An Interest-Driven Approach to Integrated Unicast and Multicast Routing in MANETs

PRIME: Protocol for Routing in Interest-defined Mesh Enclaves

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Motivation

- MANET applications require point-to-point and many-to-many communication
  - very few destinations are such that a large percentage of the nodes in the network have interest in them
- These application requirements are in stark contrast with the way in which today's MANET routing protocols operate
Motivation

- Current approaches
  - Support either unicast routing or multicast routing
  - Proactive and on-demand routing protocols for unicasting and multicasting are such that the network is flooded frequently
  - This is the case even when protocols maintain routing information on demand (e.g., AODV and ODMRP)
Motivation

- What We Know from Capacity Results:

  Signaling overhead of routing protocols should be close to $\Theta(1)$

  Confine signaling to "regions of interest" and limit floodings
Our proposal

- Integrated routing:
  - The same control signaling to support unicast and multicast routing
  - The distinction between on-demand and proactive signaling for routing is eliminated
  - Interest-driven signaling is used instead

- Interest-defined mesh enclaves are established and maintained
  - Connected components of a MANET over which control signaling and data packets for unicast or multicast flows are disseminated
Our proposal

- The Protocol for Routing in Interest-defined Mesh Enclaves (PRIME)
  - Interest-defined Routing
    - Enclaves
      - Activated and Deactivated
    - Enclaves for Data Packet Forwarding
      - Local Repairs
    - Adaptive Enclaves
Enclaves
Enclaves
Enclaves: unicast

Confine signaling to “regions of interest” and limit floodings.

A region of interest, or enclave, contains those nodes that are relevant for the flow.
Enclaves: unicast
A new active source force a set of nodes to join to D’s enclave.
Enclaves: unicast

The source lose its “interest” in destination D
Enclaves: unicast
Enclaves: multicast
Enclaves: multicast

A multicast enclave has to cover all the members of the multicast group

As well as paths from sources to the multicast group
Enclaves: multicast
Enclaves: multicast
Enclaves: multicast
Enclaves: multicast
Enclaves

The frequency with which multicast control messages are forwarded outside of the enclave decreases exponentially.

Algorithm 1: ENCLAVE(MA)

1. if \( \text{AddressType(MA.destination)} = \text{multicast} \) then
2. \hspace{1em} if \( \text{rc} \lor \text{sd} \lor \text{mm} \lor \text{pn} \) then
3. \hspace{2em} else
4. \hspace{3em} if \( r \mod R = 0 \) then
5. \hspace{4em} \( r++; \)
6. \hspace{4em} else
7. \hspace{5em} \( r++; \)
8. \hspace{5em} return \( false; \)
9. \hspace{2em} else
10. \hspace{3em} if \( \text{pn} \) then
11. \hspace{4em} else
12. \hspace{5em} return \( false; \)
13. return \( true; \)

Unicast control packets are not forwarded beyond a unicast enclave.
Enclaves: Activation and Deactivation
Enclaves: Activation and Deactivation

First data packet is piggybacked in a mesh-activation request (MR)
Enclaves: Activation and Deactivation

A **MR** contains, among other fields, an horizon threshold and the persistence of the interest.

First data packet is piggybacked in a mesh-activation request (**MR**).
Destinations, relays needed between them and the sources should remain active for as long as there are active sources in the connected component of the network.
Enclaves and k-Extended Enclaves
Enclaves and k-Extended Enclaves

We define the **k-extended enclave** as the union of the original enclave with those nodes located k-hop away from them.
Enclaves and k-Extended Enclaves
Mesh Establishment and Maintenance

Once a destination becomes active, it starts advertising its existence using mesh announcements (MA).

MAs establish a **partial ordering** of the nodes based on the nodes’ distance to the destination.
Data Packet Forwarding: Unicast

Data packets are routed using the inverse of the gradients established by the MAs.
Mesh Establishment and Maintenance: Multicast
Mesh Establishment and Maintenance: Multicast
Using **MAs**, multicast group members elect the core of the group.
Mesh Establishment and Maintenance: Multicast

Multicast mesh: Connected component that contains the group members

Shortest paths from sources to the multicast mesh
Data Packet Forwarding: Multicast
Data Packet Forwarding: Multicast

Directed meshes: Directed links
Data Packet Forwarding: Multicast

Multicast mesh: undirected links
Local Repairs

- Nodes located at directed meshes employ the transmission of data packets by their next hops as implicit ACKs.
- If a node fails to receive three consecutive implicit ACKs from a neighbor:
  - It removes that node from the neighborhood list and locally repair the mesh to the core or unicast destination.
  - These repairing mechanisms guarantee **instantaneous loop freedom**.
Adaptive Enclaves

- Nodes employ information collected at the MAC layer to select the strategy that best fits the nodes perceived channel conditions.

- We use the following three strategies to take advantage of that information:
  - Adjust the size of the mesh
  - Adjust the mesh dynamics
  - Adjust timers
Performance Results

- We present simulation results comparing PRIME against ODMRP and PUMA for the case of multicast traffic, as well as 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 and
  - Total overhead
## Performance Results: Simulation Environment

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Nodes</td>
<td>100</td>
</tr>
<tr>
<td>Node Placement</td>
<td>Random</td>
</tr>
<tr>
<td>Data Source</td>
<td>MCBR</td>
</tr>
<tr>
<td>MAC Protocol</td>
<td>802.11</td>
</tr>
<tr>
<td>Pkts. sent per src.</td>
<td>1000</td>
</tr>
<tr>
<td>Simulation Time</td>
<td>150s</td>
</tr>
<tr>
<td>Simulation Area</td>
<td>1800x1800m</td>
</tr>
<tr>
<td>Channel Capacity</td>
<td>2000000 bps</td>
</tr>
<tr>
<td>Transmission Power</td>
<td>15 dbm</td>
</tr>
<tr>
<td>Mobility Model</td>
<td>Random Waypoint</td>
</tr>
<tr>
<td>Pause Time</td>
<td>10s</td>
</tr>
<tr>
<td>Min-Max Vel.</td>
<td>1-10m/s</td>
</tr>
<tr>
<td>Mobility Model</td>
<td>Group Mobility</td>
</tr>
<tr>
<td>Grp. Pause Time</td>
<td>10s</td>
</tr>
<tr>
<td>Grp. Min-Max Vel.</td>
<td>1-10m/s</td>
</tr>
<tr>
<td>Node Pause Time</td>
<td>10s</td>
</tr>
<tr>
<td>Node Min-Max Vel.</td>
<td>1-10m/s</td>
</tr>
</tbody>
</table>
Increasing Number of Sources: Group Mobility – Delivery Ratio
Increasing Number of Sources: Group Mobility – Group Delivery Ratio
Increasing Number of Sources: Group Mobility – E2E Delay

Group Mobility: 100 nodes, 1 group of 20 nodes, 10 packets per second

Average End-to-End Delay (Seconds) vs. Number of concurrent active sources
3 Sources per Group, Group Areas of 900x900m – Delivery Ratio

Grp area 900x900m, grps of 15 nodes, 3 sources per grp and 10 pkts per second
3 Sources per Group, Group Areas of 900x900m – Group Delivery Ratio
3 Sources per Group, Group Areas of 900x900m – E2E Delay

Grp area 900x900m, grps of 15 nodes, 3 sources per grp and 10 pkts per second

Average End-to-End Delay (Seconds)

Number of concurrent active groups
Combined Multicast and Unicast Traffic – Delivery Ratio (5 ucast flows)
Combined Multicast and Unicast Traffic – Group Delivery Ratio (5 unicast flows)

Grp area 900x900m, grps of 15 nodes, 3 src per grp, 5 unicast flows

- PRIME
- ODMRP+AODV
- ODMRP+OLSR

Group Delivery Ratio (60%) vs Number of concurrent active groups
Combined Multicast and Unicast Traffic – E2E Delay (5 unicast flows)

Grp area 900x900m, grps of 15 nodes, 3 src per grp, 5 unicast flows

- PRIME mcast
- PRIME ucast
- ODMRP with AODV
- AODV with ODMRP
- ODMRP with OLSR
- OLSR with ODMRP

Number of concurrent active groups

Average End-to-End Delay (Seconds)
Combined Multicast and Unicast Traffic – Ctrl and Total Overhead (5 unicast flows)
Conclusions

We have shown by example that it is possible and perhaps desirable to support the dissemination of information for end user applications using a single routing protocol, and

- Should Interest-driven routing be adopted for MANETs?
Conclusions

The results of a series of simulation experiments illustrate that PRIME attains:

- Higher delivery ratios than ODMRP and PUMA for multicast traffic
- Higher delivery ratios than AODV and OLSR for unicast traffic.
- At the same time, PRIME induces much less communication overhead and attains lower delays than the other routing protocols.
Thanks!

Questions?