MultiHop Routing for Delay Minimization in WSN

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Abstract—Wireless sensor network, consists of sensor nodes in capacity of hundred or thousand, which deployed in a particular manner. The goal of these sensor nodes is to capture the environmental data and send it to sink node. Various nodes deployment strategies like square, triangle, hex grid have been proposed. In this paper minimum numbers of sensor nodes are used to cover the specified geographical area using hex grid deployment. The study shows that the deployment of nodes in a hex grid manner is the best deployment to cover the maximum area by using the minimum number of nodes. In this paper a hex grid based multi hopping routing scheme is proposed. This scheme minimizes the data transmission delay as well as improves the reliability of minimally connected network. The simulation result shows that the performance of the proposed scheme is better when sink positioned in the middle of the network.

Index Terms—Delay, energy efficiency, multihop, spanning tree.

I. INTRODUCTION

Wireless Sensor Network (WSN) is the network of sensor nodes that are spatially distributed autonomous to monitor physical or environmental conditions such as temperature, sound, pressure etc[1]. The sensed data is cooperatively passed through the network to a specific location (Sink). The development of wireless sensor networks was motivated by military applications such as battlefield surveillance. Today such networks are used in many industrial and consumer applications such as machine health monitoring, industrial process monitoring and control and so on. The constraints in a WSN are many, but the size and cost constraints result in corresponding constraints on resources such as energy, memory, computational speed and communication bandwidth.

There is a need of an efficient routing algorithm which is optimal in terms of resources for sending and receiving data packets rather than the traditional methods to enhance the lifetime of the entire networks[2]. In this paper, we propose a routing algorithm based on the hex grid topology of nodes in a specified geographical area. Data gathering plays a significant role in the wireless sensor network because there should not be any kind of data duplicity while receiving and sending the data to one sensor node to another. Some of the deployed nodes act as the coordinator nodes and collect the sensed information from the sensing nodes and route the same information through the coordinators in an energy efficient way using data aggregation, thereby improving the lifetime of the network. The proposed algorithm also minimizes the delay in data transmission between source and sink by the formation of the tree of the coordinators.

The algorithm is mainly divided into two phases: Organization of nodes in a hex grid manner followed by formation of a coordinator tree. The organization of the sensor nodes in the hex grid manner provides better coverage area (reachability). Tree formation is on the basis of sensing range of the nodes. A coordinator is then selected considering the minimum delay taken to the neighborhoods. The proposed algorithm can better handle heterogeneous energy circumstances as compared to other existing algorithms which select the coordinator on the basis of the residual energy of a node.

The remaining of the paper is organized as follows: section II explains the related work. In section III the network model and assumptions for the proposed work is discussed. In section IV the proposed algorithm is given. In section V the simulation results are produced along with the analysis of the performance of the network in the form of different graphs. The conclusion is presented in the last section VI.

II. LITERATURE REVIEW

End to end delay and reliability in data transmission have gained much interest in recent years and a large variety of recent work lays emphasis on both the parameters. Recent works have shown the advantage of using clustered routing as a reliable technique for data transmission in WSN. Nodes organized in a hex grid structure give maximum coverage [7]. In the work proposed in [7], initially the nodes are organized in hex grid structure to cover a specified geographical area. The problem is to send/transmit the desired data packet to sink node with minimum latency. The work done so far uses methodologies like-Nodes acting as relay nodes to deliver message to sink. Nodes send message to their respective coordinator and coordinator relays it to other coordinator for delivering messages to sink. LEACH (Low Energy Adaptive Clustering Hierarchy) [3] uses the randomized rotation of the coordinators to distribute the energy load among the sensor nodes in a network. The idea is to form the cluster of sensor nodes based on the signal strength and use the coordinator as a router to forward data of other nodes in the cluster to the base station. It is the dynamic clustering algorithm in which the processing of data is done through the coordinators [5]. Time is divided into rounds with equal length. In the starting, coordinators are generated randomly among the nodes which have the remaining energy higher than the average remaining energy of all the nodes. After each round coordinators are generated to form the new cluster. LEACH assumes a homogeneous distribution of sensor nodes in the given area.
This scenario is not very realistic. In addition, coordinators are randomly selected so the possibility of occurrence of two or even more coordinators is very close to each other, is very high, so it is very clear that when multiple coordinators are randomly selected within a small area, a big energy loss occurs. Because, the amount of energy required is approximately proportional to the number of coordinators in the area.

Since, the nodes can be deployed in a large geographical area so they may or may not be in the range of each other[4]. So we can say that coordinators may or may not be in the range of each other. The work in [6] assumes that the coordinators are in the range of each other. Cluster wise candidate coordinators are identified through k-theorem. The coordinator is selected from the set of candidate coordinators for each cluster. In the given scenario k-theorem approach computes the coordinator set based on the maximum frequency count of the node from the list of nodes with its k-nearest neighbor. However, if the chosen coordinator is not in the communication range of another coordinator, the reachability issue arises. As a result one coordinator forward/relay packets to the others.

TBRP (Novel Tree Based Routing Protocol) proposed in [8], is used to form the fuzzy spanning routing tree on the basis of the nodes residual energy and its distance to the base station. It computes fuzzy number for the selection of coordinator node which is having the maximum fuzzy number becomes the coordinator for that cluster. This protocol also assumes that each sensor node is in the range of each other in the specified geographical area. The range in which the coordinator falls can be an important factor which can affect the routing strategy in such an environment. The proposed work focuses on this important factor and comes out with a solution in which the coordinator is not always necessarily in the range of other coordinators.

III. NETWORK MODEL

The assumptions with respect to the proposed model and algorithm are as follows:
- Sensor nodes are static on the other hand the sink may or may not be static.
- Sensor nodes are aware of their geographic location.
- Sensor nodes are aware of the relative position of the sink in the field.
- The sensor nodes are placed in a hex grid structure over the sensing field.
- Sensor nodes are homogeneous in their architectures in terms of their sensing range and power.

IV. PROPOSED APPROACH

In this work sensor nodes are deployed to cover the specified geographical area with the minimum number of nodes. After deploying these nodes a routing technique is designed so that every node can send their data to sink node with minimum energy and delay. In this paper, we have organized the model design in the different part which is as follows:

1. Nodes Organization.
2. Tree Formation.
3. Communication through Coordinator.

A. Nodes Organization

The node organization in this network is in the form of hex grid structure because of full network coverage. Studies showed various grid based node deployment schemas for WSN in the form of square grid, rectangle, grid, triangular grid, hexagonal grid etc. So under some deployment assumptions, research [1] showed that hexagonal grid deployment provides better area coverage than other schemes. The deployment of the sensor nodes in the form of hex grid structure is represented in the fig. 1.

![Fig. 1. Hex Grid Organization of sensor motes](image)

B. Tree Formation

After deploying the nodes in a hex grid structure, a path is established between the sink nodes to other nodes so that the data captured by these nodes should take minimum delay to reach at the sink node. The goal of this scheme is to find the minimum delay path from nodes to sink node.

The working of the proposed algorithm for the coordinator selection is as follows:

Initially the sink node will broadcast the HELLO message containing its id within its communication range. The nodes that are in the communication range of the sink node will set their parent id as the sink node id. After getting this HELLO message these nodes will send the acknowledgement message to their parents and also broadcast the HELLO message containing their id. Once the nodes get the parent ID they discard received HELLO message from other nodes. This is a kind of top to button approach from root to child nodes. The process will be repeated till every node has their unique parent id. This parent id will be treated as coordinator node and other nodes, which receive this id, will be treated as its child node. After covering all the nodes spanning tree of the coordinators is formed so that every node is reachable to sink node through the path formed by broadcasting tree. This tree is dynamic with reference to sink node. If position of the sink node changes, the tree will also change, because the distance of the root node to the sink node changes.
Communication through Coordinators: In this section, we only consider the simple case, where we want to send a message from source to sink node.

The delay taken by the motes to sink node is calculated as:
\[
\text{Delay} = \text{Transmission time} + \text{Propagation time} \tag{1}
\]

Where, \( \text{Transmission time} = \frac{\text{Distance}}{\text{Speed}} \) and \( \text{Propagation time} = \frac{\text{Data size}}{\text{Data rate}} \)

The fig. 2 shows the sensor motes are arranged in hex grid manner and the distance between these motes are \( d \). The communication range for the sensor motes are \( r \).
Let the value of $d$ be 30m and $r$ be 55m. As shown in Fig. 3, motes B, D, M, C, E, F come inside the range of A where the distance between A to D, C, B is 30m and the distance from A to M, E, F is $30\sqrt{3}$ i.e. 51.96. Initially sink will broadcast the Hello message as shown in Fig. 5, where node A & B will receive the ID since they are in the range of sink as shown in Fig. 4. After getting the HELLO message from the sink node A & B will set the parent as sink node. Now A & B will be broadcast the Hello message as shown in the fig. 6 and 7. As A will broadcast the HELLO message and the motes inside the range of A will receive the HELLO message. The delay taken to REACH the HELLO message from A to D is 8301.8ms and for E is 8302.532 for C 8302.532 as shown in Fig. 8. Similarly when node B will broadcast the HELLO message delay will be for node B to C is 8301.8, to F delay is 8302.532, to D 8302.532 and to G it is 8302.532 as shown in Fig. 9. So for D there are 2 HELLO message from A & from B so D will choose min 8301.8, 8302.54 i.e. 8301.8 from A. So D will choose A as a parent. Similarly for E, F, C, G. Similarly, when C will broadcast the message G, H, J, F, E will receive the HELLO message. Mote E will discard the HELLO message because it already receives the HELLO message from A. Similarly G & F will discard. Only H & J will receive the HELLO message and set the C as their Parent and send the acknowledgement message.
The fig. 17 shows the Broadcasting tree that has been created after the every mote has their Parent Id. The sink is placed at the middle and outside the sensing field.

V. IMPLEMENTATION AND RESULTS

In order to evaluate the latency between the source node and the sink node, several simulations were performed on MATLAB simulator (Test bed for TELOSb sensor mote). The latency was evaluated at different sink positions. This latency refers to the interval between the transmissions of a HELLO packet from a mote to sink node using path formed by tree.

For the simulations, a network of N sensor nodes is considered. The nodes are deployed in the hex grid manner on the test bed within a geographical area. The sink generates a HELLO message at a rate of 20HZ toward the sensor motes. Since the sensor nodes are not in the range of each other, the simulation is aimed at forming a coordinator (broadcasting) tree so that it would be easy to send data packets for any sensor nodes to destination (sink node). As soon as the sink starts broadcasting the HELLO packets towards the sensor nodes, the nodes broadcast the received HELLO packet within its communication range. Finally, the broadcast tree is formed in different scenarios i.e. at different sink positions. For the simulations, the proposed algorithm was implemented with the sink node inside and outside the network. A node that intends to send a data packet to the sink, it follows the path formed by the broadcasting tree through coordinators. Such a topology allows the coordinator to send the received data packets to other coordinators in its path. The proposed algorithm reduces the latency thereby improving the network lifetime.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency Band</td>
<td>2400 MHz to 2483.5 MHz</td>
</tr>
<tr>
<td>Transmit Data Rate</td>
<td>250 kbps</td>
</tr>
<tr>
<td>Outdoor Range</td>
<td>75m to 100m</td>
</tr>
<tr>
<td>Indoor Range</td>
<td>20m to 30m</td>
</tr>
<tr>
<td>Battery</td>
<td>0.5 Joule</td>
</tr>
<tr>
<td>Temperature Sensor Range</td>
<td>-40 degree to 123.8 degree</td>
</tr>
</tbody>
</table>

Table I: Simulation parameter

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The fig 19 shows that the delay in data reporting is dependent upon the different position of the base station outside the network.

Simulation results show that when the sink is placed at the middle position in the network, it gives overall minimum latency to send data packets from the source to the sink node. The eccentricity of the network is best when the sink is placed at the middle position in the network. The overall delay is also relatively less with the sink in this position.

VI. CONCLUSION

This paper presents the routing algorithm for low delay and energy efficient communication in hex grid structure of the sensor network. The proposed algorithm selects coordinator on the basis of the coverage of the nodes and perform packet routing within the network while other nodes remain in power saving mode and periodically check if they should awaken and become a coordinator in case sink node location changes. Furthermore, it also introduces a simple and efficient approach, namely spanning tree formation of the coordinators for sending aggregated data to sink node through one coordinator to another coordinator. This approach not only decreases the communication latency from source to sink, but also improves the energy conservation.

REFERENCES