Announcements

- reading
  - for Thursday 5.5
- midterms
  - Mt #1 Tuesday March 6
  - Mt #2 Tuesday April 15
  - Final project design due **April 11**

Network Layer

- Responsibility
  - end-to-end delivery of packets to the network
  - selecting routes for the packets to take
    - implies knowledge of the network topology
  - managing utilization of the links
    - provide flow control (across multiple links)
    - spread load among different routes
- Interface Design
  - should be independent of subnet technology
  - hide number, type, and topology of network from upper layers
  - export a common number plan for entire network

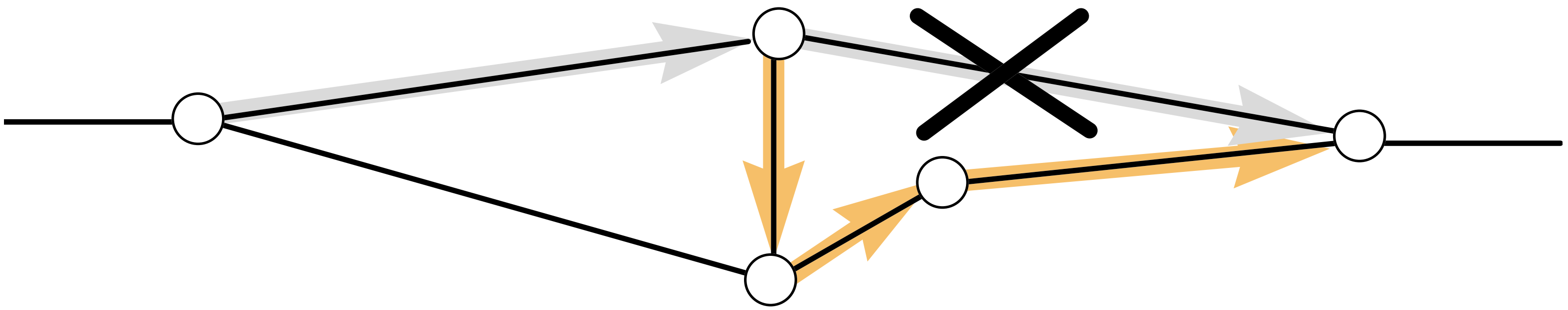
Connection vs. Connectionless

- Two possible designs for network layer
  - connection oriented service (ATM)
    - based on experience of telcos
  - connectionless service (IP)
    - based on packet switching (ARPANET)
- Connectionless
  - transport datagrams from source to destination
    - end-point addresses in every datagram
  - less complex network layer, more complex transport
- Connection oriented
  - also called virtual circuits
  - establish an end-to-end connection with network state
    - can use VCI (global or next hop) in each packet

Datagram vs. VC Addresses

- Datagrams
  - must include full address in each packet
  - addresses must be unqiue for entire network
    - don’t re-use too often
    - addresses per src/dest pair
- Virtual Circuit
  - globally unique
    - requires allocation scheme to ensure its unique
    - consumes many bits per packet
  - per link
    - requires translation at each switch
    - uses fewer bits (important for small packets like ATM)

Link Failue in Virtual Circuits



- Re-establish virtual circuit
  - router near failure can patch up link
  - original host/router creates new virtual circuit
- Virtual circuit is dropped
  - transport layer can handle recovery

Virtual Circuit vs. Datagram

Issue	Datagram	Virtual Circuit
Circuit setup	not needed	necessary
Addresses	full source/dest per packet	next hop vc sufficient
state	no state in network	per connection data at each router
routing	each packet individually	once at VC setup
router/link failure	a few packets may be lost	all VCs through router are terminated
congestion control	difficult	many pre-allocation and policing policies permitted

Routing: Goals

- Correctness
  - packets get where they are supposed
- Simplicity
  - easy to implement correctly
  - possible to make routing choices fast (or updates easy)
- Robustness
  - failures in the network still permit communication
- Stability
  - small changes in link availability results in a small change in the routing information
- Fairness
  - each host, VC, or datagram has the same chance
- Optimality
  - best possible route
  - best utilization of bandwidth

Do Routes Change During Network Operation?

- nonadaptive routing (static routing)
  – information loaded a boot time
  – never changes during network operation
- adaptive routing
  – changes in network operation alter routes
  – issue: where to get this data to make choices
    - locally from neighbors
    - globally from all routers (or a NIC - network information center)
  – issue: when to change routes
    - only on topology changes (links or routers change)
    - in response to changes in load
  – issue: metric to optimize
    - distance, number of hops, estimated latency