Announcements

- Reading
  - Today: Chapter 5 (5.4)
  - Next Tuesday: Chapter 5 (5.5-5.6)
- Midterm #1 is Thursday
  - covers material through chapter 5.3
  - sample exams on class web page
- Password for student photo page was distributed
- Program #2 is due Friday at 5:00 PM

Choke Packets

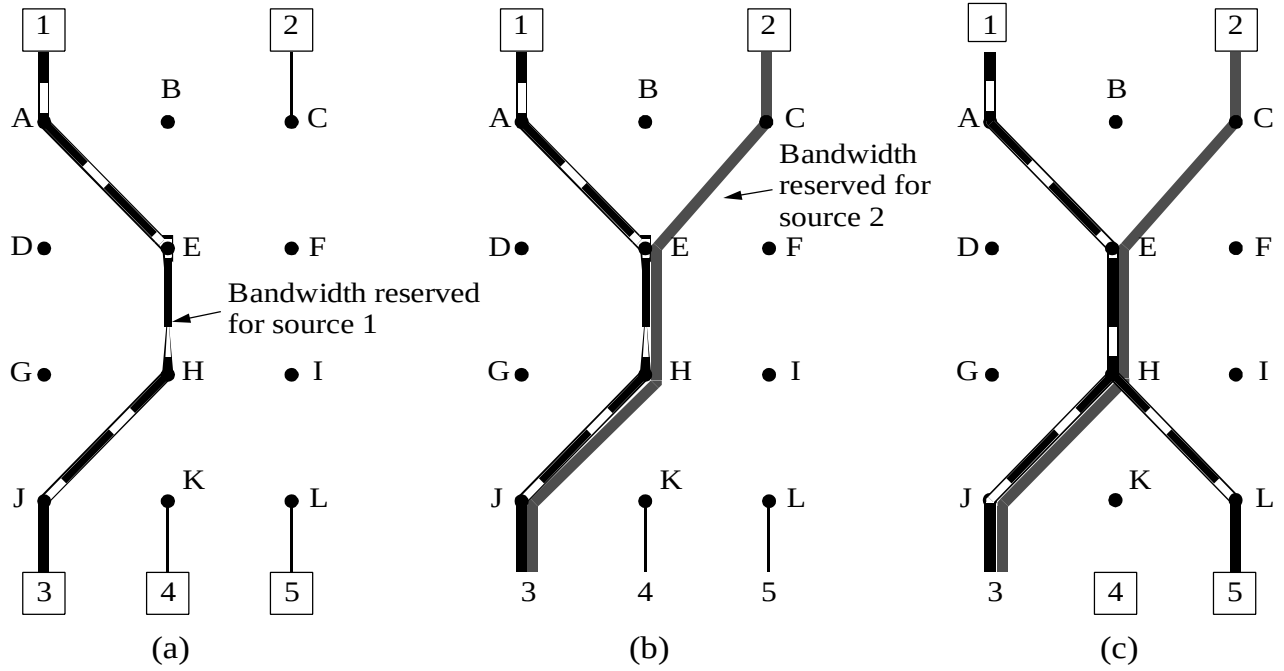
- Monitor link utilization
  - keep an estimate (u) of average utilization over time
  - $u_{new} = au_{old} + (1 - a)f$
    - f is a 0/1 sampling of link state
    - a is a parameter to control history
  - can also use queue length or buffer utilization
- When utilization is above a threshold
  - for each new packet to be sent over congested link
    - send “choke” packet back to sender
    - tag forwarded data packet to prevent more coke packets
  - when sender receives choke packet
    - must reduce rate to “choked” destination
- Hop-by-hop coke
  - on path back to sender, each router reduces traffic
  - consumes buffer space along path to sender
  - provides faster relief to congested router/link

Load Shedding

- When all else fails, routers drop (discard) packets
- Policy question: what packets to drop?
  - oldest ones: they are likely to be useless now
  - newest ones: helps to close open window in file transfer
  - less important ones
    - requires cooperation of application
    - in MPEG I frames are more important than B frames
  - drop all related packets
    - fragmentation: loss of one packet renders others useless
    - requires information from higher levels
- Preemptive shedding
  - when traffic starts to get high, dropping packets can prevent additional congestion

RSVP - Multicast Bandwidth Reservation

- Receivers send request to reserve BW up spanning tree
- Routers propagate request if request up tree
  - only sent if greater than prev. request for this group
- Dest. can request BW for multiple alternative sources
  - routers only allocate bandwidth for maximum channel request



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Internetworking

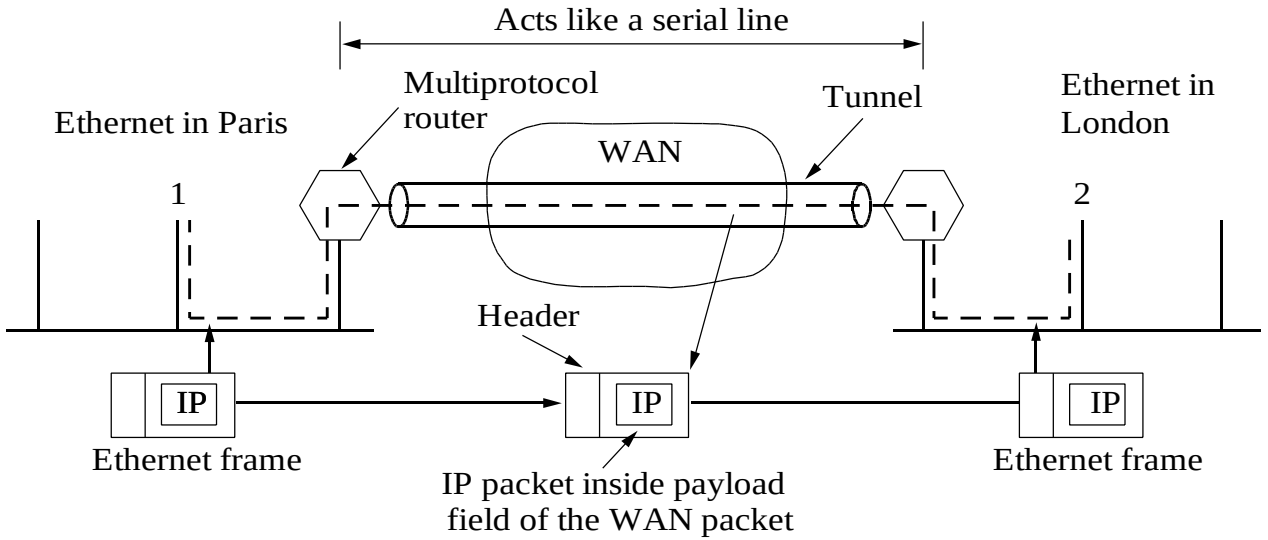
- Goal: seamless operation over multiple subnets
  - could be two similar LANs
  - link WANs to LANS
  - link two different LANs together
- Issues:
  - packet size limits (different networks may have different limits)
  - quality of service (is it provided, how is it defined)
  - congestion control
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



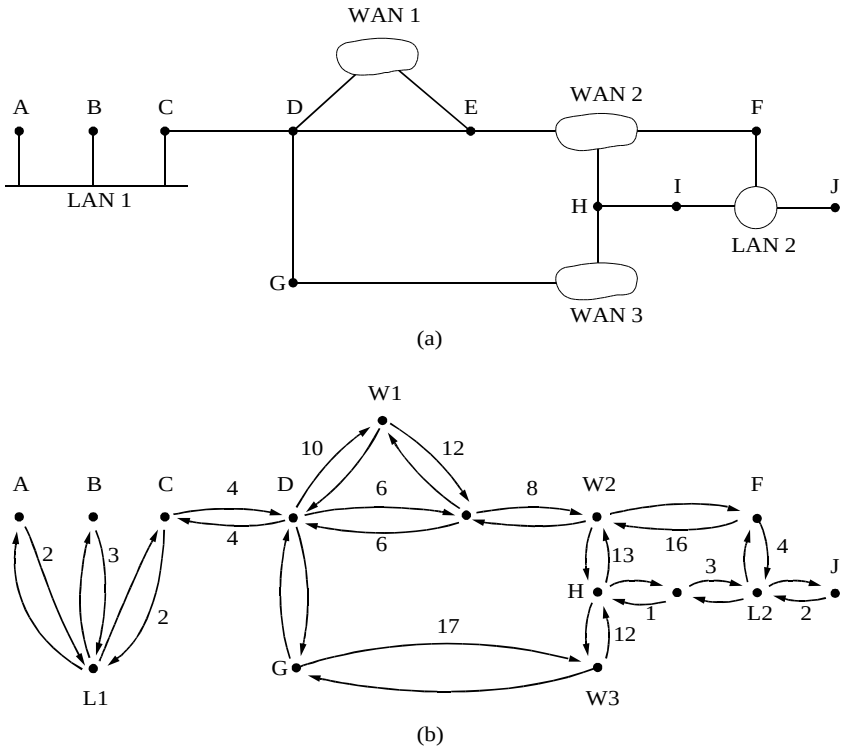
Internet Routing

- 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

- Routes 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



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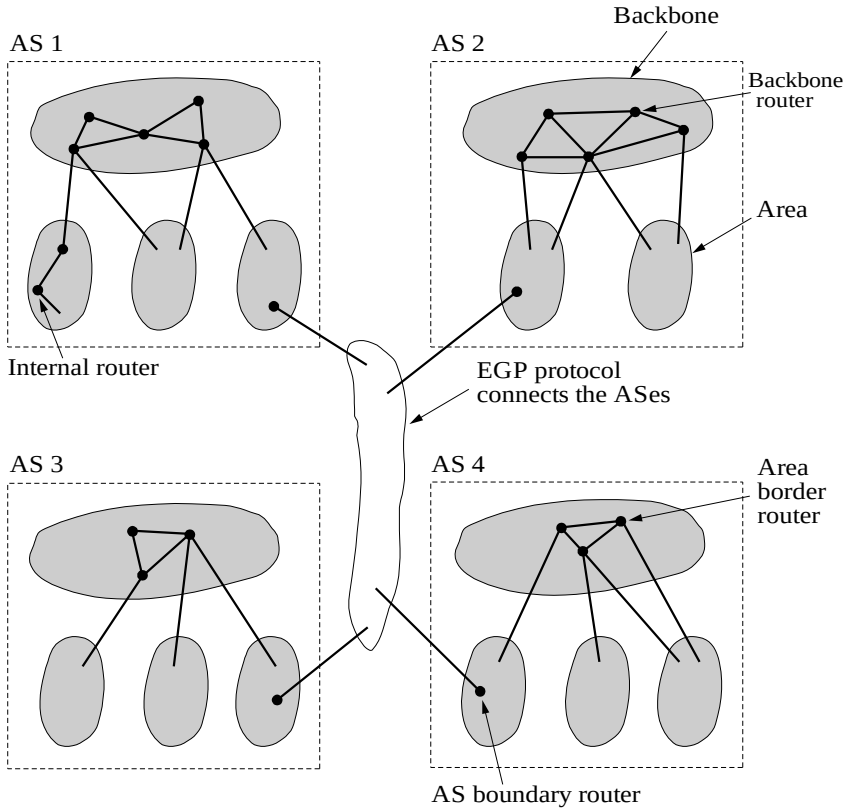
Graph representation of an Autonomous system.



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Relationship between areas an ASes