Energy-Efficient MANET Routing: Ideal vs. Realistic Performance

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- Review: Link-State Routing
- Prerequisite: OLSR (Optimized Link-State Routing) Protocol
- Modified OLSR
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- Discussion
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**MANET Characteristics**

- **MANET**
  - Autonomous system of mobile *routers* and hosts connected by *wireless links*

- **Resource constraints:**
  - Wireless medium bandwidth
  - Battery power
  - Processing speed
  - Memory

- **Protocol Performance:**
  - Packet delivery ratio
  - Packet latency
  - Control message overhead
Accurate versus Inaccurate Energy Levels

- Observations from the paper
  - Ideal case
    - Nodes know 'actual' energy levels
  - Real case
    - Nodes know energy levels through exchange of control messages

- 'Ideal' is always better than 'Real'
Unicast MANET Routing

Taxonomy for MANET Protocols

- **Table-Driven/Proactive**
  - Distance Vector
  - Link-State
  - DSDV
  - OLSR
  - TBRPF
  - FSR
  - STAR

- **Hybrid**
  - ZRP

- **On-Demand-driven/Reactive**
  - DSR
  - AODV
  - TORA

- **Clusterbased/Hierarchical**
  - LANMAR
  - CEDAR
Reactive versus Proactive routing approach

- **Proactive Routing Protocols (e.g. OLSR)**
  - Periodic exchange of control messages
  - + Immediately provides the required routes when needed.
  - - Larger signalling traffic and power consumption.

- **Reactive Routing Protocols (e.g. AODV)**
  - Attempts to discover routes only on-demand by flooding
  - + Smaller signalling traffic and power consumption.
  - - A long delay for application when no route to the destination is available.
LSR Protocol
Link-State Routing Tables

- The local metric information is flooded to all routers
- After convergence, all routers have the same information

<table>
<thead>
<tr>
<th>rtr</th>
<th>net</th>
<th>cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>A n1</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>A n2</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>B n3</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>B n2</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>B n4</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>C n1</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>C n4</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>C n5</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>D n6</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>D n5</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>E n6</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>E n7</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>F n1</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>F n7</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>
- Only arrows with metrics between routers
- Every node executes the shortest path computation on the graph – same graph, but different sources
Routing Table at A using Dijkstra’s
OLSR Protocol
OLSR

Overview

- Inherits Stability of Link-state protocol
- Reduces the size of control packets
  - declares only a sub-set of links
- Minimizes flooding
  - only Multipoint Relays (MPRs) retransmit control messages
- Suitable for large and dense networks
Multipoint Relays (MPRs)

- **MPRs** = Set of selected neighbors
- **MPR Selector** = a node which has selected node as MPR

Each node selects its MPRs among its one hop neighbors

- The set covers all the nodes that are two hops away
- Links to MPR’s are bi-directional
- Nodes calculate routes through MPR’s

4 retransmissions to diffuse a message up to 2 hops
Optimal MPR set = \{M\}

• MPR set = subset of 1-hop neighbors providing access to 2-hop neighbors = \{M\}

• Optimal \{M\} = NP- Hard

• MPR Selection Heuristic:

  For node (N)
  – \{M\} = 0
  – Add to \{M\}
    1-hop neighbors of (N) with maximum # of 2-hop neighbors
  – Until all 2-hop neighbors are covered
Neighbor Sensing

Figure. Building neighbor table

<table>
<thead>
<tr>
<th>Neighbor’s id</th>
<th>State of Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Bidirectional</td>
</tr>
<tr>
<td>B</td>
<td>Unidirectional</td>
</tr>
<tr>
<td>M</td>
<td>MPR</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Neighbor’s id</th>
<th>Access through</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z</td>
<td>M</td>
</tr>
<tr>
<td>R</td>
<td>M</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>
Which nodes have chosen (*) as their MPR:

Selector table of (M)

N

Selector table of (N)

S, P

Figure. Building MPR selector table
Topology Control (TC) Messages

- Each MPR node **periodically broadcasts** TC messages to the entire network to declare its MPR selector set.
- TC message holds list of neighbors who have selected this node as a MPR.
- TC messages may be sent before period if any change in sector set, or not sent if set is empty.

<table>
<thead>
<tr>
<th>Senders address</th>
<th>MPR Set</th>
<th>MPR Selector sequence number</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>{N, ….. }</td>
<td></td>
</tr>
</tbody>
</table>

**Originator of TC message**

**MPR Selector set of sender**

**Fig. TC message**

**TC message (M send to N)**

<table>
<thead>
<tr>
<th>TC’ originator</th>
<th>MPR selector</th>
<th>MPR selector sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>X</td>
<td>2</td>
</tr>
<tr>
<td>M</td>
<td>Y</td>
<td>2</td>
</tr>
<tr>
<td>M</td>
<td>Z</td>
<td>2</td>
</tr>
<tr>
<td>M</td>
<td>R</td>
<td>2</td>
</tr>
</tbody>
</table>
Each node maintains a Topology Table based on TC messages

- Nodes record info of MRPs of other nodes in this table
- Routing tables are built based on topology tables

<table>
<thead>
<tr>
<th>Destination address</th>
<th>Destination MPR</th>
<th>MPR Selector sequence number</th>
<th>Holding time</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>M</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- MPR Selector in the received TC message
- Last-hop node to the destination.
- Originator of TC message

### N’s Topology table

<table>
<thead>
<tr>
<th>Dest’ address</th>
<th>Dest’ MPR</th>
<th>MPR Selector sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>M</td>
<td>1</td>
</tr>
<tr>
<td>Y</td>
<td>M</td>
<td>1</td>
</tr>
<tr>
<td>Z</td>
<td>M</td>
<td>1</td>
</tr>
<tr>
<td>..</td>
<td>..</td>
<td>..</td>
</tr>
</tbody>
</table>

Figure. Topology table
Routing Table Information

- Each node maintains a routing table to all known destinations in the network

- After each node receives TC message, store connected pairs of form (last-hop, node)

  Routing table:
  ◆ Destination address
  ◆ Next Hop address
  ◆ Distance

- Routing Table is recalculated after every change in neighbor table or in topology table
Building Routes

Figure. Building a route from topology table

<table>
<thead>
<tr>
<th>Dest’ address</th>
<th>Next hop</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>D</td>
<td>5</td>
</tr>
</tbody>
</table>

H’s Routing table
Modified OLSR Protocol
(for Energy Efficiency)
Why Energy Efficiency?

- Nodes expend energy in packet sending and receiving modes
- *Minimum hop count* tends to choose packets in the center of the network:
  - many packets contend, causing high collisions, retransmissions and packet loss
  - central nodes disproportionately loose energy first
- **OLSR** uses minimum hop count metric
Objective

- Explores the impact of inaccurate/imprecise energy information

- Each node accurately knows the *remaining* energy levels of other nodes

  vs

  The energy level information is at best an *approximation*

- Modified OLSR – propagate residual energy values through control msgs

- **Assumption**: each node has access to other nodes energy levels
Modified OLSR

• MPR Selection Heuristic:

For node (N)
- \{M\} = 0
- Add to \{M\}
  1-hop neighbors of (N) with maximum residual energy levels
- Until all 2-hop neighbors are covered

• *Avoids* routes with low residual energy levels
New Path Selection

For link (i,j)
- use reciprocal energy level of node i
- assign level to (i,j)

Build path from S to D
shortest path with min link weight
(i.e - maximum residual energy levels)

- *Avoids* routes with low residual energy levels
Modified OLSR Messages

● Extended HELLO msgs:
  - List of addresses of neighbors + most recent energy level association (senders perspective)

● Extended TC msgs:
  - List of addresses of a nodes MPR selector + most recent energy level association (originators perspective)
Variants

- Modified Routing:
  - Original MPR selection, new path selection algorithm

- Modified MPR/ Routing:
  - New MPR selection, new path selection algorithm

Modified OLSR Variants

- Modified MPR/ Routing
  - Ideal
  - Real

- Modified Routing
  - Ideal
  - Real
Simulation Settings

- NS-2 Simulator
- 1000m x 1000m area, 50 nodes
- 802.11 wireless interface, 250m tx range
- 4 intervals: 0.2, 0.14, 0.09, 0.04 seconds
- Performance:
  - Total number of packets successfully delivered (not PDR)
Protocol Variant Performance for Static Network Scenario

Randomly placed, nodes do not move
Protocol Variant Performance for Low Mobility Network Scenario

RWP, 2m/s pausetime 10 seconds = pedestrian mobility
Protocol Variant Performance for High Mobility Network Scenario

20m/s (72 km/h) = vehicular mobility
Conclusions

- Ideal case is better than real case
- When more congested network, MPR energy matters
- Delivery degrades due to mobility
- Future work: improving realistic accuracy
  - Increasing TC and HELLO msgs may return better results
References

- Prof. UT's slides for CSE-6590, Fall '13
- OLSR RFC-3626
- “Mobile ad-hoc networks based on wireless LAN” - Qamar Abbas Tarar (Presentation)
- “Link State Routing” – Jean-Yeavs Le Bourdec (Presentation)