Overview

- Aims and assumptions
- Basic approach of disaster reporting
- HexNet mapping scheme
- Proposed protocol for disaster reporting
- Features of the protocol
- HexNet routing algorithm
- Simulations
- Conclusion

Motivation

- Monitoring of remote disaster-prone environments using sensor networks.
- Reporting the disaster’s scale (size of disaster) and location.
- Sensor nodes are destroyed!
  - Must be kept cheap and easily replaceable.

Aims and Assumptions

- A sensor network which reports disaster-scale (size) and location
- Sensor nodes are not equipped with global positioning system (GPS)
  - reduce cost of the sensors as they are prone to destruction in the targeted application scenario.
- A mapping scheme for sensors in order for the sink to effectively determine location and scale of disaster
- Sensor nodes are static and their placement follows rules, outlined in the mapping scheme.
- Sensor nodes perform one-hop transmission.

Basic Approach

- When a disaster occurs, the nodes in the affected region are destroyed.
- The nodes surrounding the affected area notice the disaster by death of their neighbor nodes that resided in the affected area.
- Nodes which notice the disaster issue alert messages which are forwarded to the sink via other intermediate nodes.
- Only nodes which physically sense the disaster and neighbor nodes leading in the direction of the sink take part in routing alerts.

Mapping Scheme

- Sensors are arranged at equal distances from each other in a hexagonal-style grid.
- Sensors closer to the sink have a lower Range ID than nodes further away.
- The sensors’ Range IDs increment with increasing distance from sink.
- The position of individual sensors is determined by a combination of two identifiers involving a Range ID and Angular ID.
**Range ID and Angular ID**

The node’s Range ID (RID) together with the Angular ID (AID) is used to determine the location of the node. This combination gives the precise location of the node relative to the sink.

Although neither the RID nor AID is unique by itself, the combination of the two is unique for each node in the network.

**The AID increments for each repeating RID.** E.g., the next node with RID of 4 (clockwise) would have AID of 11.

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**The Mapping System and Angular ID Calculation**

\[ \text{AID} = 3(1 - \sin \theta) + 1 \]

where \( \theta \) is the angle (in degrees) relative to the sink and \( n \) is the RID of the node.

Using the sine rule, the actual physical distance from sink to node for \( D \) is:

\[ D = \frac{m_1}{2} \cos \theta R \]

where \( m \) is node’s RID of the node, \( R \) is the distance between sink and the location of the node (constant), \( \theta \) is the relative angle of node \( n \) from the sink.

\[ \theta = \sin^{-1} \left( \frac{D}{R} \right) \]

**Disaster Reporting Scheme Overview**

- When a sensor node “senses” a disaster, it will respond to this by broadcasting an “alert request” to its neighboring nodes. Neighboring (1-hop) nodes that receive this message will then reply to this alert request stating their “alert” status.
- Sensors know the number of neighbors in their vicinity \( n_0 \) (6 in the normal case) and hence the number of replies they are supposed to receive upon their alert request.
- If a sensor node does not receive \( n_0 \) replies, where \( n_0 \) is the number of neighbors informing the node ID of nodes which have not replied. Neighbors which are closer to the sink than the node issuing the alert message will rebroadcast the message unless all better nodes are destroyed, in which case the next best node either forwards or decides to simply not forward the message*. This continues until the sink receives the disaster messages (from nodes surrounding the disaster area).
- The sink then sends all the messages to the appropriate authority centre (via the internet/satellite/etc.) where the region of disaster and disaster scale is determined using knowledge of all nodes which have been destroyed.

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**Disaster Reporting Scheme Flowchart**

- **Local alert**
- **Broadcast alert request**
- **Collect alert replies**
- **Issue alert message**
- **No. of replies \( n_0 \)**
- **Do nothing**

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**Sensing and Reporting**

*Neighbor node’s responses to the Alert request messages.*

<table>
<thead>
<tr>
<th>Sensing Node</th>
<th>Expected Replies</th>
<th>Actual Replies</th>
</tr>
</thead>
<tbody>
<tr>
<td>51</td>
<td>( 4_{13} 5_{14} 6_{15} 3_{16} 4_{17} )</td>
<td>( 4_{13} 5_{14} 6_{15} 3_{16} 4_{17} )</td>
</tr>
<tr>
<td>61</td>
<td>( 5_{21} 5_{22} 3_{23} 4_{24} 6_{25} )</td>
<td>( 5_{21} 5_{22} 3_{23} 4_{24} 6_{25} )</td>
</tr>
<tr>
<td>52</td>
<td>( 5_{21} 5_{22} 3_{23} 4_{24} 6_{25} )</td>
<td>( 5_{21} 5_{22} 3_{23} 4_{24} 6_{25} )</td>
</tr>
<tr>
<td>62</td>
<td>( 4_{21} 5_{22} 3_{23} 4_{24} 6_{25} )</td>
<td>( 4_{21} 5_{22} 3_{23} 4_{24} 6_{25} )</td>
</tr>
<tr>
<td>71</td>
<td>( 3_{21} 4_{22} 5_{23} 6_{24} 3_{25} )</td>
<td>( 3_{21} 4_{22} 5_{23} 6_{24} 3_{25} )</td>
</tr>
<tr>
<td>72</td>
<td>( 3_{21} 4_{22} 5_{23} 6_{24} 3_{25} )</td>
<td>( 3_{21} 4_{22} 5_{23} 6_{24} 3_{25} )</td>
</tr>
</tbody>
</table>

*Note: The exact replies may vary depending on the network topology and node placements.*
Node Types and their function

<table>
<thead>
<tr>
<th>Node Type</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Failed/Destroyed Node</td>
<td>Nothing</td>
</tr>
<tr>
<td>Sensing Node</td>
<td>Broadcast alive request messages</td>
</tr>
<tr>
<td></td>
<td>Collect ‘alive’ messages</td>
</tr>
<tr>
<td></td>
<td>Send Alert to neighbors</td>
</tr>
<tr>
<td>Forwarding Node</td>
<td>1. Check the Alert message to see whether it is the best node to forward.</td>
</tr>
<tr>
<td></td>
<td>2. If so, broadcast, otherwise ignore.</td>
</tr>
<tr>
<td>Sink</td>
<td>Forward messages to Disaster Management centre</td>
</tr>
</tbody>
</table>

Cost Metric

The cost of node X to the sink is

\[ \text{Cost}_X = w_1E_1 + w_2HCP_X + w_3D_X \]

where \( E_1 \) is the current normalized energy of node X, \( HCP_X \) is the HCP of node X to the sink, \( D_X \) is the physical distance of node X to the sink (calculated using \( R_{D_{heat/sound/electrical}} \), \( w_1, w_2, \) and \( w_3 \) are the weights for the significance of (individual node) energy and delay in routing respectively, and \( 0 \leq w_1, w_2, \leq 1 \).

HexNet Routing Algorithm

1. A sensor node X senses a physical change in its environment (heat/sound/electrical surge), which could be caused by a potential disaster.
2. Node X broadcasts an Alive Request (AREQ) to its 1-hop neighbors, and initiates a timer for Alive Reply (AREP) collection.
3. If node X also receives an AREQ, it will wait until it receives AREPs from its neighbors.
4. Once all the expected number of AREPs are received from X’s alive neighbors, or when the timeout is reached, node X will calculate its own HCP using knowledge of failed neighbors, then append this value to the AREP and broadcast it. At this time, the LNNT is updated.
5. Node X will then use the collected information (parameters shown in LNNT) to calculate the cost and decide on Alert broadcasting.

Hop Prediction to Sink

- A node can predict the number of hops to the sink from the knowledge of its failed neighbor nodes.
- The prediction is represented and updated in an integer field called the Hop Count Predictor (HCP) in the Alert message header. The HCP is defined as follows:
  1. HCP is set to the RID initially.
  2. It is incremented by 1 if the new best node for forwarding has a RID equal to the parent node.
  3. It is incremented by 3 if the new best node for forwarding has a RID greater than the parent node.

Local Neighbor Node Table (LNNT)

Each node possesses a local neighbour node table (LNNT) containing information about its neighbour, such as their status, HCP, and the neighbours which are within a 1-hop range of each other.

<table>
<thead>
<tr>
<th>Node</th>
<th>Neighbors</th>
<th>Status</th>
<th>HCP</th>
<th>Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>3, 4, 5</td>
<td>ALIVE</td>
<td>78</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>2, 5</td>
<td>ALIVE</td>
<td>78</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>2, 3, 5</td>
<td>ALIVE</td>
<td>78</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>3, 2, 4</td>
<td>ALIVE</td>
<td>78</td>
<td>10</td>
</tr>
</tbody>
</table>

In this case, 2激烈的 has a HCP of 5. It knows that one of its neighbours namely 3激烈的 has a lower HCP of 4. When it receives an Alert from 4激烈的 via 3激烈的, it will NOT broadcast it as it knows that 3激烈的 (being a neighbor of 2激烈的) can broadcast it with a smaller cost as it has a smaller HCP.

Packet Format

- Alive Request (AREQ)
  - \( \text{RID}_{AREQ} \)
- Alive Reply (AREP)
  - \( \text{RID}_{AREP} \)
  - HCP
  - energy level
- Alert Message
  - \( \text{RID}_{alert} \)
  - Failed Neighbor Nodes (RID)
  - HCP
  - energy level
Simulations

- 1260 nodes
- 1.5 m uniformly spaced
- 60 m by 60 m area
- Failed nodes located at an angle of 60 degrees relative to the sink and with a distance RID of 15-17.
- $w_1, w_2, w_3$ set to 1.
- In the model, each time a node broadcasts a message, the node loses one unit of energy.
- Two schemes simulated:
  - HexNet algorithm without LNNT
  - HexNet algorithm with LNNT

Results

<table>
<thead>
<tr>
<th>No. of failed nodes</th>
<th>No. of participating nodes in alert routing.</th>
<th>Relative energy consumption in alert forwarding.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>20</td>
<td>0.5</td>
</tr>
<tr>
<td>2</td>
<td>40</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>60</td>
<td>1.5</td>
</tr>
<tr>
<td>6</td>
<td>80</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>No. of failed nodes</th>
<th>Average energy consumption per node.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.2</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>1.8</td>
</tr>
<tr>
<td>6</td>
<td>2.6</td>
</tr>
</tbody>
</table>

Conclusions

- Proposed a new alert-based routing platform and mapping scheme for environmental field-based wireless sensor networks with the intent of reporting disaster location and scale.
- The proposed HexNet mapping and routing is aimed at disaster-monitoring environments where sensor nodes are kept at lowest cost (not equipped with localization devices such as GPS) as they are prone to inevitable destruction.
- Future work should aim at further relaxation of the strict requirements of the mapping scheme and further optimization of weight selection. Additional performance evaluation of the proposed scheme is also required.

Thank You.