Multi-hop Unequal Clustering Routing for Wireless Sensor Networks

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\section*{Abstract.} Wireless Sensor Networks (WSN) are gaining popularity with every passing day because of their many-faceted application deployment. Unfortunately, limited energy of WSNs causes unpredictability in network lifetime and connectivity. So the important constraint is limited energy, which is caused by the failure to replace batteries or power sources. This affects in designing routing protocols. Energy-Efficient Routing protocols are therefore necessary for delivering sensed data to the base station/gateway/sink. Other major constraints that affect designing different protocols for WSNs are unreliable and low quality communication, limited computational resource and scalability. To overcome these problems, we propose an algorithm that uses Multi-hop Unequal Clustering (MUC).

\textit{Keywords:} WSN, Hierarchical routing, Tentative cluster-head, Voronoi diagram, Convex Hull.

\section{1. Introduction}

Wireless Sensor Networks (WSN) has now become a popular network. This technology is expected to have a significant impact on our lives in the twenty-first century. In this network, the sensor nodes (motes) communicate with each other through wireless media. The organization of the network may be flat or hierarchical. Cluster analysis [1] or clustering is the task of grouping a set of objects (here, sensor nodes) in such a way that objects in the same group (called cluster) may have a leader (cluster-head), responsible for maintaining communication with the rest of the network, thereby forming a hierarchical network. Scalability is one of the important attributes of WSN. To allow the system to manage with additional load and be able to cover large area without degrading the service, clustering proves to be more efficient. The main aim of hierarchical routing is to efficiently maintain the energy consumption of sensor nodes by involving them in multi-hop communication within a particular cluster and by performing data aggregation and fusion in order to decrease the number of transmitted messages to the base station (BS).

\section{2. Related Work}

A number of hierarchical routing protocols are proposed in literature. Below is presented a brief critical analysis of some of these.

In LAECH [2], the cluster-heads are selected on the basis of received signal strength and clusters are formed on the basis of transmission range of selected Cluster-Heads. However, LEACH uses single-hop routing where each node can transmit directly to the cluster-head and the sink. So, it is not applicable to networks deployed in large area.

PEGASIS [2,3] is an advanced part of LEACH protocol. PEGASIS forms chains from sensor nodes and collected data is aggregated further and eventually sent to the BS. The chain is formed using greedy concept. The main difference with LEACH is the use of multi-hop. However, PEGASIS introduces excessive delay for distant node on the chain. Hierarchical PEGASIS [5] decreases the delay incurred for packets during transmission to the BS.

An important characteristic of TEEN [2,4] is responsiveness. However, TEEN is not good for applications where periodic reports are needed since the user may not get any data at all if the thresholds are not reached.

APTEEN [2,5,6] protocol is an extension of TEEN and aims at both capturing periodic data collections and reacting to time critical events. The main disadvantages of above two approaches are overhead and complexity of forming clusters in multiple levels.

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3. Basic Concepts and Assumption

To overcome the disadvantages of LEACH routing protocol, that is, equal-clustering concept, we propose here an algorithm for clustering. Let us consider a sensor network consisting of ‘\(N\)’ sensor nodes randomly deployed over a vast field to continuously monitor the environment. We assume

a) All nodes are homogeneous and have the same capabilities. Each node is assigned a unique identifier (ID).

b) There is a Base Station (BS) located away from the area of sensing field.

4. Working of MUC

The proposed protocol is a Multi-hop Unequal Clustering (MUC) routing protocol. This algorithm is divided into two phases. These are:

A) Set-up Phase
B) Data Transmission Phase

A) Set-up phase: The phase consists of two sub-parts. First one is cluster-head selection and second one is cluster formation.

a) Cluster-Head Selection: The node nearer to base station takes dual role. One is to transmit its own data and another one is to forward data of other nodes. So the life-time of this node becomes lesser than others. A node can compute its appropriate distance with another node based on the received signal strength, if the transmission power is known. The nodes can use power control to vary the amount of transmission power which depends on the distance to the receiver. Thus the range of competition radius [8] in the network needs to be calculated.

b) Cluster Formation: Using the set of final cluster-head creating clusters using Voronoi Diagram [9,10] is a well-known methodology. The procedure consists of dividing a space into a number of regions. Each region is called Voronoi cell. It is dual to the Delaunay Triangulation [11,12]. Using Convex Hull technique, Voronoi Diagram scenario can be implemented. In clustering, the set \(P\) represents the set of FINAL-CHs.

B) Data Transmission phase: This phase is subdivided into two parts. These are:

a) Intra-Cluster Data Transmission
b) Inter-Cluster Data Transmission

These transmissions will be based on PEGASIS. It is an energy-efficient chain-based algorithm. The key idea of PEGASIS is to organize all sensor nodes to form a data chain for data transmission and reception. The data from nodes are aggregated and sent by respective cluster-heads to BS. Greedy algorithm [13,15] is used to form the data chain.

\[
E_{tx}(k, d) = E_{tx-elec}(k) + E_{tx-amp}(k, d) = E_{elec} * k + \Delta_{amp} * k * d^2
\]

And to receive this message, the radio expends [16]: \(E_{rx}(k) = E_{rx-elec}(k) = E_{elec} * k\).

5. Proposed Algorithm

For common nodes, the Euclidean distance between that node and each cluster-head nodes is considered. A non-cluster-head node selects a cluster depending upon smaller Euclidean distance from the cluster-head. In the case of equal Euclidean distance we consider the strength of received message from cluster-head.

The steps of selection of CH is shown in the following figure 1.

The algorithm is presented below:

1. For \(i = 1\) to \(n\) step \(i = i + 1\) then
2. Compute Euclidean-distance (\(a_i\), nearer CH)
3. If (Euclidean_distance, \(a_i <\) Transmission_Range.CH\(_p\)) \& \& // CH\(_p\) and CH\(_q\) are
4. (Euclidean_distance(\(a_i, CH_q\)) \> Euclidean_distance(\(a_i, CH_p\))) // adjacent FINAL-CH, \(p \neq q\)
5. Insert \(a_i\) as a member of the cluster of CH\(_p\)
6. End if
7. A node sends acknowledgement to add itself as a member of the cluster.
8. End for
9. After completion of member selection, the cluster is formed on the basis of Convex Hull [14,15] Algorithm.

The Intra and Inter data transmission will be held on the basis of PEGASIS routing as mentioned earlier.
6. Comparative Analysis

<table>
<thead>
<tr>
<th>ROUTING PROTOCOL</th>
<th>CLASSIFICATION</th>
<th>POWER USAGE</th>
<th>DATA AGGREGATION</th>
<th>SCALABILITY</th>
<th>RELIABILITY</th>
<th>OVERHEAD</th>
<th>DATA-DELIVERY MODEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEACH [2,5]</td>
<td>Hierarchical/ Node-Centric (Single-hop)</td>
<td>High</td>
<td>Yes</td>
<td>Average</td>
<td>Average</td>
<td>High</td>
<td>Cluster-Head</td>
</tr>
<tr>
<td>TEEN &amp; APTEEN</td>
<td>Hierarchical (Multi-hop)</td>
<td>High</td>
<td>Yes</td>
<td>Average</td>
<td>Average</td>
<td>High</td>
<td>Active-Threshold</td>
</tr>
<tr>
<td>PEGASS</td>
<td>Hierarchical (Multi-hop)</td>
<td>Max</td>
<td>No</td>
<td>Good</td>
<td>Good</td>
<td>Low</td>
<td>Chain-Based</td>
</tr>
<tr>
<td>MUC (Proposed Protocol)</td>
<td>Hierarchical (Multi-hop)</td>
<td>Max</td>
<td>Yes</td>
<td>Good (Better than others)</td>
<td>Good (Better than others)</td>
<td>Low</td>
<td>Cluster-Head + Chain-Based</td>
</tr>
</tbody>
</table>

7. Conclusion

In this paper we have presented a multi-hop clustering based routing protocol. Our algorithm uses the competition zone of each tentative cluster-head to select FINAL Cluster-Head. The concept of voronoi cell is used for forming clusters. Afterwards, data transmission follows the chain-based greedy algorithm. We have also presented analytical study of performances of different energy-efficient routing protocols. However, this work presents the proposal and we have started experimentation with simulator.

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References