Announcements

• Upcoming dates
  – Sat, 5/3: Lab 3 due with extension
  – Mon, 5/5: In-class midterm
  – Wed, 5/14: Lab 4 due

• Lab 4 is out and is more complex than labs 1, 2, and 3
Midterm Review

1. Applications & app programming
2. IP and forwarding
3. Routing
4. Transport & reliability
5. TCP & congestion control
6. DNS
7. DCCP & NAT
8. Queuing, caching, & content distribution
9. Questions
Applications & app programming

- Telnet
- Web/HTTP
- BitTorrent
- Skype
Definitions

• End-to-End principle - dumb network, smart terminals
• Throughput – bits/time
• Latency – time for message to cross network
• Goodput – application level throughput
• Jitter – variation in latency
P2P

• BitTorrent
  – Tracker
  – Tit-for-Tat - “choked,” “top,” and “probing” peers
  – BitTyrant

• Skype
  – Distributed index located at super-peers
  – Ch. 2 R.25 “Skype uses P2P techniques for two important functions. What are they?”
    1. ?
    2. ?
P2P

- BitTorrent
  - Tracker
  - Tit-for-Tat - “choked,” “top,” and “probing” peers
  - BitTyrant
- Skype
  - Distributed index located at super-peers
  - Ch. 2 R.25 “Skype uses P2P techniques for two important functions. What are they?”
    1. Query index (find someone)
    2. Relays – get around NATs
Network layer:
IP, forwarding, routing

Big Picture

Communication Network

Switched Communication Network

Broadcast Communication Network

Circuit-switched

Packet-switched

Datagram

Virtual Circuit
IP

- Skinny waist of internet
- Connectionless
- Best-effort delivery (unreliable)
- TTL
- Fragmentation
- Classful networks – class A, B, C
- Classless Inter-Domain Routing (CIDR)
Network layer supporting protocols

• ARP – map IP to link layer ethernet address
• ICMP – ping, TTL exceeded, etc.
• DHCP – dynamic IP address assignment
• DNS (later)
Switching

• Optical switch
• Bridge – connect multiple LANs
• VLAN – broadcast to portion of LAN
• Banyan networks – one path from input to output
• Bisection bandwidth – worst-case aggregate bandwidth between two equal-sized sets
Routing

• Forwarding – moving packets from input port to output port
• Routing – populating forwarding table
• Goal – find lowest cost path between two nodes
• Distance Vector (Bellman-Ford) algorithm – local, issues dealing with failures, RIP
• Link State (Dijkstra’s) algorithm – global, broadcasts LSP, OSPF
• Path Vector – next slide
Autonomous Systems

• Each AS corresponds to an administrative domain
• Want own intra-domain routing protocol
• Want to set inter-domain routing based on policies (financial, legal, ...)
• Issues – transit/peering relationships, local/transit traffic, multihomed,
• Path Vector – BGP, ASPATH announces, allows policy choices based on ASes in path, Multi-Exit Discriminators
Datagram Congestion Control Protocol

- Make UDP play well with TCP
- Connection oriented – Acks for congestion control NOT for reliable transport
- Acks are for last packet received rather than cumulative
- Uses sequence number windows to protect against attacks – need to resynchronize when a large burst of losses cause packets to fall past window
- Congestion Control IDs (CCIDs) – what type of congestion control you use
  - CCID 2: TCP CC (AIMD)
  - CCID 3: TCP-friendly CC – uses sending rate rather than congestion window – receiver reports loss rate once per RTT
NAT

- Expand 32 bit address space
- Translates local IP addresses to globally routable IP addresses, and vice versa
NAT types & problem

• Full cone, restricted cone, port restricted, symmetric

• Problems
  – Incoming connections
  – Port mapping constraints

• Solutions
  – Rendezvous servers (Skype)
  – STUN
  – NAT Hole-Punchingb
Queuing

• Routers handle burstiness of traffic by queuing incoming packets
• Routers try to provide fairness, high throughput, and low delay
• Fair Queuing – provide each flow an equal portion
  – Packets placed in per flow FIFO
  – Calculate $F_i$ for each packet, or time it would complete being transmitted if we served just that flow
  – Next packet to transmit is one with lowest $F_i$ timestamp
  – Packets will be sent out within one maximum packet transmission time of perfect “fairness”
Congestion avoidance

• Random Early Detection (RED)
  – Dropped packets imply congestion in the internet
  – Drop random packets early to fairly signal to all flows that congestion is increasing
  – Use *average* queue length
  – Make drop probability a function of time since last drop to avoid over penalizing one flow.
Caching & content distribution

- Web proxies, DNS servers, network file systems use to decrease latency and save bandwidth
- TTL, polling, callbacks, leases to deal with consistency
- Internet Cache Protocol – allow proxies to query each other
- Reverse proxies – content distribution networks like Akamai
- Use some kind of hashing to locate cached data