Queen Mary
University of London

Multicast Routing

EBU5211: Ad Hoc Networks

Dr. Yan SUN (Cindy)

Outline

Queen Mary University of London

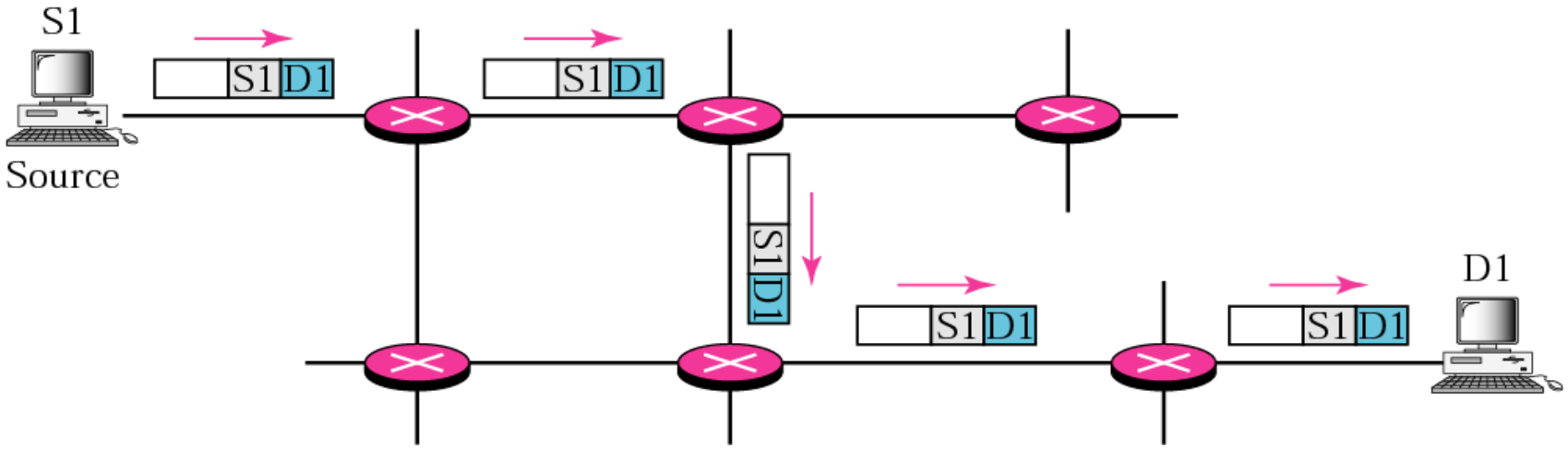
- **IP Multicasting in Wired Networks**
  - **Source-based multicast**
  - **Core-based multicast**
- **MANET multicast routing**
  - On-Demand Multicast Routing Protocol, ODMRP
  - Location-Based Multicast, LBM routing

References: C. Siva Ram Murthy, B.S. Manoj, *Ad Hoc Wireless Networks: Architectures and Protocols*, Prentice Hall, 2004.

C.K. Toh, *Ad Hoc Mobile Networks: Protocols and Systems,* Prentice Hall, 2002.

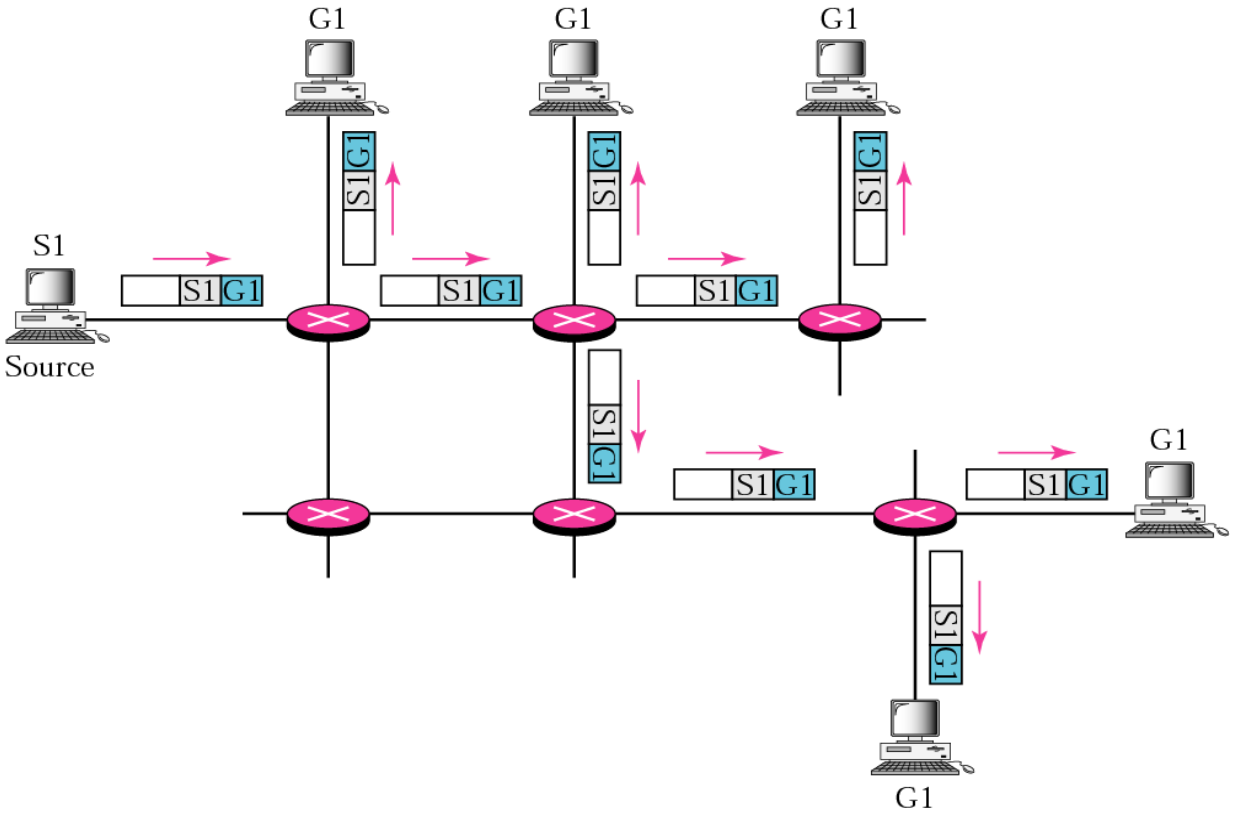
Unicast

- Packets from single source to single destination.
- In unicasting, the router forwards the received packet through only one of its interfaces

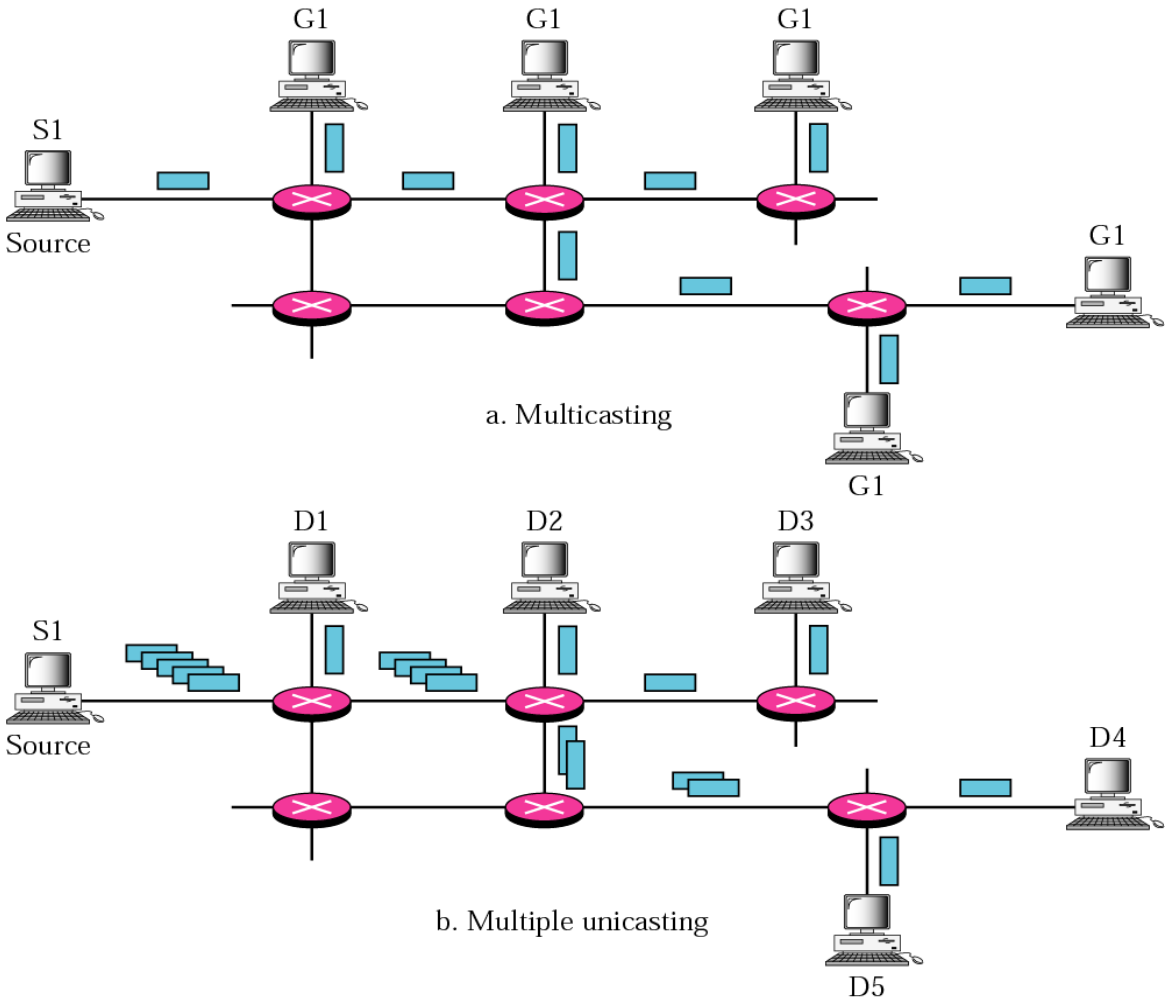


Multicast

- Packets from one source to multiple, chosen destinations.
- In multicasting, the router may forward the received packet through several of its interfaces.



Multicast v.s multiple unicast



Multicasting in Wired Networks

Queen Mary University of London

- In multicast routing, each involved router needs to construct a shortest path tree for each group
- Multicast Group (Class D) :
  - single IP address 224.0.0.0 to 239.255.255.255
  - ➢ Any sender can send to any group but receivers are the members of multicast group.
  - ➢ All routers have to support multicast routing.

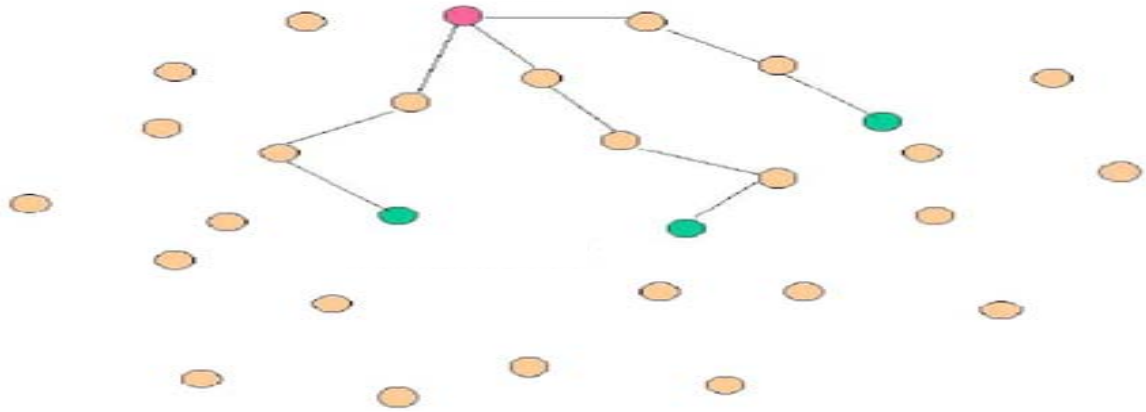
Multicasting in Wired Networks

Queen Mary University of London

- In the source-based tree approach, each router needs to have one shortest path tree for each group.
- In the group-shared tree approach, only the core router, which has a shortest path tree for each group, is involved in multicasting.
- Example protocols:
  - Source-based multicast: MOSPF
  - Core-based multicast: CBT

Source-based multicast

Queen Mary University of London

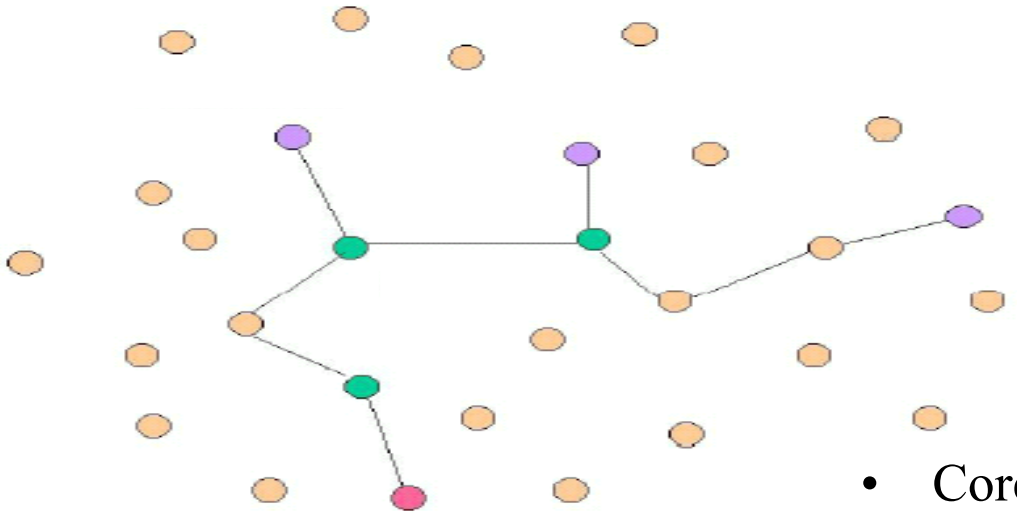


- Multicast tree rooted at SRC
- SRC runs a multicast tree algorithm
  => shortest (least-cost) path to each receiver
- SRC needs topology information.
- Source based routing tree for each individual sender

- Disadvantages:
  - Not Scalable.
  - Not efficient.
  - Control overhead and too slow

Core-based multicast

Queen Mary University of London

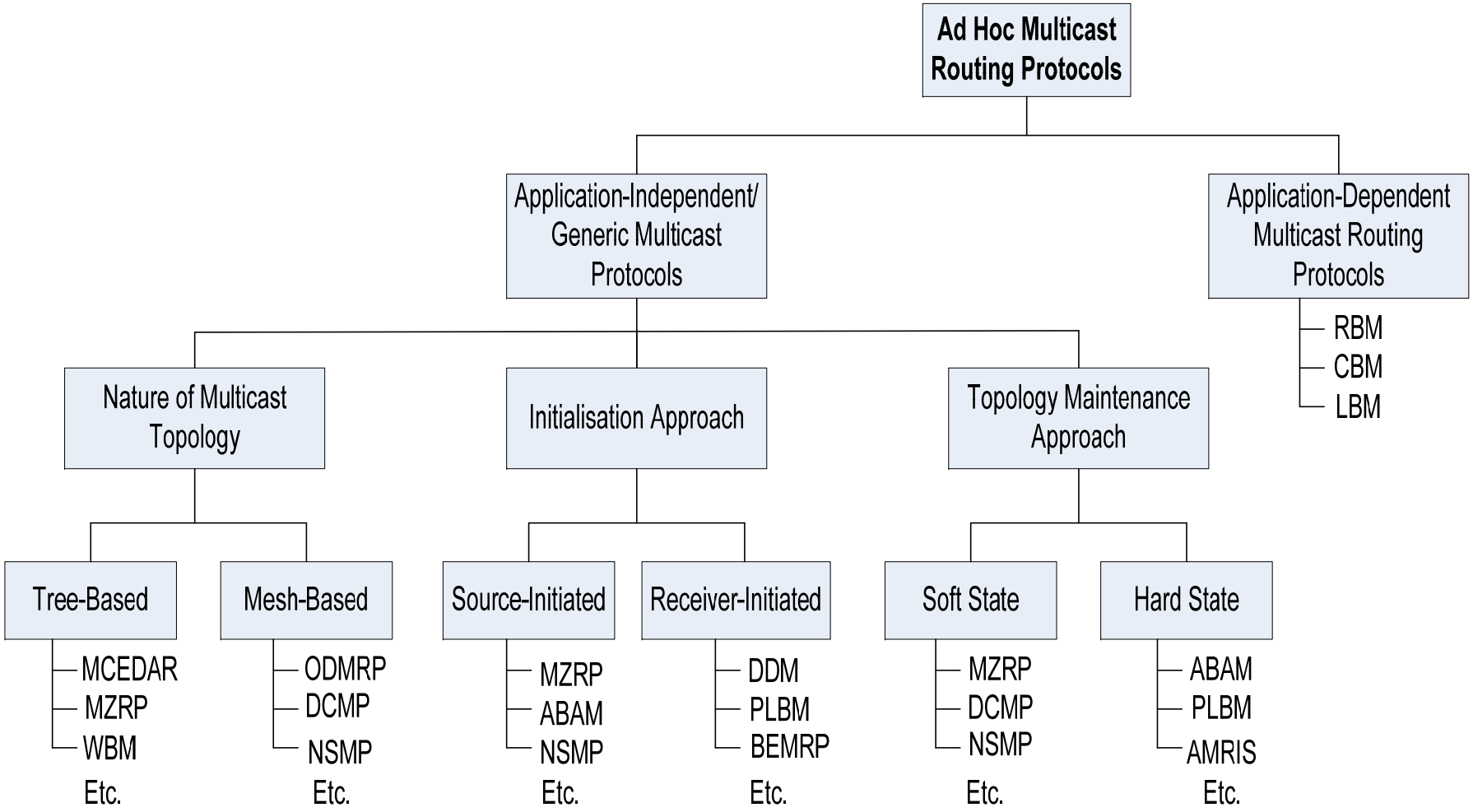


- Multicast tree is originated from core(s)
- Need core selection algorithm, CSA
- Control overhead reduced but may not be shortest path

- Core nodes can be interconnected via bidirectional links.
- Receiver-initiated join.
- Single multicast shared routing tree for each multicast group to distribute traffic for all senders in group.

Classification of MANET Multicast Routing Protocols

Queen Mary University of London



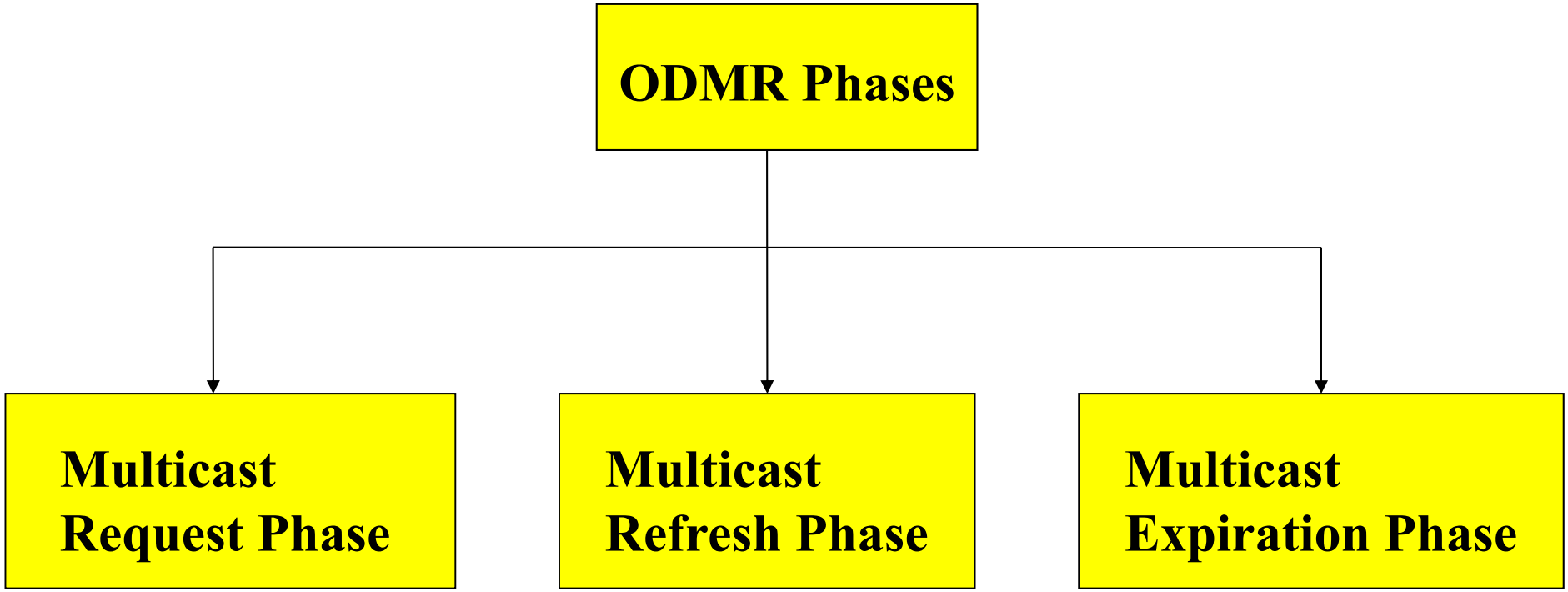
On-Demand Multicast Routing Protocol, ODMRP

Queen Mary University of London

- On Demand:
  - Multicast routes selectively derived when needed vs. periodical global route updates
- Forwarding Group:
  - Set of ad hoc nodes chosen to forward packets to particular multicast group.
  - Data flooded throughout forwarding group “mesh topology” only.
  - Forwarding group is maintained by periodic flooding of control messages.

ODMRP Operation

Queen Mary University of London



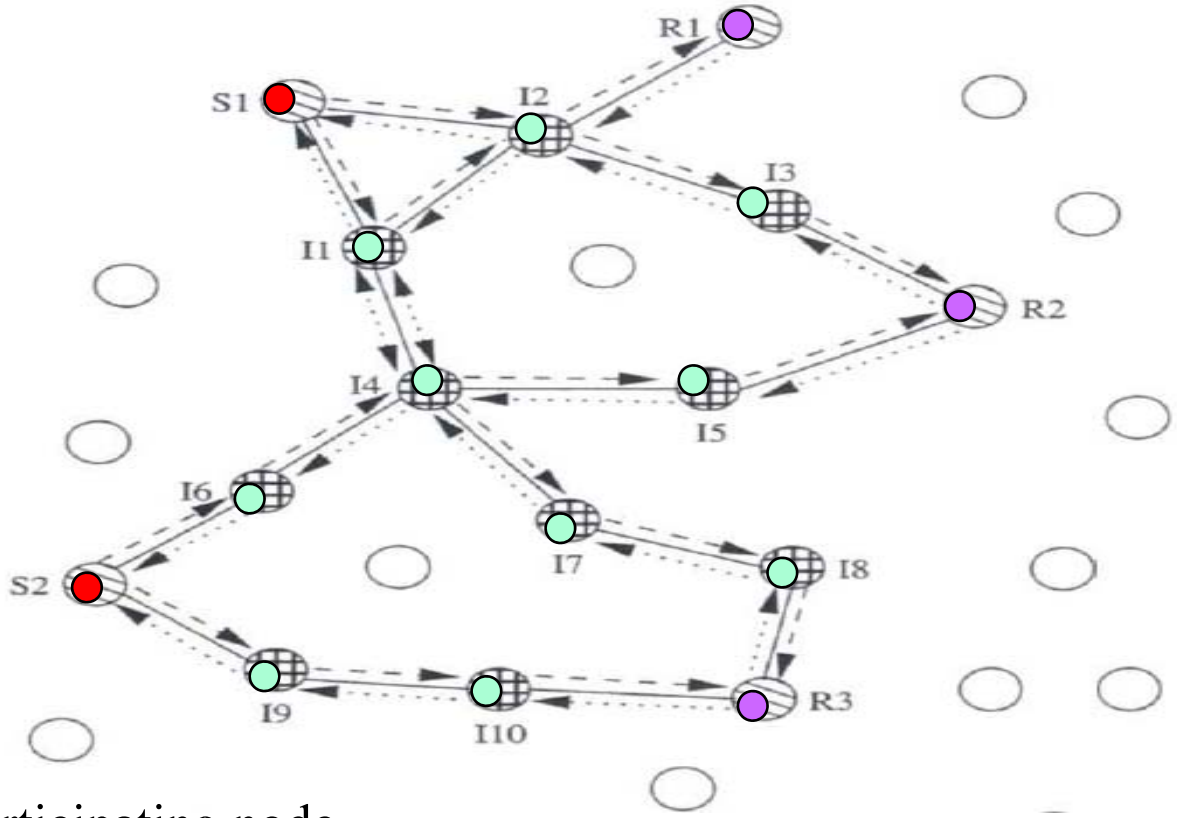
Multicast Request Phase

Queen Mary University of London

- Initiated by Source on demand-- periodically flood control packet: "*JoinReq*"
- Intermediate Node, IN
  - receives *JoinReq*,
  - stores source ID, multicast group ID, sequence number and upstream node ID,
  - rebroadcasts *JoinReq* if no duplicates and TTL>0
- Receivers send back "*JoinReply*" packet (contains source ID and next hop) through reverse shortest path to source.
- When Intermediate Node, IN receives *JoinReply* => "Forwarding Node" if its own ID matches the next hop ID (set FG_FLAG)
- After source receives *JoinReply* packet:=> routes and forwarding table

On-Demand Multicast Routing Protocol (ODMRP) Topology

Queen Mary University of London



Non-participating node

Source, SRC

Multicast Receiver, R

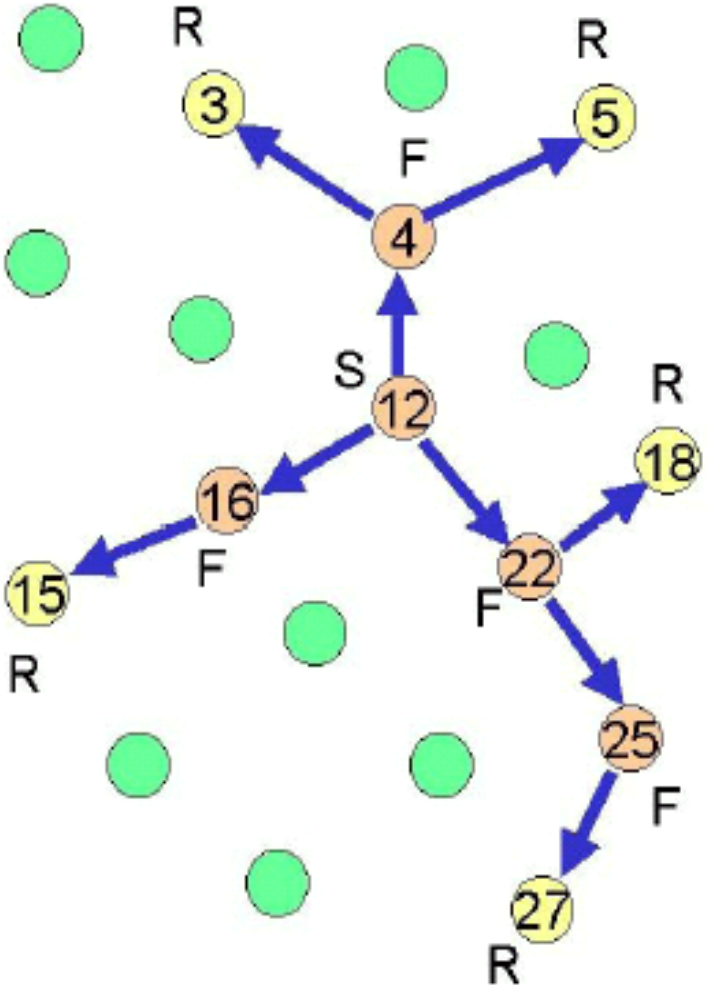
Forwarding (IN) node

JoinReq packet

JoinReply packet

JoinReply in both directions

ODMRP Forwarding Tables



Forwarding Table for Node 12

Receivers	Next Hop
3	4
5	4
15	16
18	22
27	22

Forwarding Table for Node 22

Receivers	Next Hop
27	25

Multicast Refresh Phase

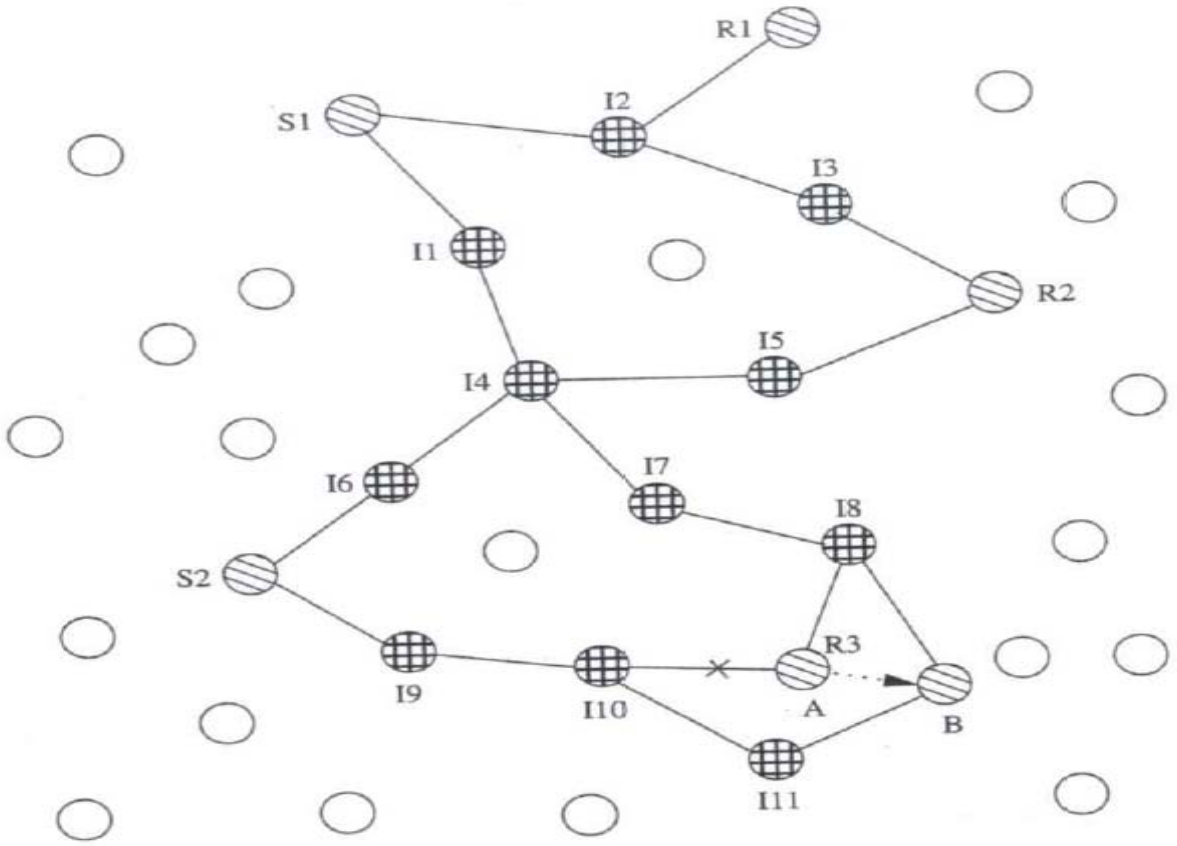
Queen Mary University of London

- Source periodically floods *JoinReq* control packet.
  - forwarding group continually refreshed.
- Generally, multiple paths always available through forwarding group
  - if link broken, data still forwarded over alternative paths (mesh topology).

Multicast Refresh Phase

Queen Mary University of London

This phase is used to adapt to changing topology due to node mobility.



Alternative route through I8 or I11c

Multicast Expiration Phase

Queen Mary University of London

- Old route entries are deleted upon timeout.
- It is time based process.

ODMRP Shortcomings

Queen Mary University of London

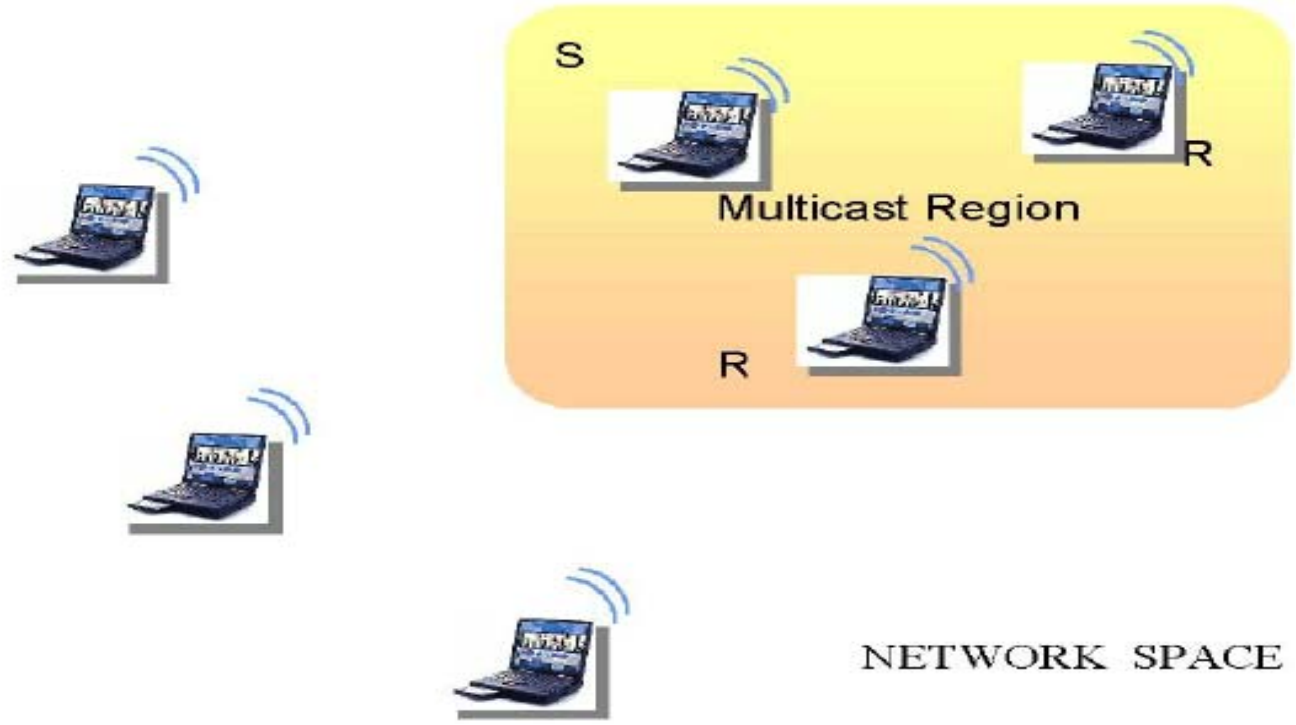
- Excessive data forwarding
  - Too many nodes become forwarding nodes
    - excessive number of retransmissions of data packets.
- High control overhead
  - Each source periodically floods JoinReq packets
    - mesh recontructed periodically
    - heavy control overhead.

Location-Based Multicast (LBM) Routing

Queen Mary University of London

- **Multicast Region:**
  - Multicast group is defined by "***multicast region***"
    - geographical region in which source addresses all nodes.
- Each multicast packet transmitted specifies target multicast region.
- LBM assumes each node knows its own location
- SRC floods packets to forwarding mesh
- Each node checks if DEST by comparing its location to multicast region
  - if DEST, accepts packet .

LBM Routing

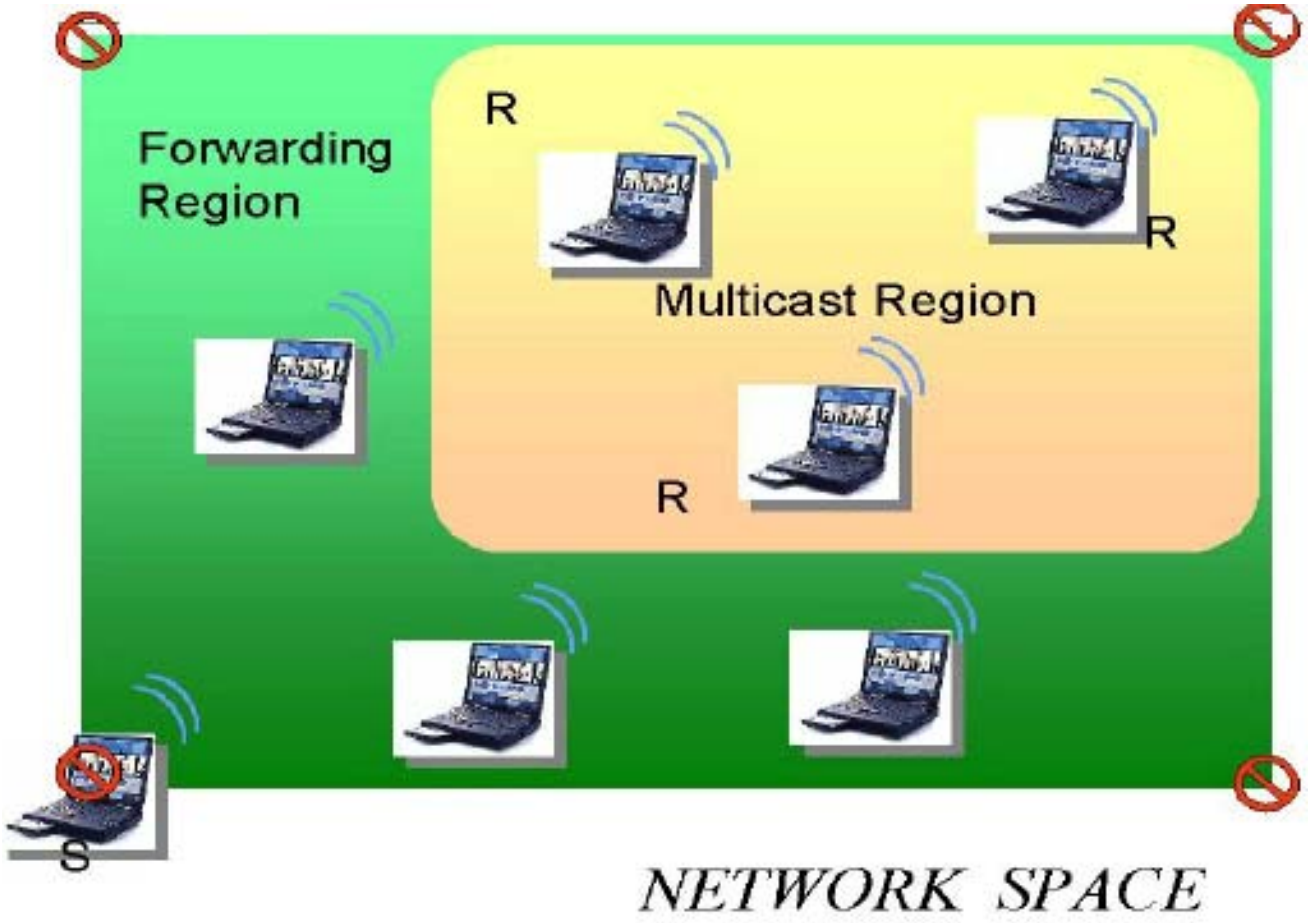


LBM Routing

Queen Mary University of London

- Forwarding Region:
  - Nodes inside forwarding region send packets to multicast region.
    - A node forwards multicast packets only if it belongs to defined forwarding region (FW membership assignment needed).
    - To increase the probability that packets will reach all intended members, the forwarding region should also include the multicast region.
- Applications:
  - Sending emergency messages to people within some area.
  - Paging someone in particular small area

LBM Routing



Shortcomings of LBM

Queen Mary University of London

- Multicast members must know own accurate location
- Accurate boundaries of forwarding region and multicast region required
- Nodes in multicast region must not be partitioned in terms of connectivity.
- High overhead when numbers of nodes are increased.
- Does not take into account signal quality and connectivity

ABAM

Queen Mary University of London

- **Associativity-Based Ad-hoc Multicast (ABAM) Characteristics**
  - **Based on Association stability**
  - **Builds multicast tree**
- **ABAM Phases**
- **ABAM Advantages & Disadvantages**

References: C. Siva Ram Murthy, B.S. Manoj, *Ad Hoc Wireless Networks: Architectures and Protocols*, Prentice Hall, 2004.

C.K. Toh, *Ad Hoc Mobile Networks: Protocols and Systems,* Prentice Hall, 2002.

ABAM Features

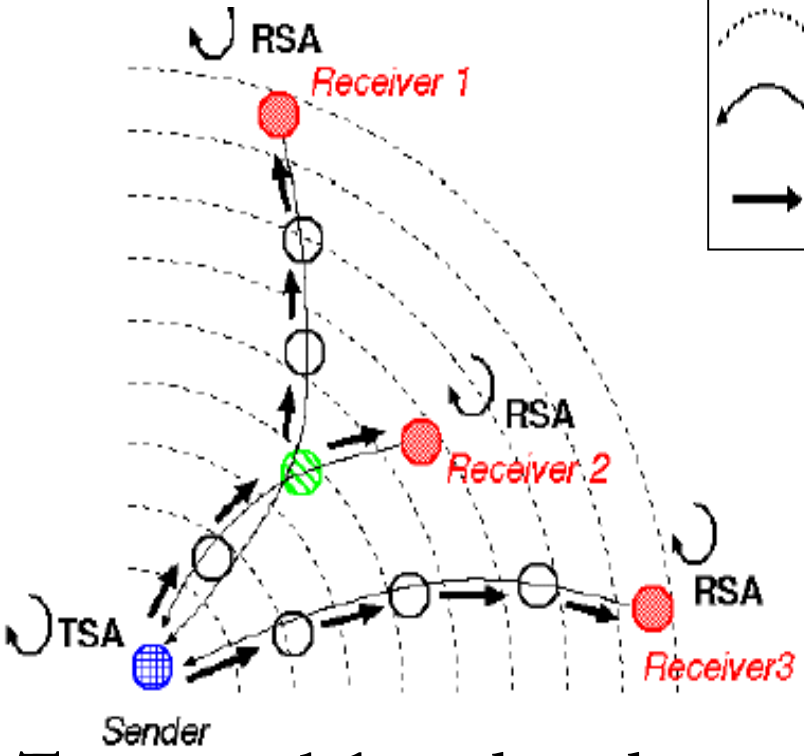
Queen Mary University of London

ABAM has 4 Components

- **Long-Lived MC Tree Establishment**
  - (When SRC want to initiate a MC session)
- **MC Tree Reconfiguration**
  - (To cope when mobility of nodes in the tree)
- **MC Tree Deletion**
  - (When the MC session is no longer needed)
- **Dynamics of Multicast Group Membership**
  - (Mobile Hosts can join and leave the group at any time)

A stable multicast tree rooted at the multicast sender is established for each multicast session

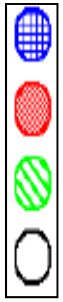
Multicast Long-Lived Tree Establishment



BroadcastQuery-Multicast, BQ-M phase

BroadcastQuery-REPLY, BQ-REPLY phase

Multicast Setup, MC-Setup phase



Multicast source

Multicast receiver

Branching node

Forwarding node

RSA = Route Selection Algorithm

TSA = Tree Selection Algorithm

Tree search based on demand

- tree discovery,
- tree selection, and
- tree setup

Multicast Long-Lived Tree Establishment

Queen Mary University of London

Tree Selection Algorithm,

- **TSA objective:**
  - Find a stable TREE and reduce total links used
- **Other heuristics:**
  - Maximum link sharing, i.e. min total tree cost.
  - Minimum delay from source to each receivers.

Receiver knows the possible routes to SRC, when it receives the tree search packet

↓

Receivers discard routes with exceeding Route Relaying Load or other predefined metrics

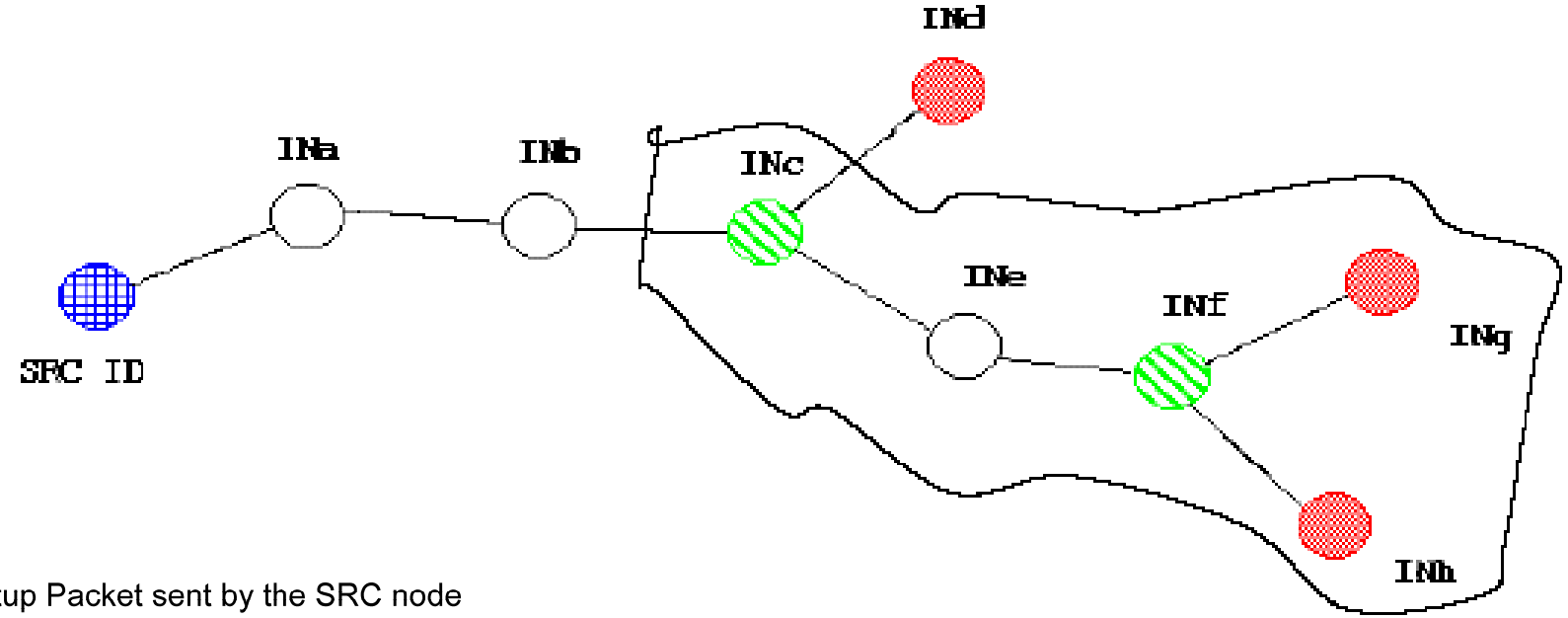
↓

Receivers discard routes with no stability characteristics

↓

If multiple routes have high acceptable association stability, select path based on other criteria, such as minimum hop count (Shortest path).

Multicast Long-Lived Tree Establishment



MC Setup Packet sent by the SRC node

TYPE	SRC ID	MC ID	INa	INb	BRN	INc	INd	END	INe	BRN	INf	INg	END	INh	CRC

MC Setup Packet relayed by the first branching node INc

TYPE	SRC ID	MC ID	INc	INd	CRC

TYPE	SRC ID	MC ID	INc	INe	BRN	INf	INg	END	INh	CRC

MC Setup Packet relayed by the second branching node INf

TYPE	SRC ID	MC ID	INf	INh	CRC

TYPE	SRC ID	MC ID	INf	INg	CRC

Multicast Tree Reconfiguration

Queen Mary University of London

Four possible scenarios for tree Reconfiguration :

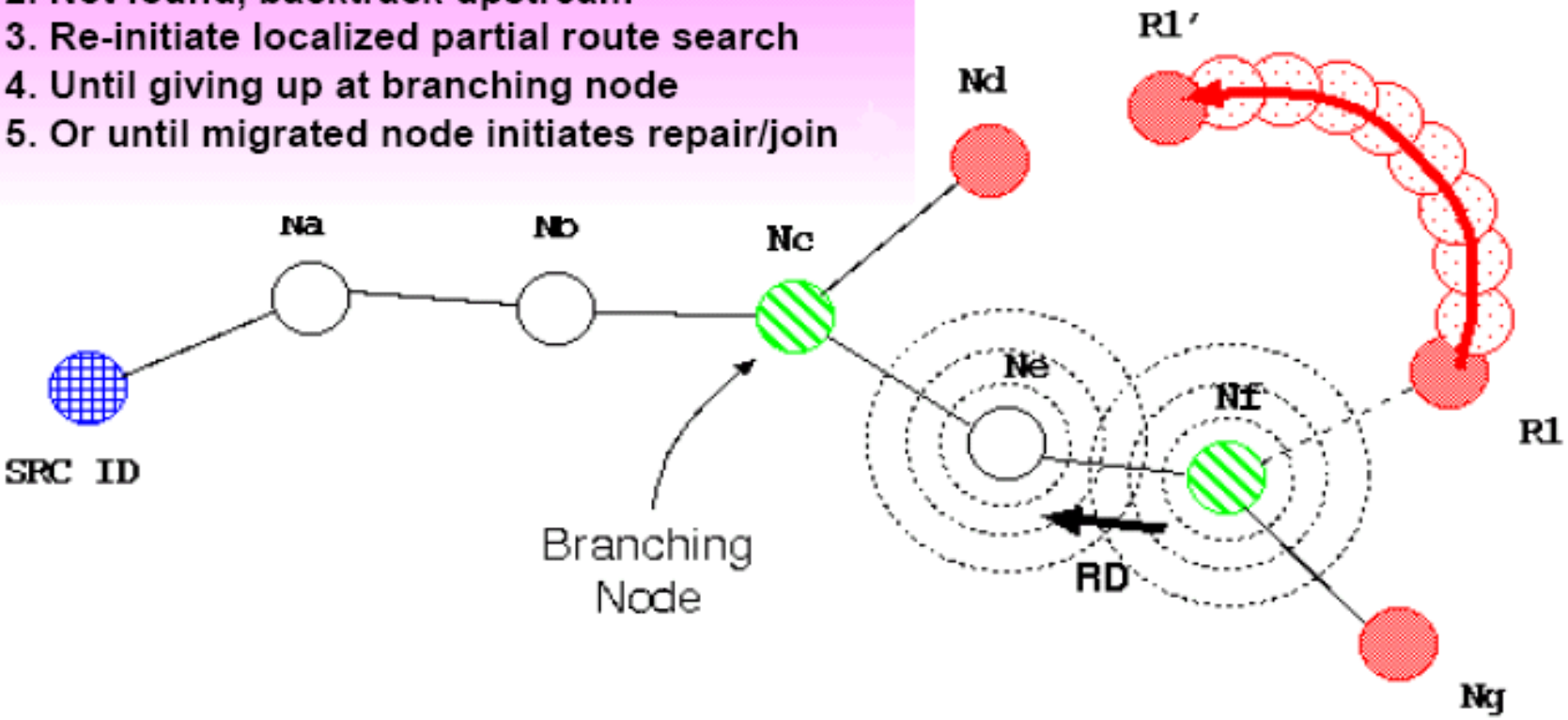
- Multicast Receiver's Migration: There are two possible approach to cope with receivers' mobility, which are:
  - Route Reconstruction (RRC) initiated by tree nodes
  - Receiver-initiated move-join
- Multicast Tree Node's Migration
- Multicast Sender's Migration
- Concurrent Node's Movements

Multicast Receiver's Migration

Queen Mary University of London

Approach1: Route Reconstruction (RRC) initiated by tree nodes

1. Localized partial route search
2. Not found, backtrack upstream
3. Re-initiate localized partial route search
4. Until giving up at branching node
5. Or until migrated node initiates repair/join

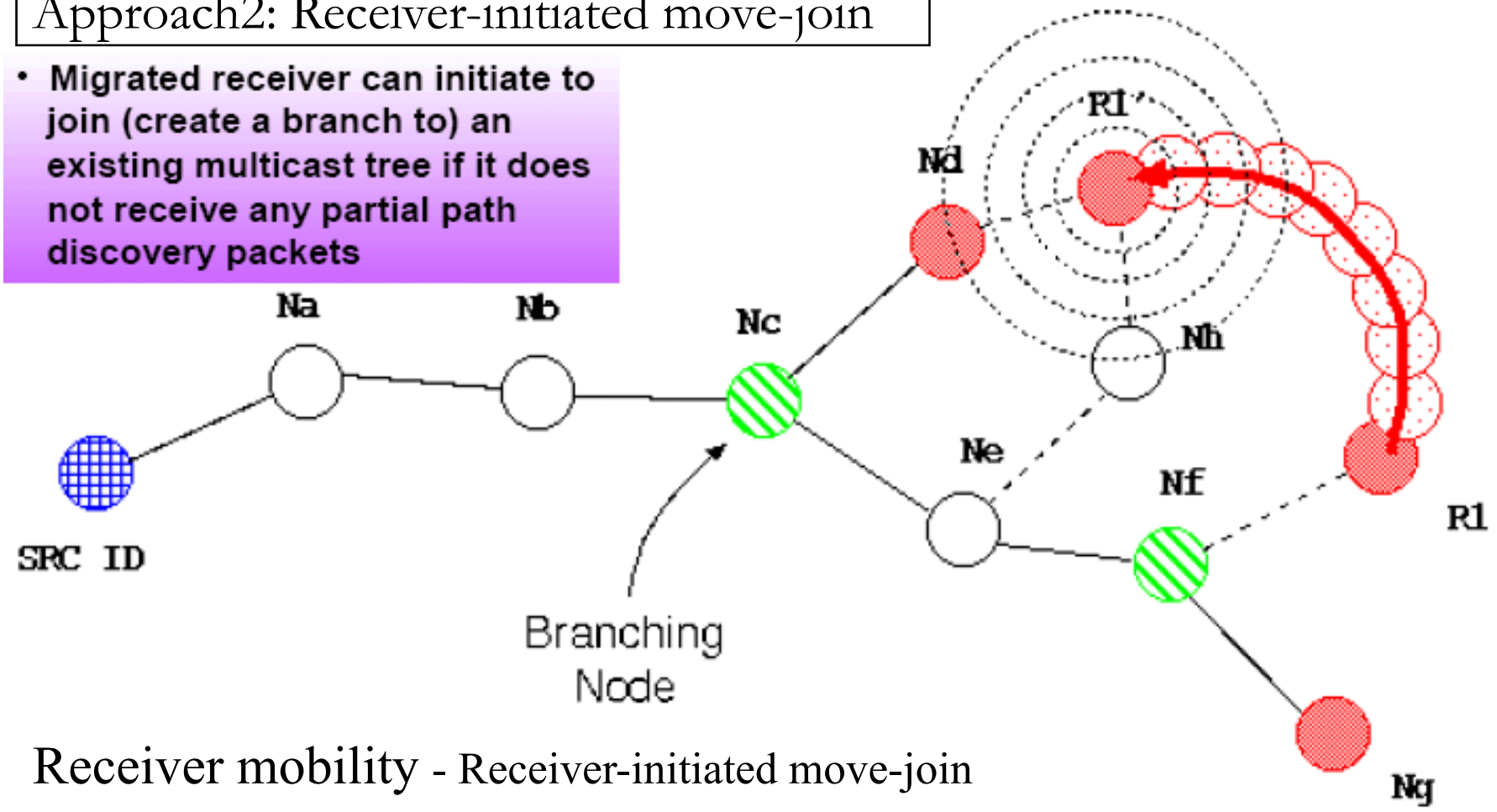


Multicast Receiver's Migration

Queen Mary University of London

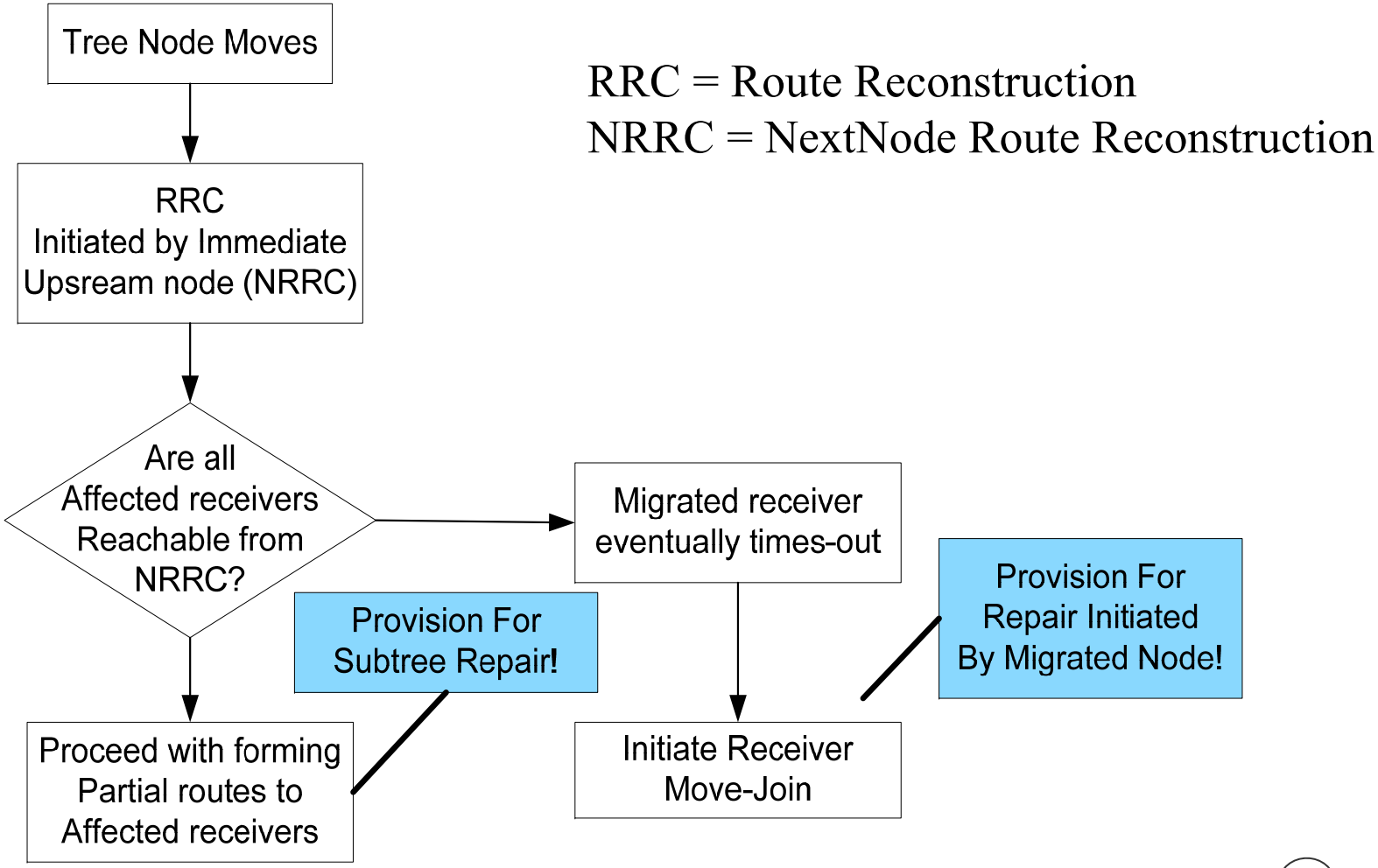
Approach2: Receiver-initiated move-join

- Migrated receiver can initiate to join (create a branch to) an existing multicast tree if it does not receive any partial path discovery packets



Receiver mobility - Receiver-initiated move-join

Multicast Tree Node's Migration



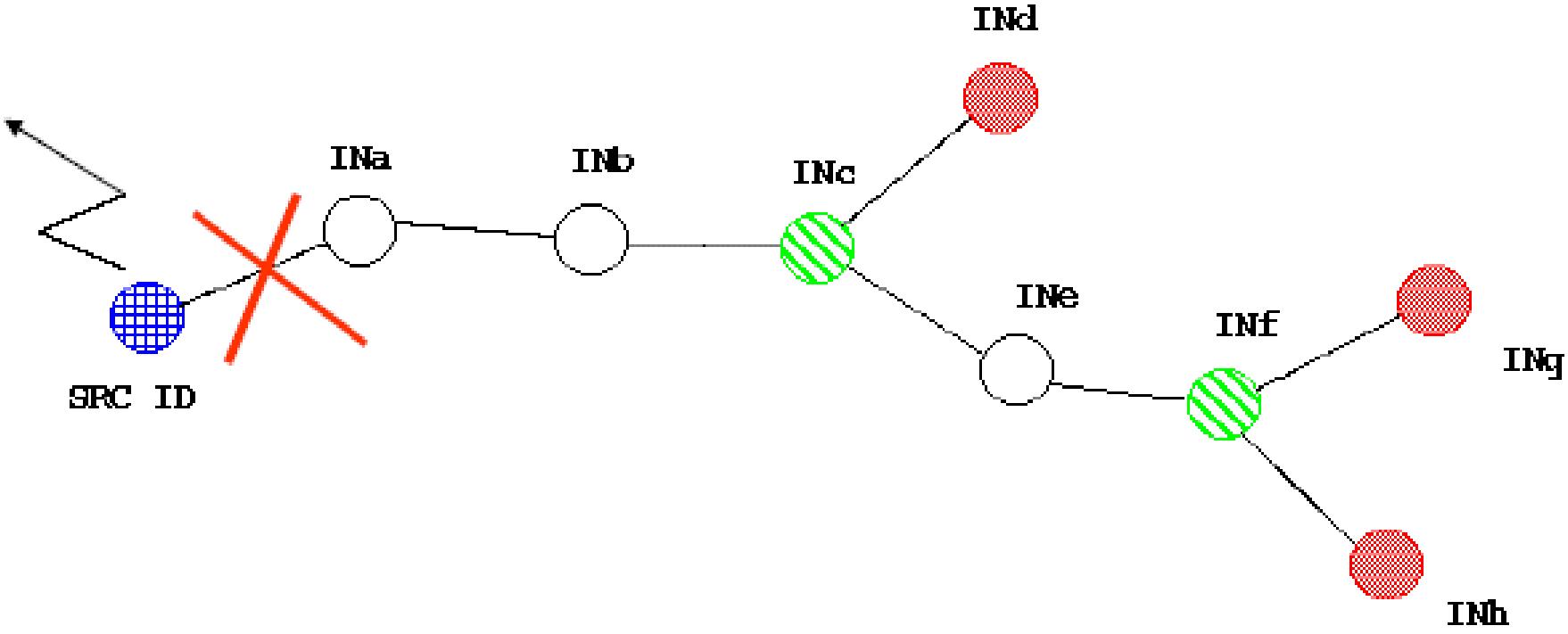
RRC = Route Reconstruction
NRRC = NextNode Route Reconstruction

Multicast Sender's Migration

Queen Mary University of London

Source node, SRC mobility

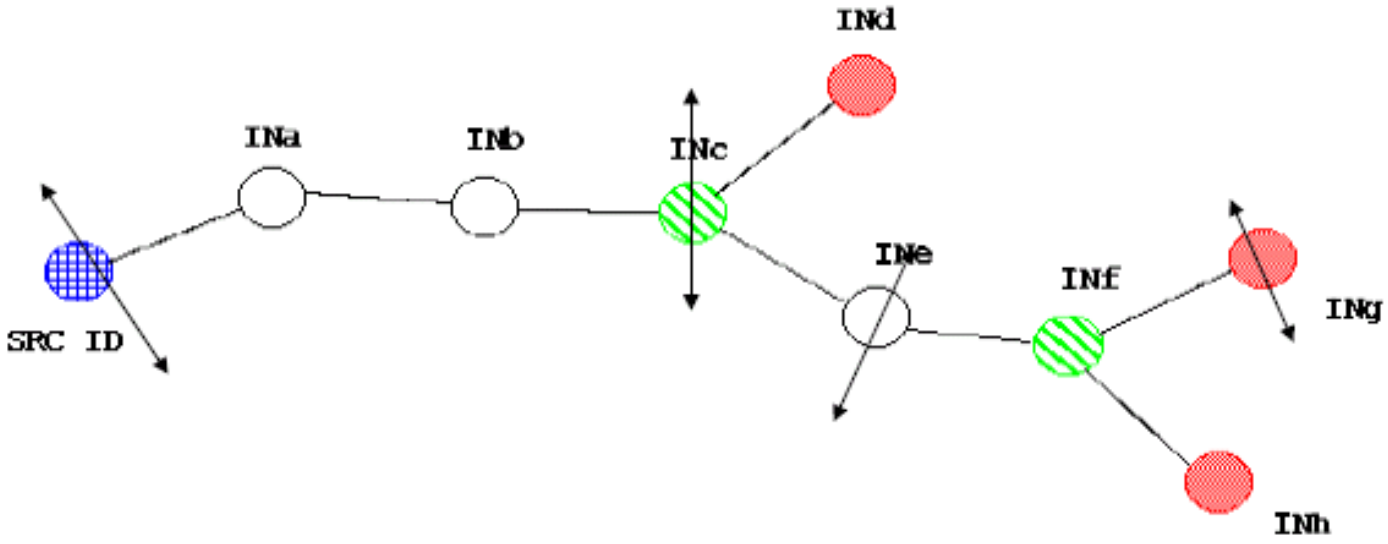
If SRC movement results => link breakage derive new multicast tree



Concurrent Node's Movements

Queen Mary University of London

- Repair [Originator, Route ID, ref from SRC] or
- Repair [Originator, Route ID, Time of Event] or
- Redo [SRC ID, Route ID]
- For multiple concurrent movement (tree nodes, source nodes or receiver nodes), only one RRC will eventually succeed.



ABAM Reconfiguration

Queen Mary University of London

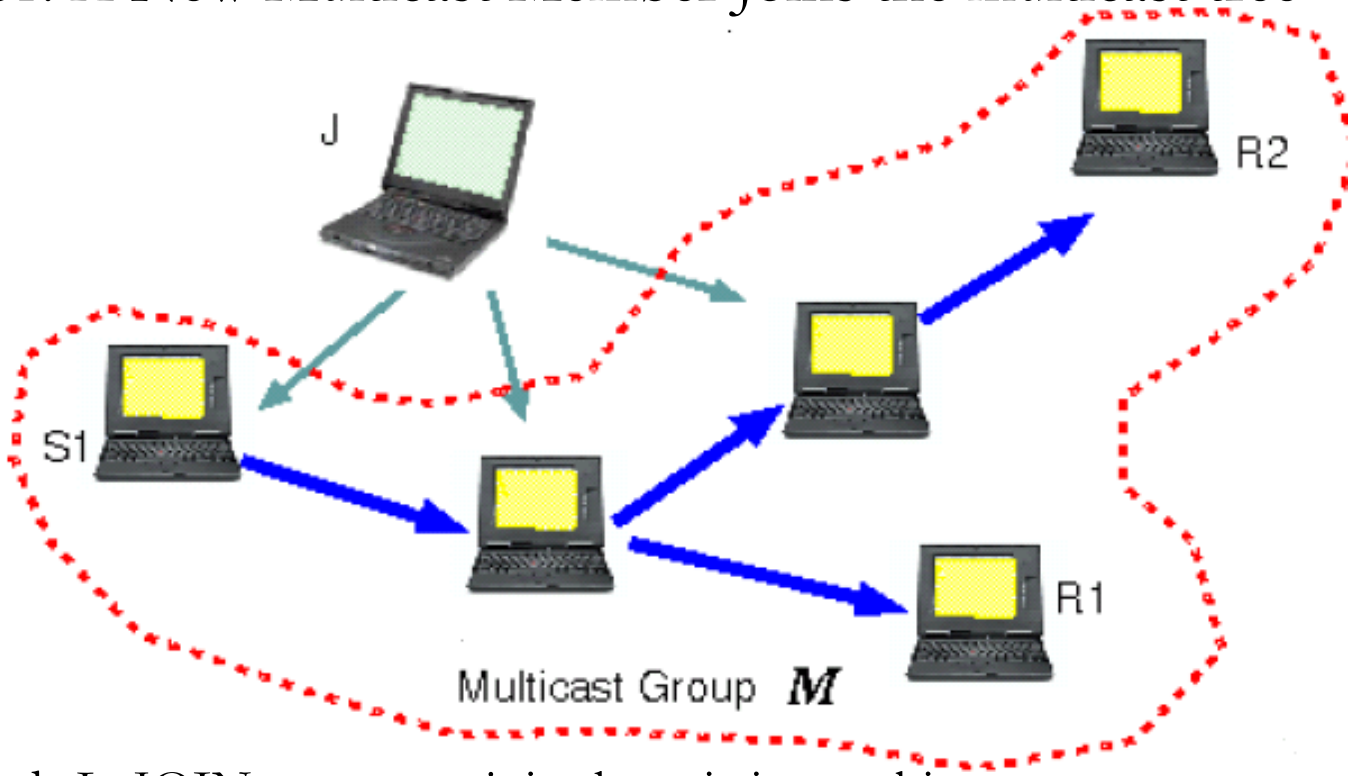
Tree delete

- **Case 1: No more receivers**
  - Each departing receiver prunes its branch
  - Eventually, tree is pruned completely
- **Case 2: Sender stops acting as multicast source**
  - Sender broadcast tree delete message
  - Receiver and tree nodes remove their roles

Handling Dynamic Multicast Groups

Queen Mary University of London

Case1: A New Multicast Member Joins the multicast tree

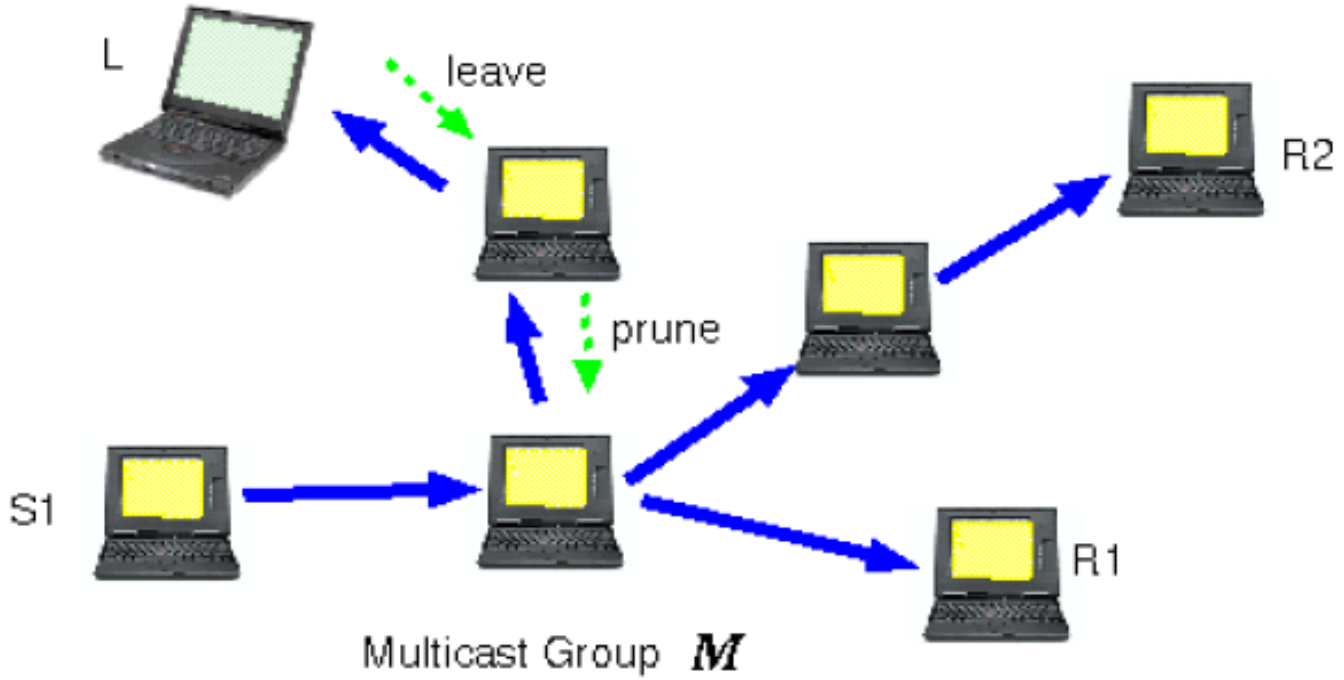


- J sends L_JOIN request to join the existing multicast tree.
- INs sends JOIN-REPLY packets to node J.
- J selects the most stable route and informs the IN to update their routing table.

Handling Dynamic Multicast Groups

Queen Mary University of London

Case2: A Multicast Member leaves the multicast tree



- J sends L_LEAVE message to its upstream node.
- L_LEAVE message propagates to multicast tree to update the routing tables

Advantages & Disadvantages

Queen Mary University of London

Advantages:

- Path source => receiver is more stable vs. other multicast protocols
- Achieves higher packet delivery
- Control overhead is less due to a fewer number of link failures

Disadvantages:

- Congestion in most stable path.
- Result in increased delay and reduction in packet delivery
- Not scalable