CMPE 257: Wireless and Mobile Networking

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Lecture 7

CMPE 257 Winter'11
Announcements

• Project proposals.
  – Everyone who submitted proposals should have gotten feedback.
  – If I miss anyone, please let me know ASAP!
Announcements (Cont’d)

• Student presentations.
  – So far:
    • Jim: security in MANETs.
    • Philip: power management or DTNs.
    • Tyler: mobility management.
    • Seth: security in sensor networks.
  – Need to hear from others ASAP!
Announcements (Cont’d)

• Next class, Wed, 02.02:
  – Prof. Hamid Sadjadpour from UCSC EE
guest lecturing on capacity of wireless
  networks.
Today

• Multicast routing.
MANET Multicast Routing
What is multicast routing?

- Unicast, multicast, anycast, broadcast, geocast, ...

Multicast routing or application-level multicast?
Multicast Communication in Ad Hoc Networks

• Group communication applications:
  – Tele-conferencing.
  – Emergency response.
  – Interactive games, etc.
Multicast Routing: 
Classification

• Based on type of routing “fabric”:
  – Tree- versus mesh-based.
  – E.g., ODMRP and CAMP are mesh-based, while MAODV is tree-based.

• Route discovery and maintenance:
  – Proactive versus reactive.

• Multicast session initialization:
  – Sender- versus receiver-initiated.
Multicast Routing Model

• Similar to IP multicast.
• A multicast group is defined with a unique group identifier.
• Nodes may join or leave the multicast group anytime.
MAODV [Royer00Mobicom]

• 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.
• In becoming a group leader, the node broadcasts a Group Hello message.
AODV Group Sequence Number

• In our illustrations, we will ignore the group sequence numbers

• However, note that a node makes use of information received only with recent enough sequence number
AODV Multicast Tree

- Group leader
- Multicast tree links
- Group and multicast tree member
- Tree (but not group) member
Joining the Multicast Tree: AODV

Group leader

N wishes to join the group: it floods RREQ

Route Request (RREQ)
Joining the Multicast Tree:
AODV

E
L
H
J
D
C
G
A
K
N

Group leader

RREPs are generated in response to N’s REQ.

Route Reply (RREP)
Joining the Multicast Tree: AODV

Group leader

N activates the branch where it received the RREP that arrives first.

Multicast Activation (MACT)
Joining the Multicast Tree: AODV

Group leader

N has joined the group. Note that K is a tree member now but not a group member.

Group member

Tree (but not group) member
Sending Data on the Multicast Tree

• Data is delivered along the tree edges maintained by the Multicast AODV algorithm.

• If a node that does not belong to the multicast group wishes to multicast a packet.
  – It sends a *non-join* RREQ which is treated similar in many ways to RREQ for joining the group.
  – 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 edges.
Leaving a Multicast Tree: AODV

J wishes to leave the group

Multicast tree links
Leaving a Multicast Tree: AODV

Since J is not a leaf node, it must remain a tree member.
Leaving a Multicast Tree: AODV

N wishes to leave the multicast group

Group leader

MACT (prune)
Leaving a Multicast Tree: AODV

Node N has removed itself from the multicast group.

Now node K has become a leaf, and K is not in the group. So node K removes itself from the tree as well.
Leaving a Multicast Tree: AODV

Nodes N and K are no longer in the multicast tree.
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 that 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.
Handling Partitions: AODV

• When failure of link (X,Y) results in a partition, the downstream node, say X, initiates Route Request
• If a RREP is not received in response, then node X assumes that it is partitioned from the group leader
• A new group leader is chosen in the partition containing node X
• If node X is a multicast group member, it becomes the group leader, else a group member downstream from X is chosen as the group leader
Merging Partitions: AODV

• If the network is partitioned, then each partition has its own group leader

• When two partitions merge, group leader from one of the two partitions is chosen as the leader for the merged network
  – The leader with the larger identifier remains group leader
Merging Partitions: AODV

- Each group leader periodically sends Group Hello
- Assume that two partitions exist with nodes P and Q as group leaders, and let \( P < Q \)
- Assume that node A is in the same partition as node P, and that node B is in the same partition as node Q
- Assume that a link forms between nodes A and B
Merging Partitions: AODV

• Assume that node A receives *Group Hello* originated by node Q through its new neighbor B
• Node A asks *exclusive* permission from its leader P to merge the two trees using a special *Route Request*
• Node A sends a special *Route Request* to node Q
• Node Q then sends a *Group Hello* message (with a special flag)
• All tree nodes receiving this *Group Hello* record Q as the leader
Merging Partitions: AODV

Hello (Q)
Merging Partitions: AODV

RREQ (can I repair partition)

RREP (Yes)
Merging Partitions: AODV

RREQ (repair)
Merging Partitions: AODV

Q becomes leader of the merged multicast tree

New group sequence number is larger than most recent ones known to P and Q both
Summary: Multicast AODV

- Similar to unicast AODV.
- Uses leaders to maintain group sequence numbers, and to help in tree maintenance.
- Tree-based approach.
  - Less robust.
  - Shared-tree.
On-Demand Multicast Routing Protocol (ODMRP)

- ODMRP builds a multicast mesh for multicast packet delivery.
- A sender node wishing to send multicast packets periodically floods a Join Query packet throughout the network.
  - Periodic transmissions are used to update the routes.
On-Demand Multicast Routing Protocol (ODMRP)

• Assume that S is a sender node
On-Demand Multicast Routing Protocol (ODMRP)

Diagram:

- **S**: Source
- **N**: Intermediate node
- **M**: Intermediate node
- **A**: Multicast group member
- **T**: Intermediate node
- **D**: Intermediate node
- **C**: Intermediate node
- **B**: Intermediate node

Join Query:
- From S to N
- From N to M
- From M to A
- From T to D
- From D to C
- From C to B

*Multicast group member*
On-Demand Multicast Routing Protocol (ODMRP)

- Each multicast group member on receiving a Join Query, broadcasts a Join Table to all its neighbors
  - Join Table contains \((\text{sender } S, \text{next node } N)\) 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 \(S\)
On-Demand Multicast Routing Protocol (ODMRP)

[Diagram showing network nodes and multicast group members]

- Multicast group member

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On-Demand Multicast Routing Protocol (ODMRP)

F marks a forwarding group member
On-Demand Multicast Routing Protocol (ODMRP)

Join Table: \((S, S)\)

Multicast group member
On-Demand Multicast Routing Protocol (ODMRP)

Multicast group member

Join Query (T)
On-Demand Multicast Routing Protocol (ODMRP)
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
ODMRP

- No explicit join or leave procedure
- A sender wishing to stop multicasting data simply stops sending Join Query 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 Query floods from the senders
CAROM: Context-Aware Routing over Ordered Meshes

JJ Garcia-Luna
Rolando Menchaca

From Rolando’s presentation at Infocom 2010
Interest-Driven Routing

• Integrated routing:
  – The same control signaling is used to support unicast and multicast routing.
• The distinction between on-demand and proactive signaling for routing is eliminated.
• Interest-driven signaling is used instead.
Enclaves
A region of interest, or enclave, contains those nodes that are relevant for the flow.

Confines signaling to “regions of interest” and limits floodings.
A new active source forces a set of nodes to join to D’s enclave.
Enclaves: multicast
A multicast enclave has to cover all the members of the multicast group
A region of interest is composed by possibly many shortest paths
But, which one is the best?
But, which one is the best?
Let’s use end-to-end context information to compute the cost of the paths!
But, only consider paths in the region of interest!
CAROM

• A **cost metric** obtained from context information is collected by each node and disseminated along the regions of interest
• The cost of using a node to reach a destination is proportional to
  – its degree of local mobility
  – its local contention
  – the length of its data and control queues
• This cost is also inversely proportional to the number of feasible parents that the node has to reach the intended destination
Performance Results

• We present simulation results comparing
  – CAROM against ODMRP for the case of multicast traffic
  – CAROM against AODV and OLSR for the case of unicast traffic, and
  – CAROM against AODV with ODMRP and OLSR with ODMRP for the case of combined unicast and multicast traffic

• Performance metrics:
  – Packet delivery ratio
  – Generalized group delivery ratio (multicast)
  – End-to-end delay
  – Path-length specific end-to-end delay (unicast)
  – Group end-to-end delay (multicast)
  – Total and control overhead
Simulation Environment

• Qualnet 3.9
  – 100 nodes in a simulation area of 1700×1700m²
  – Combination of Group and Random Waypoint mobility models
    • 1-10m/s and pause time of 10s – R.W.
    • 1-10m/s and pause time of 10s – Group mobility
  – 802.11b at 2000000bps
  – MCBR and CBR
    • 1000 pkts per source, 10 packets per second
    • Exponentially distributed flows with variable mean inter arrival time and mean flow duration equal to one third of the total simulation time
Combined Multicast and Unicast Traffic – Delivery Ratio (5 ucast flows)

~25% delivery ratio

Twice as many groups
Combined Multicast and Unicast Traffic – E2E Delay (5 ucast flows)

Two orders of magnitude

one order of magnitude

Number of Concurrent Active Groups

Average End-to-End Delay (Seconds)
Combined Multicast and Unicast Traffic – E2E Group Delay

Three orders of magnitude
Combined Traffic – Path-length specific E2E Delay

three orders of magnitude
Combined Multicast and Unicast Traffic – Ctrl and Total Overhead (5 unicast flows)

- CAROM
- ODMRP
- AODV
- ODMRP
- OLSR

- ~constant
- >Ten times

Number of Concurrent Active Groups

Ctrl and Total Overhead (Avg. Num. of Pkts Tx. per Node)