Shared v.s. Source-based Trees
- Source-based trees
  - Separate shortest path tree for each sender
- Shared trees:
  - Single tree shared by all members
  - Data flows on same tree regardless of sender.

Multicast Forwarding
- How do the forwarding entries at a router look like?
- Shared tree:
  - (, list of outgoing interfaces)
- Source-based tree:
  - (, list of outgoing interfaces)
- Compare to Unicast:
  - (prefix, outgoing interface)

Protocol taxonomy
- DVMRP – Distance-Vector Multicast Routing Protocol - source-based trees
- MOSPF – Multicast Open Shortest Path First Protocol - source-based trees
- PIM – Protocol Independent Multicast - shared and source-based trees
- CBT: Core-Based Trees – shared tree

Distance-Vector Multicast Routing Protocol
- DVMRP consists of two major components:
  - a conventional distance-vector routing protocol (like RIP)
  - a protocol for determining how to forward multicast packets, based on the routing table

Multicast Forwarding
- A DVMRP router forwards a packet if
  - The packet arrived from the link used to reach the source of the packet (Reverse path forwarding - RPF)
    - Similar (but not quite the same) to flooding each packet once
  - If downstream links have not pruned the tree

Rendezvous
- With source-based trees senders and receivers meet by:
  - Flooding and pruning
  - LS distribution of group and receiver state
- How do we solve the problem with shared trees?
  - Establish a meeting place: center, core or rendezvous point
  - Associate the meeting place with G

Observations - Shared Trees
- Core placement affects efficiency
- Finding the optimal core location is an NP-hard problem
Most protocols use heuristics
- Foy dynamic groups core location may have to be calculated frequently
- Need multiple cores for robustness

Status of IP Multicast
- IP multicast has had limited deployment
  - Even though most routers support the protocols
  - Problems include, pricing, service model (not what users wanted), security, scalability
- Two ways forward:
  - Single source multicast (SSM)
  - Application-layer multicast: a form of overlay, also known as end-point multicast.

Changing the Service Model
- What we've discussed so far
  - Any-source multicast
- Problems:
  - How do you charge users?
  - How do you manage the bandwidth allocation?
  - How can you ensure secure communication?
  - All of these are still research topics
- Other problems
  - Multicast state aggregation
- Is there a simpler alternative we can deploy now?

Single Source Multicast (SSM)
- ISP acceptance will be higher
  - If the multicast service model restricted the senders
  - If there was a way to figure out how many receivers there were
- They can then have a viable billing and accounting model
- Simple such scheme
  - Single-source per multicast group
  - Receivers can still join and leave at will

SSM Groups
- A group in SSM is denoted by (S,G)
  - S is the source's address
  - G is the group identifier
- Address allocation
  - Aside: we haven't talked about multicast address allocation
  - But this immediately solves the multicast address allocation problem!
    - Unlike for any source multicast, G doesn't have to be globally unique.

SSM Details
- Receiver specifies that it wants to join source S on group G
  - Already being designed in IGMP v3
- Routers send source-specific joins towards S
  - PIM-SM already does this
- Only source S allowed to send traffic to group G
- Routers silently drop other traffic if there is no state.
- Note that we don't need a special inter-domain multicast routing protocol.

**Overlay Networks**
- A logical network built on top of a physical network
  - Overlay links are tunnels through the underlying network.
- Many logical networks may coexist at once
  - Over the same underlying network
  - And providing its own particular service
- Nodes are often end hosts
  - Acting as intermediate nodes that forward traffic
  - Providing a service, such as access to files
- Who controls the nodes providing service?
  - The party providing the service (e.g., Akamai)
  - Distributed collection of end users (e.g., peer-to-peer)

**End-System Multicast**
- IP multicast still not widely deployed
  - Technical and business challenges
  - Should multicast be a network-layer service?
- Multicast tree of end hosts
  - Allow end hosts to form their own multicast tree
  - Hosts receiving the data help forward to others
  - How to do routing?

**Routing for Mobile Hosts**
- Mobile IP
  - Home agent
    - Router located on the homework of the mobile hosts
  - Home address
    - The permanent IP address of the mobile host
    - Has a network number equal to that of the home network and thus of the home agent
  - Foreign agent
    - Router located on a network to which the mobile node attaches itself when it is away from its home network.
- Problem of delivering a packet to the mobile node
  - How does the home agent intercept a packet that is destined for the mobile node?
    - Proxy ARP
  - How does the home agent then deliver the packet to the foreign agent?
    - IP tunnel
    - Care-of-address
    - How does the foreign agent deliver the packet to the mobile node?
- Route optimization in Mobile IP
  - The route from the sending node to mobile node can be significantly sub-optimal
  - One extreme example
The mobile node and the sending node are on the same network, but the home network for the mobile node is on the far side of the Internet
  - Triangle Routing Problem

  - Solution
    - Let the sending node know the care-of-address of the mobile node. The sending node can create its own tunnel to the foreign agent.
    - Home agent sends binding update message
    - The sending node creates an entry in the binding cache
    - The binding cache may become out-of-date
      - The mobile node moved to a different network
      - Foreign agent sends a binding warning message.

Multicasting notes - 10/20/16

* to be used with slides

Shared vs. Source-based Trees
  - Source-based
    - Have some overhead (extra information)
  - Shared
    - <*,G,list of outgoing interfaces)
    - G means good number
    - * means any source (wild card)
    - Can't have shortest path from every source
    - Placement of core affects efficiency
    - Core should be placed at the shortest distance from hosts, which is an NP-hard problem

Protocol Taxonomy
  - DVMRP
    - Like RIP
    - 2 parts to building forwarding table

Phase 1: Flood using Truncated Broadcast
  - Starting from source s, the routers end up forwarding the packet to all other routers
  - Routers with no receivers do not broadcast

Phase 2: Prune
  - Prune message comes back when the flood runs into a router that is not connected to a receiver

Phase 3: Graft
  - If new receiver is added to this router without one before, then the receiver reports to the router, and the router sends a graft report back

Phase 4: Steady State
• Source s now floods and all receivers

PIM
• Def:
Protocol-Independent Multicast (PIM) is a family of multicast routing protocols for Internet Protocol (IP) networks that provide one-to-many and many-to-many distribution of data over a LAN, WAN or the Internet. It is termed protocol-independent because PIM does not include its own topology discovery mechanism, but instead uses routing information supplied by other routing protocols.

From <https://en.wikipedia.org/wiki/Protocol_Independent_Multicast>

Status of IP Multicast
• Several problems
  ○ Don’t know how many people are using the multicast
  ○ Security

SSM Details
• Routers store source and group

Application Level Multicasting possible

Routing for Mobile Hosts
• Switches DHCP services when you move