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

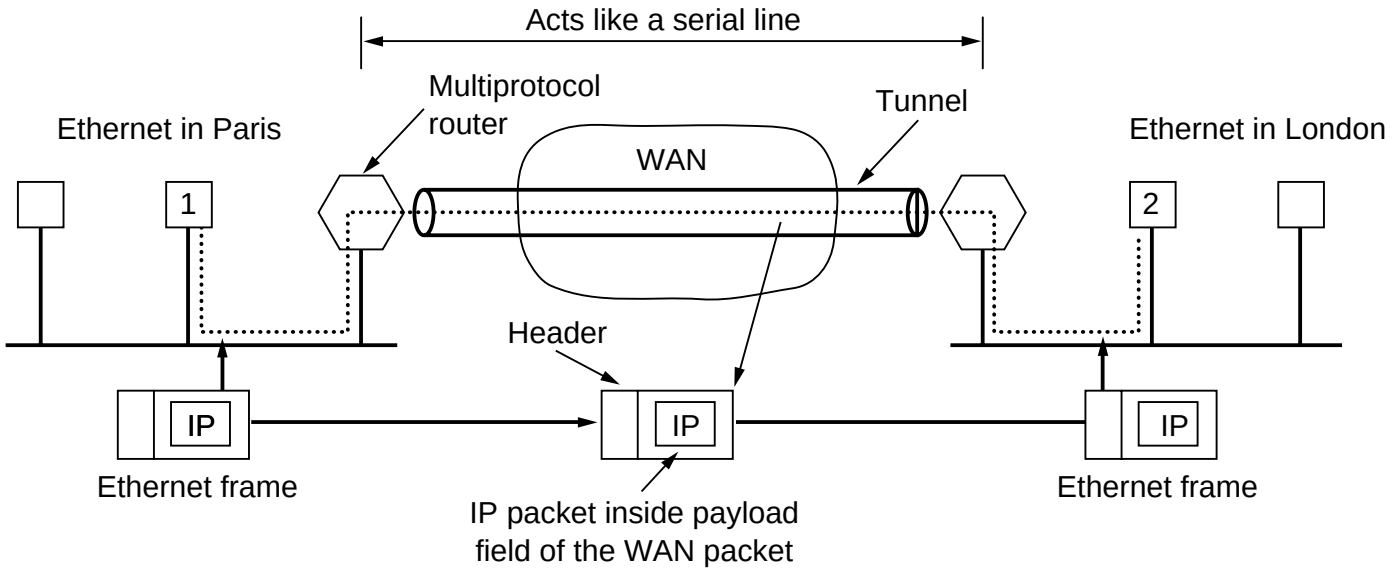
- Goals: provide seamless operation over multiple subnets
  - could be two similar LANs
  - link WANs to LANS
  - link two different LANs together
- Issues:
  - packet size limits (different networks may have different limits)
  - quality of service (is it provided, how is it defined)
  - congestion 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)



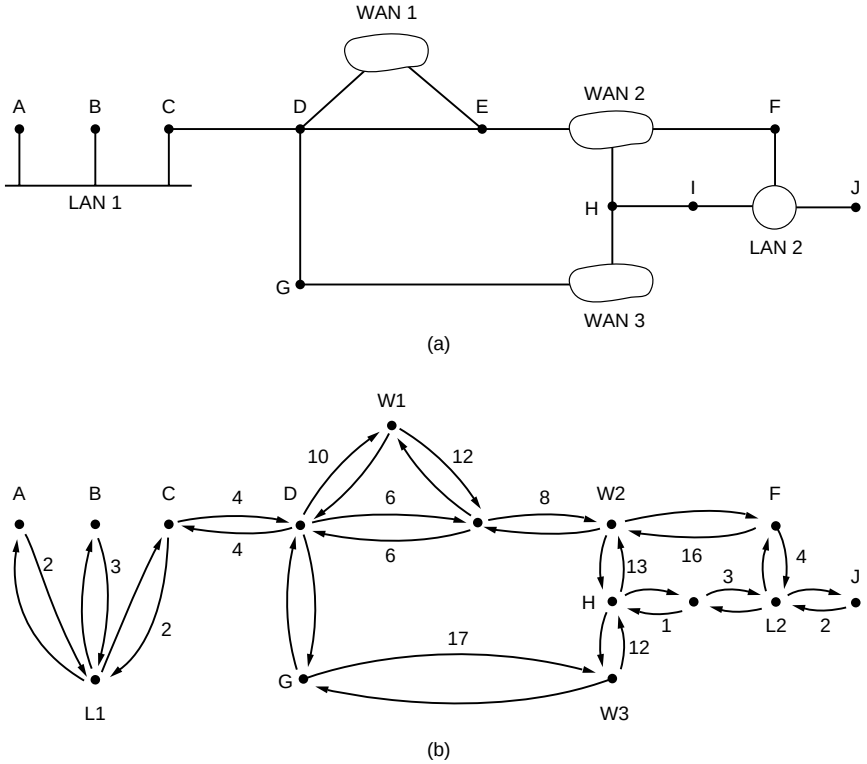
Internet Routing

- 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

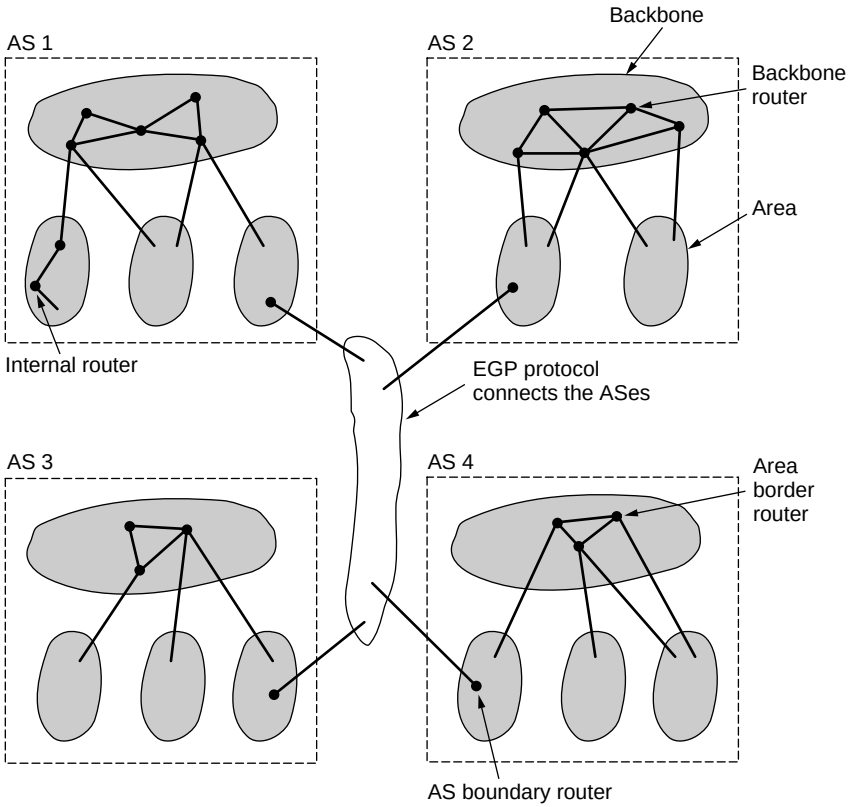
- Designed to Route within a single Autonomous System (AS)
  - An AS contains
    - areas (collection of one or more subnets)
    - backbone (to interconnect areas within AS)
  - Also Called Open Shortest Path First (OSPF)
- Divides routers into four classes
  - Internal - only within the area
  - Area boarder routers - 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

OSPF



From: *Computer Networks*, 3rd Ed. by Andrew S. Tanenbaum, (c)1996 Prentice Hall.

Graph representation of an Autonomous system.



From: *Computer Networks*, 3rd Ed. by Andrew S. Tanenbaum, (c)1996 Prentice Hall.

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