CS528: Computer Networks and Data Communications

CS 528 – Computer Networks and Data Communication
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CS Dept., SUNY–Binghamton Fall ’07

• Agenda for today:
  – Go over syllabus: Policies, Grading, Odds and Ends
  – Intro and motivation
  – Requirements of a scalable general purpose communication network
Administtrivia

- Instructor: me (nael@cs.binghamton.edu).
  - Office hours T 3-4pm, Th. 1-2pm T-12 EB, third floor
  - If you cannot make these times, email me for an appointment

- Class webpage: http://www.cs.binghamton.edu/~cs528
  - Will try to make class notes available early, but no promises
Course Goals

- Provide the background for understanding, appreciating and performing research in networking
  - Provide an understanding of the principles and tradeoffs involved in building a heterogeneous large scale network such as the Internet
  - Provide an understanding of the important protocols and applications that are shaping the Internet
  - Overview active research areas and discuss open research problems
- Provide training and practice in reading and evaluating research papers
- Provide experience in performing research
Course Mechanics/Grade breakdown

• Lectures and discussion
  – 5% of your grade based on class participation (attendance, and participation in discussions)
• Homeworks and Critiques (20%)
• Project/Programming assignments, (30%)
• Two midterms (25%) and a final (20%)
• Grade is relative to the rest of the class
• Will find ways to make your better work count for more
  – Will drop your worse critique, and try to factor your better work for a higher weight
Balance Between Graduate and Undergraduate Content

- Will not assume you have had undergraduate networking, but

- But this is a graduate class
  - Will do quick reviews of core material; you will have to read some on your own if you don’t have the background
  - Hitting the balance between core and research topics
    - Textbook (which is excellent) for core topics
    - Papers to augment the core material; you will read some, and I will cover additional ones
  - Exam problems and Projects from both core and research topics
  - In general, I am trying to make the course a little easier than previous years
Topics We will try to Cover

- Quick review of lower layers (physical, link layer, MAC)
- Internetworking
- Reliable Data Transfer
- Routing (Unicast and Multicast) and Traffic Engineering
- Congestion Control
- Quality of Service (IntServ/Diffserv, scheduling and queue management)
- Mobile Networking
- Network Security
- Applications
- Overlay Networks
- Peer-to-Peer networking
- Next Generation Internet
- Measurement, High Performance Networking, Router Architecture, ATM, ...
- More than will fit in a single semester!
Reading and Critiquing Papers

• Will rely on research papers for many of the topics we cover
• You have to read some papers, and I encourage you to read others
• Critiques will be used for the required papers (6 or 7)
  – A series of questions about the paper
    * Due before class
    * Will require only around 6 for the whole semester; will throw away your worse one
  – Class participation is expected (worth 5% of your grade)
  – Exams and quizzes will be partially based on the papers (only what we cover in class)
Reading Research Papers

• Several types of papers
  – Classic papers for mostly historical value (will not be required)
  – Fundamental issues/Position papers
  – New ideas papers
  – Analysis papers

• Average of one paper to read per week
  – Critique not required for all (roughly every other week)
  – I will cover additional papers that you won’t be required to read or critique
Projects

• A common start, then two tracks
• First project: using the NS-2 simulator, building and running some scenarios
• Second project will also be common
• After that, you can pick a standard third project or research project track
  – Standard project is well defined, non-researchy implementation project
  – Research project is a self defined (with my help) research study– Only if you are experienced/research minded
Some Advice/Hints

• Start on projects early (doubly true if you take the research project option)
  – Statistical correlation between when you start and your grade
  – Some groups that did not take it seriously in the past did not finish

• Keep up with the reading; classes will be much more useful to you if you do
First Project Assignment Next Week

• Learning NS-2: Please go through the two tutorials on the class webpage

• Assignment is straightforward, but there is a lot of stuff that you need to learn
  – Downloading/installing NS-2; make sure you have space for that or ask me for an account on a machine that does
  – Tcl/Otcl
  – awk or perl or python or your favorite scripting language to process results

• Help will be forthcoming
Reading for Next Week

- Required: The End to End Argument in System Design, Saltzer et al
- Recommended: Tussle in Cyberspace: Defining Tomorrow’s Internet, Clark, Sollins, Wroclawski and Braden, SIGCOMM 2002.
- Recommended: The Design Philosophy of the DARPA Internet Protocols, David Clark, SIGCOMM 1988 (optional; will cover parts in class)
- Downloadable from class webpage
Expectations

- This course is about:
  - General purpose communication networks
  - Fundamental concepts and principles; challenges and tradeoffs
  - Internet Perspective
  - Networking System Software (with overview of hardware)
  - Engineering of a Scalable Network
Expectations

• This course is **NOT** about:
  – Specialized networks (e.g., telephone, CATV, PCS)
  – Survey of existing protocol standards
  – OSI perspective ("layering is a good slave but a poor master")
  – Network Hardware Design
  – Queueing Theory
Computer Networks – why

- Why is networking interesting?
- What’s hard about networking?
Really Large Scale

Internet Domain Survey Host Count

Source: Internet Systems Consortium [www.isc.org]
Really *LARGE* Scale!

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Heterogeneous

- Homogeneous Network: the phone system
  - Designed for making phone calls
  - Well known behavior (call properties, bandwidth, service constraints...)
  - Small number of technologies
  - Centralized (or nearly centralized) control

- Heterogeneous Network: the Internet
  - Many types of applications
  - Few Underlying Assumptions (good and bad)
  - Wide variety of competing interacting technologies
Distributed

- Decentralized Control; how to manage updates in state?
- Long communication latency
- Partial failure possible

“A distributed system is one where I cannot do my work because some computer has failed that I’ve never even heard of” – Leslie Lamport
Requirement Definition

- Requirements and Constraints depend on your perspective:
  - Network users want the network to provide services that their applications need; e.g., guarantee that each message will be delivered in order, without errors, and within a pre-defined delay
  - Network designers want a cost-effective design; e.g., network resources are efficiently utilized and fairly allocated to users
  - Network providers want a system that is easy to administer and manage; e.g., faults can be easily found, system can be hot-swapped, and easy to track usage of users

- What do these requirements translate to?
Requirement I: Connectivity

- Building blocks:
  - Links: copper wires (coax cable, twisted pair), optical fiber, ...
  - Nodes: general-purpose workstations, dedicated routers, ...
- Direct Links:
  - Point-to-point: dedicated link connecting two nodes
  - Multiple access: many nodes access a shared “broadcast” medium
  - other?
Indirect Connectivity

• Switched Networks:

• Internetworks
Connectivity – Summary/Discussion

- “A network is two or more nodes connected by a direct link, or two or more networks connected by one or more nodes”

- Hosts connected directly or indirectly
  - Need global addressability
  - Need routing ability
  - Unicast/Broadcast/Multicast

- Network Edge vs. Network Core; does it make a difference?
Requirement II: Efficient Resource Sharing

- Must share the network resources (nodes and links) among multiple users

- Common multiplexing (sharing) techniques:
  - Time Division Multiplexing (TDM)
  - Frequency Division Multiplexing (FDM)
Switching Strategies

• Circuit Switching:
  – send/receive a bit stream over a dedicated circuit
  – Three phases: call, send data, hang up
  – Static allocation of resources
  – Example: Telephone network

• Packet switching:
  – A Packet is the unit of switching (what is a packet?)
  – Usually store-and-forward: virtual cut-through in high performance LANs
  – Dynamic sharing of bandwidth (statistical multiplexing)
Statistical Multiplexing

- On-demand TDM; enabled by packet switching
- Allocate link on a per-packet basis; packets from different sources are interleaved on link
- Cost-effective fine-grained sharing of link
- Buffer packets that are contending for the link
- No state in routers
- How to allocate the link fairly?
- How to guarantee performance?
- What happens if we run out of buffer space?
Requirement III: Functionality

- Network should provide abstractions (services) that allow application programs to communicate in a meaningful way

- How to decide what to support in the network?

- A hardware/software tradeoff?

- What are some useful communication abstractions?

- Think of examples of other desirable functionality...
Example: common process-to-process channel abstractions

- Request/Reply – client server applications such as file access and web page browsing
- Message stream – example, video application
  - video: sequence of frames
  - resolution: 1/4 TV size image = 352 x 240 pixels
  - 24-bit color: frame = (352 x 240 x 24)/8 = 247.5 KBytes/frame
  - 15-30 frames/sec for usable quality video; at 30 fps need 7.5Mbyte/sec
  - video-on-demand; video-teleconferencing

- Think of ways these applications are different; can a single network effectively support both types of application?

- Example of additional requirements: reliability; security; guaranteed level of performance
Reliability

What can go wrong in a network?

- Bit-level errors (e.g., due to electrical interference on the wire)
- Packet-level errors (e.g., due to congestion)
- Link and node failures
- Messages are delayed
- Messages are delivered out-of-order, lost or duplicated
- Malicious interference
- What level of protection should the network provide?
Functionality – Summary

• Many useful abstractions could be required by users
• Other functionality such as reliability and security
• Different performance levels required
• What should the network support?
• Balance application requirements and technology limitations
  – The semantic gap: filling the gap between the application requirements and the underlying network technology
  – Computer architecture analogy
  – The End-to-End Principle in System Design (Saltzer et al)—our first reading assignment
Requirement IV: Performance

- **Bandwidth (throughput)**
  - Amount of data that can be transmitted per time unit
  - Link vs. end-to-end
  - Notation
    - $\text{KB} = 2^{10}$ bytes
    - $\text{Mbps} = 10^6$ bits per second
  - Bandwidth related to bit-width
Performance (cont’d)

- **Latency (delay)**
  - Time it takes to send message from one point to the other
  - Sometimes we are interested in round-trip time (RTT)

- **What determines the latency?**
  - Latency = Propagation + Transmit + Queue
  - Propagation is the distance / speed of light
  - Speed of light (3.8 x 10^8 m/s in vacuum; 2.3 in copper; 2.0 in fiber)
  - Transmit = size / bandwidth
  - No queuing delays in direct link

- **Bandwidth not relevant if size = 1 bit**

- **process to process latency include software overhead, which can dominate if the distance is small**
Interaction of Latency and Bandwidth

- What contributes more to the performance of required operation?
  - Small messages: 1ms vs 100ms latency dominates 1Mbps vs 100Mbps bandwidth
  - Large messages: 1Mbps vs. 100Mbps dominates 1ms vs. 100ms

- Delay Bandwidth product defines amount of data “in flight” – why is this important?

- Application needs: bandwidth (burst vs. stable), latency (jitter = variance in latency)
Example

Consider a network consisting of three hosts, A, B, and C. A is connected to B using a 40 kbit/sec, 10 msec delay link. B is connected to C using a 20 kbit/sec link with 20 msec delay.

(1) How long does it take to send a 2000 bit packet from A to C?

(2) Suppose that A starts transmitting 2000 bit packets to C at the maximum rate possible on the link from A to B. How much buffering does B need to provide such that the first packet will not be dropped until after 1 second has elapsed?

(3) Suppose that C immediately signals A to stop sending packets after it receives the first packet. Assume that this ‘‘signal’’ packet experiences the minimum possible delay. A stops sending packets immediately after receiving the signal packets. How many packets has A sent?
High Speed Networks

- “High Speed” networks – bandwidth is increasing
- Latency is much harder to improve (limited, for example, by the speed of light)
- “can always buy more bandwidth”
- think about the implications
Other Performance Metrics?

- What are some other performance metrics of interest?