Announcements

- Project proposal drafts due March 14, 1997
- Midterm #1
  - exam booklets were returned
  - class average was 61.8 (60.5 for undergrads)
  - standard deviation was 14.7 (14.5 for undergrads)
- Reading
  - Today: 5.4-5.5
  - Thursday: 5.6
Internetworking

- **Goals:** provide seamless operation over multiple subnets
  - could be two similar LANs
  - link WANs to LANS
  - link two different LANs together
- **Issues:**
  - packet size limits (different networks may have different limits)
  - quality of service (is it provided, how is it defined)
  - congestion control
  - connection vs. connectionless networks
- **Possible at many levels**
  - physical layer: repeaters
  - link layer: bridges - regenerate traffic, some filtering
  - network: routers - route packets between networks
  - transport: gateway byte streams
  - application: gateway email between two different systems
Firewalls

- **A way to limit information flow**
  - selective forwarding of information based on **policy**
  - policy: rules about what should be permitted
  - mechanism: way to enforce policy

- **Can be implemented at many levels**
  - at higher layers have more information
  - at lower layers can share filtering between multiple higher level entities

- **Possible Layers**
  - link layer: filter based on MAC address
  - network layer: filter based on source/destination, transport
  - transport: filter based on service (e.g. port number)
  - application: filter based on user name in email, based on content
Tunneling

● **Problem**
  – Source and Destination are compatible
  – something in the middle is not compatible

● **Solution: Tunnel though the middle**
  – only multi-protocol routers need to understand conversion
  – possible to tunnel through almost anything
    • can tunnel IP through IP (for mobile computing perhaps)
Internet Routing

- Use two levels of routing
- local (subnet) level routing
- Internet routing between multi-protocol gateways
  - multiple protocol gateways are generally fully connected
    - since they hide the underlying network
  - policies (politics) can dictate acceptable routes
    - don’t route IBM packets of the Microsoft network
    - all packets starting and ending in Canada must stay in Canada
- Can use any of the standard routing algorithms
  - link-state
  - distance vector
Interior Gateway Routing Protocol

- **Designed to Route within a single Autonomous System (AS)**
  - An AS contains
    - areas (collection of one or more subnets)
    - backbone (to interconnect areas within AS)
  - Also Called Open Shortest Path First (OSPF)

- **Divides routers into four classes**
  - Internal - only within the area
  - Area border router - connect two or more areas
  - Backbone routers - connect to backbone
  - AS boundary routers - talk to other AS

- **Exchanges info between adjacent routers**
  - not the same as a neighbor since could have many hops in-between

- **Uses link-state**
  - flooding with sequence numbers
  - supports multiple metrics: throughput, reliability, delay
  - backbone computes inter-area routes
Graph representation of an Autonomous system.

Relationship between areas an ASes
Exterior Gateway Protocol (BGP)

- **Used to route between AS’s**
  - concerned with politics and turf battles
  - supports specific policies
    - don’t send my packets of network X
    - don’t send packets through me
- **Two types of nodes**
  - stub networks (one connection to BGP)
  - multi-connected networks (more than one connection)
    - might also be transit networks (carry traffic for others)
- **Uses Distance Vector**
  - but includes complete path in table and sent to neighbors
  - uses “scoring” function to select among possible routes
Fragmentation

- Sometimes need to split packets into smaller units
  - limits of the hardware being used
  - operating system buffer constraints
  - protocol limits (max permitted packet is x bytes)
  - reduce channel occupancy (head of link blocking)

- Fragmentation
  - where to split it into smaller packets
    - source (requires end-to-end information on max size)
    - when it reaches boundary
  - how to represent split packets
    - need to encode fragment offset

- Reassembly
  - where to re-combine packets
    - destination (may result in poor performance)
    - at the gateway to the subnet that supports the full size