Chapter 3: Booadcasting, Multicasting, and Geocasting

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Routing Approaches

- **Broadcasting**
  - Is a common operation in many applications, e.g., graph-related and distributed computing problems
  - It is also widely used to resolve many network layer problems
- **Multicasting**
  - Transmission of datagrams to a group of hosts identified by a single destination address
  - Hence is intended for group-oriented computing
  - Can efficiently support a variety of applications that are characterized by close collaborative efforts
- **Geocasting**
  - Aims at delivering data packets to a group of nodes located in a specified geographical area
  - Can be seen as a variant of the conventional multicasting problem, and distinguishes itself by specifying hosts as group members within a specified geographical region
- Since all these three do communication to a group of recipients, it is imperative to determine what is the best way to provide these services in an ad hoc (MANET) environment
- Comparison of broadcast, multicast and geocast protocols for ad hoc networks provided

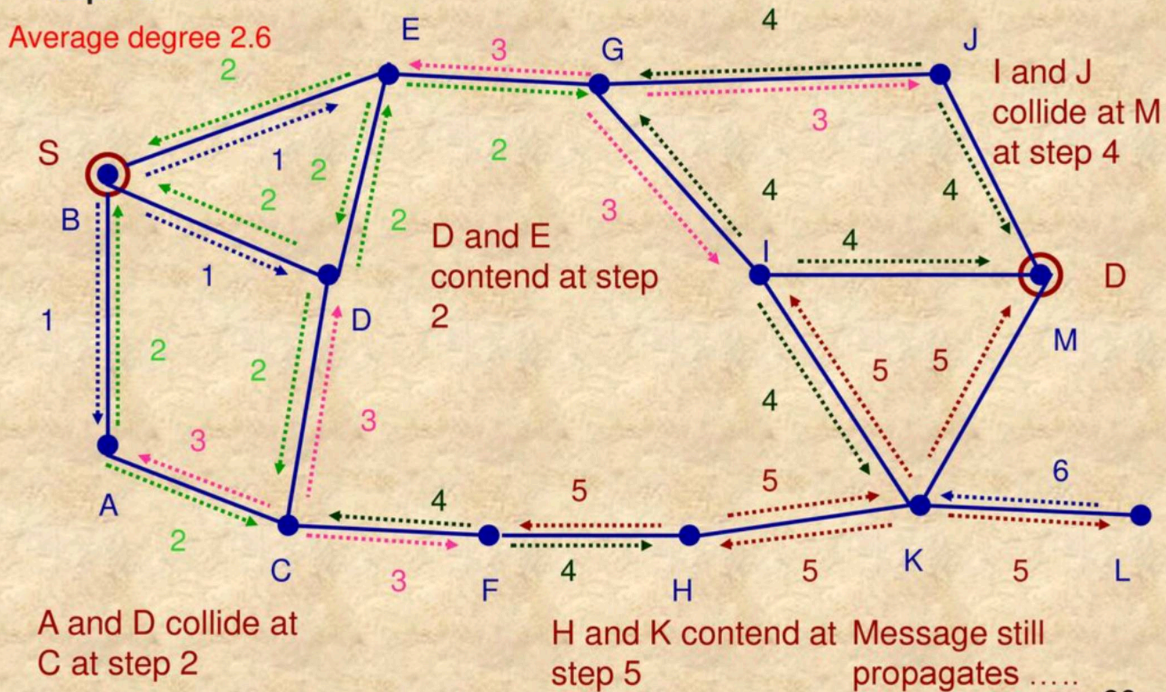
The Broadcast Storm

- MANET consists of a set of MHs that may communicate with one another from time to time
  - No base stations are present
  - Each host is equipped with a CSMA/CA
  - Transmission of a message to all other MHs required
- The broadcast is spontaneous
  - Due to MH mobility and lack of synchronization, any kind of global topology knowledge is prohibitive
  - Little or no local information may be collected in advance
- The broadcast is frequently unreliable
  - Acknowledgement mechanism is rarely used
  - Distribute a broadcast message to as many MHs as possible without putting too much effort
  - A MH may miss a broadcast message because it is off-line, it is temporarily isolated from the network, or it experiences repetitive collisions

The Broadcast Storm

- Broadcast
  - Acknowledgements may cause serious medium contention
  - In many applications 100% reliable broadcast is unnecessary
  - MH can detect duplicate broadcast messages
  - If flooding is used blindly, many redundant messages will be sent and serious contention/collision will be incurred
- Redundant rebroadcasts
  - When a MH decides to rebroadcast, all its neighbors may already have the message
- Contention
  - Transmissions from neighbors may severely contend with each other
- Collision
  - Due to absence of collision detection, collisions are more likely to occur and cause more damage

Example broadcast storm problem in a 13 node MANET



Rebroadcasting Schemes

- Minimize number of retransmissions of a broadcast message
- Attempt to deliver a broadcast packet to each and every node in the network

Common Attributes of Broadcast Protocols

- Jitter and Random Delay Timer (RDT)
  - Jitter allows one neighbor to acquire the channel first while other neighbors detect that the channel is busy
  - RDT allows a node to keep track of redundant packets received over a short time interval
- Loop Prevention
  - Node rebroadcasts a given packet no more than one time by caching original source node ID of the packet and the packet ID

Categories of Broadcasting Protocols

- Simple flooding
  - A source node broadcasting a packet to all neighbors
  - The neighbors, upon receiving the broadcast packet, rebroadcast the packet exactly once
- Probability-based methods
  - Similar to ordinary flooding
  - Nodes only rebroadcast with a predetermined probability
  - In dense networks, multiple nodes share similar transmission coverage
  - Counter-Based Scheme: relationship between number of times a packet is received and the probability of a node's transmission to cover additional area on a rebroadcast
- Area-based methods
- Neighbor knowledge methods

Categories of Broadcasting Protocols

- Area-based methods
  - If a sender is located only one meter away, the additional area covered by the retransmission by a receiving node rebroadcasts is quite low
  - *Distance-based scheme* compares the distance between itself and each of its neighbor nodes that has previously rebroadcast a given packet
  - *Location-based scheme* uses a more precise estimation of expected additional coverage area
- Neighbor knowledge methods
  - Flooding with Self Pruning requires each node to have knowledge of its one-hop neighbors
  - Scalable Broadcast Algorithm (SBA) requires that all nodes have knowledge of their neighbors within a two-hop radius
  - Each node searches its neighbor tables for the maximum neighbor degree of any neighbor node, say, d_{Nmax}
  - Calculates a Random Time Delay (RDT) based on the ratio of $\left(\frac{d_{N\max}}{d_{me}}\right)$ where d_{me} is the number of current neighbors for the node

Categories of Broadcasting Protocols

- Neighbor knowledge methods…..
  - Dominant Pruning: Uses two-hop neighbor knowledge, but proactively choosing some or all of its one-hop neighbors as rebroadcasting nodes
  - Multipoint Relaying: Similar to Dominant Pruning, but rebroadcasting nodes, [Multipoint Relays (MPRs)] are explicitly chosen by upstream senders

Algorithm for a node to choose its MPRs

1. Find all two-hop neighbors that can only be reached by one one-hop neighbor and assign those one-hop neighbors as MPRs
2. Determine the resultant cover set (i.e., the set of two-hop neighbors that will receive the packet from the current MPR set)
3. From the remaining one-hop neighbors not yet in the MPR set, find the one that would cover the most two-hop neighbors not in the cover set
4. Repeat from step 2 until all two-hop neighbors are covered

Categories of Broadcasting Protocols

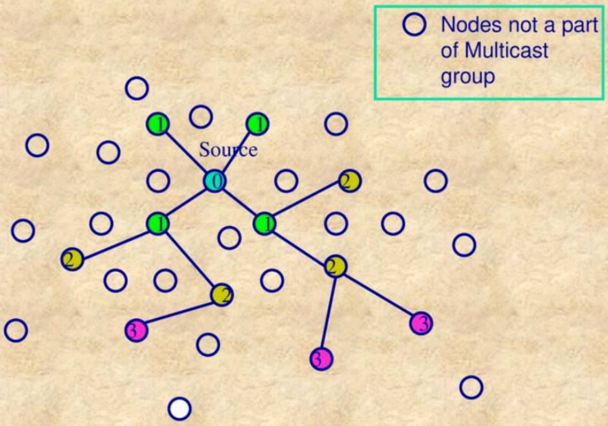
- Ad Hoc Broadcast Protocol (AHBP)
  - Approach similar to Multipoint Relaying by designating nodes as a Broadcast Relay Gateway (BRG)
  - AHBP differs from Multipoint Relaying in three ways:

    1. A node using AHBP informs one-hop neighbors of the BRG designation by a field in the header of each broadcast packet as opposed to done by hello packets in Multipoint Relaying
    2. In AHBP, when a node receives a broadcast packet listed as a BRG, it uses two-hop neighbor knowledge to find which neighbors also received the broadcast packet in the same transmission so as to remove from the neighbor graph
    3. AHBP is extended to account for high mobility networks

Multicast Routing Protocols

- Broadcast protocols cannot be used as multicasting requires a selected set of MHs to receive the message
- Protocols are classified into four categories based on how route to the members of the group is created:
  - Tree-Based Approaches
  - Meshed-Based Approaches
  - Stateless Multicast
  - Hybrid Approaches

Illustration of Tree-Based Multicast



Tree-Based Approaches

- **Extend tree-based approach to provide multicast in a MANET**
- **A packet traverses each hop and node in a tree at most once**
- **Very simple routing decisions at each node**
- **Tree structure built representing shortest paths amongst nodes, and a loop-free data distribution structure**
- **Even a link failure could mean reconfiguration of entire tree structure, could be a major drawback**
- **Consider either a shared tree or establish a separate tree per each source**
  - **For separate source trees, each router in multiple router groups must maintain a list of pertinent information for each group and such management per router is inefficient and not scalable**
  - **For shared trees, there is a potential that packets may not only not traverse shorter paths, but routed on paths with much longer distances**

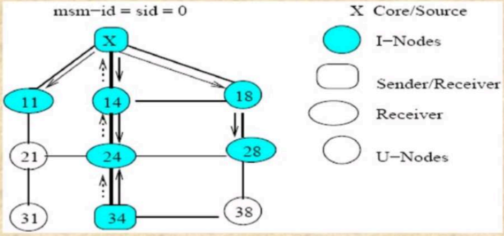
Tree-Based Approaches

Ad hoc Multicast Routing Protocol Utilizing Increasing Id-Numbers

- Utilizing Increasing id-numberS (AMRIS) is an on-demand protocol, which constructs a shared multicast delivery tree to support multiple senders and receivers in a multicast session
- AMRIS dynamically assigns an id-number to each node in each multicast session and a multicast delivery tree – rooted at a special node with Sid (Smallest-ID and is usually a source that initiates a multicast session) – is created and the id-number increases as the tree expands from the Sid
- In case of multiple senders, a Sid is selected among the given set of senders
- Once a Sid is identified, it sends a NEW-SESSION message to its neighbors
- This message includes Sid's msm-id (multicast session member id) and the routing metrics
- Nodes receiving the NEW-SESSION message generate their own msm-ids, which is larger than the msm-id of the sender
- In case a node receives multiple NEW-SESSION messages from different nodes, it keeps the message with the best routing metrics and calculates its msm-ids
- To join an ongoing session, a node checks the NEW-SESSION message, determines a parent with smallest msm-ids, and unicast a JOIN-REQ to its potential parent node
- If parent node is already in the multicast delivery tree, it replies with a JOIN-ACK.
- If a node is unable to find any potential parent node, it executes a branch reconstruction (BR) process to rejoin the tree

Tree-Based Approaches

- *Ad hoc Multicast Routing Protocol Utilizing Increasing Id-Numbers (AMRIS)*
  - Packet forwarding example



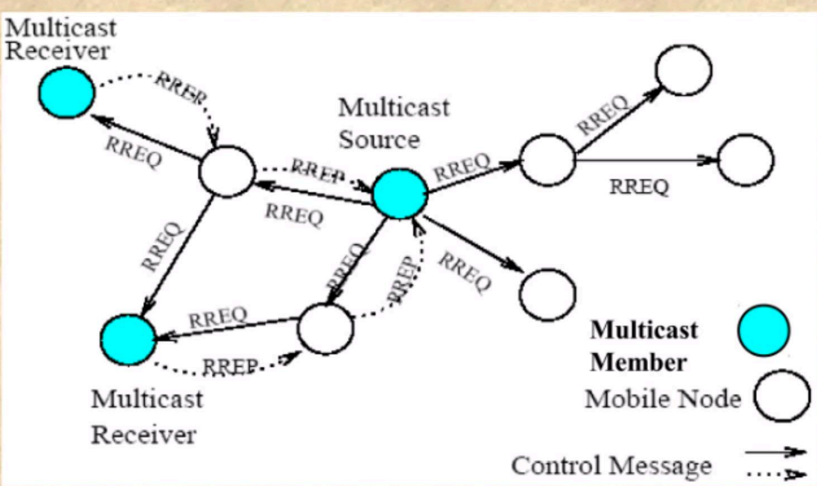
- Nodes X and 34 are sources
- Nodes 11, 24, and 28 are recipients

Route Discovery and Join for Multicast

- Multicast Ad hoc On-Demand Distance Vector Protocol
  - Follows directly from the unicast AODV
  - Discovers multicast routes on-demand using a broadcast route discovery mechanism employing the same Route Request (RREQ) and Route Reply (RREP) messages
  - A MH originates a RREQ message when it wishes to join a multicast group, or when it has data to send to a multicast group but it does not have a route to that group
  - Only a member of the desired multicast group may respond to a join RREQ
  - If the RREQ is not a join request, any node with a fresh enough route to the multicast group may respond
  - As the RREQ is broadcasted across the network, nodes set up pointers to establish the reverse route in their route tables
  - A node receiving a RREQ first, updates its route table to record the sequence number
  - For join RREQs, an additional entry is added to the multicast route table and is not activated unless the route is selected to be a part of the multicast tree

Multicast AODV

- Multicast Ad hoc On-Demand Distance Vector Protocol
  - Follows directly from the unicast AODV



Mesh based Approach

- Mesh-based multicast protocols may have multiple paths between any source and receiver pairs
- Mesh-based protocols seem to outperform tree-based proposals due to availability of alternative paths
- A mesh has increased data-forwarding overhead
- The redundant forwarding consumes more bandwidth
- The probability of collisions is higher when a larger number of packets are generated

On-Demand Multicast Routing Protocol

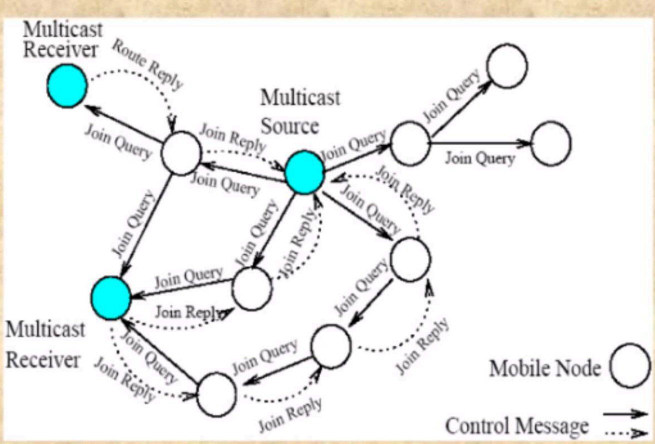
- Mesh-based protocol employing a forwarding group concept
- Only a subset of nodes forwards the multicast packets
- A soft state approach is taken in ODMRP to maintain multicast group members
- No explicit control message is required to leave the group
- The group membership and multicast routes are established and updated by the source on demand
- If no route to the multicast group, a multicast source broadcasts a Join-Query control packet to the entire network
- This Join-Query packet is periodically broadcasted to refresh the membership information and updates routes

On-Demand Multicast Routing Protocol

- After establishing a forwarding group and route construction process, a source can multicast packets to receivers via selected routes and forwarding groups

- To leave the group, source simply stops sending Join-Query packets

- If a receiver no longer wants to receive from a particular multicast group, it does not send the Join-Reply for that group



Core-Assisted Mesh Protocol

- Supports multicasting by creating a shared mesh for each multicast group
- Meshes thus created, helps in maintaining the connectivity to the multicast users, even in case of node mobility
- It borrows concepts from CBT, but the core nodes are used for control traffic needed to join multicast groups
- Assumes a mapping service by building and maintaining the multicast mesh
- Nodes are classified as: simplex, duplex and non-member
- CAMP uses a receiver-initiated method for routers to join a multicast group
- CAMP ensures the mesh to contain all reverse shortest paths between a source and the recipients

- **Multicast Mesh Creation:**

- CAMP creates a shared mesh for each multicast group, which helps maintain connectivity among multicast users, even when nodes move.
- The mesh is essentially a network of interconnected nodes that support multicast communication.

· **Control Traffic and Core Nodes:**

- CAMP uses core nodes to handle control traffic related to joining and maintaining multicast groups.
- Core nodes are crucial for managing group membership and facilitating communication within the multicast group.

· **Router Classification:**

- **Simplex Mode:** A router in this mode only sends multicast traffic received from specific nodes to the rest of the group. It does not forward multicast packets from other nodes.
- **Duplex Mode:** A router in this mode forwards multicast packets for the group and participates actively in the multicast mesh.
- **Non-Member:** A router that does not participate in the multicast mesh and does not need to forward multicast traffic.

· **Joining and Leaving Groups:**

- **Receiver-Initiated Method:** Routers join a multicast group by announcing their membership. If a router has multiple neighbors that are already members, it updates its routing table and announces itself to these neighbors.
- If no direct neighbors are members, the router sends a join request to a core node or uses an expanding ring search to find a member.
- Routers can leave a multicast group if they no longer have hosts that need the group or if they are not required for efficient packet dissemination.

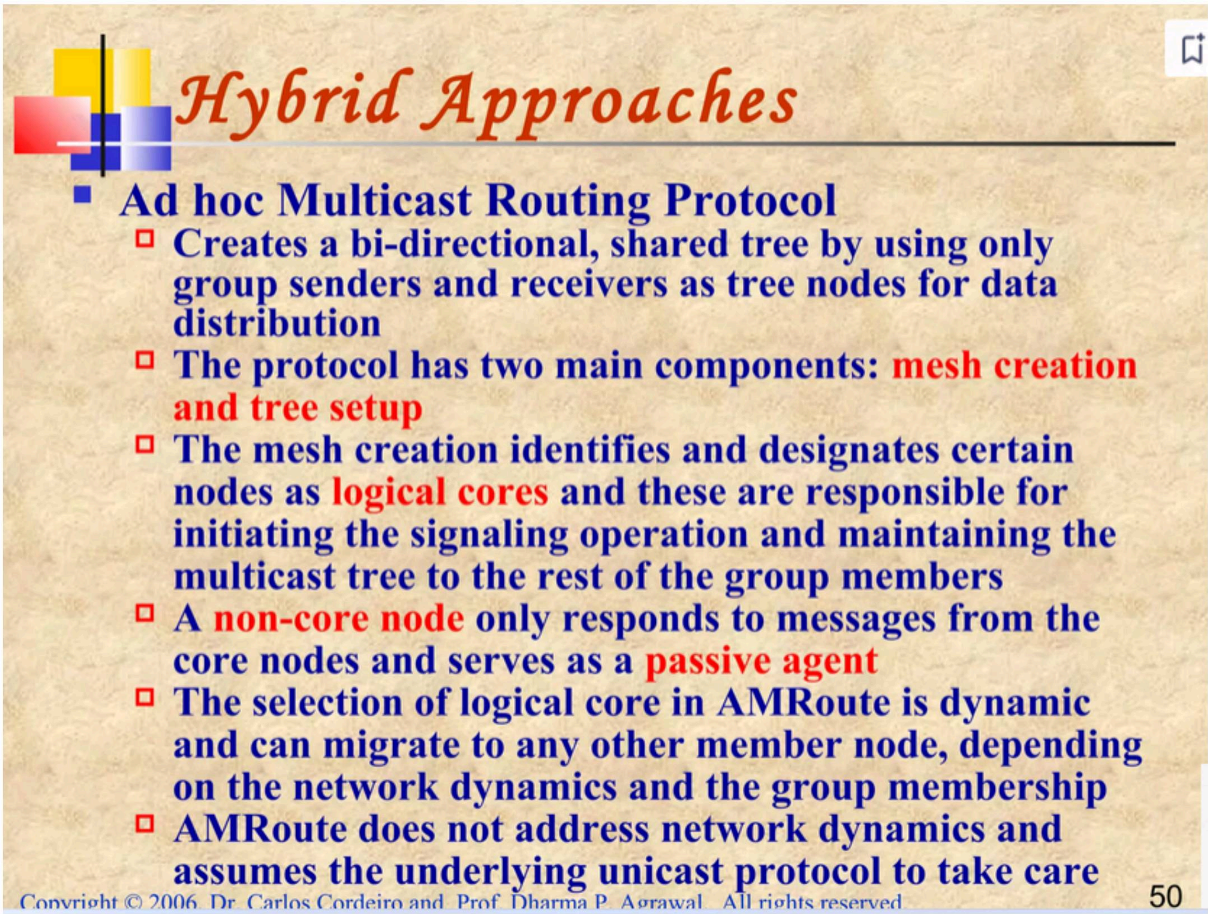
· **Maintaining Connectivity:**

- CAMP ensures that all reverse shortest paths between a source and recipients are maintained in the mesh.
- Receiver nodes periodically check if they are receiving data packets via the shortest path. If not, they send a HEARTBEAT message to their successor, which triggers a PUSH JOIN (PJ) message. This process forces non-member nodes in the path to join the mesh.

· **Advantages and Disadvantages:**

- **Advantages:**
    - o CAMP avoids flooding, which limits the spread of multicast join requests to mesh members only.
- **Disadvantages:**

- It depends on an underlying unicast routing protocol to ensure that distances to all destinations are accurate and updated within a finite time frame.

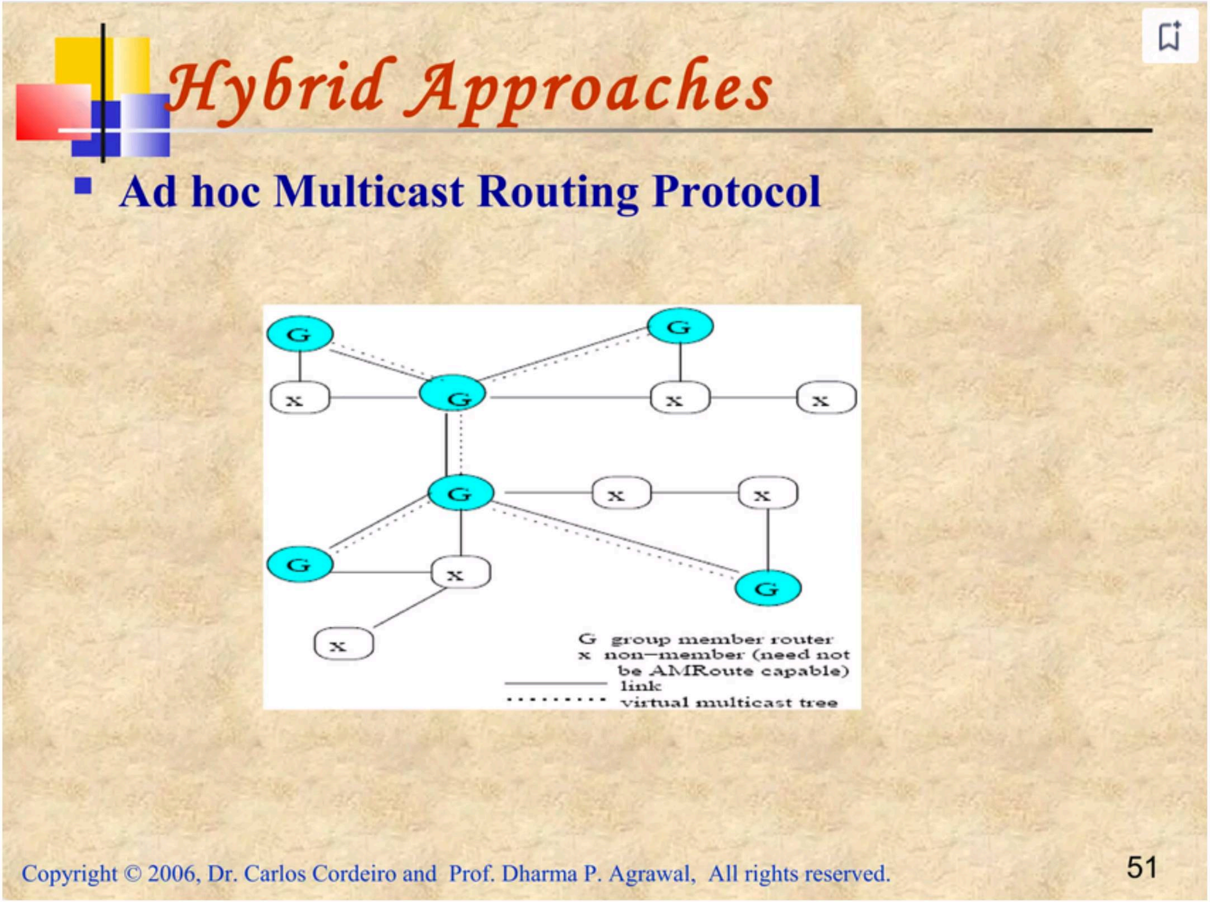


AMRoute Protocol Overview

1. **Core Nodes and Their Role:**
   - **Non-Core Nodes:**
     - Serve as passive agents that only respond to messages from other core nodes.
     - The selection of a logical core is dynamic and can change based on network dynamics and group membership.
2. **Mesh Creation:**
   - **Initial Process:**
     - Each member node starts by identifying itself as a core and broadcasts JOIN_REQ packets.
     - These packets use increasing Time-to-Live (TTL) values to discover other core nodes in the network.
   - **Core Response:**

- When a core node receives a JOIN_REQ from another core node in a different mesh for the same group, it replies with a JOIN_ACK.
- This creates a bi-directional tunnel between the two cores and one of them is selected as the core after the mesh merger.

3. **Tree Creation:**
   - **Initiation:**
     - Once the mesh is established, the core node initiates the tree creation process.
     - The core node sends periodic TREE_CREATE messages along all links in its mesh.
   - **Message Forwarding:**
     - TREE_CREATE messages are sent using unicast tunnels only to group members.
     - Group members receiving a non-duplicate TREE_CREATE message will forward it to all mesh links except the incoming one.
     - They mark the incoming and outgoing links as tree links.
   - **Handling Unused Links:**
     - If a link is not going to be used as part of the tree, the TREE_CREATE message is discarded, and a TREE_CREATE_NAK message is sent back to the incoming link.
4. **Leaving a Group:**
   - **Process:**
     - A member node wishing to leave the group sends a JOIN_NAK message to its neighboring nodes.
5. **Virtual Mesh Links:**
   - **Function:**
     - Virtual mesh links are used to establish and maintain the multicast tree.
     - This helps keep the multicast delivery tree consistent even with changes in network topology, as long as routes between core nodes and tree members exist via mesh links.
6. **Disadvantages:**
   - **Temporary Loops and Non-Optimal Trees:**
     - AMRoute may experience temporary loops and create non-optimal multicast trees due to network mobility.



The Multicast Core-Extraction Distributed Ad Hoc Routing (MCEDAR) protocol is designed to enhance multicast routing by combining the strengths of tree-based and mesh-based forwarding protocols. Here's a detailed breakdown of its components and operations:

MCEDAR Protocol Overview

1. **Objective:**
   - MCEDAR aims to integrate the efficiency of tree-based forwarding with the robustness of mesh-based protocols.
2. **Combining Approaches:**
   - **Tree-Based Forwarding:**
     - Creates a source-based forwarding tree on a mesh to ensure efficient data delivery.
   - **Mesh-Based Protocols:**
     - Provides robustness by using a mesh structure that can tolerate link failures.
3. **Forwarding Tree on a Mesh:**
   - **Source-Based Forwarding Tree:**
     - Built on top of the mesh infrastructure.

        - Ensures that data forwarding occurs over the shortest paths (minimum height trees).

4. **Decoupling Control and Data Forwarding:**
    - **Control Infrastructure:**
        - Separate from actual data forwarding to reduce control overhead.
    - **Unicast Protocol:**
        - The underlying unicast protocol, CEDAR, handles core broadcasting for multicasting.
5. **Core Nodes and Mesh Infrastructure:**
    - **Core Nodes:**
        - Used for routing management and link state inspection.
    - **Mesh Infrastructure (mgraph):**
        - Cores form the mesh structure (referred to as mgraph) and use join IDs to perform join operations.
6. **Mesh Tolerance:**
    - **Link Breakage Tolerance:**
        - MCEDAR can tolerate some link failures without needing reconfiguration, thanks to its mesh-based approach.
7. **Forwarding Mechanism:**
    - **Implicit Route-Based Forwarding Tree:**
        - The mesh uses this mechanism to ensure packets travel the shortest distance.
    - **Efficiency:**
        - Achieved by creating a forwarding tree on the mesh.