EEC 687 Mobile Computing (Spring 2007)

Multicasting in Mobile Networks

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Contents

- Physical layer issues
  - Communication frequency
  - Signal propagation
  - Modulation and Demodulation
- Channel access issues
  - Multiple access / Random access / Asynchronous
  - 802.11 / Bluetooth
  - Capacity / Energy / Fairness / Directional
- System issues
  - Embedded processor
  - Low power design
- Network issues
  - Location management
  - Mobile IP / Cellular IP
  - MANET routing / Clustering
  - Multicast
  - Interoperability
  - Network reliability (TCP)
  - Quality of service (QoS)

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Multicasting

- Communication models are characterized by the number of receivers targeted by a sender
  - Unicast
  - Broadcast
  - Multicast is a generalization of unicast & broadcast
- Why multicast ?
  - Resource conservation via sharing
  - Multicast route is a tree rooted at the sender with a receiver at each leaf (and possibly at internal nodes)
  - IPv6 encourages the replacement of broadcasting with multicasting whenever possible

3

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Multicasting in Fixed Networks

- IP Multicasting
  - Uses the best-effort delivery semantics as other IP datagram delivery : can be lost, delayed, duplicated or delivered out of order
  - IP Multicast vs Transport Multicast ("reliable" : all or none)
  - Host group may be permanent or transient
    - Permanent : well-known addresses assigned by Internet authority
    - Transient : exist as long as they have members
  - Host groups are identified by a single class D IP address
    - 1110 + 28-bit
    - Or 224.0.0.0~239.255.255.255
    - What's the corresponding Ethernet / Token-ring address?

4

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Address	Meaning
224.0.0.0	Base Address (Reserved)
224.0.0.1	All Systems on this Subnet
224.0.0.2	All Routers on this Subnet
224.0.0.3	Unassigned
224.0.0.4	DVMRP Routers
224.0.0.5	OSPFIGP All Routers
224.0.0.6	OSPFIGP Designated Routers
224.0.0.7	ST Routers
224.0.0.8	ST Hosts
224.0.0.9	RIP2 Routers
224.0.0.10	IGRP Routers
224.0.0.11	Mobile-Agents
224.0.0.12	DHCP Server / Relay Agent
224.0.0.13	All PIM Routers
224.0.0.14	RSVP-Encapsulation
224.0.0.15	All-CBT-Routers
224.0.0.16	Designated-Sbm
224.0.0.17	All-Sbms
224.0.0.18	VRRP
224.0.0.19 through 224.0.0.255	Unassigned
224.0.1.21	DVMRP on MOSPF
224.0.1.84	Jini Announcement
224.0.1.85	Jini Request
239.192.0.0 through 239.251.255.255	Scope restricted to one organization
239.252.0.0 through 239.255.255.255	Scope restricted to one site

Figure 17.2 Examples of a few permanent IP multicast address assignments. Many other addresses have specific meanings.

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Multicasting in Fixed Networks

- IP Multicasting
  - Packet forwarding handled by "multicast routers (MRs)" which can be co-resident with internet gateways
  - Steps to multicasting
    - Hosts sends it locally to all attached members
    - If TTL ≥ 2, local MR forwards it to all other networks that have members
    - In all reachable (based on TTL) networks, local MRs complete delivery
  - Delivery within a single network using local network multicasting capability
    - Ethernet 0000,0001+40-bit
    - Mapping rule : IP 1110+28-bit => 1110+5-bit+23-bit =>
      Ethernet 0000,0001,0000,0000,0101,1110,0+23bit
      (01 00 5E, 0+23bit)

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Multicasting in Fixed Networks

- IP Multicasting
  - IP software must
    - Remember its enrollment in a group to decide to receive a multicast datagram or not
    - If multiple applications joined a group, it has to know all of them leave the group or not
    - Inform the multicast gateways of its group membership status
  - We need mechanisms to
    - Track group membership
    - Route diagrams toward group members
    - Local members are easy but members in global area are difficult

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Multicasting in Fixed Networks

- "Local" multicasting mechanism
  - Locating hosts belonging to multicast groups
  - Based on IGMP (Internet Group Management Protocol)
  - Operation
    - Multicast gateway periodically sends "queries" for group membership in its local area
    - Each host reply with "reports" identifying the participating groups (need periodic reports)
    - Multicast gateway then builds a list of all groups present in its local area and arrange for multicast delivery

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Multicasting in Fixed Networks

- "Global" multicasting mechanisms
  - Multicast routing from senders toward remote group members
- DVMRP (Distance Vector Multicast Routing Protocol)
  - Based on distance vector scheme, so every router knows the next hop for a specific destination
  - Only when a multicast packet is delivered via the best reverse path to its source, it is forwarded (otherwise dropped)
  - When a multicast datagram is sent, the router
    - Checks its source
    - Finds what is the next hop interface to the source
    - Determines if the multicast datagram is sent via that interface or not
    - Forwards if yes, drops it otherwise

9

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Multicasting in Fixed Networks

- "Global" multicasting mechanisms
  - Multicast routing from senders toward remote group members
- DVMRP (Distance Vector Multicast Routing Protocol)
- MOSPF (Multicast Open Shortest Path First)
  - Based on link state scheme
  - All routers know the complete topology and the location of all group members
  - When a multicast packet arrives, the shortest path tree from the sender to all members is calculated and forwarded accordingly

10

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Multicasting in Fixed Networks

- "Global" multicasting mechanisms
  - Multicast routing from senders toward remote group members
- DVMRP (Distance Vector Multicast Routing Protocol)
- MOSPF (Multicast Open Shortest Path First)
- CBT (Core-based Tree)
  - Single shared tree rather than per-source tree
  - All multicast datagrams are initially sent to a chosen core
- PIM (Protocol Independent Multicast) : mixes per group or host

11

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Multicasting in Fixed Networks

- PIM (Protocol Independent Multicast): SM and DM
  - This protocol is named **protocol independent** because it is not dependent on any particular unicast routing protocol for topology discovery
  - Sparse-Mode (PIM-SM) is a protocol for efficiently routing to multicast groups that may span wide-area (and inter-domain) internets. This is called **sparse-mode** because it is suitable for groups where a very low percentage of the nodes (and their routers) will subscribe to the multicast session.
  - PIM-SM explicitly constructs a tree from each sender to the receivers in the multicast group. Multicast packets from the sender then follow this tree.

12

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Multicasting in Fixed Networks

- PIM (Protocol Independent Multicast): SM and DM
  - In dense-mode multicast routing protocols such as DVMRP and PIM-DM (dense mode), packets are flooded everywhere and then pruned off branches where there were no receivers
  - Dense mode is ideal for groups where many of the nodes will subscribe to receive the multicast packets, so that most of the routers must receive and forward these packets (groups of a high density).
  - The source initially broadcasts to every router, and thus every node. Then each node that does not wish to receive packets destined for that group will send a prune message to its router. Upon receiving a prune message, the router will modify its state so that it will not forward those packets out that interface. If every interface on a router is pruned, the router will also be pruned.

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Multicast in ns-2

- Chapter 30
- Implements Shared tree mode (ST) and Dense-mode (DM)
- ~tcl/ex/mcast.txt & mcast.tcl

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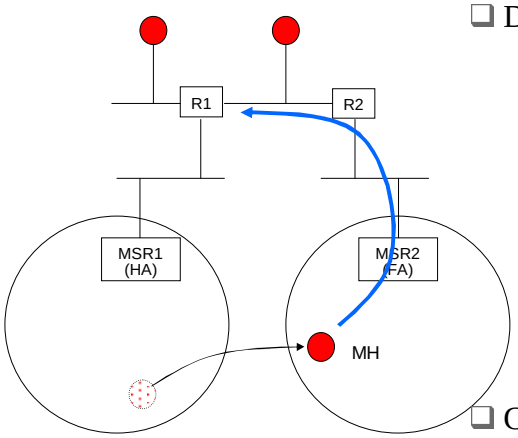
Multicasting in Mobile Networks (Mobile IP-based)



- DVMRP, MOSPF
  - MH sends a multicast datagram via MH -> MSR2 -> R2 -> R1
  - DVMRP
    - R1 thinks the source is in HA and the best reverse path is from MSR1 but the datagram is delivered from R2
    - R1 just drop the multicast datagram
  - MOSPF
    - Forwards them, but based on erroneous distribution tree
- CBT may be OK

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Multicasting in Mobile Networks (Mobile IP-based)

Mobile host is a sender of a multicast packet

- IETF Mobile IP approaches (**solutions for sending**)
  - Remote subscription
    - Use FA's address as the source
    - Re-subscribe to its desired multicast groups with foreign agents whenever it moves
    - But, replies are delivered to the FA while the MH may move to other place
  - Bi-directional tunneling
    - Tunnel the multicast datagram to HA, so that the datagram is originated from the HA

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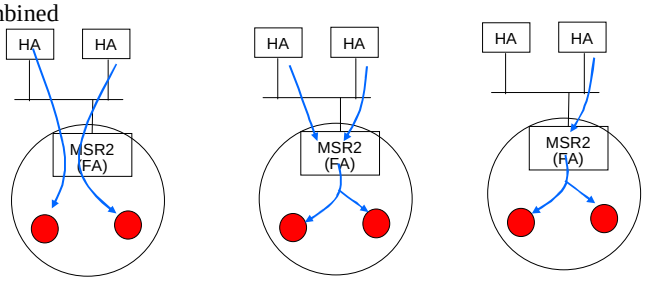
Multicasting in Mobile Networks (Mobile IP-based)

- IETF Mobile IP approaches (**solutions for receiving**)
  - HA routing
    - Interoperable : only the interested MH's and HA's need to be modified
    - But, inefficient since multiple encapsulation for FA's who do not recognize multicast address : tunnel convergence problem
  - FA routing
  - Combined



17

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Multicasting in MANET

- Need to take topology change into account when designing a multicast protocol
- Several new protocols have been proposed for multicasting in MANET
- Per-source tree
  - Shortest tree comes for free
  - Distributes the traffic evenly in the network
  - Requires minimal initialization and maintenance
  - But, fast moving node problem is serious
- Shared tree
  - is more robust to mobility (construct more stable tree by selecting stable links) and more scalable
  - But, paths are not optimal traffic is centered on the shared tree, especially the RP (Rendezvous Point)

18

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AODV Multicasting

- A shared tree approach
- Each multicast group has a group leader
- Group leader is responsible for maintaining group sequence number (which is used to ensure freshness of routing information)
  - Similar to sequence numbers for AODV unicast
- First node joining a group becomes *group leader*
- A node on becoming a group leader, broadcasts a *Group Hello* message

19

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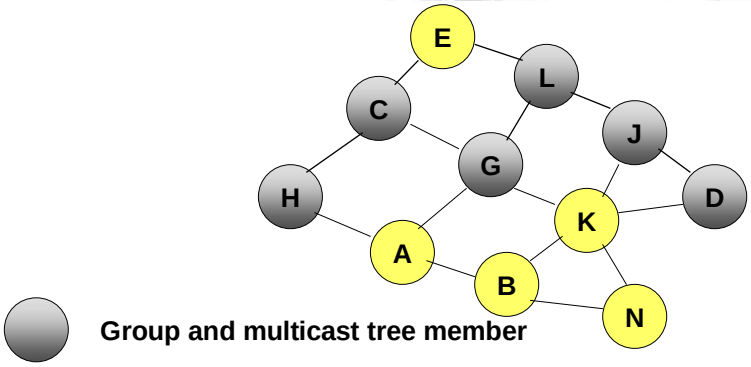
AODV Multicast Tree



20

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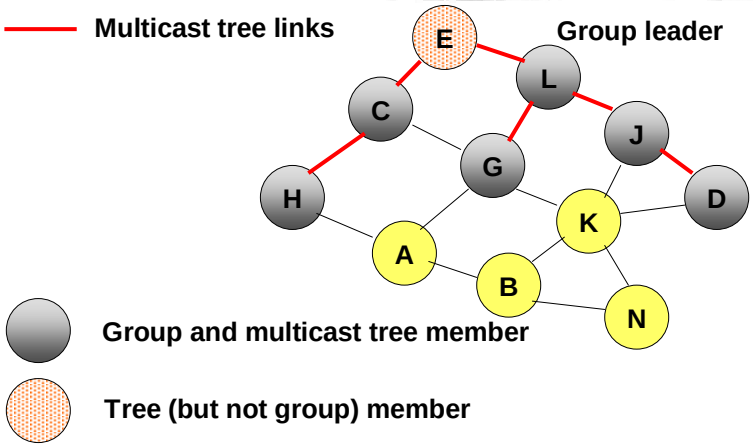
AODV Multicast Tree



21

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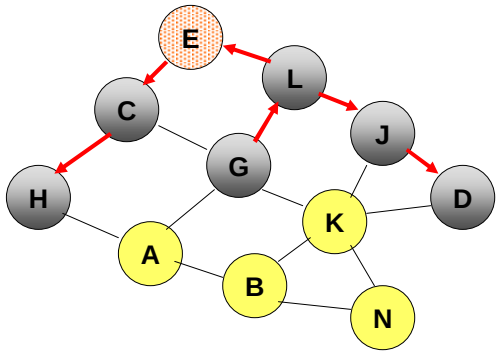
Sending Data on the Multicast Tree

- Data is delivered along the tree edges maintained by the Multicast AODV algorithm (e.g. G to group)



22

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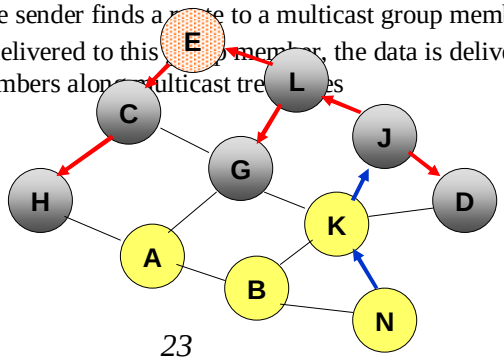
Sending Data on the Multicast Tree

- If a node which does not belong to the multicast group wishes to multicast a packet (e.g. N to group)
  - It sends a (*non-join)* RREQ to find the nearest group member
  - As a result, the sender finds a route to a multicast group member
  - Once data is delivered to this group member, the data is delivered to remaining members along multicast tree branches



23

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Joining the Multicast Tree: AODV

- Node N wishes to join
  - Broadcast (join) RREQ to members
  - Group members reply
  - Node N selects the best path and sends MACT (multicast activation) via the best path
  - Updated tree has been constructed

24

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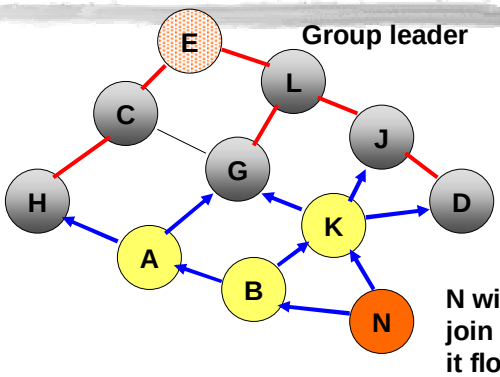
Joining the Multicast Tree: AODV



N wishes to join the group: it floods RREQ

Route Request (RREQ)

25

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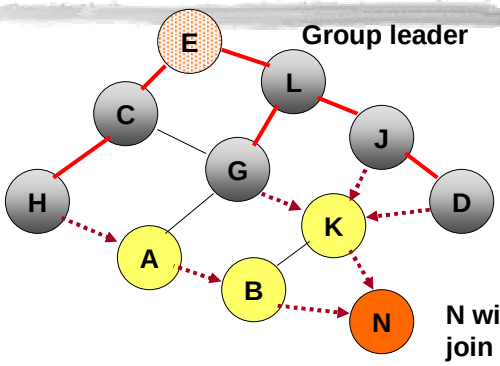
Joining the Multicast Tree: AODV



N wishes to join the group

Route Reply (RREP)

26

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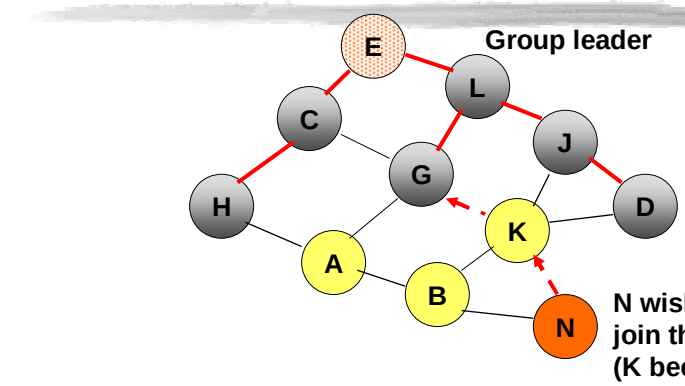
Joining the Multicast Tree: AODV



N wishes to join the group (K becomes a tree node)

Multicast Activation (MACT)

27

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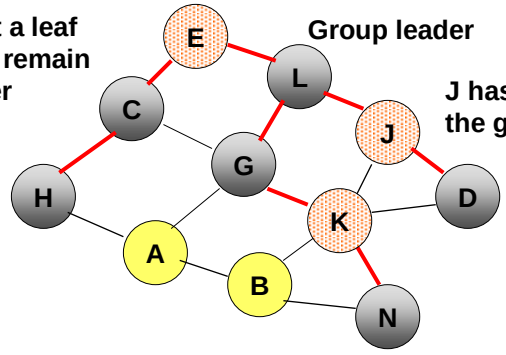
Leaving a Multicast Tree: AODV

J wishes to leave the group
Since J is not a leaf node, it must remain a tree member



J has left the group

28

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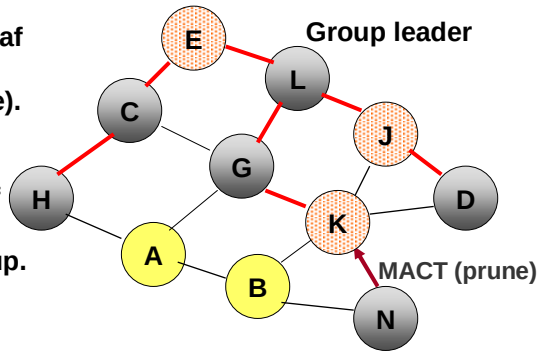
Leaving a Multicast Tree: AODV

N wishes to leave the group
Since N is a leaf node, it sends MCAST (prune).

Node N has removed itself from the multicast group.



N wishes to leave the multicast group

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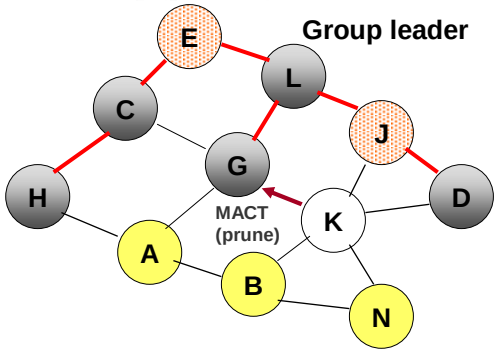
Leaving a Multicast Tree: AODV



Now node K has become a leaf, and K is not in the group.
So node K removes itself from the tree as well after forwarding MACT (prune).

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Handling a Link Failure: AODV Multicasting

- When a link (X,Y) on the multicast tree breaks, the node that is further away from the leader is responsible to reconstruct the tree, say node X
- Node X, which is further downstream, transmits a Route Request (RREQ)
  - Only nodes which are closer to the leader than node X's last known distance are allowed to send RREP in response to the RREQ, to prevent nodes that are further downstream from node X from responding

31

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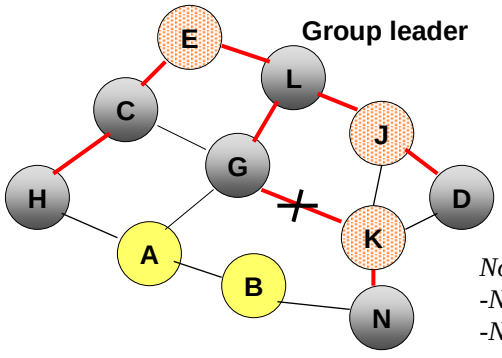
Handling a Link Failure: AODV Multicasting



Node K sends RREQ
-Node J responds
-Node N or D doesn't

32

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Other Multicasting Approaches in MANET

- AM-Route (Ad hoc Multicast Routing) : shared tree approach
- AMRIS (Ad hoc Multicast Routing protocol utilizing Increasing id-numberS) : shared tree approach
  - Core node sends NEW-SESSION message with msm-id (multicast session member ID)
  - Neighbors increases the msm-id and resend it
  - Ranking order of msm-id tells the flow direction
  - Shared tree from the core can be constructed
- ODMRP (On-Demand Multicast Routing Protocol) / CAMP (Core-Assisted Mesh Protocol) : shared mesh approach

33

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On-Demand Multicast Routing Protocol (ODMRP)

- ODMRP requires cooperation of nodes wishing to send data to the multicast group
  - To construct the multicast *mesh*
- A sender node wishing to send multicast packets *periodically* floods a Join Data packet throughout the network
  - Periodic transmissions are used to update the routes

34

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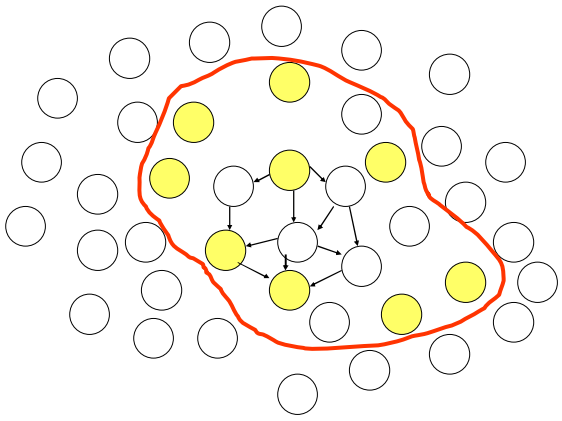
On-Demand Multicast Routing Protocol (ODMRP)



Multicast mesh:

Multicast packets flood within the mesh

How do you compare With multicast tree?

35

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On-Demand Multicast Routing Protocol (ODMRP)

- Each multicast group member on receiving a Join Data, broadcasts a Join Table to all its neighbors
  - Join Table contains (sender S, next node N) pairs
  - next node N denotes the next node on the path from the group member to the multicast sender S
- When node N receives the above broadcast, N becomes member of the *forwarding group*
- When node N becomes a forwarding group member, it transmits Join Table containing the entry (S,M) where M is the next hop towards node S

36

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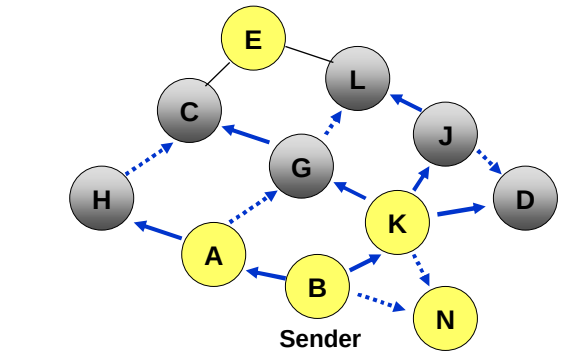
On-Demand Multicast Routing Protocol (ODMRP)



Join Data

Join Data (first arriving)

37

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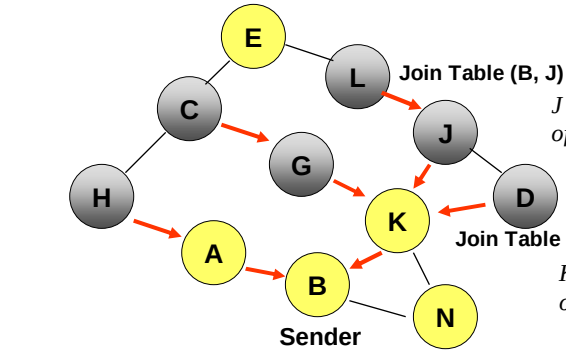
On-Demand Multicast Routing Protocol (ODMRP)



J becomes a member of the forwarding group

K becomes a member of the forwarding group

Join Table

38

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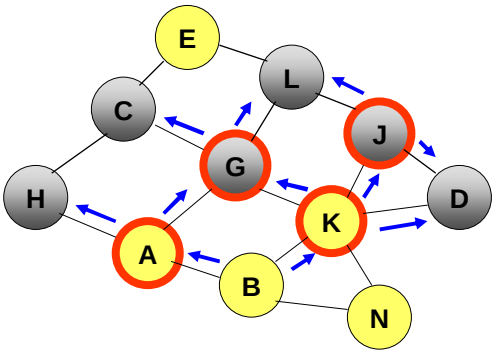
On-Demand Multicast Routing Protocol (ODMRP)



Nodes G, J, K and A form the forwarding group

When the sender sends a multicast packet, they will broadcast

Members get the packet with a higher probability

E.g., node D receives two copies of the packet

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ODMRP Multicast Delivery

- A sender broadcasts data packets to all its neighbors
- Members of the forwarding group forward the packets
- Using ODMRP, multiple routes from a sender to a multicast receiver may exist due to the mesh structure created by the forwarding group members
  - Provides path redundancy (compare with tree approach !) and thus better performance in mobile environments where links are fragile

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ODMRP

- No explicit join or leave procedure
- A sender wishing to stop multicasting data simply stops sending Join Data messages
- A multicast group member wishing to leave the group stops sending Join Table messages
- A forwarding node ceases its *forwarding* status unless refreshed by receipt of a Join Table message
- Link failure/repair taken into account when updating routes in response to periodic Join Data floods from the senders

41

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