Advanced Network Design

- Organization
  - www.cs.uchicago.edu/~nugent/cspp54015
- Grading
  - Homework/project: 60%
  - Midterm: 15%
  - Final: 20%
  - Class participation: 5%
- Interdisciplinary Course
- What do you want in it?
Who are you?
What is your Network/CS background?
What are you looking for in the course?
Advanced Networking

Motivation

- IP Phone/Video war stories
- High Speed Traders
- Reliable Networks
- Routing/Traffic Engineering
- Security
- Management
Internet history of Networks

- 60s packets vs. circuits
- 70s NCP, IMPs, first TCP/IP
- 80s Routing, first voice experiments
- 90s Globalization and the web
- 00s Multimedia
- 10s Mobile, Cloud & Security
Course Outline

- It's about performance and Security
- TCP/IP review and performance
- IP Routing, Router Architectures
- Multimedia, QoS, Algorithmics, Security
- VoIP, Video, Telepresence, designing reliable networks, MPLS
Performance

- **Endnode Bottlenecks**
  - Copying, context switches, system calls, timers, demultiplexing, checksums/CRC, protocol implementations

- **Router Bottlenecks**
  - Prefix lookups, packet classification, switching, queuing, bandwidth, measurement, security
Security

- Network Security Topics
  - Successful IT Security requires multilayer approach.
  - We will consider the security aspects of different network capabilities.
TCP/IP Review

- **IP protocols**
  - UDP: stateless, best-effort
  - TCP: stateful, reliable, congestion control
- **Man-in-the-middle attacks**
- **Most relevant for stateful protocols**
The seven layer model

- Physical, Link, Network, Transport, Session, Presentation, Application
- Example with repeater, switch, router, proxy server
TCP Flow Control

- Wired flow control: x-on, x-off (Ethernet, etc.)
- TCP is designed to be media independent
- TCP flow control is more difficult
Packet Mechanics

- Counting Transmission Delays
  - Time for sending data
  - Time for Acks
  - Stop and go: line utilization < 10%
- Continuous send
  - One packet per ack
  - 10 packets per ack
  - How many packets before ack?
TCP Windows

- Sliding Window
  - Trans rate = stop & go \times \text{window size}
  - Actual = \text{min (bandwidth, Trans)}

- TCP Cumulative Acks
  - Inefficient if early packet in window lost
  - Timeout is Important
TCP Time out

- TCP Designed for Internets with adaptive routing
- Round Trip time can vary greatly
- Adjust RTT slowly
  - \( RTT = a \times \text{old}_\text{RTT} + (1-a) \times \text{new RTT} \)
- Ack ambiguity, Karn’s algorithm
- Ignore retrans, but backoff
Sequence Numbers

- Initial Sync
- Delayed duplicates
- Connection ID, machine crash
- Hop count, timestamp
TCP Seq Numbers

- Avoid requiring synchronized time on nodes
- Use clock for low order of bits of initial seq
- Seq space wrap time > max packet lifetime
- Problem of packet rate vs. time rate
- 3 Way initial handshake
TCP Close

- Avoid data loss with abrupt close
- 3 Army problem
- TCP Close state
- Many spammers don’t close
TCP Seq Security

- Guessing initial TCP Sequence numbers
  - Man-in-the-middle attacks
  - Without monitoring
    - Pseudo random numbers
    - Multiple guesses allowed
    - Phase space attacks
What is Congestion?

- End-point slowness
- Slow processors
- Too Many packets in network
- More memory to hold them?
- Counter productive with time-outs
- Internal vs external congestion
- Receiver window vs network window
Network Congestion

- Flow control vs congestion control
  - Flow control between hosts/devices: x-off, x-on
- Network congestion control
- Multiplicative Decrease
  - On loosing a segment, reduce congestion window by half (minimum of one segment)
Network Congestion Response

- Response by Routers on the Network
- ICMP Source quench
- Random Early Detection (RED)
  - Dropping packets on full buffer breaks many flows
  - Pick a flow and drop a packet
Congestion Avoidance

- Dynamic Window
  - TCP slow start
    - Double with each ack up to buffer size
    - On first packet drop, set SSThreshold, drop 1/2 size buffer
    - Grow to SSThresh, then linear growth
Principles of Congestion Control

- Monitor to detect congestion
  - Typically packets sent vs discarded
  - Not that easy, we will return to this

- Pass information to control point
  - Control data at source to avoid retrans.
  - Or Control at destination
Congestion Prevention Policies

- Data Link Layer
  - Retransmission policy
  - Out-of-order caching policy
  - Acknowledgement policy
  - Flow Control policy
Congestion Prevention Policies

- Network Layer
  - Virtual Circuits vs Datagrams
  - Packet queueing and service policy
  - Packet discard policy
  - Packet lifetime management
Congestion Prevention Policies

- Transport Layer
  - Retransmission policy
  - Out-of-order caching policy
  - Ack policy
  - Flow Control policy
  - Timeout determination
Closed Loop Congestion Control

- Admission Control in Virtual Circuits
- Routing around hot spots
- Traffic shaping
- These arrangement waste resources
TCP Performance

- Generally, CPU Speed is more important than net speed
- .96 microsecond Ethernet slot time vs 9 mSec disk seek time
- Networks now used as storage bus
  - e.g. FDI going to Ethernet
- Reduce Packet Count
- Software overhead is per packet
TCP Performance

- Minimize context switches
  - Expensive for current generation OSs
- Easy to buy bandwidth
  - But not lower delay (latency)
- Wireless hops add latency
TCP Performance

Avoid Congestion

Rather than recover

Hard with End-to-End model of the Internet

Avoid timeouts

Early timeouts are expensive
Protocol Processing

- TCP Input processing is complicated
- Header prediction
  - If expected flags and window, exp seq (SYN, FIN, RESET, PUSH, URG, ACK)
  - If header, but no data
  - do Ack
Protocol Processing

- If no new ack, but has data
  - copy and process data
    - Copy-on-write
  - Fast Packet Sending
    - Prototype header
      - TCP: seq, checksum change
Protocol Processing

- Copy-on-write
- Solves Security issues for fast packet processing
Questions?

Read Chapter 1-3 in Varghese