Robustness of Receiver-driven Multi-hop Wireless Network with Soft-state Connectivity Management

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Outline
- Background of our research
- Intermittent Receiver-driven Data Transmission (IRDT)
- Our goal
- Soft-state connectivity management
- Performance evaluation by computer simulation
- Conclusion

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Intermittent operation for energy saving
- Intermittent operation of sensor node
  - Alternating ‘active’ / ‘sleep’ states repeatedly at the intermittent interval
  - Communicating in ‘active’ state
  - Saving energy consumption with ‘sleep’ state
- Intermittent Receiver-driven Data Transmission (IRDT)

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Wireless sensor networks
- Consisted of a number of sensor nodes
  - Collect data over a large area
    - “Temperature”, “humidity”, “light”, and etc.
- Limited batteries
  - Energy saving is necessary
- Low reliability
  - Robustness is necessary
- Nodes are prone to failure
- Poor quality of wireless channel

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IRDT: MAC layer
- Receiver nodes
  - Transmit own ID periodically
  - Sleep to save energy
- Sender nodes
  - Wait for a receiver’s ID
  - Return an SREQ according to the routing layer
- Sender nodes can communicate with multiple receivers
  - Decrease of sender nodes’ active time
    - Save energy!
  - Construction of mesh networks
    - Improve robustness?
    - Depending on routing layer!

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IRDT: Routing layer
- Based on distance vector routing
  - All nodes have hop count tables and exchange them
  - SREQ transmission depends on minimum hop routing
- Hard-state management of neighbor node in hop count table and neighbor nodes’ hop count tables
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Flexible route selection!
Our goal

- Improve robustness of wireless sensor network using IRDT
  - Robustness: the property that allows network performance to maintain or recover against environmental changes
  - Propose a soft-state management of routing information in IRDT

Performance evaluation by using computer simulation
- Evaluate overhead of soft-state management
- Evaluate robustness of soft-state management

Soft-state management

- Periodical ID transmission in IRDT is used as update message
- Each node listens channel for obtaining IDs every $T_i$

Management of neighbor node
- Register ID-sender in hop count table as a neighbor node
- Delete a neighbor node from hop count table if the neighbor node’s ID cannot be arrived during $T_i$

Management of neighbor node’s hop count table
- Exchange hop count table after receiving ID
- Delete the neighbor node’s hop count table if the neighbor node’s ID cannot be arrived during $T_i$

Simulation Model

- 100 sensor nodes are randomly deployed
- 2 sink nodes are arranged at two corners

Overhead evaluation
- Compare with sender-driven MAC (AX-MAC)
- Against sink node failure

Robustness evaluation
- Small $T_i$: soft state
- Larger $T_i$: hard state

Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission speed</td>
<td>100 kbps</td>
</tr>
<tr>
<td>Transmission range</td>
<td>100 m</td>
</tr>
<tr>
<td>Data packet generation rate</td>
<td>0.003 packet/s/node</td>
</tr>
<tr>
<td>Current consumption (TX)</td>
<td>20 mA</td>
</tr>
<tr>
<td>Current consumption (RX)</td>
<td>25 mA</td>
</tr>
<tr>
<td>Current consumption (Sleep)</td>
<td>0 mA</td>
</tr>
<tr>
<td>Packet size (ID, SREQ)</td>
<td>24 byte</td>
</tr>
<tr>
<td>Packet size (RACK, DACK)</td>
<td>22 byte</td>
</tr>
<tr>
<td>Packet size (DATA)</td>
<td>128 byte</td>
</tr>
</tbody>
</table>

Simulation Model

- IRDT (1.0 s) and AX-MAC (0.1 s) are unaffected

Evaluation of overhead of soft-state management

Traffic overhead

- Mainly caused by hop count table exchanges
- Small $T_i$ decreases packet collection ratio
- IRDT (1.0 s) and AX-MAC (0.1 s) are unaffected
Evaluation of overhead of soft-state management

**Energy overhead**

- Mainly caused by update message listening
- Nodes must listen at least for one intermittent interval
- Energy consumption of IRDT (1.0 s) is smallest
- Packet collection ratio of IRDT (1.0 s) is highest

Evaluation of robustness against sink node failure

**Robustness of energy consumption**

- Soft-state management improves robustness of maximum energy consumption
- Average energy consumption slightly increases

Conclusion

- Evaluate overhead of soft-state management in IRDT
  - On packet collection ratio, traffic overhead is very low
  - On energy consumption, lower overhead than sender-driven MAC protocol
- Evaluate robustness against sink node failure in IRDT with soft-state management
  - 44 % improvement of packet collection ratio 1000 s after sink node failure
  - 87 % reduction of 90 % recovery time of packet collection ratio
  - 63 % reduction of maximum energy consumption
- Future work
  - Improvement of scalability in IRDT
  - All nodes use $N^2$ size of hop count table ($N$ is the number of nodes)

Thank you