Multicast Operation of the Ad-hoc On-Demand Distance Vector Routing Algorithm

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Desired Characteristics

- Ability to find multi-hop paths
- Dynamic topology maintenance
- Loop freedom and rapid route convergence
- Low consumption of memory, bandwidth
- Unicast, broadcast, AND MULTICAST capability
  - Streamline for enhanced general routing knowledge
  - Simplification of coding
  - Improvements to basic algorithm benefit unicast and multicast
- Many others...

Ad-hoc On-Demand Distance Vector Routing

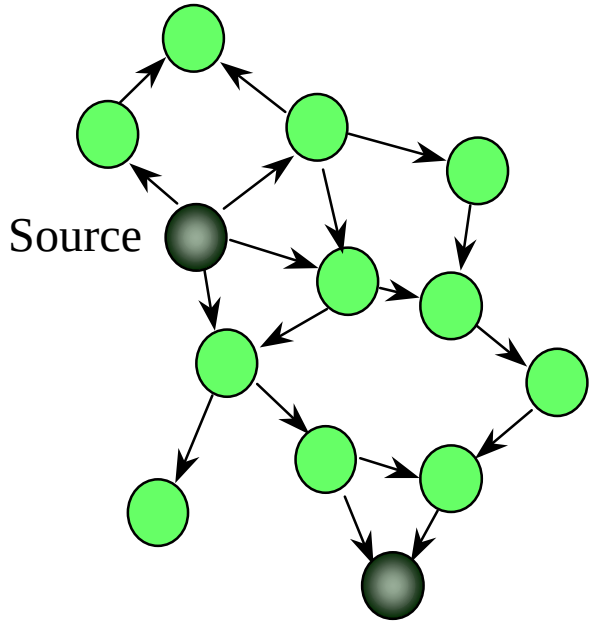
- Primary Objectives
  - Provide unicast, broadcast, and multicast capability
  - Minimize broadcast of control packets
  - Disseminate information about link breakages to those neighboring nodes utilizing the link
- Characteristics
  - *On-demand* routing creation
  - Two dimenstional routing metric: <Seq#, Hcnt>
  - Storage of routes in routing tables

Unicast Route Discovery

- Source broadcasts *Route Request* (RREQ)

  <J_flag, R_flag, Bcast_ID, Src_Addr, Src_Seq#, Dst_Addr, Dst_Seq#, HopCnt>

- Node can reply to RREQ if
  - It is the destination
  - It has a "fresh enough" route to the destination
- Nodes create *reverse route* entry
- Record Src IP Addr / Broadcast ID to prevent multiple processing



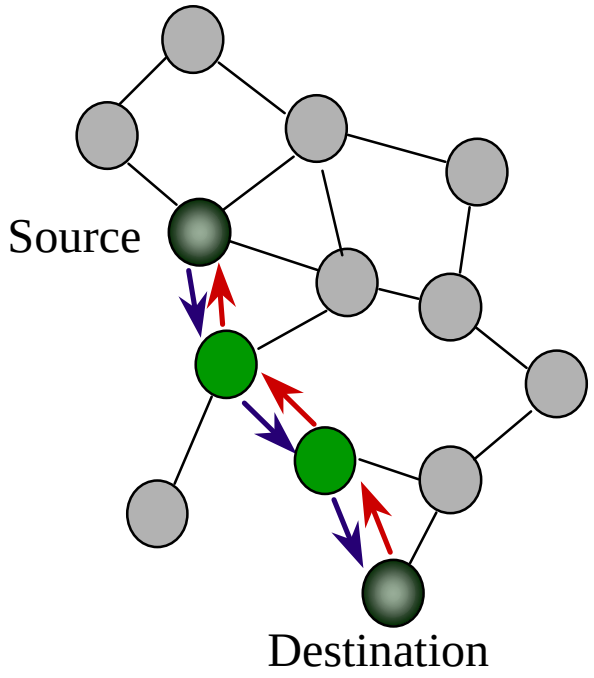
Route Request Propagation

Forward Path Setup

- Destination, or intermediate node with current route to destination, unicasts *Route Reply* (RREP) to source

  <R_flag, Dst_Addr, Dst_Seq#, Prev_Hop_Addr, HopCnt, Lifetime>

- Nodes along path create *forward route* to dest
- Source begins sending data when receives first RREP



Forward Path Formation

Local Connectivity Management

- Node must periodically hear from *active* neighbors to know they are still within range
- Every time hear broadcast, update lifetime
- If no broadcast with **hello_interval**, broadcast *Hello* packet
- Failure to hear from a neighbor for

  (1 + ***allowed_hello_loss*** *) ** ***hello_lifetime***

  indicates loss of link

Multicast Overview

- Utilizes same RREQ/RREP message cycle
- Shared tree composed of group members and connecting nodes is formed
- Dynamic group membership
- Group Leader
  - Maintains and distributes group sequence number
  - Not a central point of failure
- Multicast group members are also routers for the tree

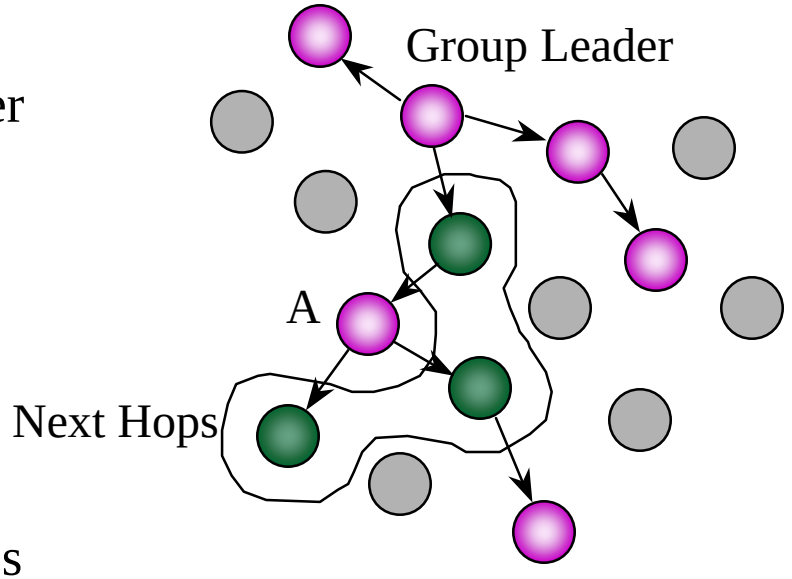
Routing Tables

Multicast Route Table

- Multicast Group IP Address
- Group Leader IP Address
- Group Sequence Number
- Hop Count to Group Leader
- Next Hops
  - Direction of Link
  - Enabled Flag
- Lifetime

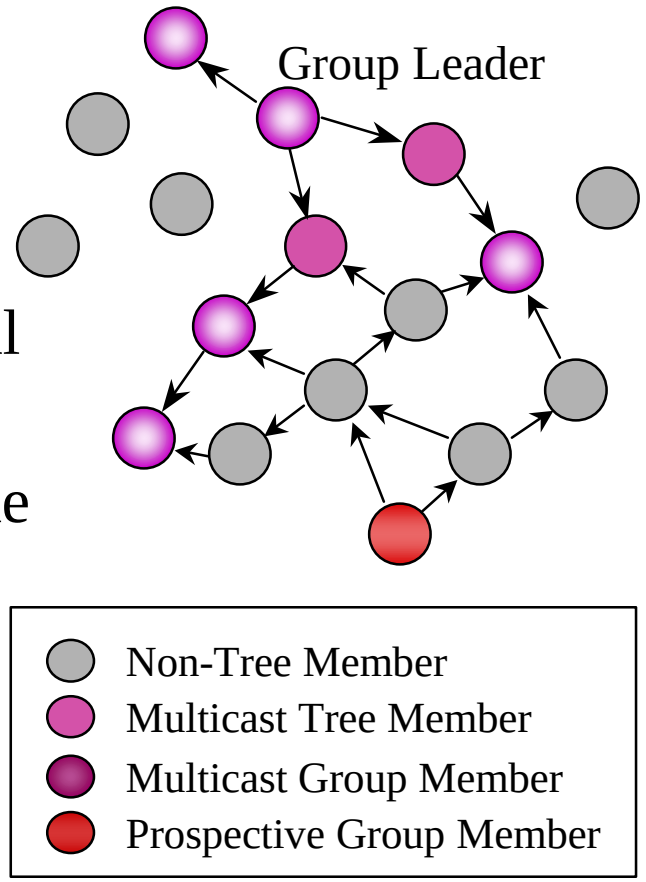
Group Leader Table

- Multicast Group IP Address
- Group Leader IP Address



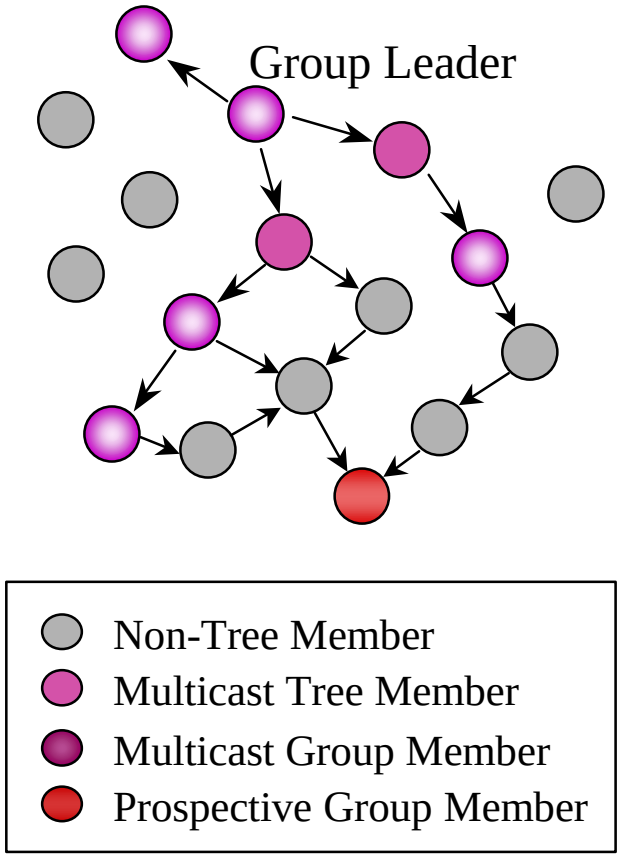
Multicast Route Discovery

- Source node broadcasts RREQ
- Sets ‘J’ (*join*) flag if wishes to join group
- If no reply received, rebroadcast RREQ up to **rreq_retries** additional attempts
- After **rreq_retries** attempts, become group leader
- Nodes receiving RREQ set up *reverse route* entries



Route Reply Generation

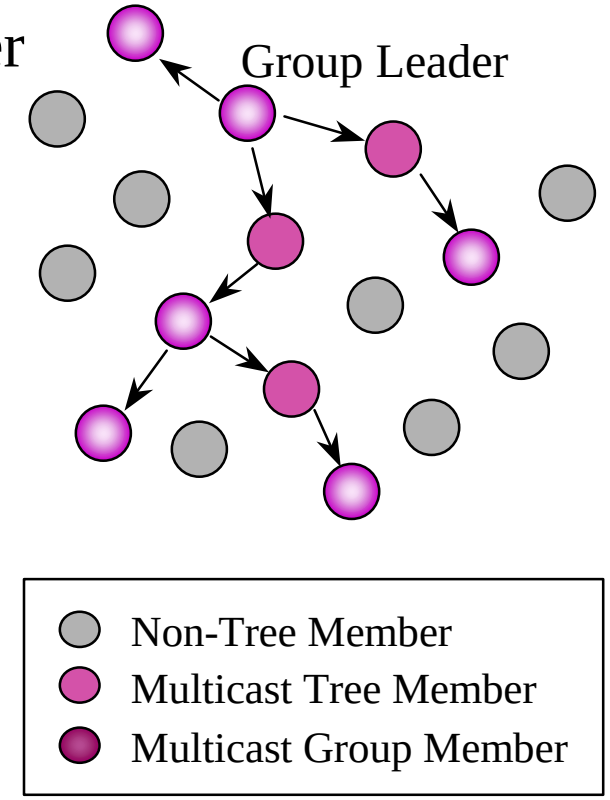
- Only members of multicast tree can respond to *join* request
- Any node with route to multicast tree can reply to non-join request
- RREP generated and unicast back to source
- RREP contains address of group leader and distance of responding node from nearest tree member
- Nodes forwarding RREP set up forward path RT and MRT entries



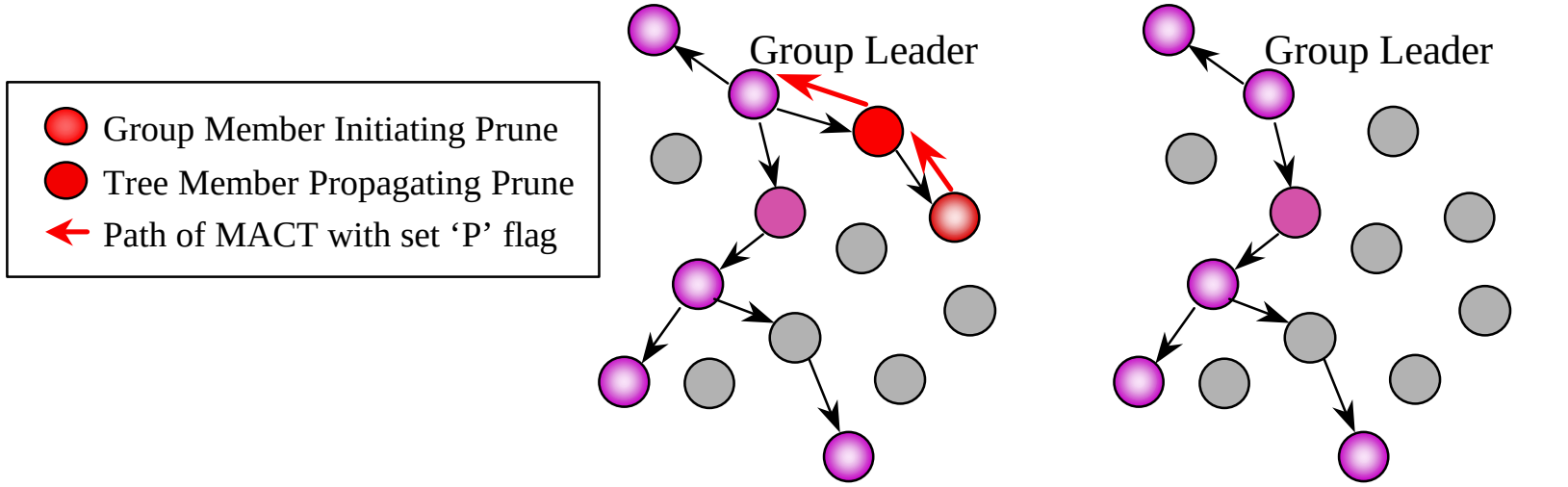
Route Activation

- Source waits **rte_disc_tmo**
- Notes route with largest seq# and smallest hcnt to nearest tree member
- After **rte_disc_tmo**, unicast *Multicast Activation* (MACT) to selected next hop

  <P_flag, GL_flag, Src_Addr, Src_Seq#, Dst_Addr>
- Node receiving MACT enables MRT entry for source
- Unicasts own MACT if not previously member of tree



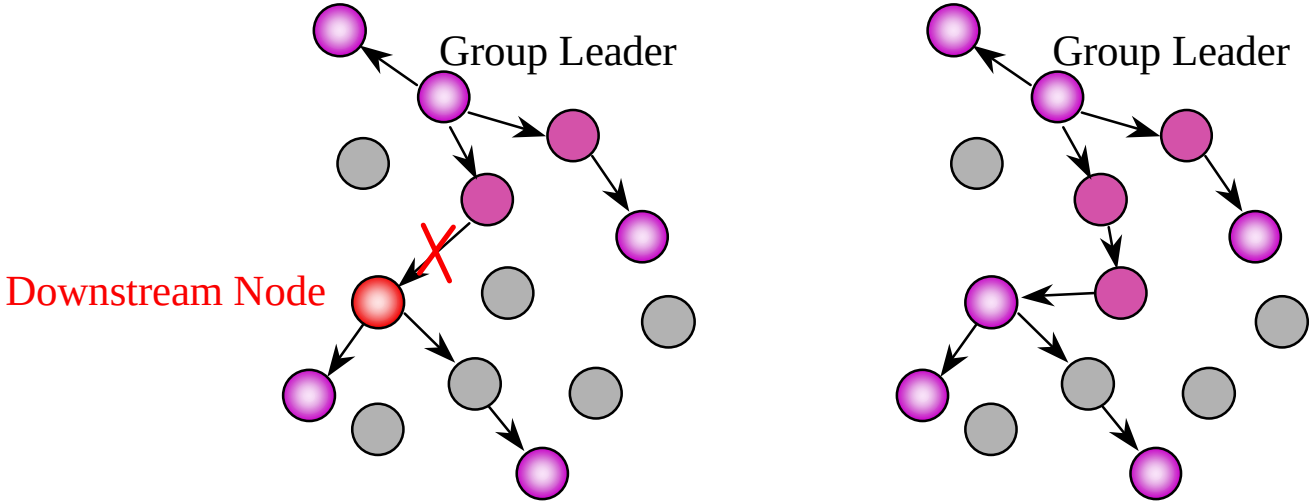
Leaving the Group



Pruning of Group Member Multicast Tree after Prune

- Node may revoke its member status at any time
  - Leaf nodes may prune themselves from tree
  - Non-leaf nodes must continue to be routers for tree
- Unicast MACT with 'P' (*prune*) flag set to next hop
- If node is then a leaf and not a group member, prunes self

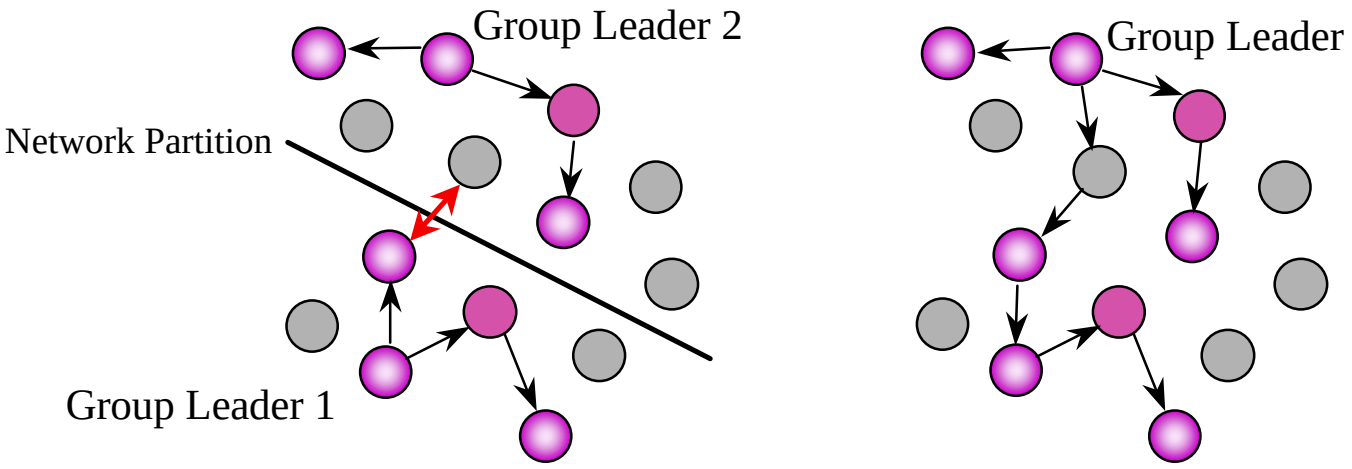
Link Breakages



Link Breakage: Mgroup_Hop=2 Repaired Multicast Tree

- Node *downstream* of break initiates repair
- Broadcast RREQ with Multicast Group Hop Count extension field and small Time to Live (TTL)
- Accepts RREPs as before

Reconnecting Partitioned Trees



Partitioned Network before the Repair Reconnected Network

- New partition detected by differing group leader information
- Group leader with lower IP Address (GL1) initiates repair
- Unicasts RREQ with set ‘R’ (*repair*) flag to other group leader (GL2)
- GL2 unicasts RREP to GL1, becomes overall group leader

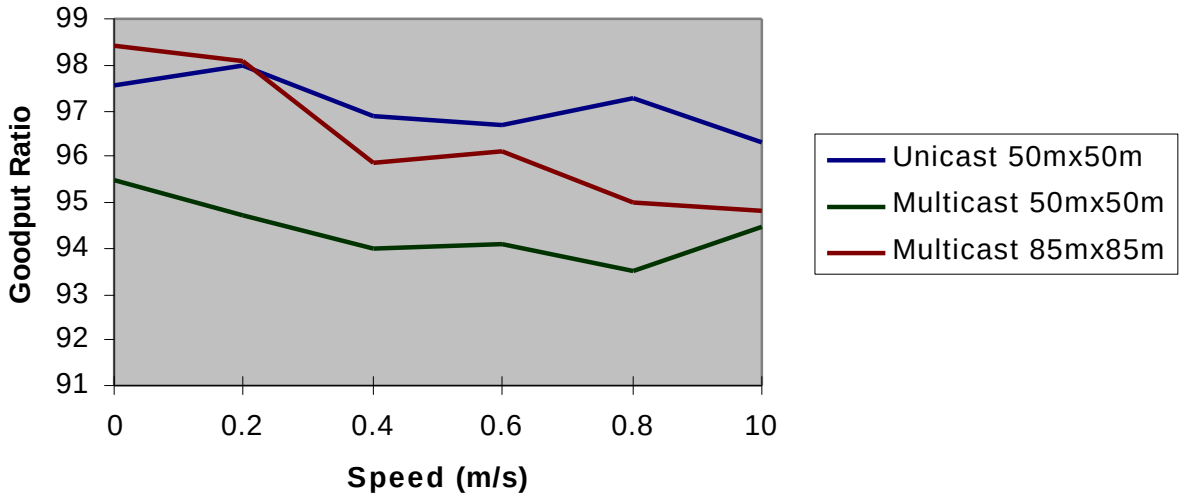
Group Hello Messages

- First member of group becomes group leader
- Maintains, disseminates group sequence number
- Broadcasts *Group Hello* every **group_hello_interval** seconds
  - Multicast Group IP Address
  - Multicast Group Leader IP Address
  - Current group sequence number
  - Hopcount
- Used by multicast tree members to update current distance to group leader

Simulation Environment

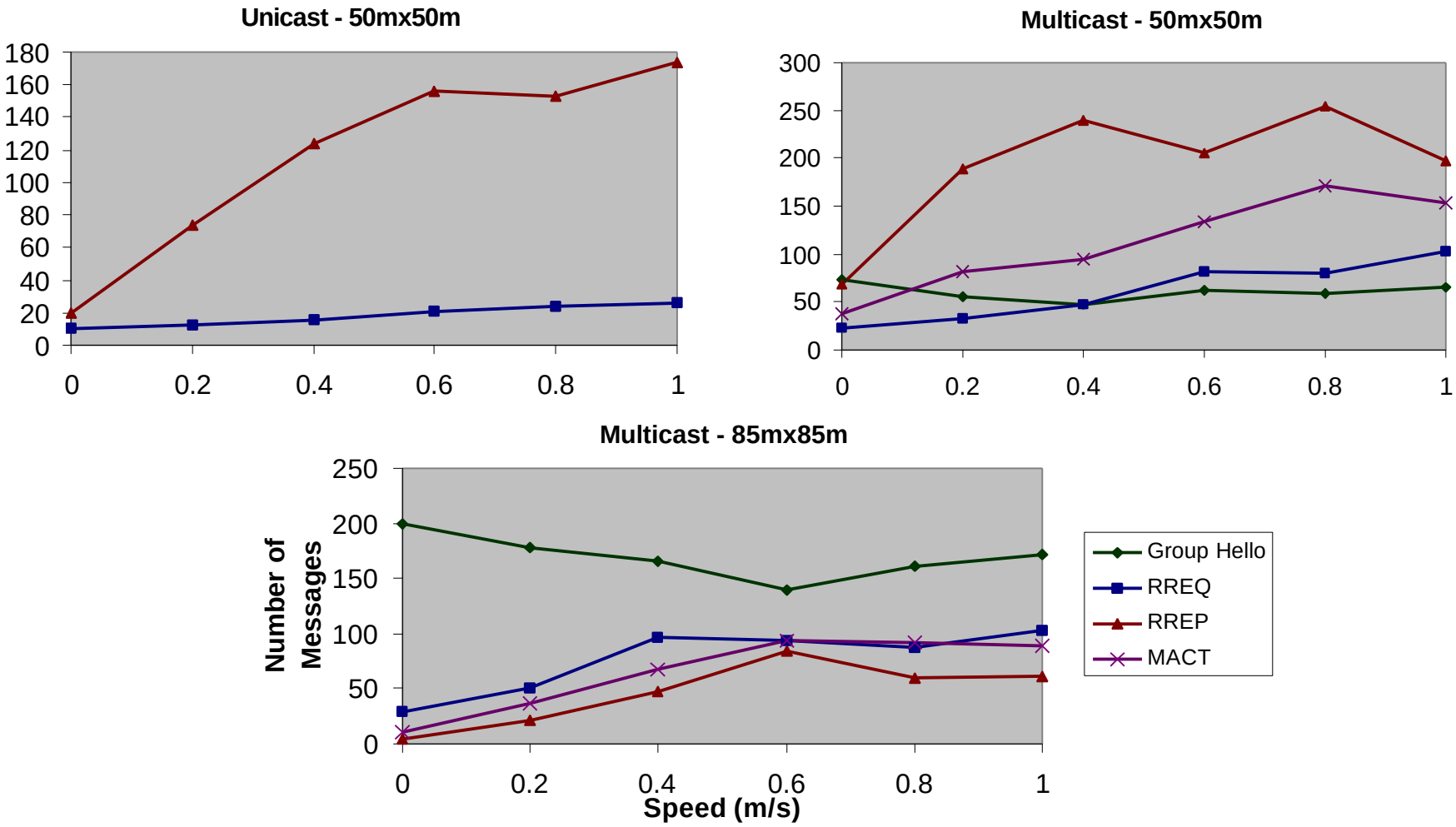
- All simulations executed in PARSEC
- Each node chooses destination, speed
- After reaching destination, node rests, then selects new destination, speed
- Carrier sensing performed before each transmission
- Simulated length of time: 300 seconds
- Data rate: 1.0 Mbit/sec
- Data packet size: 64 bytes
- Transmission Radius: 10m

Goodput Ratio



- 50m*x*50m Multicast slightly decreased goodput ratio
  - Multiple destinations must receive each data packet
  - More route reconstructions
- 85m*x*85m multicast simulation
  - High rate of group merges / partitions

Control Overhead



Future Work

- Continue simulations with varying channel models
- Smooth handoff
- Security
- Reliable delivery
- Quality of Service
- Interoperate with Mobile IP

Conclusion

AODV Main features

- Unicast, Broadcast, and Multicast communication
- On-demand route establishment with small delay
- Multicast trees connecting group members maintained for lifetime of multicast group
- Link breakages in active routes efficiently repaired
- All routes are loop-free through use of sequence numbers

AODV is an effective and efficient routing protocol for all forms of ad-hoc mobile communication

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