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An Energy Efficient Protocol on Hexagonal Grid-Based Wireless Sensor Network using Super nodes

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Abstract*— Wireless Sensor Networks (WSN) differ from traditional wireless communication networks in various characteristics. One of them is the power awareness since the batteries of sensor nodes have a limited lifetime and are difficult to be replaced. Therefore, all protocols must be designed to minimize energy consumption and to preserve the long life of a network. Routing protocols in WSN aim at accomplish power conservation. Most of the researchers have focused on energy efficient solutions regardless of the communication between Cluster Heads (CH) and Base Station (BS). To solve this problem, we present an Energy-Efficient Hexagonal grid -Based protocol (EEHS) for wireless sensor networks having hexagonal area and super nodes. This protocol is significantly reduced the energy consumption and network lifetime especially to sensor networks with high node density. Both hexagonal area and super nodes in a cluster have been proved to be efficient ways to reduce the energy consumptions in WSNs. Our analysis to shows that EEHS consumes less energy and has a longer network lifetime compared with other approaches.

***Keywords*— Hexagonal grid- Based, Super nodes, Power Levels, Energy Efficiency, Wireless Sensor Networks.**

I. INTRODUCTION

Sensor network technology has been widely used in variety of domains dealing with monitoring, such as health monitoring, environmental monitoring [1]; control, such as agriculture control, surveillance control, such as battle field control. A wireless sensor network (WSN) is a composed on tiny battery powered devices, called sensor nodes. A sensor node has two components. The first one, named mote, is responsible for storage, computation and communication. The second node, component called sensor is responsible for sensing physical phenomena such as temperature, light, sound and vibration, etc. to cooperatively pass their data through the network to a main location. A sensor is always is attached to a mote. In the network, Sensing nodes circuitry measures the ambient conditions related to the surrounding and sensor transforms them into an electric signal. Processing of a signal reveals some properties about objects which is located in the vicinity of the sensor. The sensor nodes send collected data through radio transmitter to a sink. Thus collected data sends either directly or through a data super node. Due to advancement in technology, decrease in size and cost of sensors resulting interest in the possible use of large set of disposable unattended sensors. Such interest has motivated severe research in the past few years addressing the potential of collaboration among sensors in data gathering and processing. Generally a sensor node is made up of four basic components as shown in Fig. 1: a sensing unit, a processing unit, a transceiver unit and a power unit.

They may also have application dependent other components such as a location finding system, a power generator and a mobilizer. Sensing unit has further two subunits: sensors and analog to digital converters (ADCs). The sensors observed physical phenomenon which is an analog signal. Then this analog signal is converted into digital signals by the ADC, and after then fed into the processing unit. The processing unit is generally associated with a small storage unit. The storage unit manages the procedures that make the sensor node work together with the other nodes to carry out the assigned sensing tasks. A transceiver unit connects the node to the network.

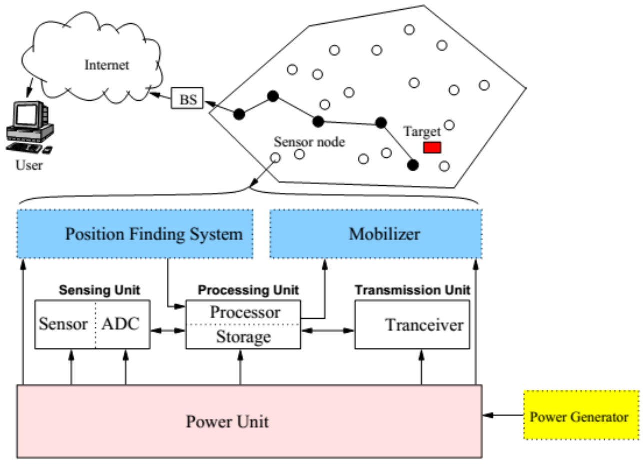

Fig. 1 components of sensor node

One of the most important components of a sensor node is the power unit. Power units may be supported by solar cells. There are also additional subunits, which are application dependent. In most of the sensor network routing techniques and sensing tasks require the knowledge of location with high accuracy. Thus, it is common that a sensor node has a location finding system. A mobilizer may sometimes be used to move the sensor nodes when it is required to carry out the assigned tasks. In this paper, we study about the target coverage in WSNs. It contains of two types: Hexagonal coverage of the area and predepolyed super nodes. Data packet is reached to a super node. After than , they are forward fast super node to super node communication. Additionally, super nodes could process sensor data before forwarding.

The main objective in this paper is to increase the lifetime of the wireless sensor nodes. The sensor measurements are transmitted to a super node and from here it uses the fast super node to super node communication to transmit data to the user application. The method used to extend network lifetime is to organize the sensor nodes into a number of set covers such that all targets are monitored continuously. In addition, sensor networks can enable a more public use of landmines by making them remotely controllable and target specific in order to prevent harming civilians and animals.

II. RELATED WORK

The routing techniques are classified into three categories depending on the network structure: flat, hierarchical, and location-based routing [2] [3]. Hierarchical clustering techniques can aid in reducing useful energy consumption. Hierarchical or cluster-based routing are well-known techniques with special advantages related to scalability and efficient communications [4] [5]. Data aggregation in WSN is a data transfer technique by which several packets from sensor nodes are combined into one. This technique is essential because the reduction of data packets may reduce energy consumption, increase network lifetime, and therefore increase successful data transmission ratio [6]. There are many clustering algorithms used in WSN. Clustering is an effective approach to hierarchically organizing network topology and to prolong the lifetime of WSN. Thus, the main issue in sensor networks is often to extend the lifetime of the network by reducing energy consumption. For the development of routing protocols in wireless sensor network, a large number of current works are on the go. There are the some factors which are considered during developing of the routing protocols. In these factors energy efficiency is the most important factors which directly effects the lifetime of the sensors. In general, routing in WSNs can be divided into flat-based routing, hierarchical-based routing, and location-based routing depending on the network structure. In a hierarchical architecture, higher energy nodes can be used to process and send the information while low energy nodes can be used to perform the sensing in the closeness of the target. This means that creation of clusters and transfer special tasks to cluster heads can greatly contribute to overall system scalability, lifetime, and energy efficiency. Heinzelman, ET. al. [7] introduced a hierarchical clustering algorithm for sensor networks, called Low Energy Adaptive Clustering Hierarchy (LEACH). The operation of LEACH consists of two phases:

- The Setup Phase: In the setup phase, the clusters are organized and the cluster heads are selected. In every round, a stochastic algorithm is used by each node to determine whether it will become a cluster head. If a node becomes a cluster head once, it cannot become a cluster head again.
- The Steady State Phase: In the steady state phase, the data is sent to the base station. The duration of the steady state phase is longer than the duration of the setup phase in order to minimize overhead.

This will save energy since the transmissions will only be done by such cluster heads rather than all sensor nodes. All the data processing such as data fusion and aggregation are local to the cluster. However, it has several problems. One problem is the five percent of nodes transmit the fused data to distance BS. Another problem is that it uses only the single ho routing path. LEACH-C [8] uses a centralized clustering algorithm to produce better clusters, thus achieves better performance.

As a representative of chain-based protocol, Power-Efficient Gathering in Sensor Information Systems (PEGASIS) [9] is an improvement of the LEACH protocol. In PEGASIS, each node communicates only with a nearby neighbour in order to exchange data. It takes turns in order to transmit the information to the base station, thus reducing the amount of energy spent per round. The nodes are organized in such a way as to form a chain, which can either be formed by the sensor nodes themselves using a greedy algorithm starting from a certain node, or the BS can compute this chain and broadcast it to all the sensor nodes. Threshold-sensitive Energy Efficient Protocols (TEEN and APTEEN) 'Threshold-sensitive Energy Efficient sensor Network protocol) are proposed in [10] and [11], respectively. These protocols were proposed for time-critical applications. In TEEN, sensor nodes sense the medium continuously, but the data transmission is done less frequently. The transmission of current sensed depends upon two conditions: The current sensed data must be greater than HT and difference between the current sensed data and previous data is greater than ST. By this mechanism the network can control the data transmission. Energy-aware routing for cluster-based sensor networks: Younis et al. [12] have proposed a different hierarchical routing algorithm based on three-tier architecture. We present a novel approach for energy-aware and context-aware routing of sensor data. The approach calls for network clustering and assigns a less-energy-constrained super node that acts as a centralized network manager. Based on energy usage at every sensor node and changes in the mission and the environment, the super node sets routes for sensor data, monitors latency throughout the cluster, and arbitrates medium access among sensors. Small Minimum Energy Communication Network (MECN) [13], a protocol is proposed that computes an energy-efficient sub network, namely the minimum energy communication network. (MECN) for a certain sensor network by utilizing low power GPS. MECN identifies a relay region for every node. The relay region consists of nodes in surrounding area where transmitting through those nodes is more energy efficient than direct transmission. The main idea of MECN [13] is to find a sub-network, which will have less number of nodes and require less power for transmission between any two particular nodes. In this way, global minimum power paths are found without considering all the nodes in the network. However, the proposed algorithm is local in the sense that it does not actually find the minimum-energy path; it just constructs a sub network in which it is guaranteed to exist. GAF Geographic Adaptive Fidelity (GAF) [14] is an energy-aware location-based routing algorithm designed primarily for mobile ad hoc networks, but may be applicable to sensor networks as well. GAF conserves energy by turning off unnecessary nodes in the network without affecting the level of routing fidelity. It forms a virtual grid for the covered area. Each node uses its GPS-indicated location to associate itself with a point in the virtual grid. Nodes associated with the same point on the grid are considered equivalent in terms of the cost of packet routing. Such equivalence is exploited in keeping some nodes located in a particular grid area in sleeping state in order to save energy. Thus, GAF can substantially increase the network lifetime as the number of nodes increases.

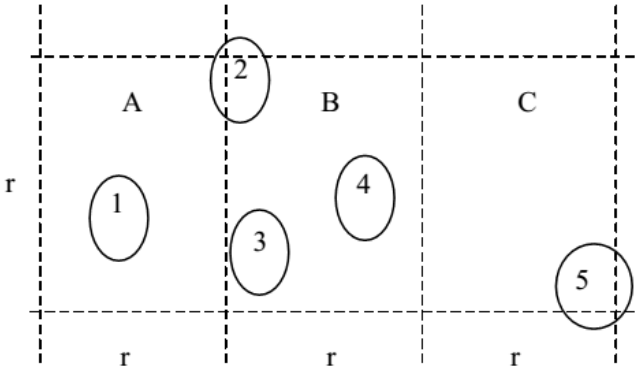

Fig. 2: Example of virtual grid in GAF

Wendi Rabiner Heinzelman, MTE [15], Minimum Transmission Energy Protocol is based on the minimum energy transmission is proposed, which optimizes clustering process based on the energy strategy, and effectively avoids the low-energy nodes as the CH. EEDD (Energy- Efficient Data Dissemination Protocols) uses location information to divide the sensor network into virtual grids. This information may be provided by the Global Positioning System (GPS) [16]. In GPS, receivers are used to estimate positions of the nodes in mobile ad hoc networks. Each grid is a square of size (d×d). From this we got an idea that for large coverage of wireless sensor network we can use a hexagonal area which covers the maximum density of the sensor nodes. We have proposed EEHS protocol to reduce the coverage and energy problems. In this pattern, the network nodes configure themselves into a cellular hexagonal structure, in which the network nodes are partitioned into hexagonal cells each with a radius.

III. PROPOSED PROTOCOL

Our proposed protocol has three main features: The first one is that to cover the maximum area. We divided our wireless sensor network area into hexagonal area to cover the maximum number of nodes. Hexagonal cells are the ideal shape for clustering in network. It is the larger polygon in terms of number of sides. One node in each cell is distinguished, as super node (head) of the cell, to represent this cell in the network.

The second feature is that our protocol tries to reduce the number of transmissions. To reduce the interference and delay, two amplification power levels are used. The power levels are based on the communication between super node to super node and nodes to super nodes in a cluster. Amplification power levels are of different types. Less amplification power is required intra cluster communication and higher amplification power level is used in inter cluster communication. Amplification energy used in inter cluster is 10 times more than that of intra cluster communication

i. Threshold Power levels: Two different types of threshold power levels are used. They are of following two types:

1) Hard Threshold: The absolute value of the sensed attribute beyond or equal to which data is transmitted from the source to destination. When energy of the sensor node is greater or equal to hard threshold only then they participated in data transmission

2) Soft Threshold: This is the smallest value of the sensed attribute when data is transmitted from the source to BS.

The third feature is concerned with the communication. In single hop sensor networks, CH use direct communication to reach the BS and the problem of unbalanced energy consumption among CH arises. CH farther away from the BS have heavier energy burden due to the long-haul communication links. Consequently, they will die earlier. Clustering is an effective way to enhance the performance and lifetime WSNs. In clustering, whole network is divided into fixed or variable sized clusters containing sensor nodes in it. Our protocol model is based on a WSN which consists of a BS and a set of heterogeneous sensor nodes which are randomly distributed over a bounded area of interest. In our system model, there are two types of sensor nodes, i.e., the super nodes and normal nodes.

The super nodes have more energy than the normal ones. Both the BS and the sensor nodes are considered to be stationary. The end user can access to data from the sensor network through the BS. Only the BS is considered to have an unlimited power supply. The network nodes are energy constrained.

A) REGULAR HEXAGONAL DEPLOYMENT:

Circle area is compared with the area of hexagon and square. The area of an equilateral triangle to a circle approx = 17.77 .The area of a square to a circle approx = 63.7, area of a hexagon to a circle approx = 83. This means hexagon has highest coverage area and satisfies all the conditions. That’s why we have proposed EEHS protocol to reduce the coverage and energy problems. In this pattern, the network nodes configure themselves into a cellular hexagonal structure, in which the network nodes are partitioned into hexagonal cells each with a radius. In the proposed model, first of all area of the wireless sensor network is taken in the form of hexagon which can cover the maximum number of nodes and clusters are formed.

B) ELECTION OF SUPERNODE:

The main idea of our protocol consists in using super CH to reduce the data transmission ranges of CH nodes. When a CH collects data from all its cluster member nodes, it forwards the data to a super node, and then the data would be transmitted to the BS by this super node. The BS creates a TDMA (Time Division Multiple Access) schedule according to which the nodes are requested to advertise themselves. We assume that the initial number of nodes is known by the BS. The size of this schedule is equal to the number of existing nodes. As soon as the TDMA schedule is broadcast, all nodes, during their allocated time slots, transmit their advertisements (the id node and its location).We assume that each node is GPS-enabled and each node is aware of its geographic location. When the node advertisement procedure is completed, the BS randomly elects some nodes as CH. The BS broadcasts the id and the locations of super nodes and the selected CH. The total number of nodes, which are assigned to be super nodes and CH, is supposed to be predefined.

C) CLUSTERING:

After the selection of the CH, each node decides which cluster it belongs to and informs its CH that it will be a member of its cluster. This node must choose the closest one as the CH. Each node transmits this information back to the CH using a CSMA (Carrier-Sense Multiple Access) MAC protocol. After a certain time determined a priori, each CH receives all the messages from the nodes that want to be included in its cluster and according to their number, creates a TDMA schedule of corresponding size. Next, it informs each one of its cluster nodes when it can transmit, according to the TDMA schedule which is broadcasted back to the nodes in the cluster. The radio of each cluster node can be turned off until the node's allocated transmission time comes, in the goal to minimize energy dissipation in these nodes. Thus, the first level of clustering is terminated.

D) MULTI-AMPLIFICATION POWER LEVELS:

To reduce the interference and delay, two amplification power levels are used. The power levels are based on the communication between super node to super node and nodes to super nodes in a cluster. Amplification power levels are of different types. Less amplification power is required intra cluster communication and higher amplification power level is used in inter cluster communication. Amplification energy used in inter cluster is 10 times more than that of intra cluster communication

i. Threshold Power levels: Two different types of threshold power levels are used. They are of following two types:

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2) Soft Threshold: This is the smallest value of the sensed attribute when data is transmitted from the source to BS.

D) DATA TRANSMISSION:

Each node, during its allocated transmission time, sends to the CH quantitative data concerning the sensed events. Each node, during its allocated transmission time, sends to the CH quantitative data concerning the sensed events. The data transmission consists of three phases. At first, in each cluster, none CH nodes transmit sensed data to CH. Then, in second phase, the CH transmits aggregated data to their super CH. Finally, each super CH transmits aggregated data to the BS. In the first phase, every non-CH node waits for their TMDA slot to transmit data. When the time slot arrives, the node transmits the data to CH. In the second phase, each CH receives the data from its cluster nodes. When all the data have been received, each CH aggregates the data it has received along with its own data into a single composite message (intra-cluster aggregation). After a CH has created its aggregate message, it forwards the data to its super CH and then, the data would be transmitted to the BS by this super CH., the CH can preserve some energy in data forwarding since their data transmission ranges are reduced. The super nodes do not engage in clustering. Their role is uniquely to connect the CH to the BS. They are responsible for transmitting packets received from the CH to the BS.

IV. SIMULATION RESULTS:

The simulation model was examined using a hexagonal based topology under various conditions and several results were collected. Some assumptions were made concerning the node features and these are as follows:

i. The base station is fixed and located far from the sensors.

ii. All nodes in the network are homogeneous and energy constrained.

iii. All nodes start with the same initial energy.

iv. Clusters and nodes are static randomly selected.

v. Normal nodes transmit directly to their respective super nodes (CH) within a particular cluster;

vi. Super nodes use two power levels routing to relay data to the data sink.

vii. For every round, it will check if energy of super node has fallen in a defined threshold then it will undertake CH and cluster formation process. Else same CH will continue its operations. .

The figure 3 illustrates the simulated environment of the 100 nodes and hexagonal area of the wireless sensor network we deployed.

viii. This is how much of energy that goes wasted in cluster head formation process can be saved. An efficient procedure or algorithm to enhance the life time of the wireless sensor network is used. We will find the best deployment method as well as density effect of sensor nodes on network. Using MATLAB, all 100 nodes were randomly distributed as shown in Fig. 4

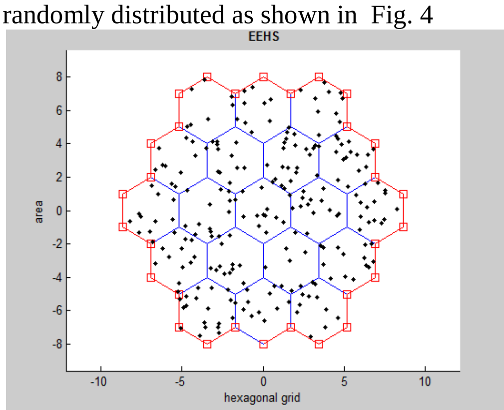


Fig 4 Hexagonal Deployments of Nodes

The parameters used in the simulation are listed in Table

Table 1: The Initial Simulation Parameters

Network Parameters	Values
Network Size	400m x 400m
Initial Energy of the Sensor Nodes	0.5 jule
Packet size	5000 bits/sec
Transceivers Idle Energy State Consumption	50 nj/ bits/report
Amplification Energy (Cluster to BS)	Efs=10 pj/bit/meter2
Amplification Energy (intra cluster comm.)	Efs/10

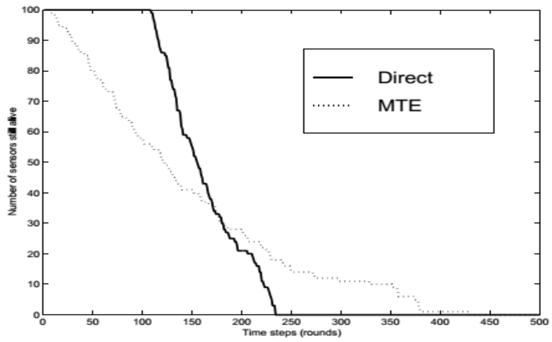
The initial energy level of all nodes is set at 0.5 joule/ node and the size of the sensor data set to 5000 bits. There can be three kinds of communications with respect to distances.

A) NETWORK LIFETIME:

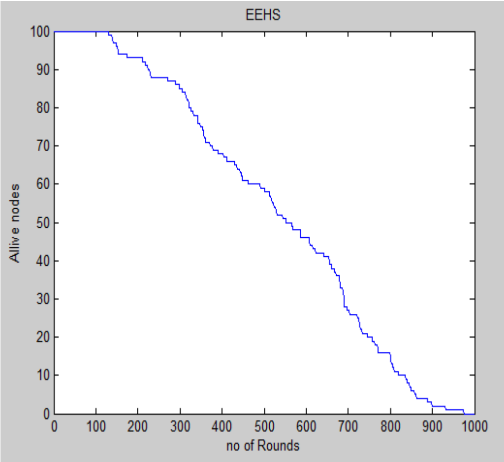
It can be proved that the proposed hierarchical routing technique increases the network lifetime of the wireless sensor network when compared to the hierarchical routing protocol MTE (Minimum Transmission Energy) protocol. We investigated the advantage of the proposed technique by comparing the time in which nodes die during the 1000 rounds of simulation (network lifetime) to that of the hierarchical routing technique used in MTE. With optimization in energy usage, we observed that the lifetime in our proposed hierarchical technique extends to an impressive range when compared to another hierarchical technique.

The impressive increment in life span of the network from our proposed hierarchical technique is seen as a result of efficient routing decision and optimization of energy in cluster head selection of each cluster formed

The simulated results for data transmission between nodes to the base station employing EEHS and MTE protocols are shown in figure 1.2



(a)



(b)

Figure1.3 System lifetime using (a) direct transmission and MTE routing [1]and (b) EEHS using 100-node network with energy of 0.5 J/node.

V. CONCLUSION:

This paper is concerned with hierarchical routing in WSN. A new protocol, named EEHS, is proposed. It is evident that our proposed algorithm has produced better results as compared to MTE. Specifically, in EEHS nodes are taking longer time (rounds) to die out; number of rounds are 1000 in comparision with 480 of MTE. The longer life time node implies lower energy consumption per node and hence increased energy efficiency of the sensor network(main motive of the dissertation). EEHS consumes less energy and has a longer network lifetime compared with other approaches In addition, as nodes take longer to die out, environmental conditions of the network can be more controllable.

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