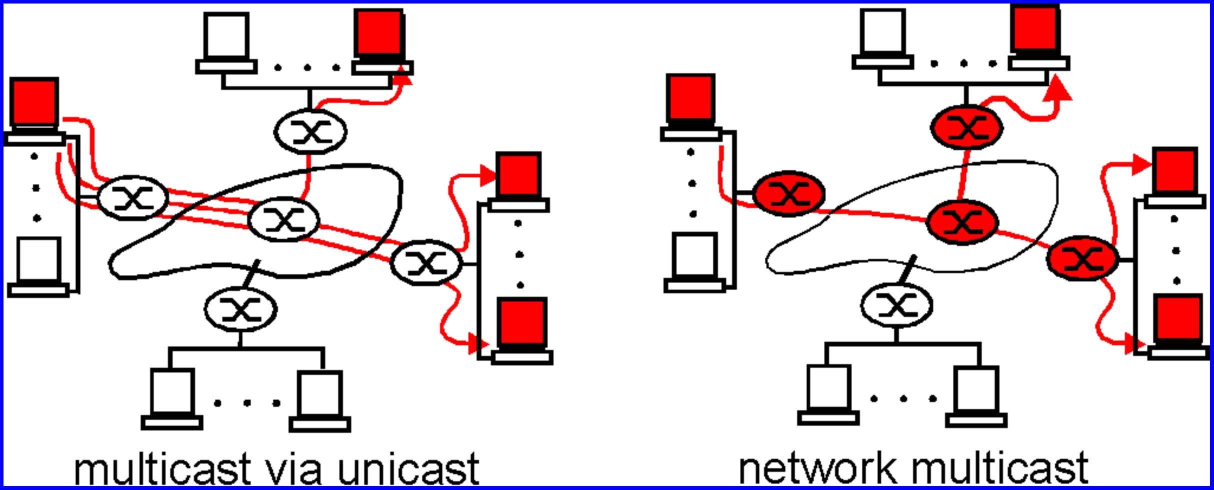
Multicast ad hoc networks

CS 218 - Monday Oct 20, 2003

- Review of Multicasting in wired networks
- Tree based wireless multicast
- Mesh based wireless multicast – ODMRP
- Performance comparison
- Reliable, congestion controlled multicast
- Scalable multicast, M-LANMAR

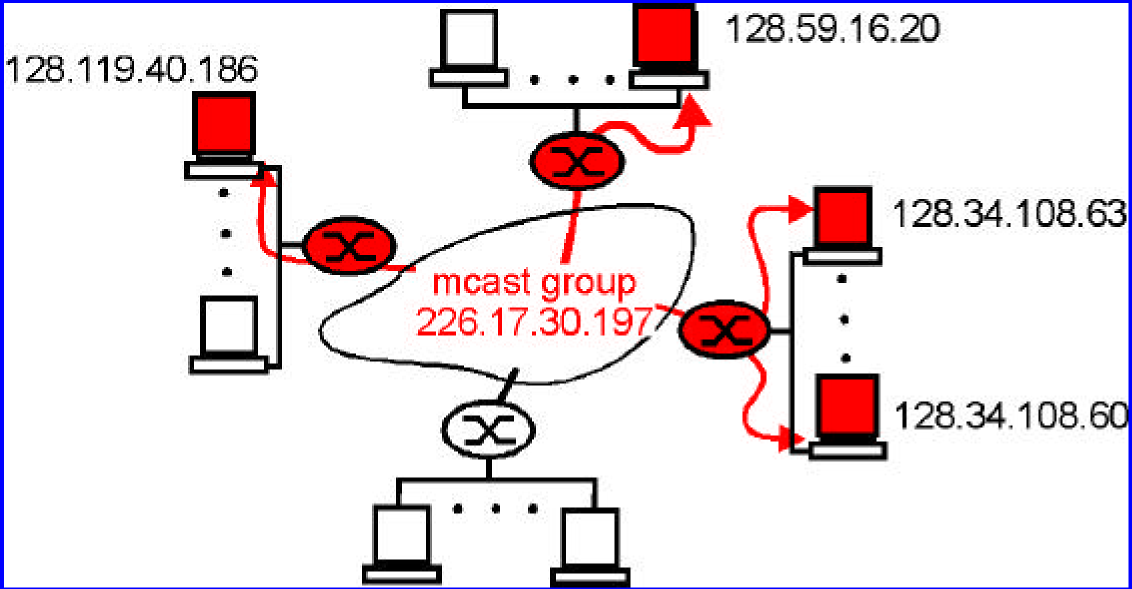
Multicast Routing

- Multicast: delivery of same packet to a group of receivers
- Multicasting is becoming increasingly popular in the Internet (video on demand; whiteboard; interactive games)
- Multiple unicast vs multicast



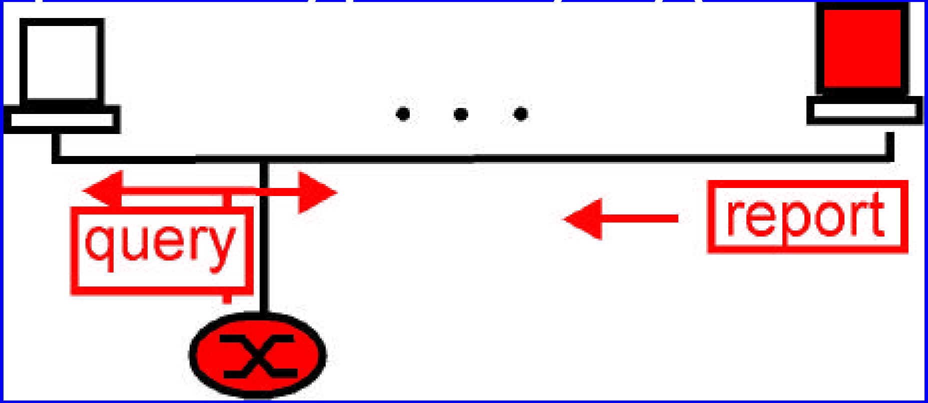
Multicast Group Address

- M-cast group address installed in all receivers in the group
- Internet uses Class D address for m-cast
- M-cast address distribution etc. managed by IGMP Protocol



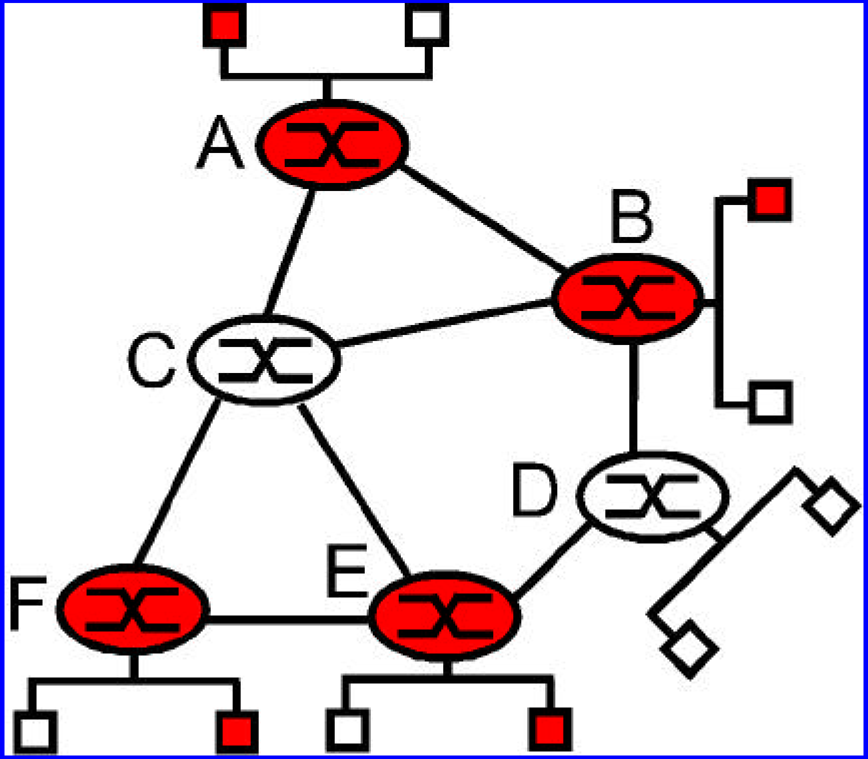
IGMP Protocol

- IGMP (Internet Group Management Protocol) operates between Router and local Hosts, typically attached via a LAN (e.g., Ethernet)
- Router queries the local Hosts for m-cast group membership info
- Router "connects" active Hosts to m-cast tree via m-cast protocol
- Hosts respond with membership reports: actually, the first Host which responds (at random) speaks for all
- Host issues "leave-group" msg to leave; this is optional since router periodically polls anyway (soft state concept)



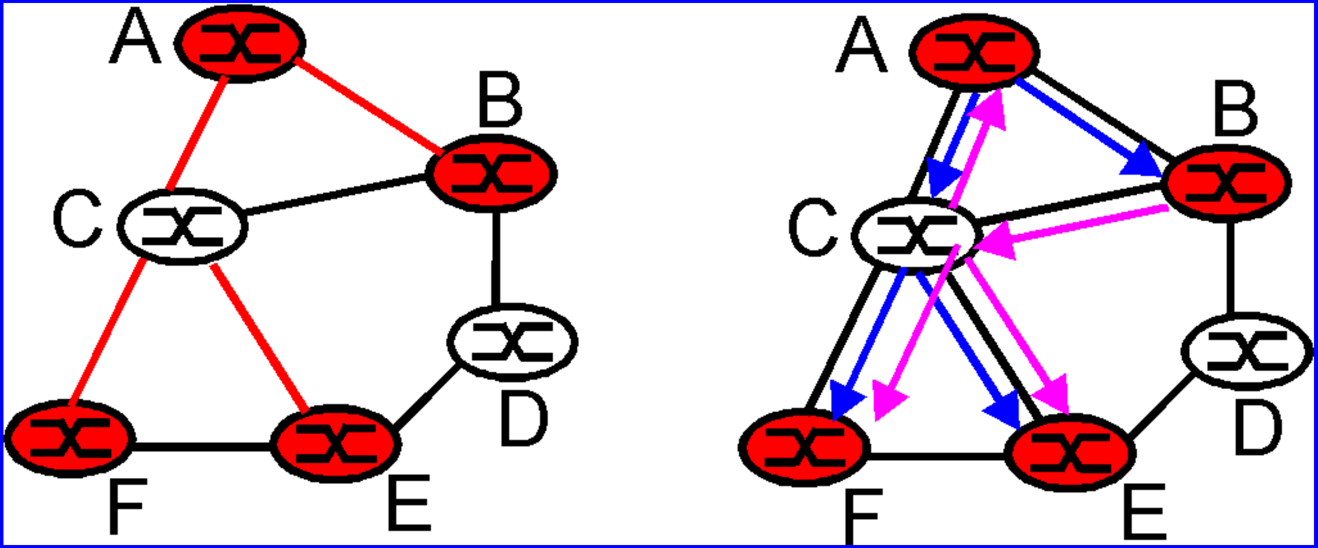
The Multicast Tree problem

- **Problem: find the best (e.g., min cost) tree which interconnects all the members**



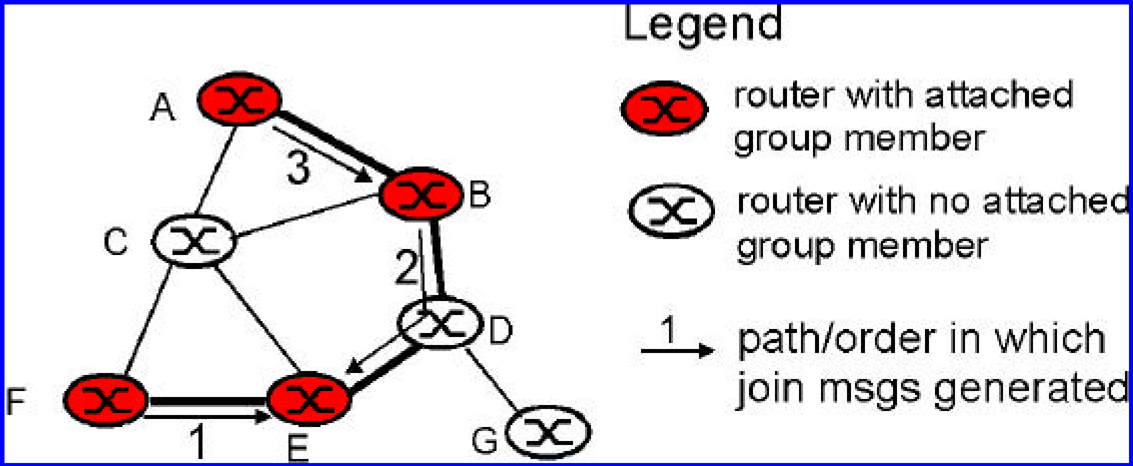
Multicast Tree options

- **GROUP SHARED TREE: single tree; the root (node C below) is the "CORE" or the "Rendez Vous" point; all messages go through the CORE**
- **SOURCE BASED TREE: each source is the root of its own tree connecting to all the members; thus N separate trees**



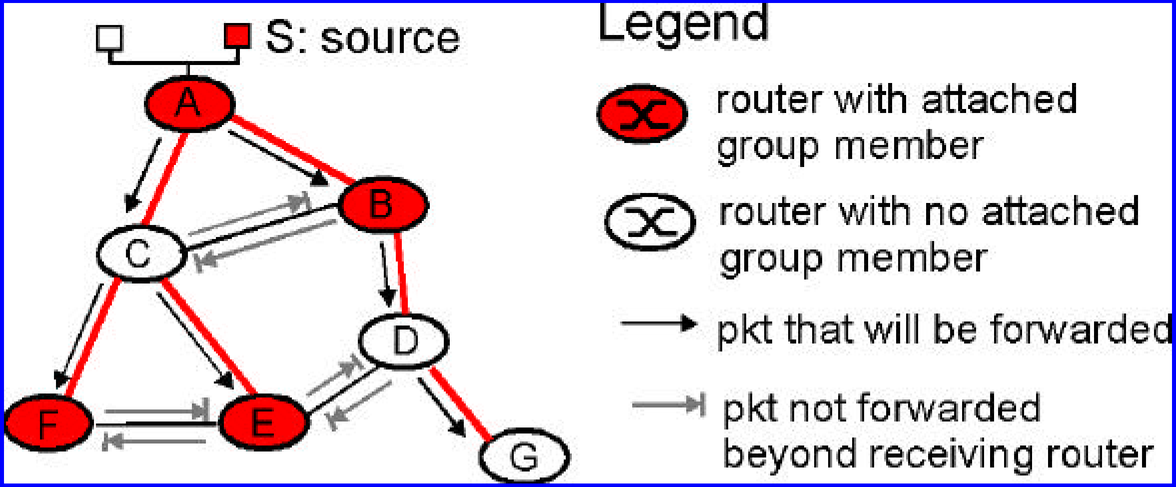
Group Shared Tree

- Predefined CORE for given m-cast group (eg, posted on web page)
- New members “join” and “leave” the tree with explicit join and leave control messages
- Tree grows as new branches are “grafted” onto the tree
- CBT (Core Based Tree) and PIM Sparse-Mode are Internet m-cast protocols based on GSTree
- All packets go through the CORE



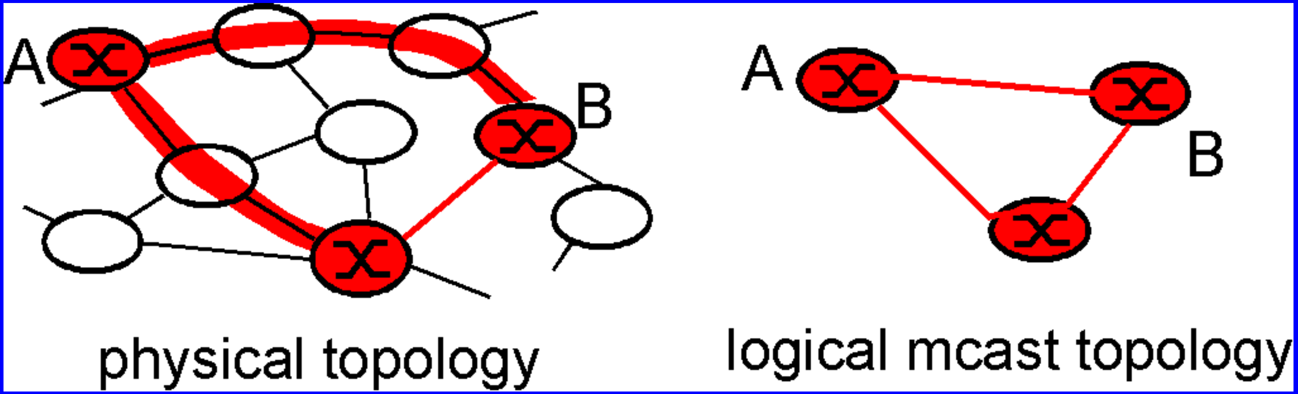
Source Based Tree

- Each source is the root of its own tree: the tree of shortest paths
- Packets delivered on the tree using "reverse path forwarding" (RPF); i.e., a router accepts a packet originated by source S only if such packet is forwarded by the neighbor on the shortest path to S
- In other words, m-cast packets are "forwarded" on paths which are the "reverse" of "shortest paths" to S



Source-Based tree: DVMRP

- DVMRP was the first m-cast protocol deployed on the Internet; used in Mbone (Multicast Backbone)
- Initially, the source broadcasts the packet to ALL routers (using Rev Path Fwd)
- Routers with no active Hosts (in this m-cast group) “prune” the tree; i.e., they disconnect themselves from the tree
- Recursively, interior routers with no active descendents self-prune. After timeout pruned branches “grow back”
- Problems: only few routers are mcast-able; solution: tunnels



PIM (Protocol Independent Multicast)

- PIM (Protocol Independent Multicast) is becoming the de facto intra AS m-cast protocol standard
- “Protocol Independent” because it can operate on different routing infrastructures (as a difference of DVMRP)
- PIM can operate in two modes: PIM Sparse Mode and PIM Dense Mode.
- Initially, members join the “Shared Tree” centered around a Rendez Vous Point
- Later, once the “connection” to the shared tree has been established, opportunities to connect DIRECTLY to the source are explored (thus establishing a partial Source Based tree)

Wireless Ad Hoc Multicast

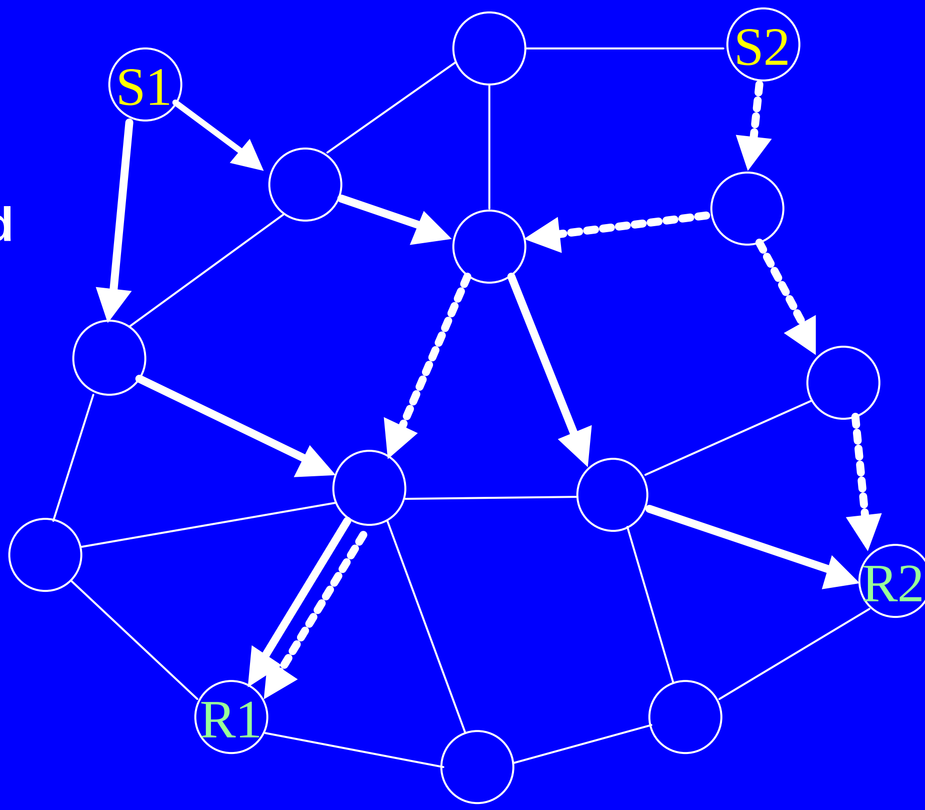
References

ODMRP reference

- S.-J. Lee, M. Gerla, and C.-C. Chiang, "On-Demand Multicast Routing Protocol," Proceedings of IEEE WCNC'99, New Orleans, LA, Sep. 1999, pp. 1298-1302.

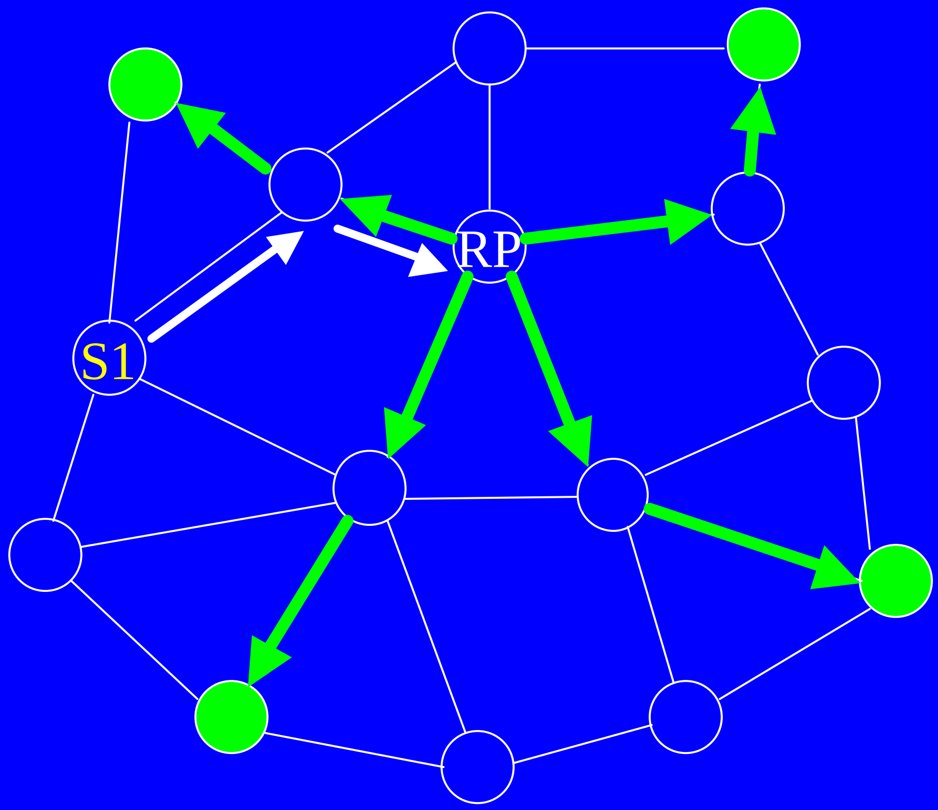
Per-Source Tree Multicast

- Each source supports own separate tree
- "Probing and Pruning" tree maintenance
- Reverse Path Forwarding (to avoid endless packet circulation)
- "Fast Source" problem



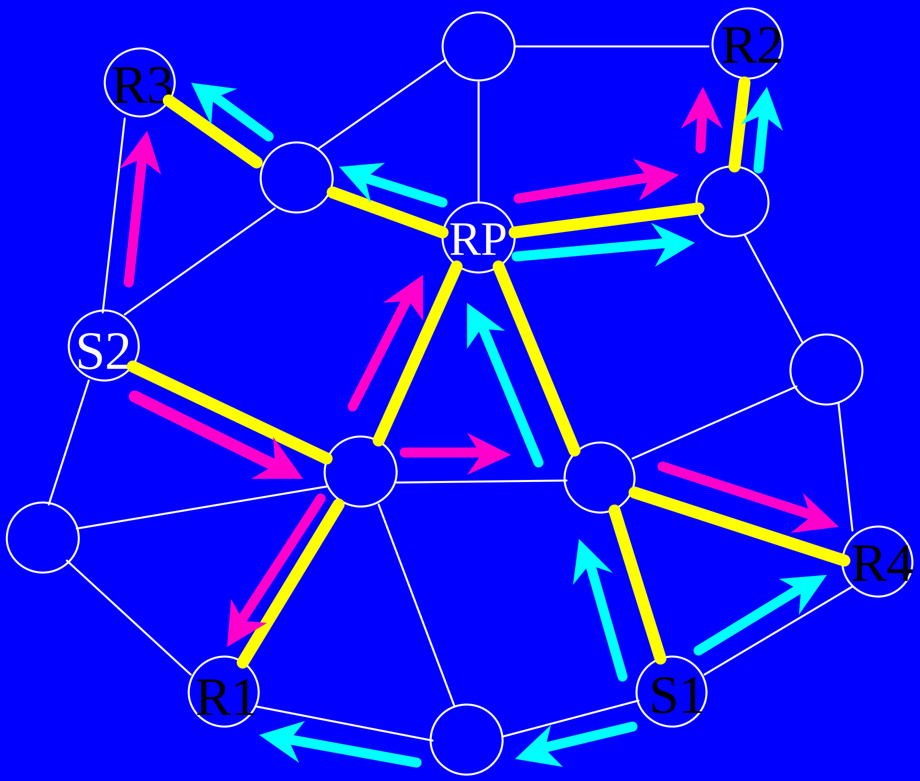
RP-based Shared Tree Multicast

- RP (Rendezvous Point)-based "Shared" tree
- Tree maintenance:
  - soft state
- "off-center" RP
- longer paths than shortest path tree

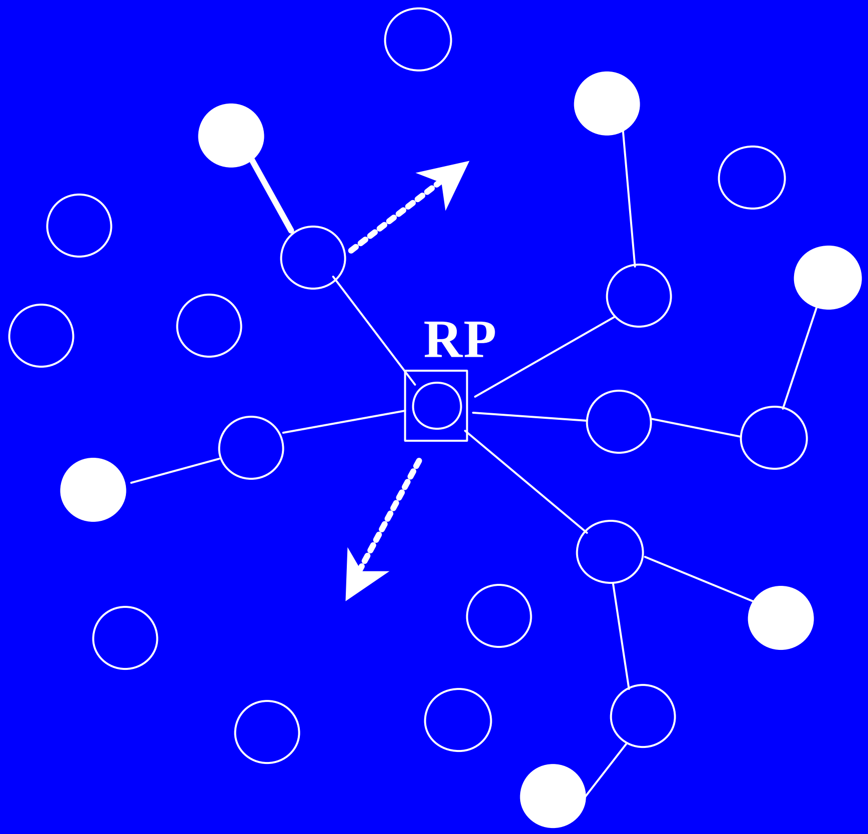


Shared Tree vs. Per-source Tree

- **Shared Tree:**
  - \+ scalability
  - \+ less sensitive to fast source
  - – longer path
  - – off center RP
- **Per-Source Tree:**
  - \+ shortest path
  - \+ traffic distribution
  - \+ no central node
  - – scalability problem
  - – fast source problem

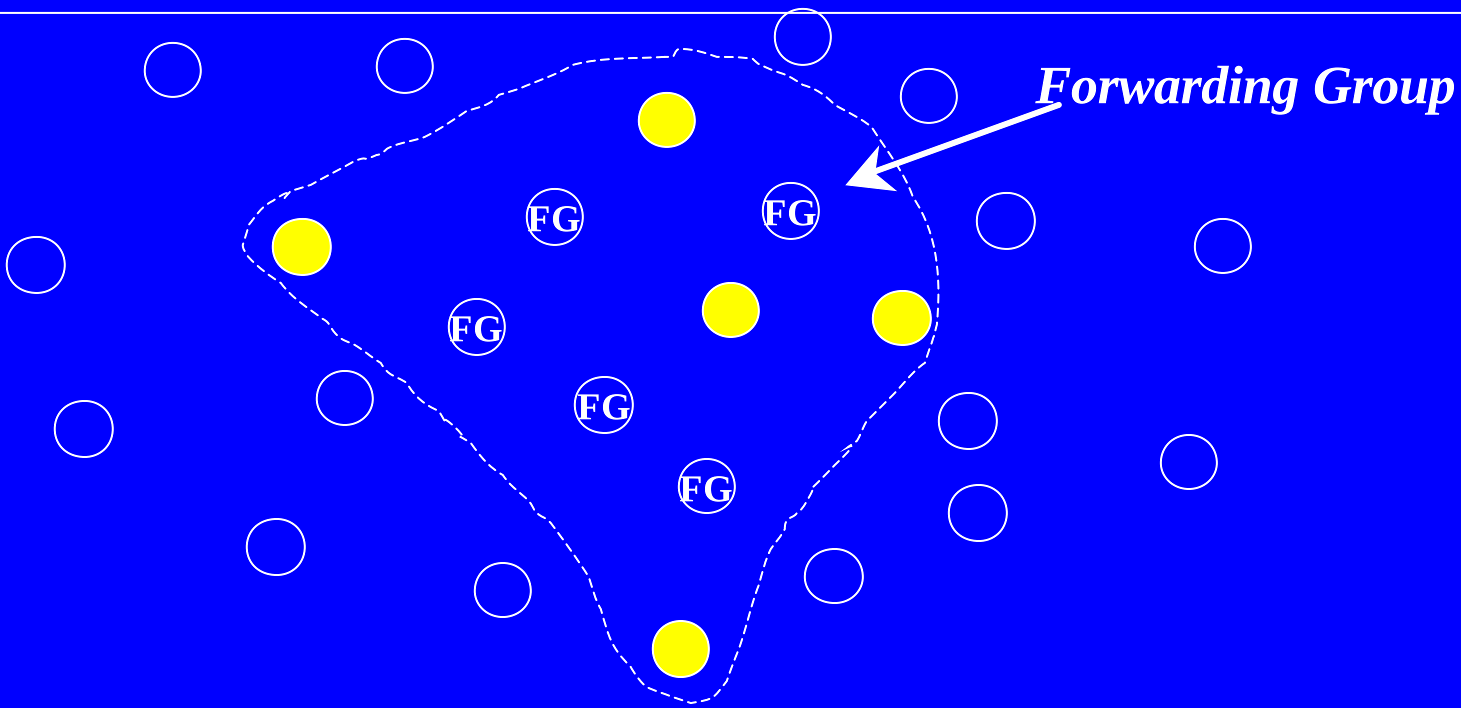


Wireless Tree Multicast Limitations in High Mobility



- In a mobile situation, tree is fragile: connectivity loss, multipath fading
- Need to refresh paths very frequently
- High control traffic overhead

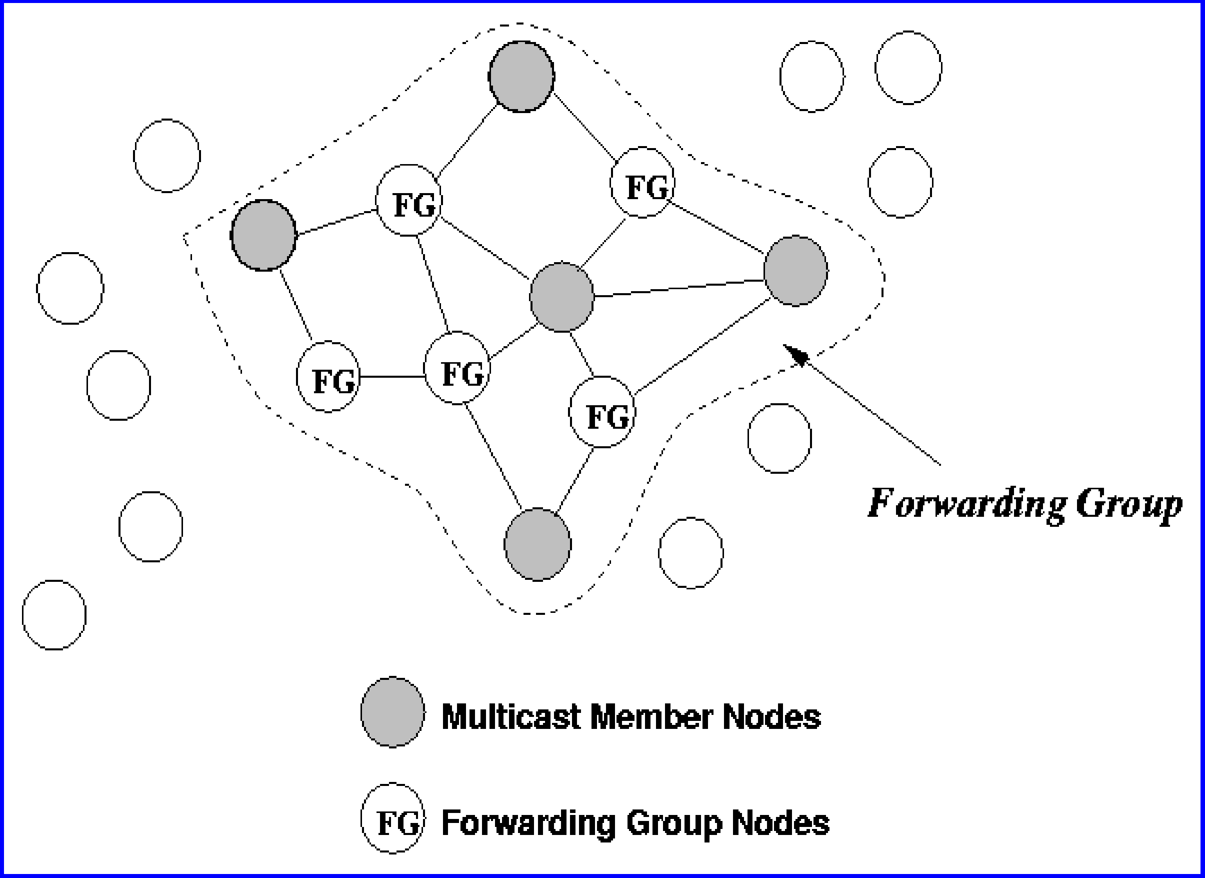
Proposed solution: Forwarding Group Multicast



- All the nodes inside the "bubble" forward the M-cast packets via "restricted" flooding
- Multicast Tree replaced by Multicast "Mesh" Topology
- Flooding redundancy helps overcome displacements and fading
- FG nodes selected by tracing shortest paths between M-cast members

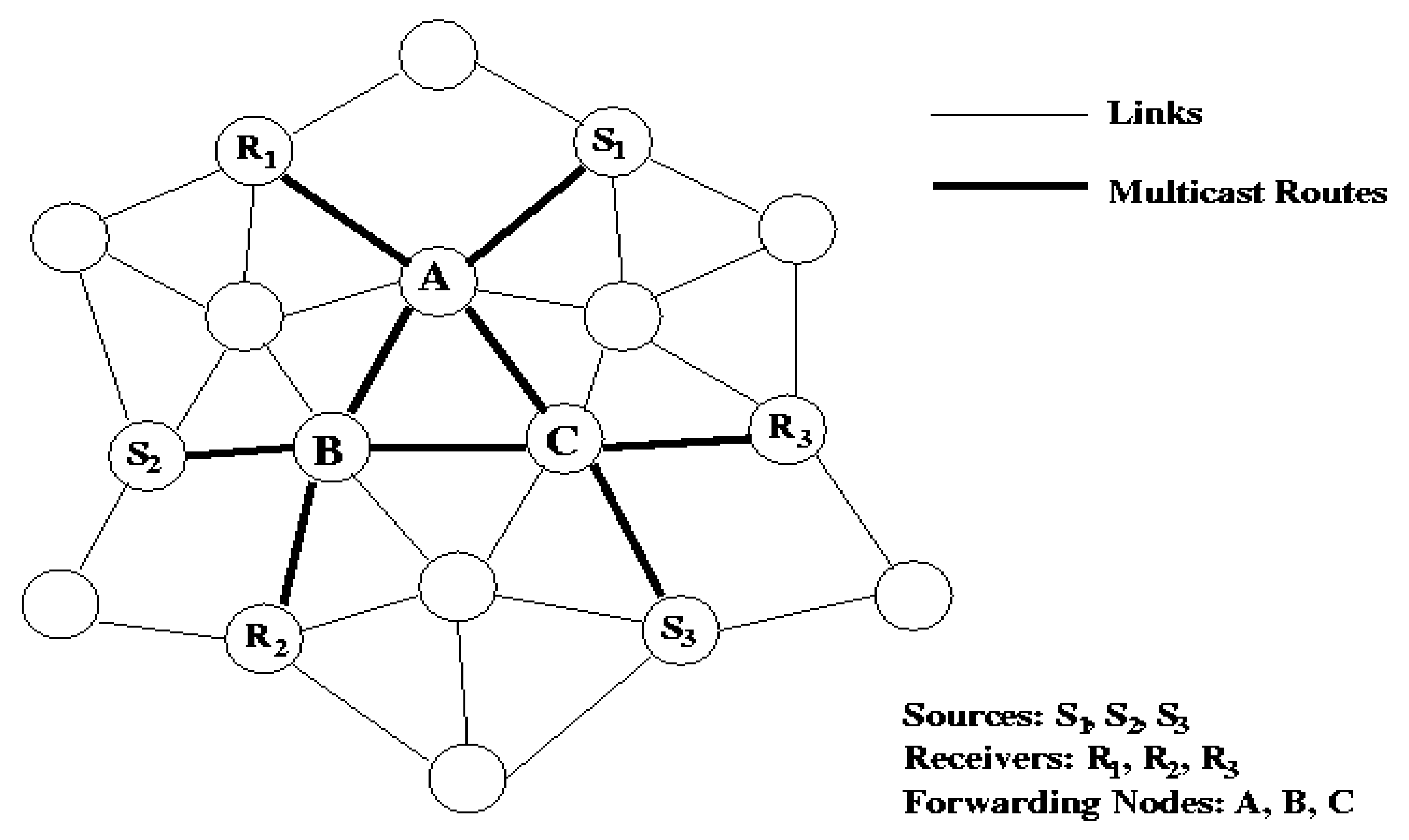
Forwarding Group Concept

- A set of nodes in charge of forwarding multicast packets
- Supports shortest paths between any member pairs
- Flooding helps overcome displacements and channel fading



Mesh vs Tree Forwarding

- Richer connectivity among multicast members
- Unlike trees, frequent reconfigurations are not needed

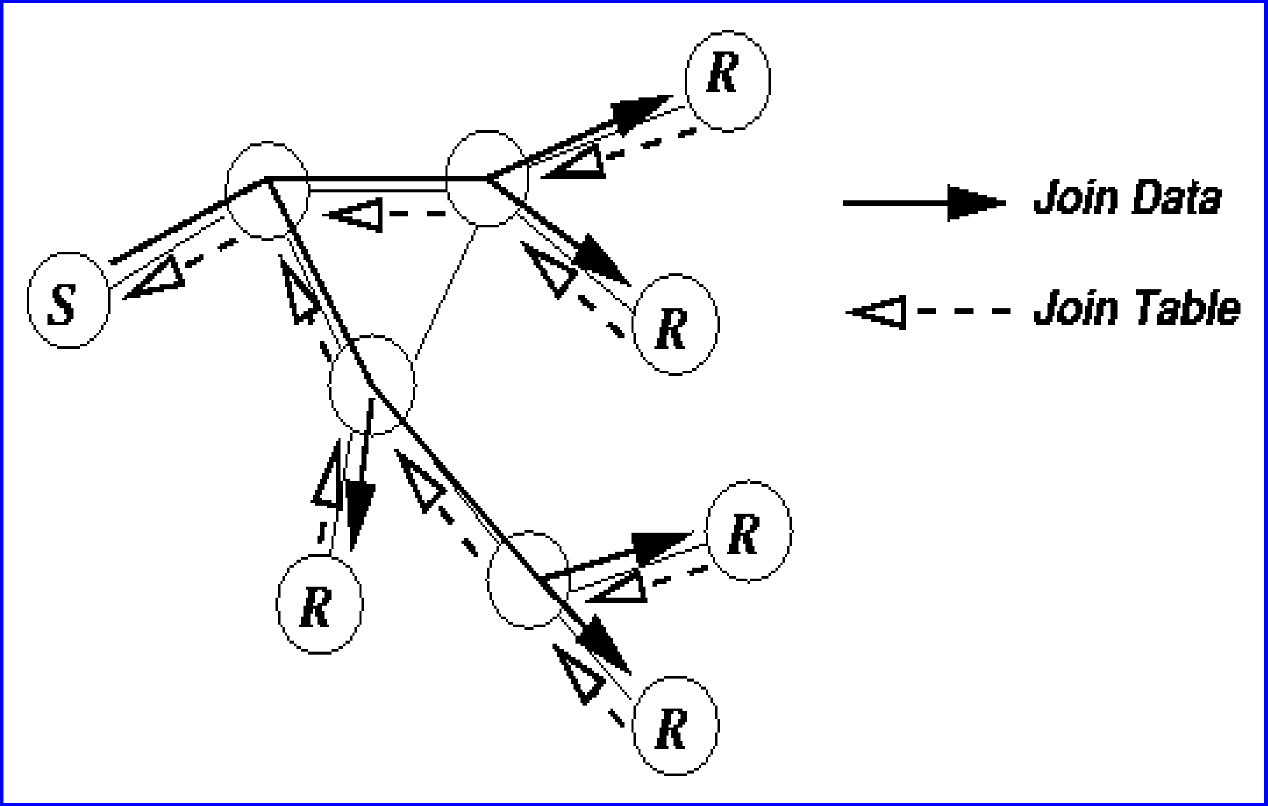


ODMRP (On Demand Multicast Routing Protocol)

- Forwarding Group Multicast concept
- Tree replaced by Mesh
- *On-demand* approach
- Soft state

FG Maintenance
(On-Demand Approach)

- A sender periodically floods control messages when it has data to send
- All intermediate nodes set up route to sender (backward pointer)
- Receivers update *Member Tables* ; periodically broadcast *Join Tables*
- Nodes on path to sources set FG_Flag; FG nodes broadcast *Join Tables*



Soft State Approach

- No explicit messages required to join/leave multicast group (or FG)
- An entry of a receiver's *Member Table* expires if no *Join Request* is received from that sender entry during MEM_TIMEOUT
- Nodes in the forwarding group are demoted to non-forwarding nodes if not refreshed (no *Join Tables* received) within FG_TIMEOUT

A Performance Comparison Study of Ad Hoc Wireless Multicast Protocols

S.J. Lee, W. Su, J. Hsu, M. Gerla, and R. Bagrodia
Wireless Adaptive Mobility Laboratory
University of California, Los Angeles
http://www.cs.ucla.edu/NRL/wireless

Simulation Environment

- Written in PARSEC within GloMoSim Library
- 50 nodes placed in 1000m X 1000m space
- Free space channel propagation model
- Radio range: 250 m
- Bandwidth: 2 Mb/s
- MAC: IEEE 802.11 DCF
- Underlying unicast : Wing Routing Prot (for AMRoute & CAMP)
- Multicast members and sources are chosen randomly with uniform probabilities
- Random waypoint mobility

Goal

- **Compare mesh- and tree-based multicast protocols**
  - Mesh-based: ODMRP, CAMP, Flooding
  - Tree-based: AMRoute, AMRIS
- **Evaluate sensitivity to the following parameters:**
  - Mobility (ie, speed)
  - Number of multicast sources
  - Multicast group size
  - Network traffic load

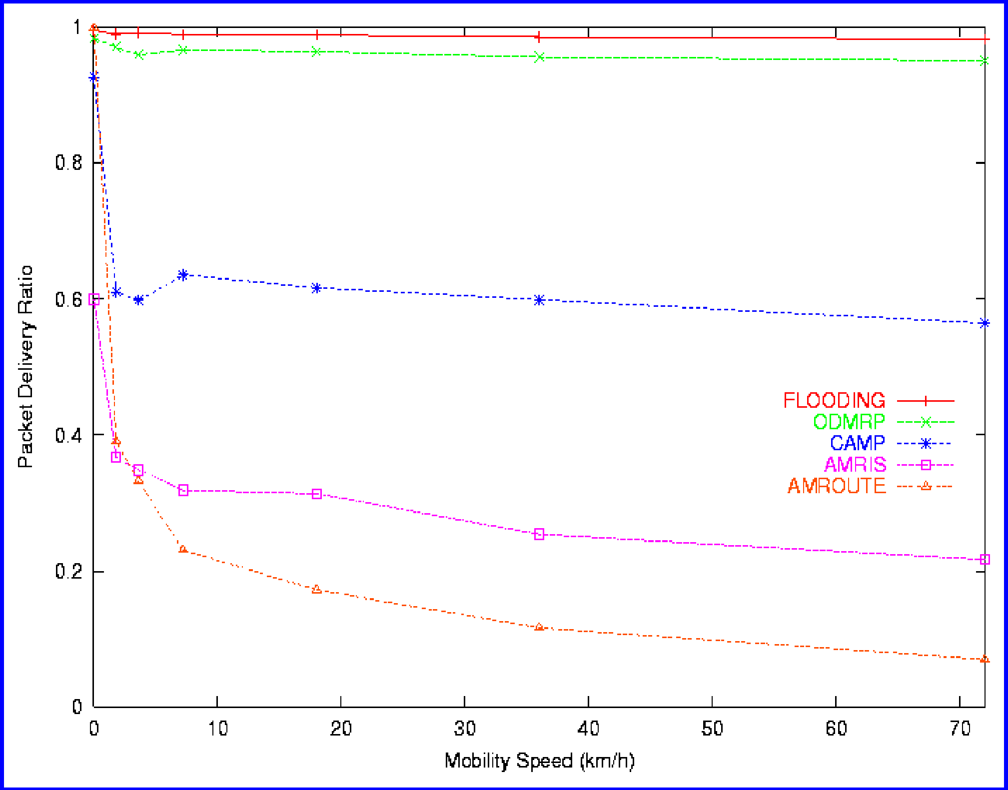
Multicast Protocols

- **Adhoc Multicast Routing (AMRoute)**
  - Bidirectional shared tree with a core
  - Relies on unicast protocol to provide routes between multicast members and to handle mobility
  - Suffers from temporary loops and non-optimal trees

Multicast Protocols (cont'd)

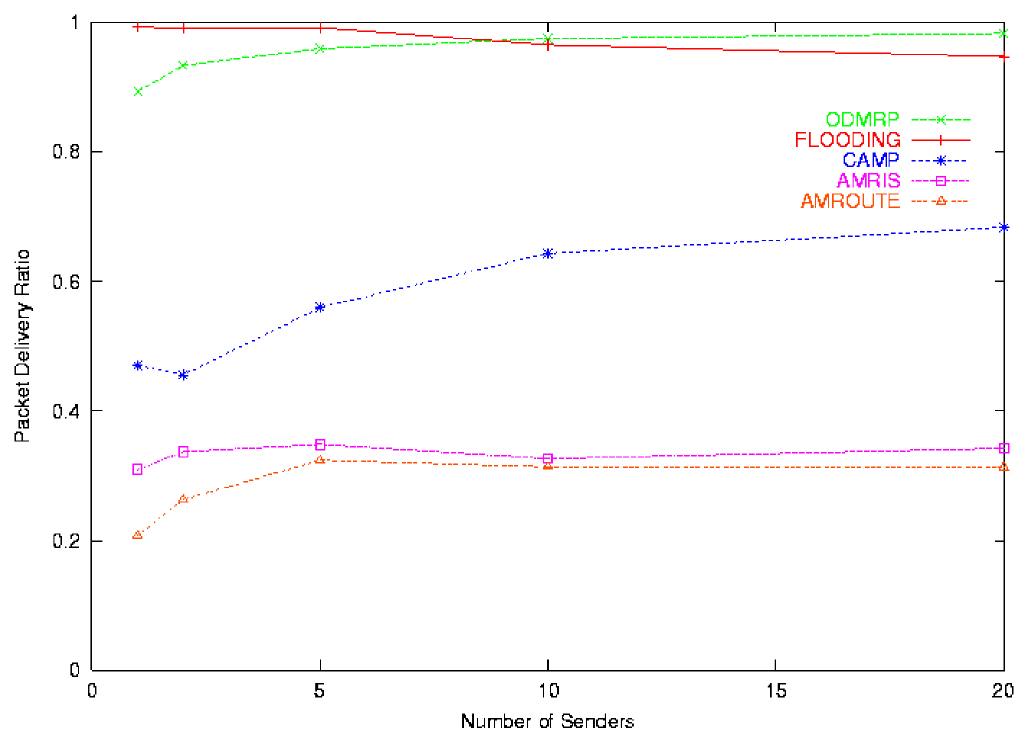
- **Ad hoc Multicast Routing protocol utilizing Increasing id-numberS (AMRIS)**
  - Each node is assigned an ID number to build a tree
  - The increasing id is used in tree maintenance and localized repair
  - Beacons are sent by each node to neighbors
- **Core-Assisted Mesh Protocol (CAMP)**
  - A shared mesh for each multicast group
  - Cores are used to limit the flow of join requests
  - Relies on certain underlying unicast protocols (e.g., WRP, ALP, etc.)

Packet Delivery Ratio as a Function of Mobility Speed



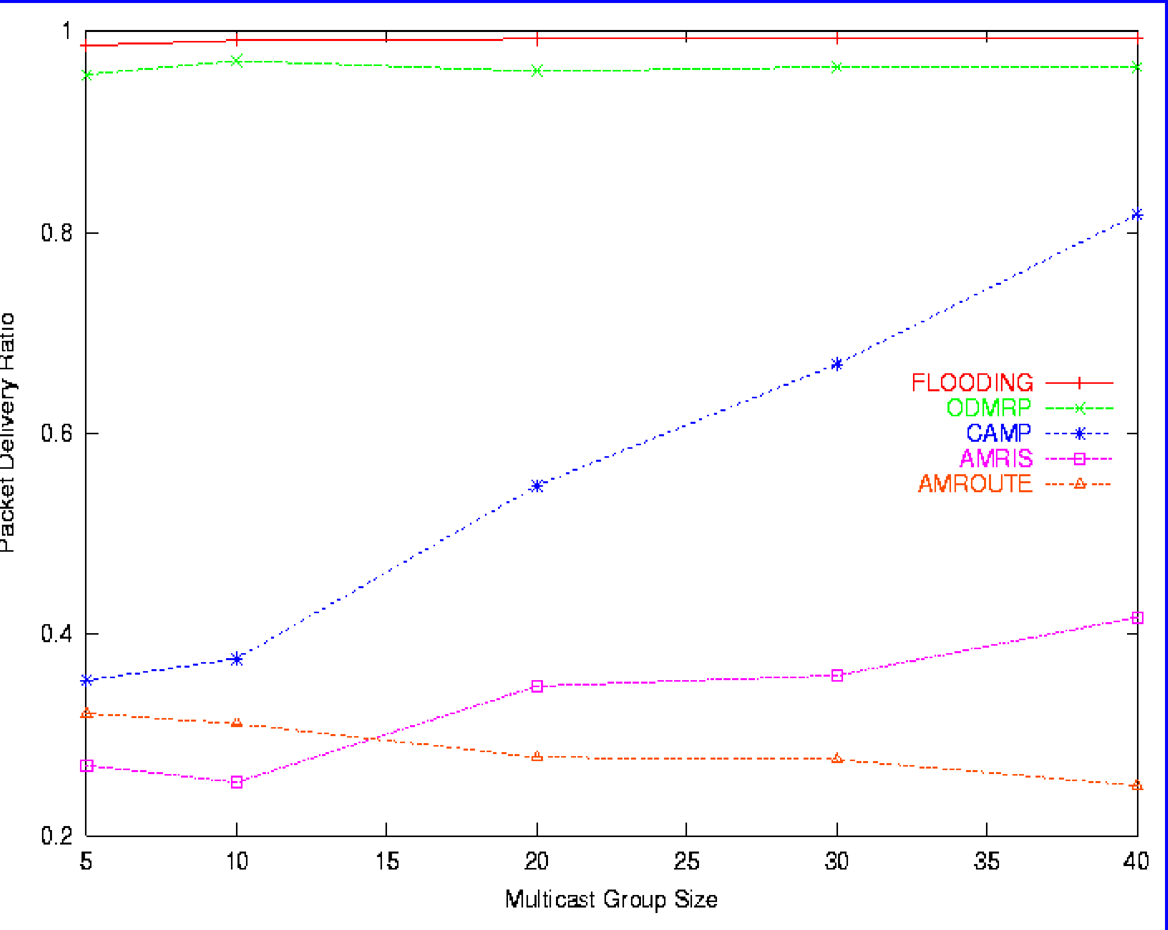
- 20 members
- 5 sources each send 2 pkt/sec
- Mesh protocols outperform tree protocols
- Multiple routes help overcome fading and node displacements

Packet Delivery Ratio as a Function of # of Sources



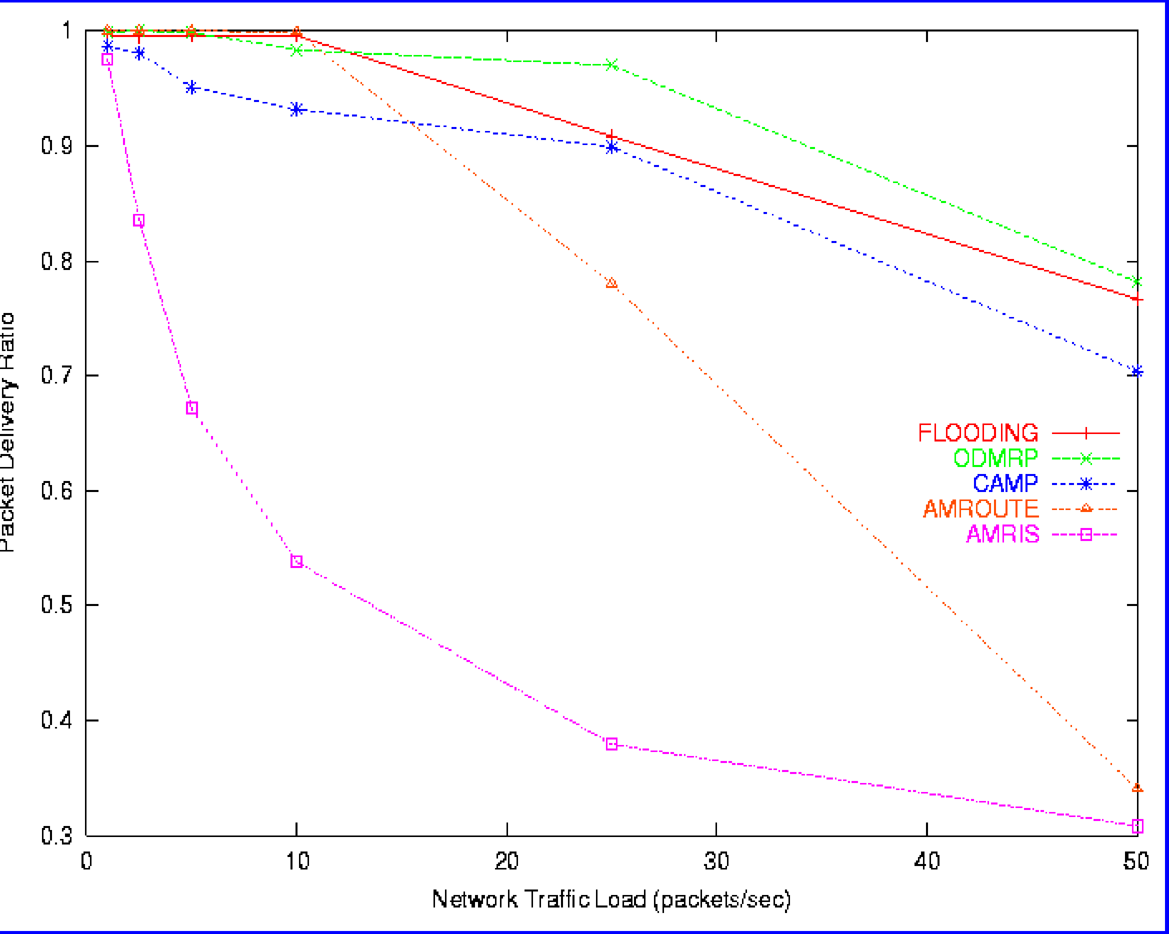
- 20 members
- 1 m/sec of mobility speed
- Total traffic load of 10 pkt/sec
- Increasing the number of sender makes mesh richer for ODMRP and CAMP

Packet Delivery Ratio as a Function of Multicast Group Size



- 5 sources each send 2 pkt/sec
- 1 m/sec of mobility speed
- Flooding and ODMRP not affected by group size
- CAMP builds massive mesh with growth of the members

Packet Delivery Ratio as a Function of Network Load



- 20 members and 5 sources
- no mobility
- AMRIS is the most sensitive to traffic load due to large beacon transmissions

Conclusions

- **Tree schemes:**
  - Too fragile to mobility
  - lower throughput in heavy load
  - lower control O/H
- **Meshed Based scheme (CAMP):**
  - Better than tree schemes (mesh more robust)
  - Mesh requires increasing maintenance with mobility
- **ODMRP:**
  - most robust to mobility& lowest O/H

Lessons learned:

- Mesh-based protocols outperform tree-based protocols
- Multiple routes help overcome node displacements and fading