

Announcements

- Midterm #1 solutions are on the web
 - last day to submit re-grade requests in Today (11AM)
- HW #2 (due 10/28/97):
 - Chapter 5: 1, 5, 6, 7, 8, 15, 16, 21, 30, 35
- Project Partner Signup Sheet was circulated
- Reading
 - Today: 5.5–5.6
 - Tuesday:

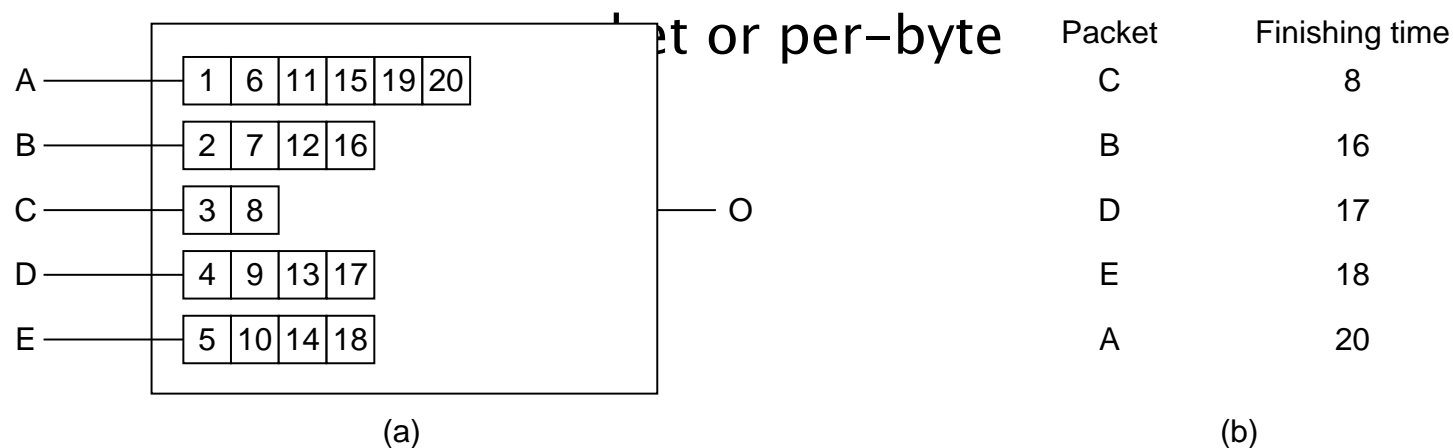
Choke Packets

- **Monitor link utilization**
 - keep an estimate (u) of average utilization over time
 - $u_{\text{new}} = au_{\text{old}} + (1 - a)f$
 - 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 choke packets
 - when sender receives choke packet
 - must reduce rate to “choked” destination
- **Hop-by-hop choke**
 - on path back to sender, each router reduces traffic
 - consumes buffer space along path to sender
 - provides faster relief to congested router/link

Fair Queuing

- Local (per router) congestion control

- each output link has n queues, one for each sender
 - need to limit max queue size or buffers will be exhausted
- use round-robin to select next packet to queue



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- Weighted Fair Queuing

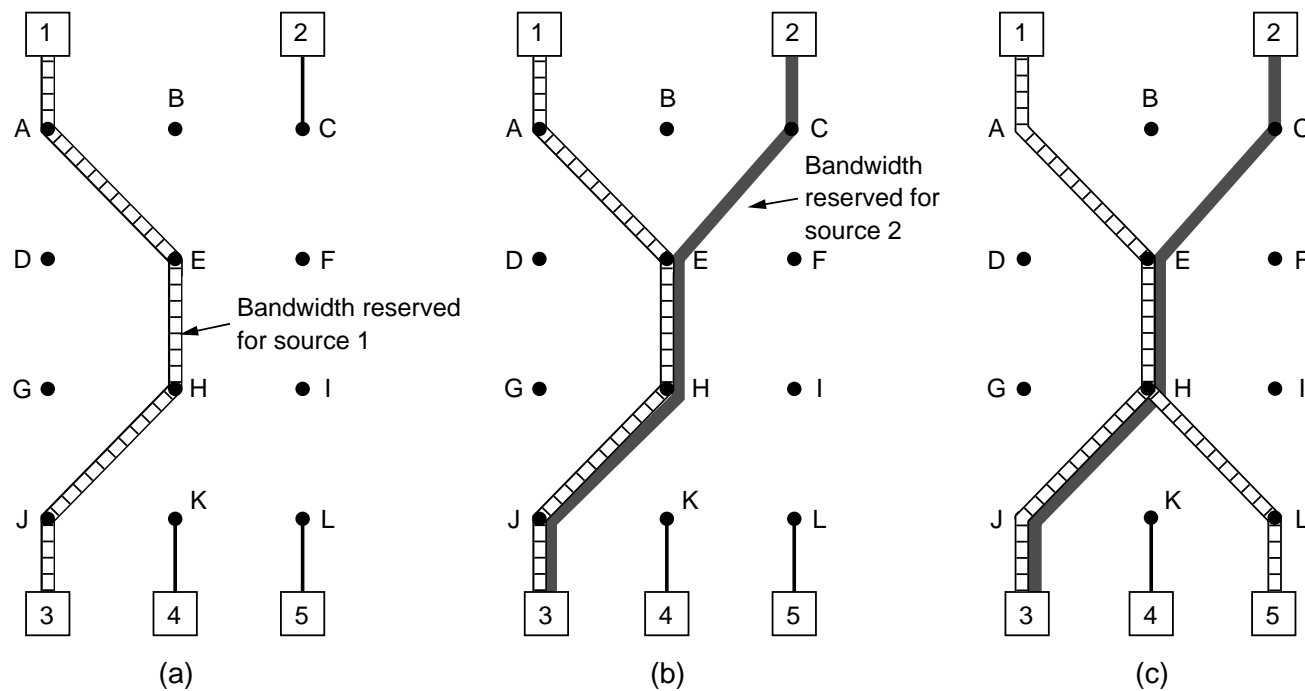
- can give different links different priorities
- give higher priority length multiple slots per round

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

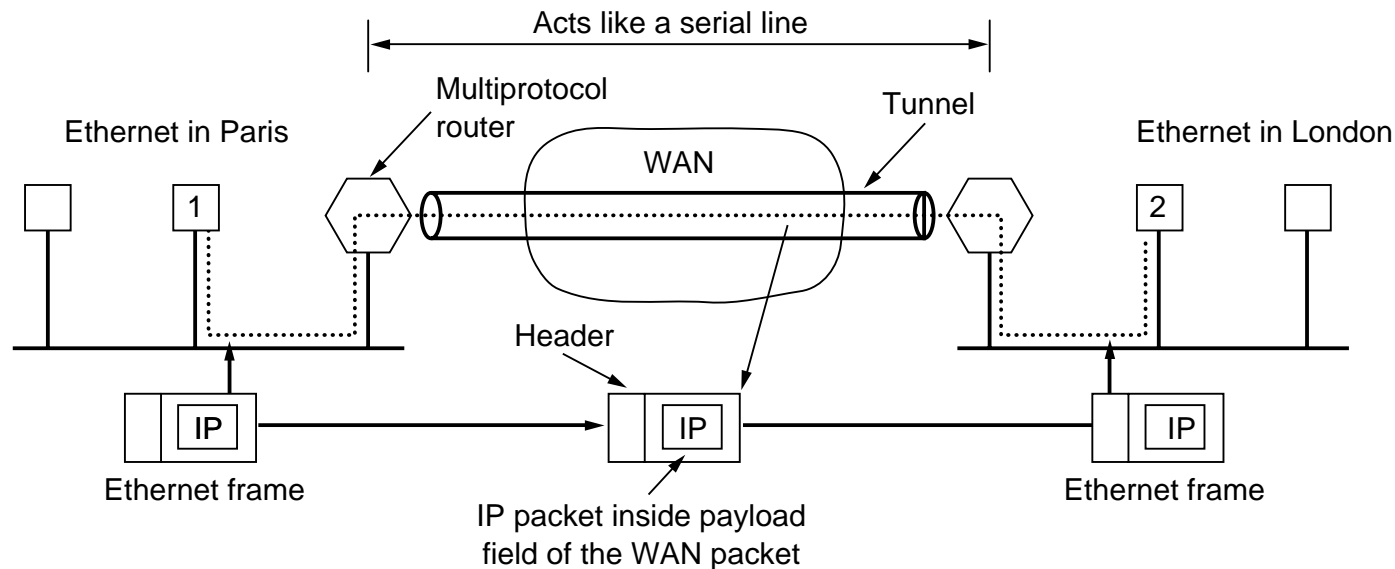
Tunneling

- Problem

- Source and Destination are compatible
- something in the middle is not compatible

- Solution: Tunnel through 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)



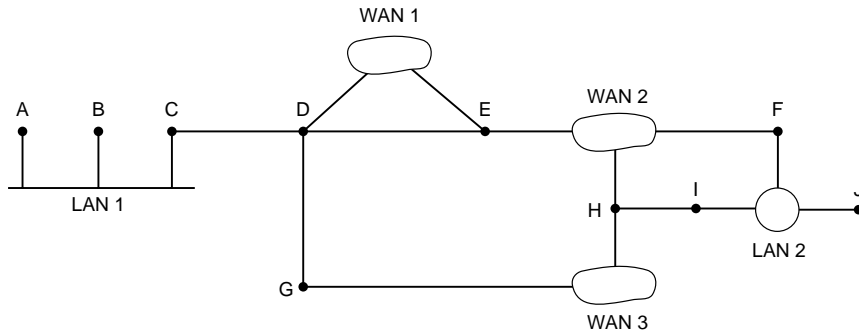
Internet Routing

- 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

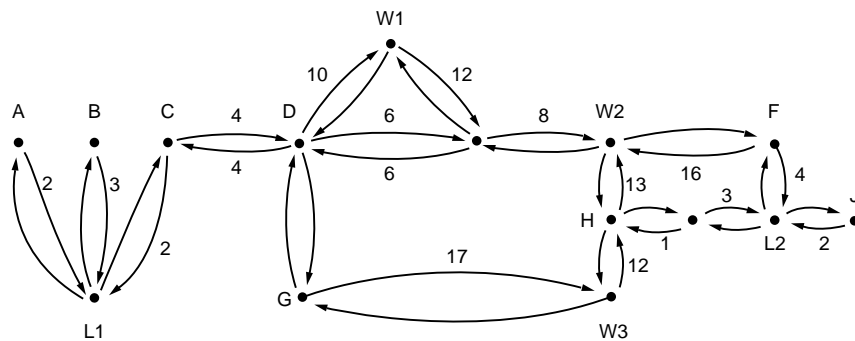
Interior Gateway Routing Protocol

- **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

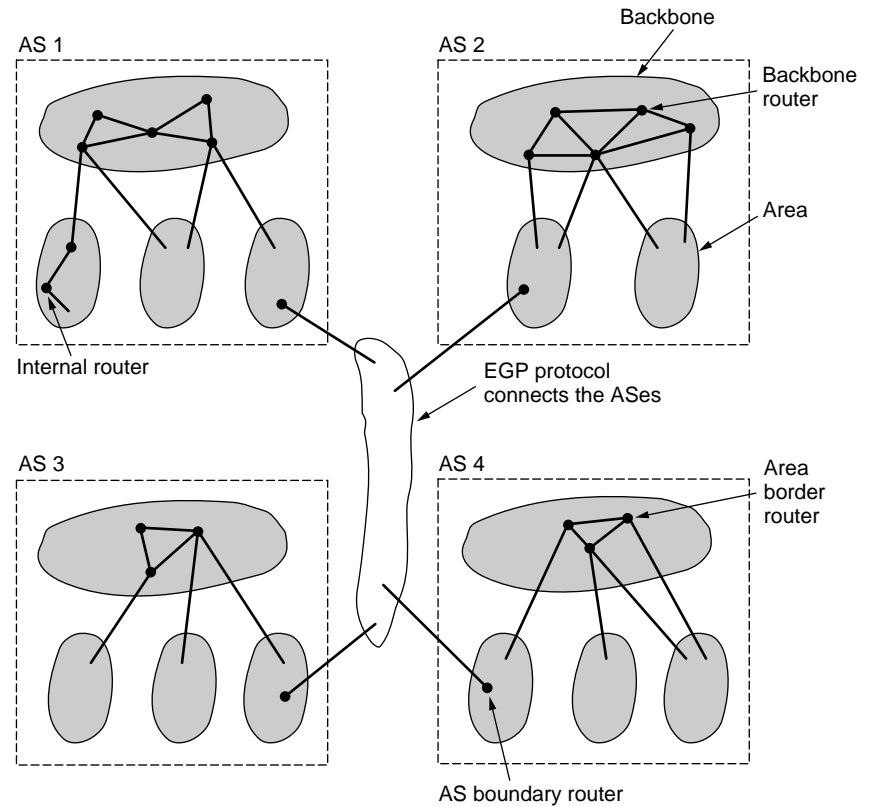


(a)



(b)

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Graph representation of an Autonomous system.

Relationship between areas and ASes

Border 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