

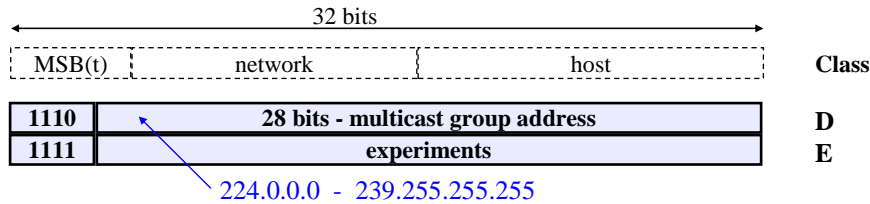
Multicast Protocols

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 - 224.0.0.255	Local network control
224.0.0.1	All systems
224.0.0.2	All routers
224.0.0.5	All OSPF routers
239.0.0.0 - 239.255.255.255	Administratively scoped multicast
239.192.0.0 - 239.195.255.255	Organization local scope

- Sender does not need to belong to the multicast group.
- 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

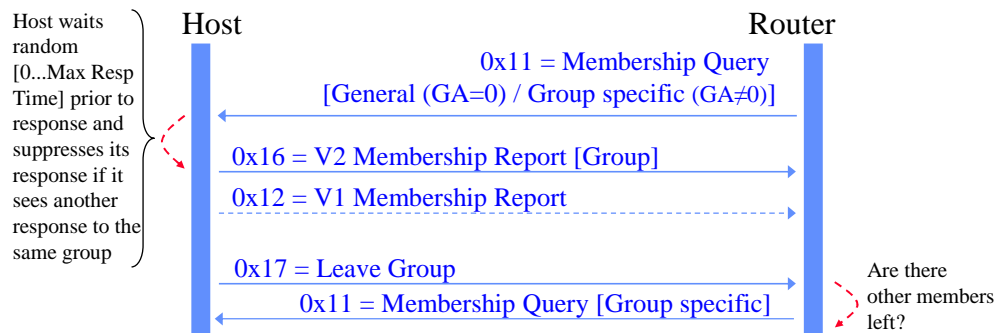
Routers discover multicast receivers using IGMP

- IGMP = Internet Group Membership Protocol
- Version 2 defined in RFC-2236, version 3 in RFC-3376
- 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

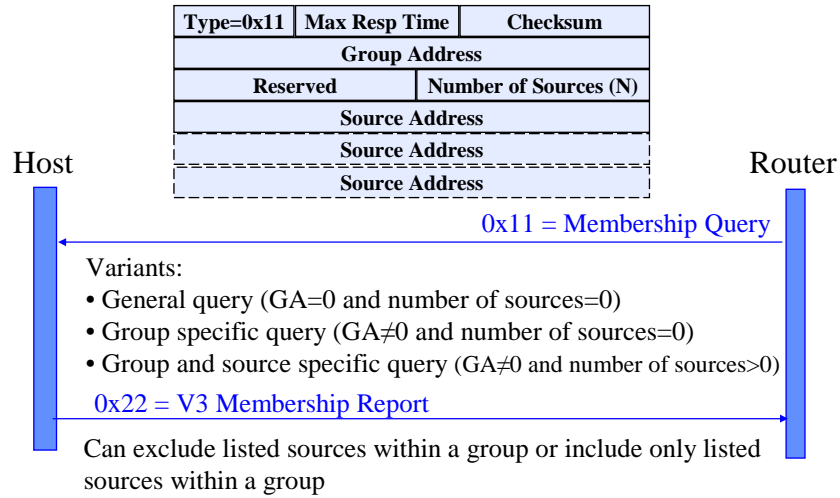
IGMPv2 - Internet Group Management Protocol

Type	Max Resp Time	Checksum
Group Address (GA)		

- Sent to "all systems" multicast address 224.0.0.1
- "Leave group" message sent to "all routers" address 224.0.0.2



IGMPv3 adds selective reception from sources within a group



MBone

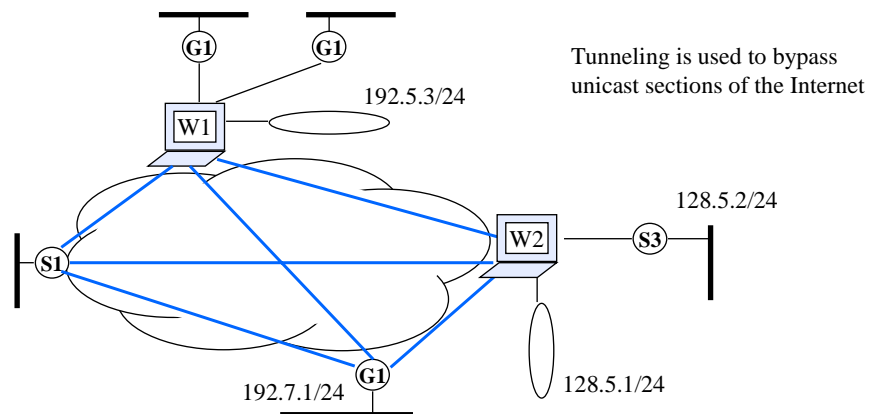
MBone – an overlay multicast Internet

- 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

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MBone overlay is based on workstations running DVMRP



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Experimental routing protocols have been developed for MBone

Tree type	Shared tree	Source based trees	
Algorithm	Center based tree	Flood and prune	Domain-wide reports
Protocols	PIM Sparse* Core Based Tree*	DVMRP PIM Dense*	MOSPF

* These rely on unicast routing protocol to locate multicast sources.
(The other ones can route multicast on routes separate from the 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 explicitly configured with
 - Destination router
 - Cost
 - Threshold

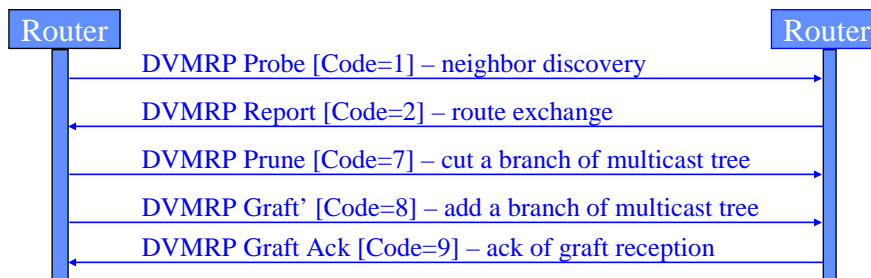
DVMRP is used for multicast routing in the Mbone

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

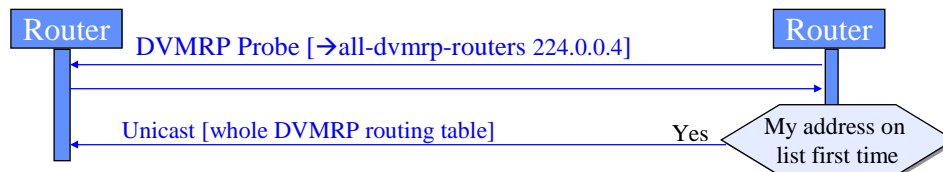
DVMRP header:

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

Version 3 (1997) presented in this course



Probes are used for neighbor discovery

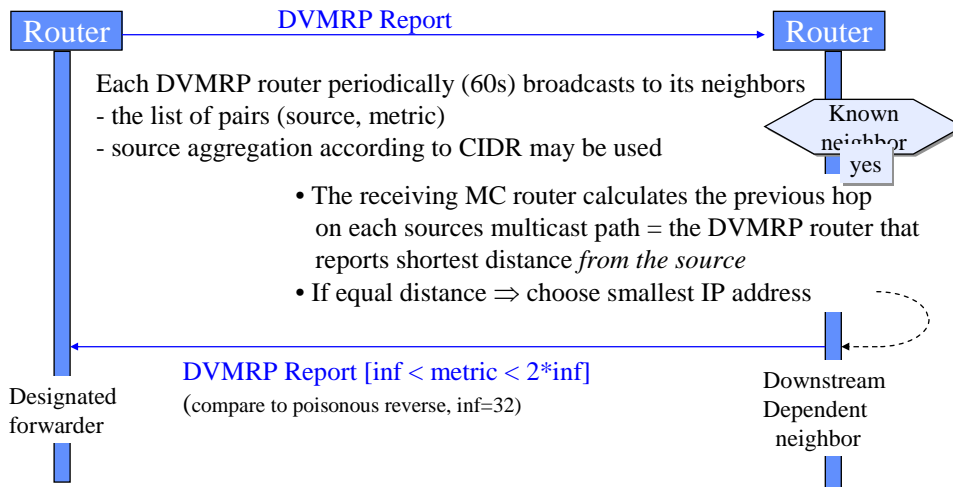


- Probes are exchanged on tunnel and physical interfaces
- Contains the list of neighbors on the interface
 - If empty, this is leaf network managed by IGMP
- Multicasts are not exchanged until two-way neighbor relationship is established
- Routers see each others versions and capability flags \Rightarrow compatibility
- Keepalive \Rightarrow 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 the route with a metric = original metric + inf

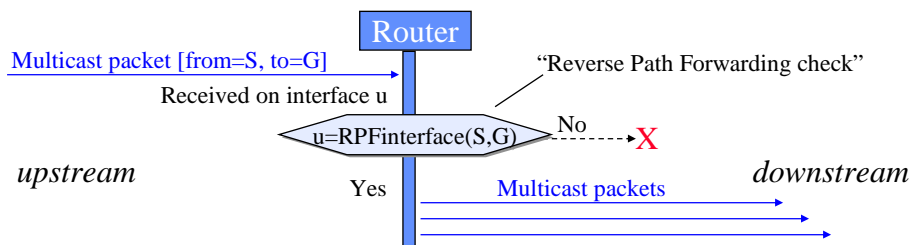
Route reports are used to build the source based trees



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

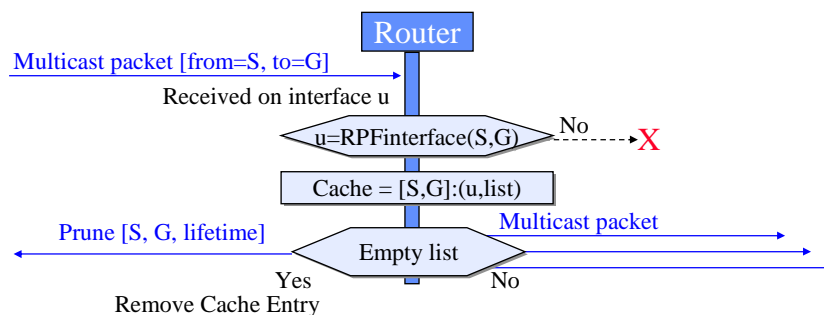


- At first multicast from RPF interface a Forwarding Cache Entry [S,G):(u,list...) is created using the DVMRP routing table
 - The list contains all downstream routers that have reported dependency on S
- The router is designated forwarder for downstream nodes
- If the designated forwarder becomes unreachable,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

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List of dependent neighbors is used to minimize the multicast tree

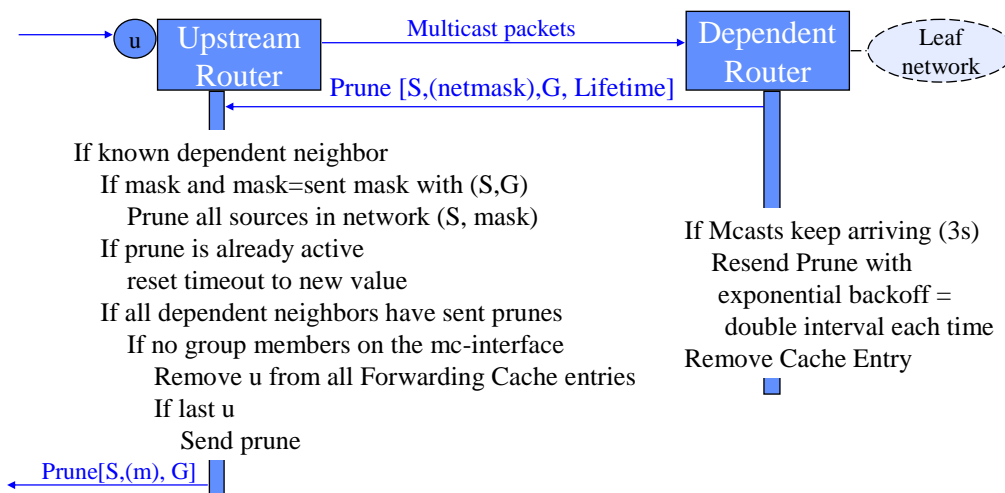


- Initially list may contain all multicast interfaces but the upstream interface
- Downstream address is removed from list if
 - It is a leaf network and G is not in IGMP DB for this phys. network
 - Downstream node has selected another designated forwarder
 - Prune received from all dependent neighbors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

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Prunes minimize the multicast tree



- If known dependent neighbor
- If mask and mask=sent mask with (S,G)
 - Prune all sources in network (S, mask)
 - If prune is already active
 - reset timeout to new value
 - If all dependent neighbors have sent prunes
 - If no group members on the mc-interface
 - Remove u from all Forwarding Cache entries
 - If last u
 - Send prune

- If Mcasts keep arriving (3s)
 - Resend Prune with exponential backoff = double interval each time
 - Remove Cache Entry

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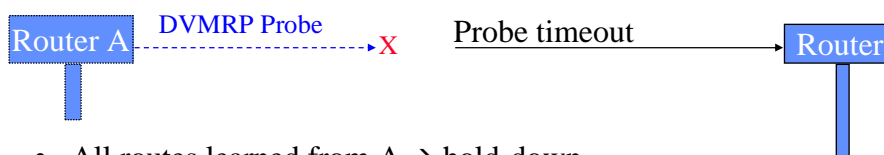
Multicast2-21

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

PIM – Protocol Independent Multicast

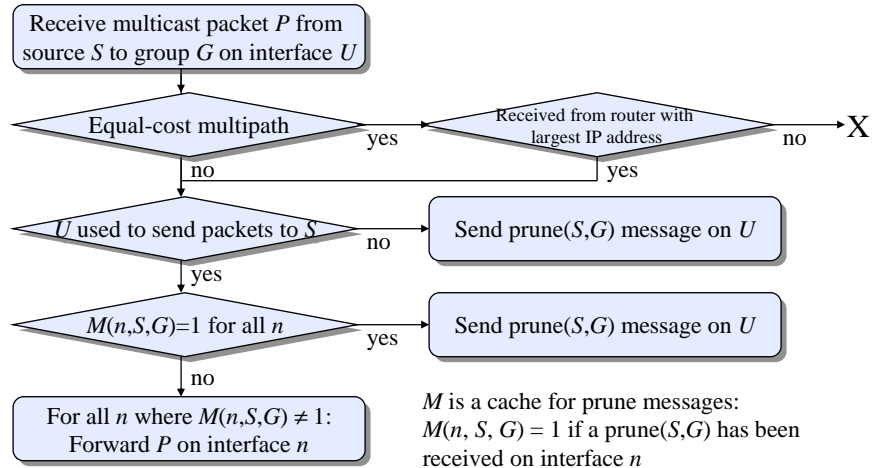
PIM – Protocol Independent Multicast

- 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

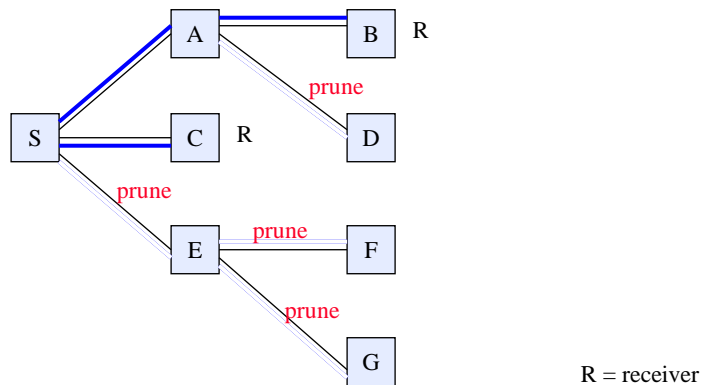
PIM Dense Mode

- For dense multicast groups
 - Dense: The probability is high that a small randomly picked area contains at least a group member, e.g. LAN
- Based on RPF / "flood-and-prune"
- Principle similar to DVMRP
 - Simpler
 - Less efficient

PIM-DM implementation of RPF

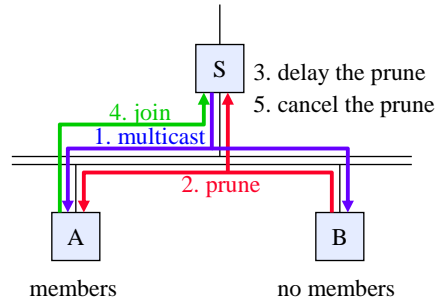


PIM-DM – Pruning

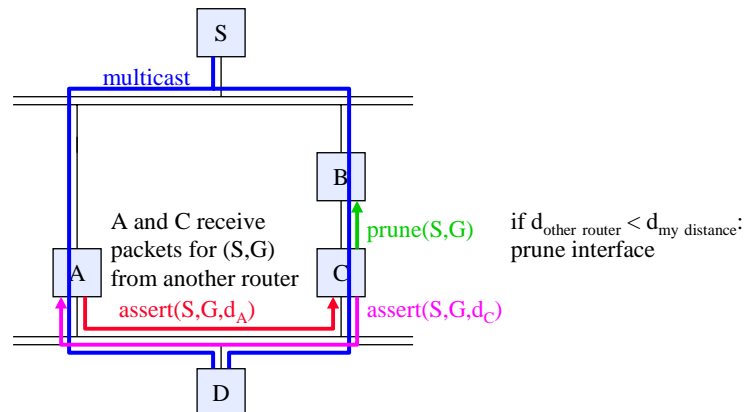


PIM-DM – Pruning on broadcast networks

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



PIM-DM – Resolving multicasts received on multiple path



PIM Sparse Mode

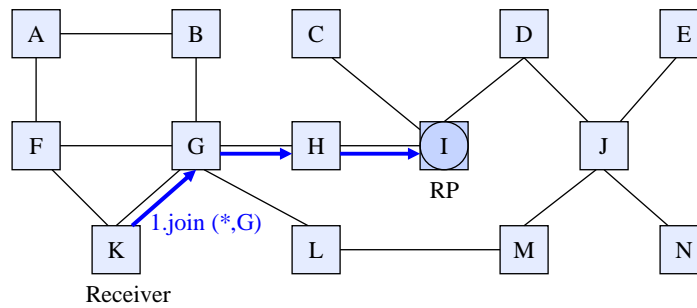
- RFC 2362
- Uses the center-based tree algorithm
- Evolved from the Core-Based Tree (CBT) protocol
- Rendezvous point (=center) connects the receivers with the senders
- Receivers must explicitly join
- Generates a shared unidirectional tree
- Can switch to source based trees to optimize routes

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 specific group
 - (*,G) – all sources in a specific group
 - (*, *, RP) – all groups that hash to a specific RP

PIM-SM example (1)

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

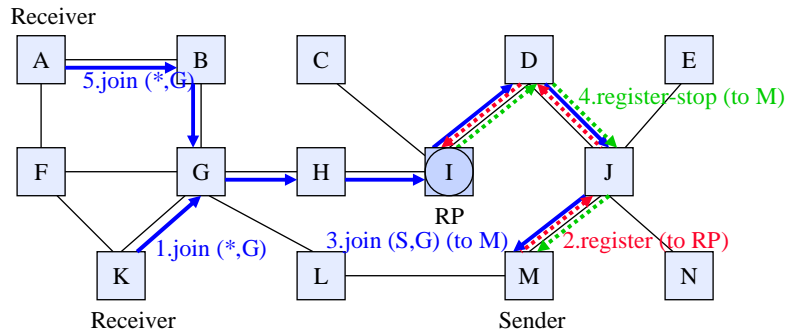


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PIM-SM example (2)

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

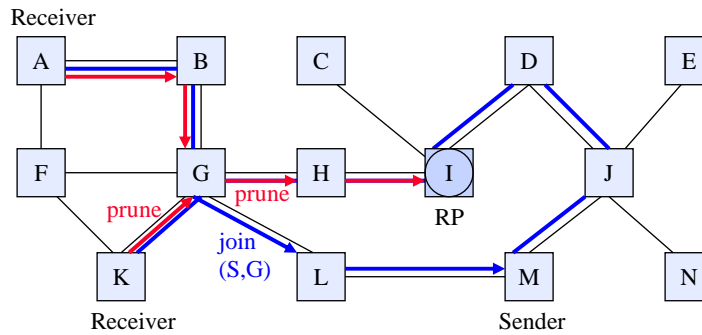


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PIM-SM example (3)

- 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

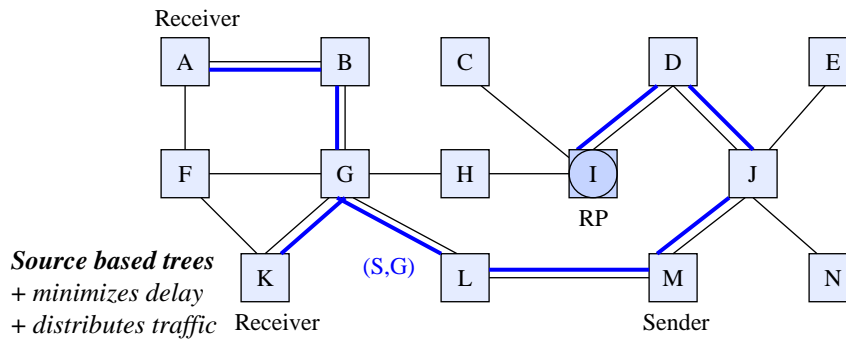


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PIM-SM example (4)

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



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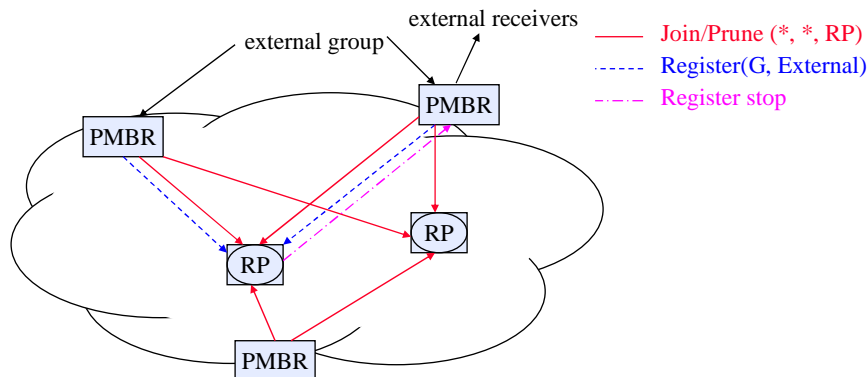
Multicast2-37

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
- BSR periodically sends **Bootstrap messages** through 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, which includes them in the Bootstrap message
 - Candidate RP's own address
 - Optional group address and mask length
- The RP is selected by a hash function from the valid candidate RPs
 - All routers use the same hash functions, therefore all routers select the same RP for a given group

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

MOSPF – Multicast extensions to OSPF

MOSPF – Multicast extensions to OSPF (1)

- Idea: 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 only
 - Desirable for high-bandwidth multicast applications or limited-bandwidth network links (or both).

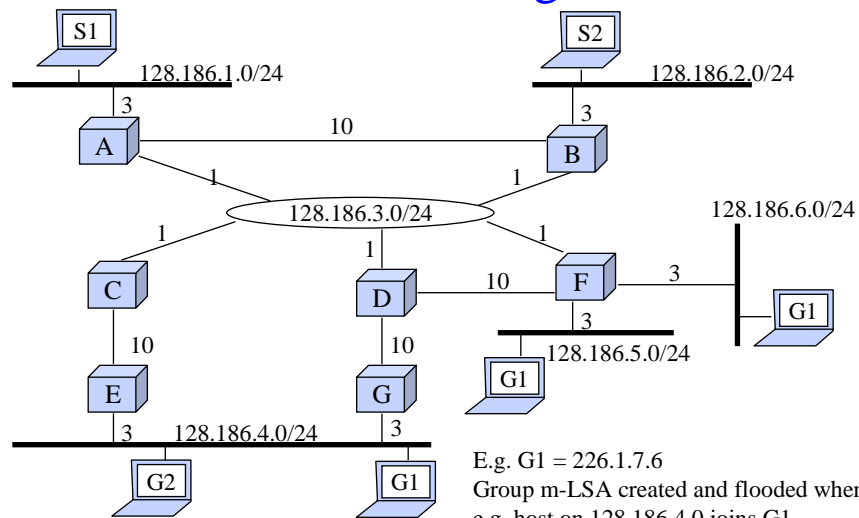
MOSPF – Multicast extensions to OSPF (2)

- 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.
- Defined in RFC 1584

MOSPF can be deployed gracefully

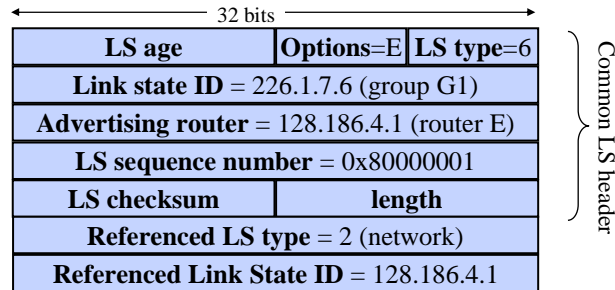
- Introduces multicast routing by
 - adding a new type of LSA to the OSPF link-state database
 - adding calculations for the paths of multicast packets
- The introduction of MOSPF to an OSPF routing can be gradual
 - Multicast capability marked with a M-bit in the option flag
 - Routers without multicast capability are ignored in calculating multicast routes \Rightarrow MOSPF will automatically route IP multicast datagrams around routers incapable of multicast routing
 - No tunnels \Rightarrow there may be a unicast path, but no multicast path

An MOSPF Routing Domain

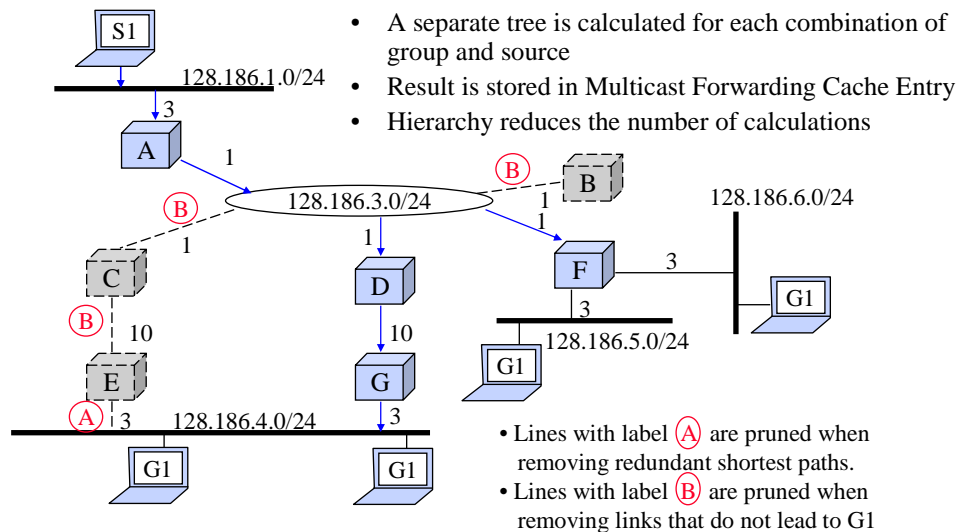


Group-membership-LSA is created and flooded when a user joins an multicast group using IGMP

LS Type 6 = Group Membership LSA:



MOSPFP calculates shortest-path trees on demand



The Multicast Forwarding Cache Entry stores multicast path routing info

- For each source network and group:

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

- When network conditions change paths are recalculated
- 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-Membership-LSA ⇒ Delete entries of that group.
- Hierarchy ⇒ The farther away the change is the fewer cache entries are deleted.
- When the first packet arrives to a multicast group, the routes are recalculated

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

- Calculation is rooted on the source
 - not in the current 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
- For equal cost routes, the previous hop router with the highest address is chosen
 - e.g. G over E

Summary of Multicast Protocols for the Internet

Tree type	Shared tree	Source based trees	
Algorithm	Center based tree	Flood and prune	Domain-wide reports
Protocols	PIM Sparse* Core Based tree*	DVMRP PIM Dense*	MOSPF

- * These rely on unicast routing protocol to locate multicast sources.
(The other ones can route multicast on routes separate from the 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.