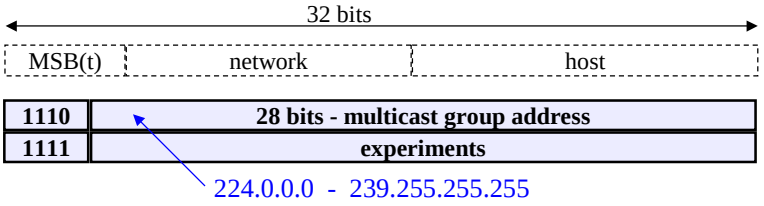
Multicast Protocols

IGMP – IP Group Membership Protocol
DVMRP – DV Multicast Routing Protocol
MOSPF – Multicast OSPF
PIM – Protocol Independent Multicast

Multicast in local area networks

Multicast addresses
IGMP – Internet Group Membership Protocol

Multicast addresses



224.0.0.1	All systems
224.0.0.2	All routers
224.0.0.4	All DVMRP routers
224.0.0.1 - 224.0.0.255	Local segment usage only
239.0.0.0 - 239.255.255.255	Admin scoped multicast (local significance)
239.192.0.0 - 239.195.255.255	Organization local scope

- Sender does not need to belong to G.
- Address space is flat.

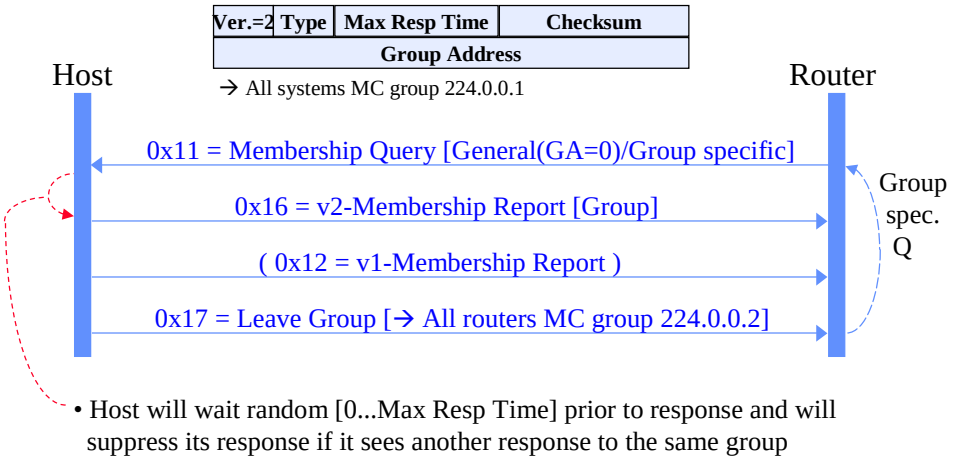
Multicast in broadcast networks

- In broadcast networks only one copy should be sent of a multicast packet
- Some broadcast network support group addresses
  - E.g. Ethernet
  - Group address is based on the IP address
    - Place low-order 23 bits of multicast address into low-order 23 bits of MAC address 01-00-5E-00-00-00
    - No ARP required
- Point-to-point links need no special arrangements

Routers discover multicast receivers using IGMP

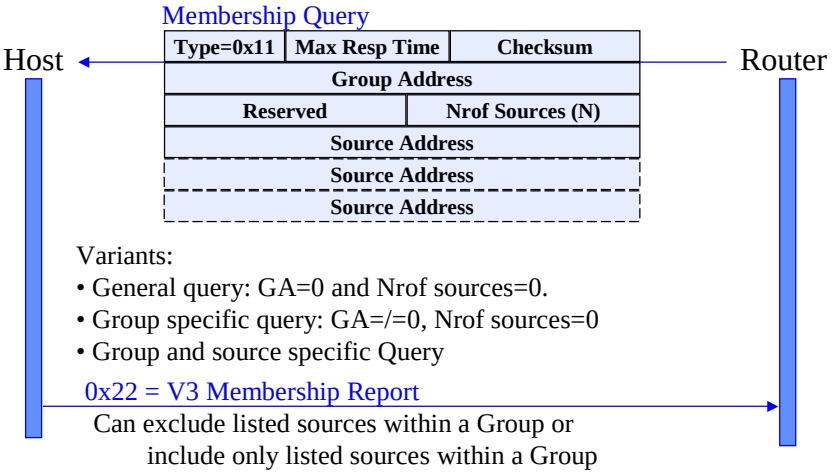
- IGMP = Internet Group Membership Protocol
- Version 2 defined in RFC-2236
- Runs directly over IP (protocol type 2)
- Used locally within a network
  - TTL=1 in all IGMP messages
- Router with lowest IP address is active on a network
- Routers do not need to know the exact members, only whether there are members for a specific group

IGMPv2 - Internet Group Management Protocol implements Group Membership



- Host will wait random [0...Max Resp Time] prior to response and will suppress its response if it sees another response to the same group

IGMPv3 adds selective reception from sources within a group



Variants:

- General query: GA=0 and Nrof sources=0.
- Group specific query: GA=/=0, Nrof sources=0
- Group and source specific Query

0x22 = V3 Membership Report

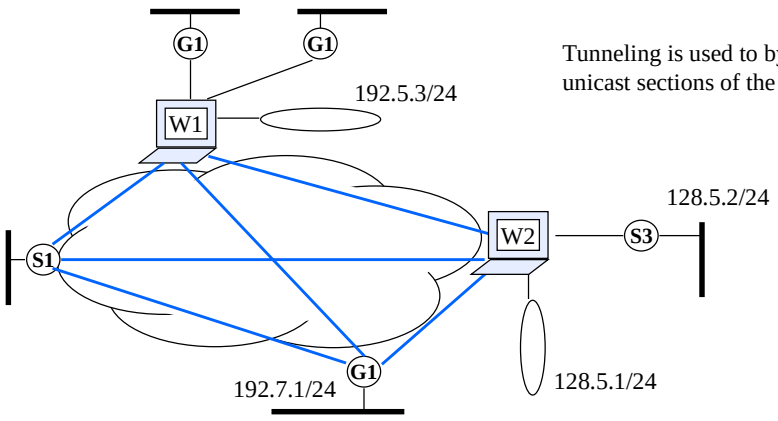
Can exclude listed sources within a Group or include only listed sources within a Group

MBone

MBone – an overlay multicast Internet

- Multicast backbone (MBone) was deployed to support research
  - Enable multicast applications without waiting for full availability of multicasting standards
- Started in 1992
- Uses tunnels to link multicast islands
  - Previously as source routed packet
  - Now with encapsulation
- Uses DVMRP and IGMP

MBone overlay is based on workstations running DVMRP



Experimental routing protocols have been developed for MBone

Shared tree	Source based trees	
	Broadcast and Prune	Domain-wide reports
PIM Sparse* Core Based tree*	DVMRP PIM Dense*	MOSPF

* Relies on Unicast routing protocol to locate multicast sources.
Those that don't, can route multicast on routes separate from unicast routes.

DVMRP – Distance Vector Multicast Routing Protocol

DVMRP – Distance Vector Multicast Routing Protocol

- First multicast protocol in the Internet (1988)
- Distance vector routing protocol similar to RIP
  - Except that sources are like destinations in RIP
- Routers maintains separate multicast routing tables
- Uses the reverse-path-forwarding (RPF) algorithm
- Nodes exchange
  - Distance in hops (reverse path distance)
  - IP address and mask of source
- Tunnels
  - Destination router
  - Cost
  - Threshold

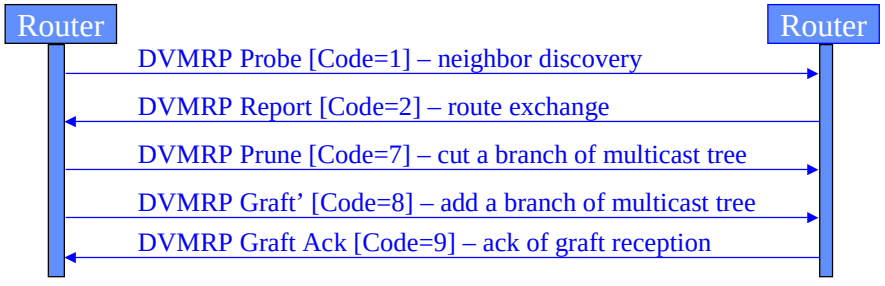
DVMRP is used for multicast routing in the MBone

- DVMRP messages are IGMP messages (IP protocol=2=IGMP, TTL=1)

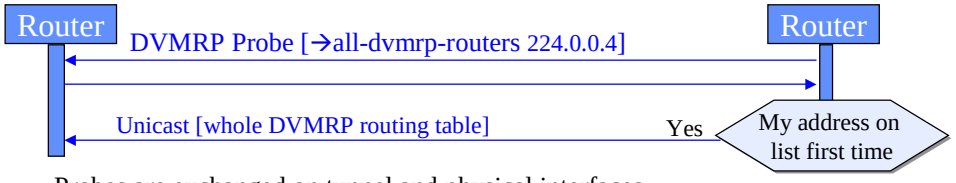
DVMRP header:

Type=0x13	**Code**	Checksum	
Reserved		Minor vers =0xff	Major vers = 3

Version 3 (1997) presented in this course



Probes are used for neighbor discovery

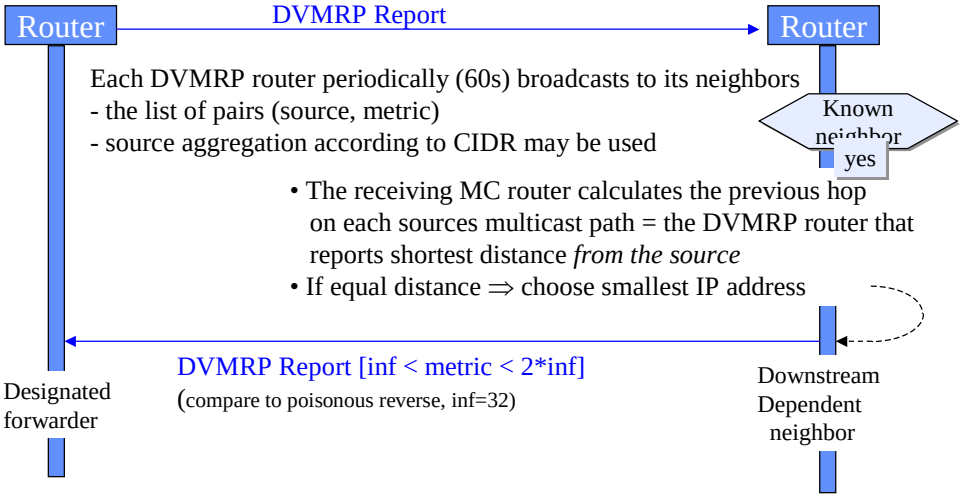


- Probes are exchanged on tunnel and physical interfaces
- Contains the list of neighbors on the interface
  - If empty, this is leaf network managed by IGMP
- Multicasts are not exchanged until two-way neighbor relationship is established
- Routers see each others versions and capability flags ⇒ compatibility
- Keepalive ⇒ fault detection, restart detection
  - sent each 10s, timeout set at 35s

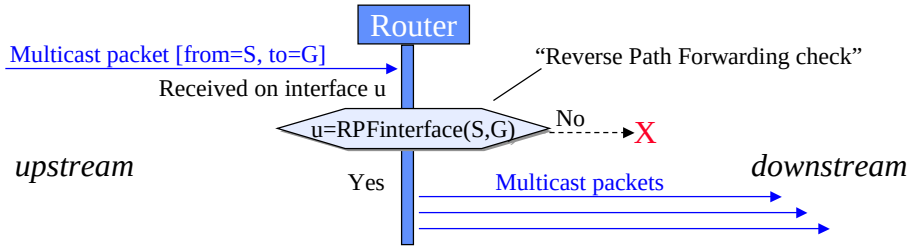
DVMRP uses the concept of dependent downstream routers

- DVMRP uses the route exchange as a mechanism for upstream routers to determine if any downstream routers depend on them for forwarding from particular source networks
  - Implemented with ”poison reverse”
  - If a downstream router selects an upstream router as the best next hop to a source, it echoes back th route with a metric = original metrix + inf

Route reports are used to build the source based trees

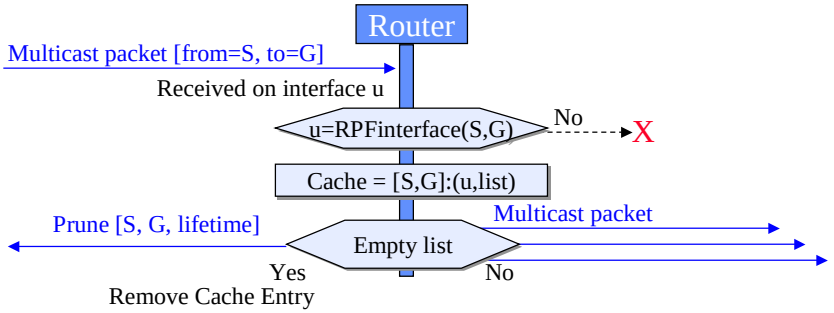


The multicast algorithm of DVMRP is based on Reverse Path Forwarding (RPF)



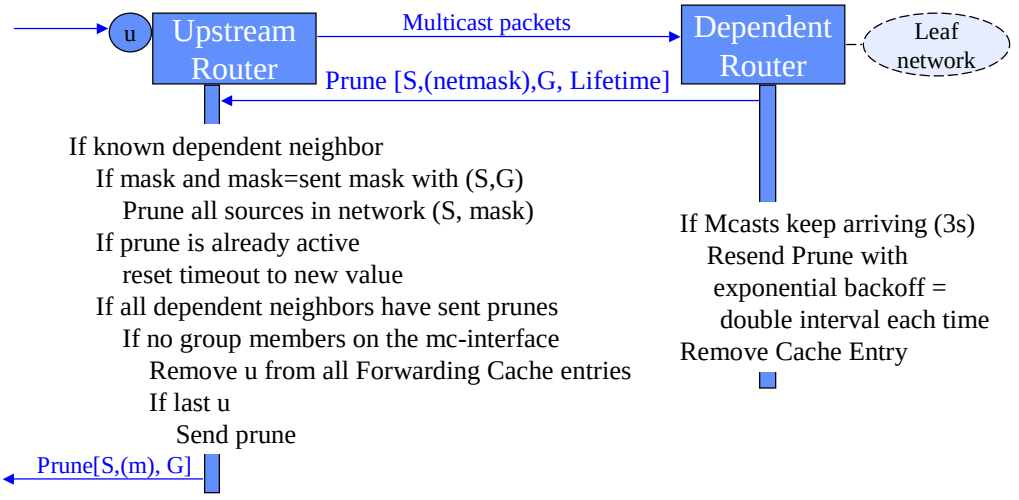
- At first multicast from RPF interface a Forwarding Cache Entry [S,G]:(u,list...) is created using the DVMRP routing table
  - The list contains all downstream routers that have reported dependency on S
- The router is designated forwarder for downstream nodes
- If the designated forwarder becomes unreachable, another router assumes the role of designated until it hears from a better candidate

List of dependent neighbors is used to minimize the multicast tree

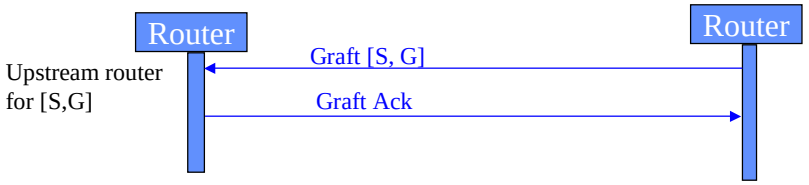


- Initially list may contain all multicast interfaces but the upstream interface
- Downstream address is removed from list if
  - It is a leaf network and G is not in IGMP DB for this phys. network
  - Downstream node has selected another designated forwarder
  - Prune received from all dependent neighbors on this interface

Prunes minimize the multicast tree

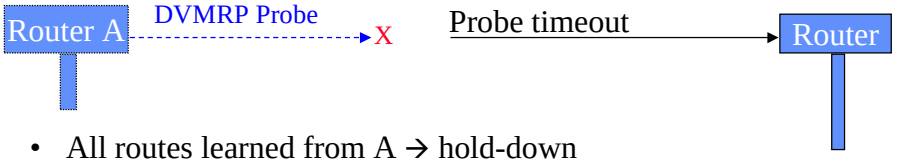


Grafts are used to grow the tree when a new member joins the group



- The graft is always acknowledged
  - if no multicast, nobody is sending
- If no ack is received, the graft is resent with exponential backoff retransmissions
- The graft is forwarded upstream if necessary

On probe timeout caches are flushed



- All routes learned from A → hold-down
- All downstream dependencies ON A are removed
- If A was designated forwarder, a new one is selected for each (source, group) pair
- Forwarding cache entries based on A are flushed
- Graft acks to A are flushed.
- Downstream dependencies are removed.
  - If last, send prune upstream

Route hold-down is a state prior to deleting the route

- Routes expire on report timeout or when an infinite metric is received
- An alternate route (that in RIP caused temporary loops) may exist
- Routers continue to advertise the route with inf metric for 2 report intervals – this is the hold-down period
- All forwarding cache entries for the route are flushed
- During hold-down, the route may be taken back, if
  - metric <inf, and
  - metric = SAME, and
  - received from SAME router

MOSPF

MOSPF – Multicast extensions to OSPF (1)

- The idea is: if the location of receivers is known to all routers, multicast should be possible to exactly the receivers only!
- MOSPF is an extension of OSPF, allowing multicast to be introduced into an existing OSPF unicast routing domain.
- Unlike DVMRP, MOSPF is not susceptible to the normal convergence problems of distance vector algorithms.
- MOSPF limits the extent of multicast traffic to group members, something e.g. DVMRP cannot always do.
  - Restricting the extent of multicast datagrams is desirable for high-bandwidth multicast applications or limited-bandwidth network links (or both).

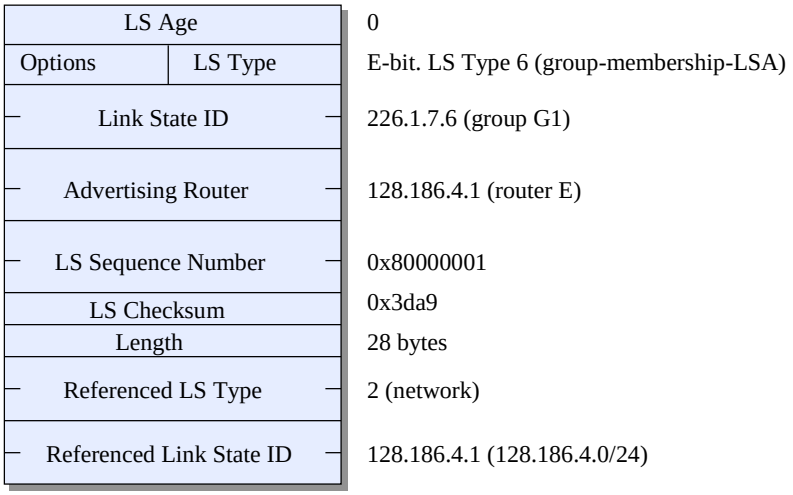
MOSPF – Multicast extensions to OSPF (2)

- Defined in RFC 1584
- Unlike OSPF, MOSPF does not support multiple equal-cost paths
- MOSPF calculates the source-based trees on demand
- MOSPF can be, and is in isolated places, deployed in the MBONE. A MOSPF domain can be attached to the edge of the MBONE, or can be used as a transit routing domain within the MBONE's DVMRP routing system.

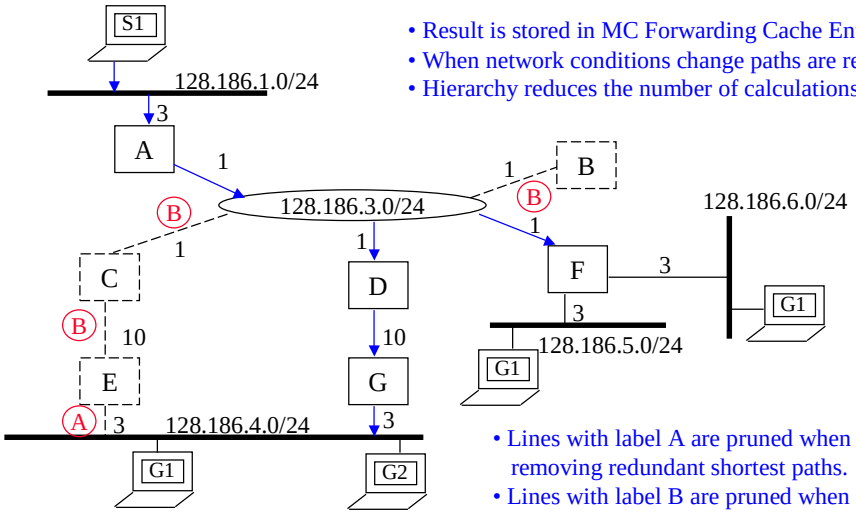
MOSPF can be deployed gracefully

- Introduces multicast routing by adding a new type of LSA to the OSPF link-state database and by adding calculations for the paths of multicast datagrams.
- The introduction of MOSPF to an OSPF routing can be gradual
  - Multicast capability marked with a M-bit in the option flag
  - MOSPF will automatically route IP multicast datagrams around those routers incapable of multicast routing, whereas unicast routing continues to function normally.
  - No tunnels ⇒ there may be a unicast path, but no multicast path

Group-membership-LSA is created and flooded when an IP user joins an MC-group using IGMP



MOSPF calculates Shortest-path trees on demand



- Result is stored in MC Forwarding Cache Entry
- When network conditions change paths are recalculated
- Hierarchy reduces the number of calculations

- Lines with label A are pruned when removing redundant shortest paths.
- Lines with label B are pruned when removing links that do not lead to G1

Forwarding cache entry stores multicast path routing info

Source network, Group ⇒

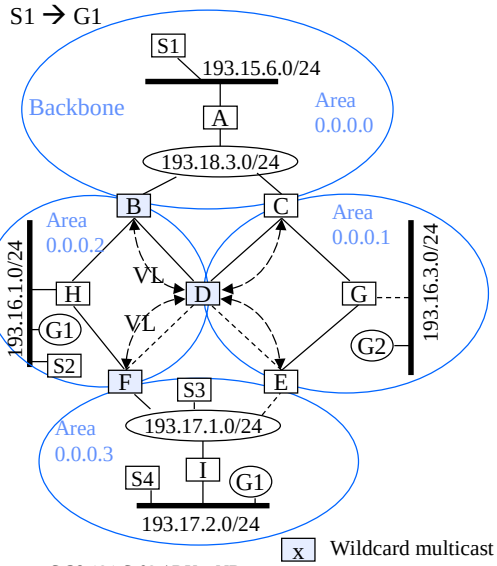
Router or network for multicast reception	
List of interfaces, multicasts must be sent	Metrics to nearest group member

- A cache entry may be deleted at any time ⇒ Will be recalculated on demand.
- Cache entries must be deleted, when changed LSAs are received
  - Router-LSA, Network-LSA (on router or link failure or cost change) ⇒ Delete all entries since it is not possible to tell which are affected.
  - Group-m-LSA ⇒ Delete entries of that group.
  - Hierarchy ⇒ The farther away the change is the fewer cache entries are deleted.

On demand route calculations use Dijkstra's shortest path first algorithm

- Calculation is rooted on the source not the router as for unicast
- For a new multicast, every router performs the same calculation
- Stub networks do not appear in MOSPF calculation (e.g router F)
- Tiebreaks for equal cost routes – previous hop router that has highest address is chosen (e.g. G over E)

Two level hierarchy aggregates both sources and group addresses



- In aggregation some info is lost ⇒ sometimes multicasts are sent needlessly: C → G: to G1
- Presence of sources is reported by summary-LSA with MC-bit set: F to H → S3+S4 entry
- Area border router advertise Group-m-LSAs to backbone (B:G1, D,E,F:G1, C,D,E:G2)
  - no exact location
- Routers in non-backbone do not know location of group members

PIM – Protocol Independent Multicast

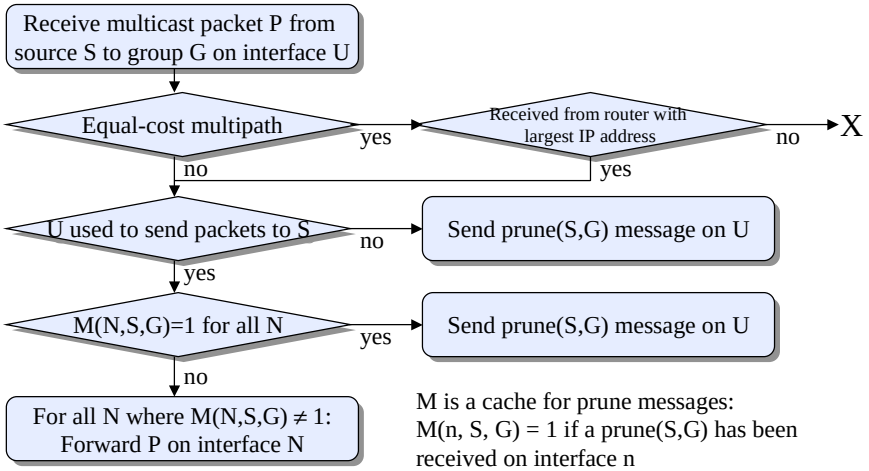
PIM – Protocol Independent Multicast

- Most popular multicast protocol
- Two modes of operation
  1. Dense mode
  2. Sparse mode
- Independent of any particular unicast routing protocol
- Uses unicast routing table
  - ⇒ Simple protocol
  - ⇒ Assumes the links are symmetric
  - ⇒ No tunnels
- Messages sent in IGMP packets

PIM Dense Mode

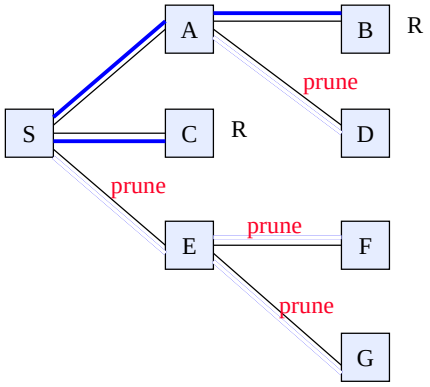
- For dense multicast groups
  - The probability is high that a small randomly picked area contains at least a group member, e.g. LAN
- Based on the RPM
- Principle similar to DVMRP
  - Simpler
  - Less efficient

PIM-DM implementation of RPF



M is a cache for prune messages:
M(n, S, G) = 1 if a prune(S,G) has been received on interface n
Least recently used entries may be dropped

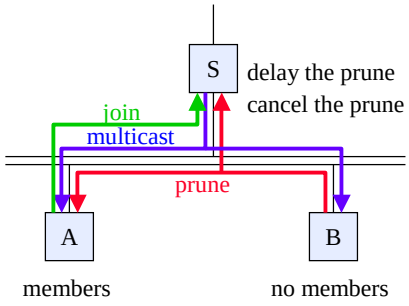
PIM-DM – Pruning



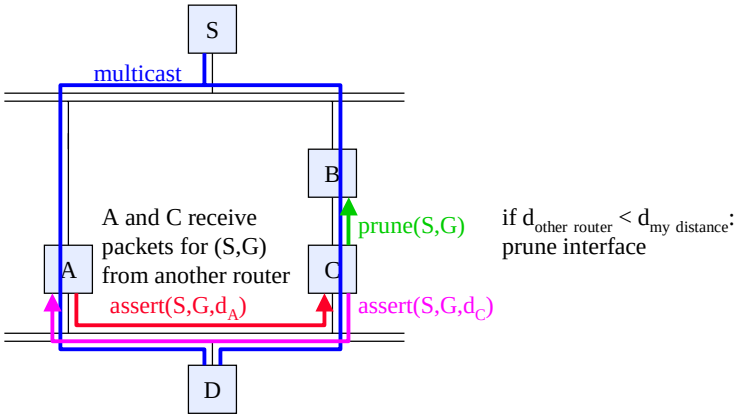
R = receiver

PIM-DM – Pruning on broadcast networks

- Prune messages sent to ”all-routers” (224.0.0.2)



PIM-DM – Resolving multicasts received on multiple path



PIM Sparse Mode

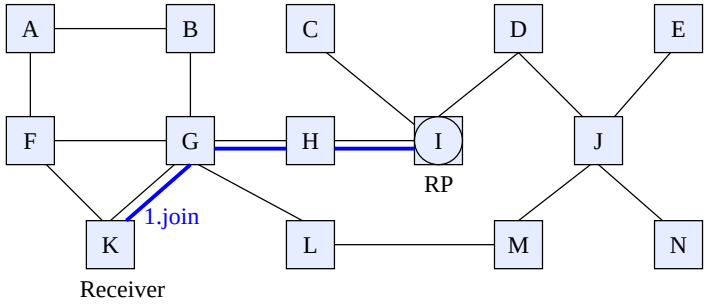
- RFC 2362
- Uses the center-based tree algorithm
- Evolved from the Core-Based Trees (CBT) protocol
- Rendezvous point (=center) connects the receivers with the senders
- Receivers must explicitly join

PIM-SM route entries

- Route entry includes
  - source address
  - group address
  - incoming interface
  - list of outgoing interfaces
  - timers, flags
- Packets match on the most specific entry
  - (S,G) – a specific source in a group
  - (*,G) – all sources in a group
  - (*, *, RP) – all groups that hash to a RP

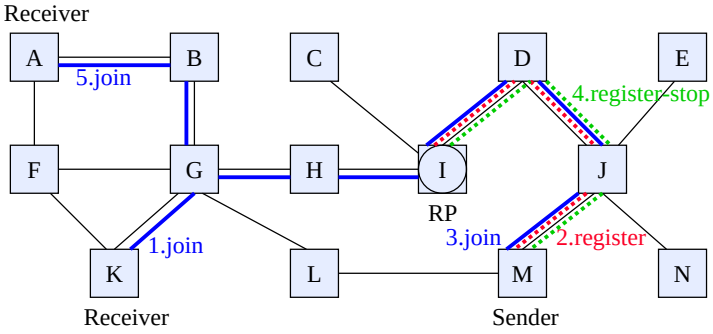
PIM-SM example (1)

- Join packets are sent toward the RP
  - Address=G, Join=RP, WC-bit, RPT-bit, Prune=(empty)
- Intermediate router set up (*, G) state and forward the join



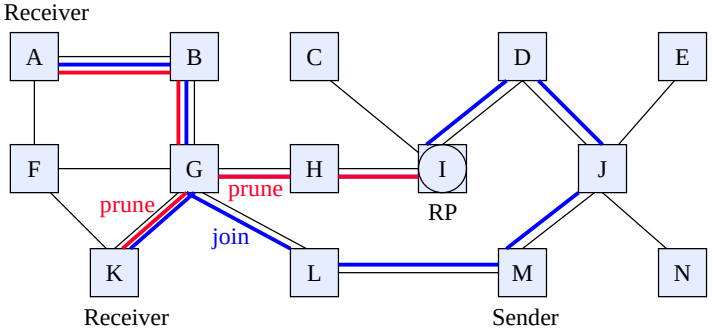
PIM-SM example (2)

- Senders send packets to RP encapsulated in register messages
- RP resends packets on the tree
- RP may contruct a (S,G) entry, and send periodic joins to the sender



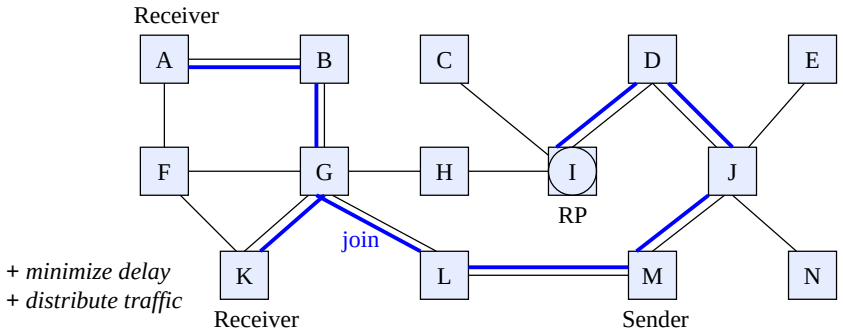
PIM-SM example (3)

- If the last-hop router (K and A) sees many packet from the source, it can switch from a shared tree to a shortest path tree for (S,G)
- It sends a join directly to the source, and prunes the previous path



PIM-SM example (4)

- Copies of the packets are still sent to RP
- Join/prune messages are sent periodically for each route entry

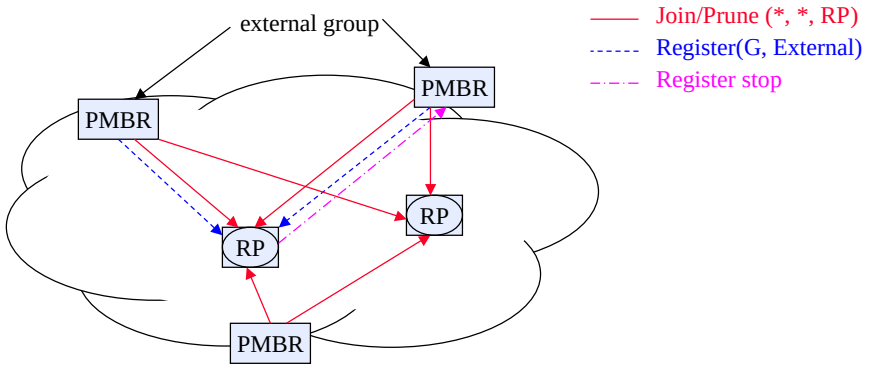


Selection of Rendezvous Point

- A small group of routers configured as bootstrap routers candidates
- One of them selected as bootstrap router (BSR) for the domain
- A set of routers are configured as candidate RPs
  - typically same as candidate BSRs
- Candidate RPs periodically unicast Candidate-RP-Advertisements to the BSR
  - Own address
  - Optional group address and mask length
- BSR periodically sends Bootstrap messages through the domain
- The RP is selected by a hash function from the valid candidate RPs

PIM-SM can interoperate with DVMRP and other multicast protocols

- PIM Multicast Border Routers (PMBR) connects PIM-SM with other multicast protocols



Considerations

- PIM can switch from sparse mode to dense mode
  - Controlled by a parameter, which defines when the group is dense enough
- The RP may be a single point of failure
- The RP may be a bottle-neck

Summary of Multicast Protocols for the Internet

Shared tree	Source based trees	
	Broadcast and Prune	Domain-wide reports
PIM Sparse* Core Based tree*	DVMRP PIM Dense*	MOSPF

* Rely on Unicast routing protocol to locate MC-sources.

- Those that don't, can route MC on routes separate from unicast routes.
- For Shared tree protocols an additional step of finding the Core or Rendezvous Point must be performed.
- Directories are useful on service management level.