Multicast

- Why multicast?
- Separation of concerns: different roles for routers and end hosts
- Why a tree?
- Shared tree
  - Minimum cost spanning tree – Steiner tree
  - Center-based tree construction
- Source-based tree
  - Least unicast-cost path tree
    - Uses link-state info at each node
  - Reverse-path forwarding
    - At router R forward packet from source S iff packet arrived on link that R would use to forward packets to S
- Tunneling

Why multicast?

- Network perspective:
  - Share network resources when sending same info to multiple destinations
  - Multicast group addressing
- Application perspective:
  - Reliably send same information (maybe in the same order) to multiple destinations
- THESE TWO ARE NOT THE SAME – and maybe have very little to do with one another

Routers and end hosts

- Routers
  - Build network-layer tree (the routing problem)
    - Optimal routing
    - pruning
  - Forward multicast traffic
    - Follow the edges of the tree
- Hosts
  - Tell nearest router of interest in a group (+ or -)
  - IGMP
    - Based on host-supplied info each router decides if it needs to participate in each group

Why are routing trees important for multicast?

- Consider what a router must do with a multicast packet:
  - Receive it on some incoming link
  - Forward it on some outgoing links
    - Which ones?
- "cost" to the network of delivering a single multicast packet
  - Sum(link cost*packets traversing link)
- "costs" to the application of communicating with multicast
  - Average, maximum delay in delivering to all recipients

Minimum cost multicast spanning tree

- Aka Steiner tree problem – NP-hard
- How is it different from the well-known spanning tree problem with an O(e log e) solution?
- Not used in practice but gives a theoretical foundation to compare other solutions against

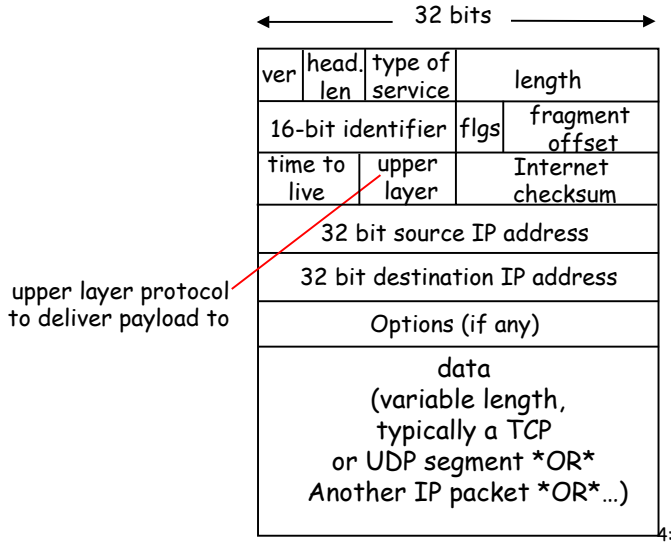
Center-based tree

- Pick one node to be the "center"
- Grow the graph by sending join messages from the edges toward the center, recording the route
- Tree depends on the order of joining

Least unicast-cost path tree

- packets follow the same path a unicast packet would take from source to destination
- Routers, not source, do packet replication
- Pre-build tree with join messages

Tunneling



Tunneling is used for

- Multicast overlay for non-multicast-aware internet (Mbone)
- Early deployment of IPv6 in the IPv4 network
- Virtual private networking
- Novell (IPX) networking over IP

Review

- Network layer services
  - VC or datagram
  - Consequences for other important characteristics
  - Which choice
- Routing as a graph problem
  - DV and LS algorithms
    - Know how to execute
- Internet Addressing
  - Host (interface) address
  - Network address
  - Netmask
  - CIDR
  - Where do addresses come from?
- Routing in the internet
  - RIP
  - OSPF
  - The need for hierarchy – why different inter- and intra- AS routing rules
- IP Datagram format
- Fragmentation/Reassembly
- Protocol maps
- 3 router architectures
  - Memory
  - Bus
  - Crossbar
- Multicast
- Did not cover IPv6
- Programming with select()