goals

- Support rich set of applications
- Efficiency – resource use; cost
- The “ilities”:
  - Evolvability
  - Managability
  - Security (securability, if you must)
- Ease of:
  - Deployment
  - Management
  - Creating useful applications
- Scalability
Must also Deal with “Real World”

• Economics and public policy play a big role in the design of the Internet
  • ISPs are competing for customers but they must also work together
  • They must make money – no ISPs, no Internet
• Public policy looks after user interests and tries to promote competition and innovation
• Users will only use the network if they get value out of it
  • Concerns such as privacy can stifle use

Today’s Lecture

• Administrivia

• Why are networks important?
  • What is a network?
  • What is the Internet
  • Internet design

• A whirlwind tour of the course
Whirlwind Tour of the Course

- Infrastructure: hardware (or close to it)
- Core networking protocols: IP, dealing with errors and congestion, routing, …
- Optimizing performance: QoS techniques, caching, CDNs, peer-peer, …
- Making it work well: security, management, …
- IP everywhere: the Internet, last mile, wireless, mobility, data center, video, IP-TV, skype, …
- Focus is on today’s Internet but also trends
  - What will the Internet look like in 10, 20, 30 years?

Infrastructure

- Why do we have different types of “wires”?
  - And why do I care?
- Ethernet is very old, so why is it so fast?
  - Can’t they find something better?
- What are the limits of some of the technologies?
  - Both physical and protocol limits
Core Networking Protocols

Think: traffic on the roads
• How do I find a path to my destination
• How do I specify addresses
• What if my car breaks down?
• How do I deal with traffic jams
• …

Optimizing Performance

• Intuitively: lots of bandwidth!
• But there is more to it:
  • Latency is often more critical!
  • For voice and video – can I offer guarantees?
  • Can I beat the speed of light?
    • Hint: this can make you rich
  • Why did we use peer to peer networks?
  • And why did they (mostly) go away?
Making the Network Work Well

- Good technology is only a small part of the puzzle – deployment and management issues are equally (or more) critical
  - Involves many people, high cost, big impact on QoE
- How do I secure my network?
  - Lots of bad guys: DOS, compromised hosts, privacy leaks, botnets, …
- How do I manage resources, reduce operator errors, deal with failures, …
  - And how does it differ in LAN, WAN, wireless, …

IP Everywhere

- Using IP technology has become attractive
  - Cheap commodity hardware, lots of tools, people trained in the technology, end-to-end support, …
- The (public) Internet: our focus
  - How do you optimize “the web”: CDNs, caching, …
- Data centers: very special requirements
  - Map-reduce, 3-tier business apps, load balancing, …
- IP TV, voice/video conferencing:
  - Very high QoE expectations
- Wireless and mobile apps
  - For many users, primary way of accessing Internet
- Residential networking
• I have to travel next week, so:
  • Three lectures this week
  • Recitations next week
• Upcoming lectures:
  • Applications requirements and protocol stack
  • Physical layer technologies
  • Datalink: ethernet and friends