An Energy Efficient Protocol for Hexagonal Grid-Based Wireless Sensor Network Using Super nodes

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Abstract— **In this paper, we proposed an Energy-Efficient Hexagonal grid -Based protocol (EEHB) for wireless sensor networks having super nodes. This protocol considers energy-efficient consumption and network lifetime specially to sensor networks with high node density. The protocol is based on hexagonal grid structure and location aware flooding of sensor networks to gain effective data dissemination between sources and super nodes. Our analysis to shows that EEHB consumes less energy and has a longer network lifetime compared with other approaches.**

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

I. INTRODUCTION

Due to advancement in various fields like microelectronics, wireless communication and digital electronics, new sensor nodes have been developed which have low cost, low power consumption. A wireless sensor network (WSN) consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network to a main location. The more modern networks are bi-directional, also enabling control of sensor activity. 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 industrial process monitoring and control, machine health monitoring. In the network, Sensing nodes circuitry measures the ambient conditions related to the surrounding and sensor transforms them into an electric signal. Processing such a signal reveals some properties about objects which is located and or events happening in the vicinity of the sensor. The sensor nodes sends such collected data via radio transmitter, to a sink either directly or through a data a super node. Due to advancement ,decrease in the size and cost of sensors, resulting interest in the possible use of large set of disposable unattended sensors.

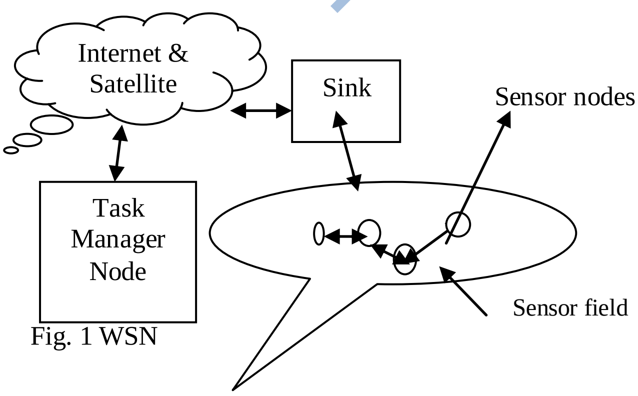

Fig. 1 WSN

A general sensor node is made up of four basic components as shown in Fig. 1: a sensing unit, a processing unit, a transceiver unit.. Such interest has motivated intensive research in the past few years addressing the potential of collaboration among sensors in data gathering and processing. A general 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 additional components such as a location finding system, a power generator and a mobilizer. Sensing units are usually composed of two subunits: sensors and analog to digital converters (ADCs). The analog signals produced by the sensors based on the observed phenomenon are converted to digital signals by the ADC, and then fed into the processing unit. The processing unit, which is generally associated with a small storage unit, manages the procedures that make the sensor node collaborate with the other nodes to carry out the assigned sensing tasks. A transceiver unit connects the node to the network.

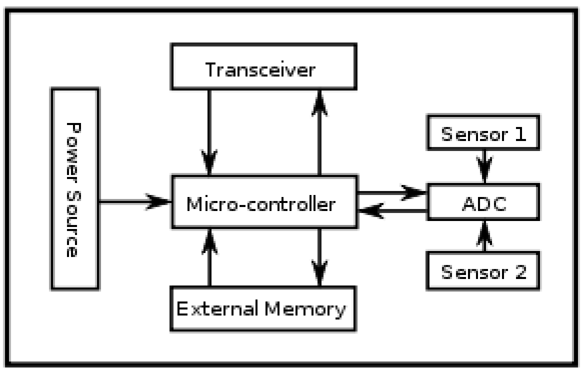

Fig. 2 components of sensor node

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 other subunits, which are application dependent. 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 sensor nodes when it is required to carry out the assigned tasks. Networking sensor nodes are expected to have significant impact on the efficiency of many military and civil applications such as combat field surveillance, security and disaster management. These systems process data gathered from multiple sensors to monitor events in an area of interest. For example, A network of Sensor Nodes can be installed in a forest to detect when a fire has started. The nodes can be equipped with sensors to measure temperature, humidity and gases which are produced by fire in the trees or vegetation. The early detection is crucial for a successful action of the firefighters to save our natural area. On the military side, applications of sensor networks are numerous. For example, the use of networked set of sensors can limit the need for personnel involvement in the usually dangerous reconnaissance missions. In addition, sensor networks can enable a more civic use of landmines by making them remotely controllable and target specific in order to prevent harming civilians and animals.

II. RELATED WORK

Wireless sensor networks are used to monitor a assured application or physical phenomena and are supposed to function for several years without any human interference for maintenance. 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. [1] 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 [2] 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) [3] 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 [4] and [5], 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. [6] have proposed a different hierarchical routing algorithm based on a 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. Simulation results demonstrate that our approach can achieve substantial energy saving. Small Minimum Energy Communication Network (MECN) [7], 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[7] 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) [8] 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. A sample situation is depicted in Fig. 11, which is redrawn from [8]. In this figure, node 1 can reach any of 2, 3 and 4 and nodes 2, 3, and 4 can reach 5. Therefore nodes 2, 3 and 4 are equivalent and two of them can sleep. Nodes change states from sleeping to active in turn so that the load is balanced. There are three states defined in GAF. These states are discovery, for determining the neighbours in the grid, active reflecting participation in routing and sleep when the radio is turned off. The state transitions in GAF are depicted in Fig. 1. Which node will sleep for how long is application dependent and the related parameters are tuned accordingly during the routing process. In order to handle the mobility, each node in the grid estimates its leaving time of grid and sends this to its neighbours. The sleeping neighbours adjust their sleeping time accordingly in order to keep the routing fidelity. Before the leaving time of the active node expires, sleeping nodes wake up and one of them becomes active. GAF is implemented both for non-mobility (GAF-basic) and mobility (GAF-mobility adaptation) of nodes.

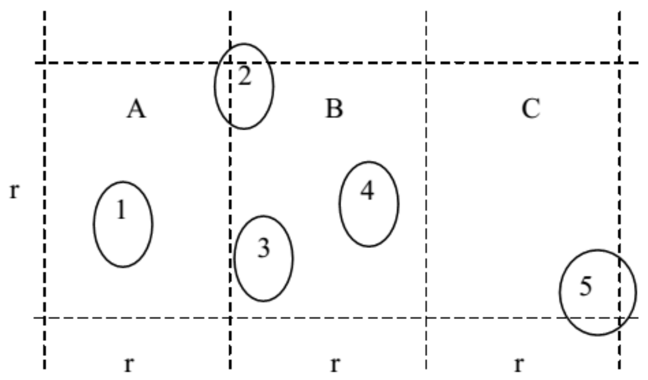

Fig. 3: Example of virtual grid in GAF

III .ENERGY-EFFICIENT DATA DISSEMINATION PROTOCOL

A. Grid Formation :

EEDD uses location information to divide the sensor network into virtual grids. This information may be provided by the Global Positioning System (GPS) [9]. 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) . Grids are identified (x,y) using the conventional xy-coordinate. For any given physical location, there should be a predefined mapping of a location to its grid coordinate. Each grid ID which has a typed [CX, CY] is assigned as follow: at the first row, from left to right, the grid IDs are [0, 0], [1, 0], [2, 0], [3, 0] and [4, 0]. Likewise, at the second row, the grid IDs are [0, 1], [1, 1], [2, 1], [3, 1], and [4, 1], and so on.

To do this, based on the coordinate),(x ,y) each node computes its CX and CY as follows :

$$CX= x/d, \quad CY= y/d \qquad (1)$$

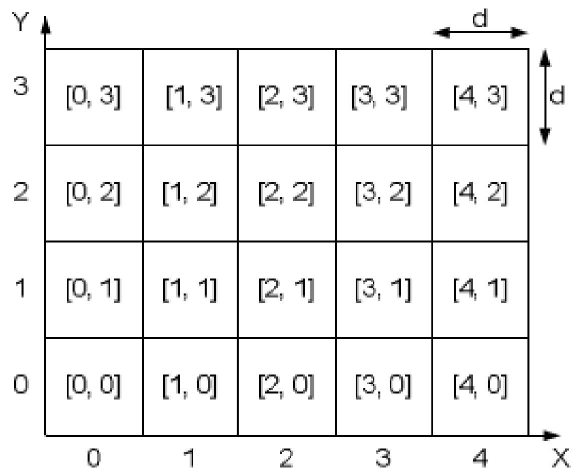

Fig.4 Grid formation and indexing

Where d is the grid size and ¬¼ k is the largest integer less than k. By equation (1), each node knows which grid it belongs to. Moreover, each node is assumed to maintain a neighboring table by using the simple HELLO protocol at the beginning of the network life [10]. Because the HELLO packet is small, the hello overhead incurred by the periodic HELLO protocol is very small.

B. Super node Election :

To maintain the super node in each grid, an efficient solution for super node election is necessary. In each grid, one node will be elected as the super node of the grid. The responsibility of the super node is to propagate information data packets to its neighboring grids. To maintain the quality of the routes, we let the super node of the grid be the node with largest residual energy in each grid. The super node will be elected periodically to keep the super node from running out of energy [11]. Figure 2 shows that a physical area partitioned into logical grids with gate way in each grid.

C. The Proposed Protocol for Energy Efficient Routing in WSNs:

We presented An Energy Efficient Protocol for Hexagonal grid-Based Wireless Sensor Network' Using Super nodes, thus avoid redundancy of energy consumption and network life-time. This protocol is based on grid structure to divide the entire network into small grids. In each grid, one sensor node with most remaining energy is selected as a super node. Super nodes are responsible for data forwarding and data dissemination in the wireless sensor networks .After Super nodes data is transferred to the super nodes where aggregation process is used to collect the data. However, the main difference with other protocols is that this one uses a more efficient mechanism of forwarding the data to super nodes, these super nodes collects the data and forward to the base station.

C(a). Description of the Adopted Energy Model

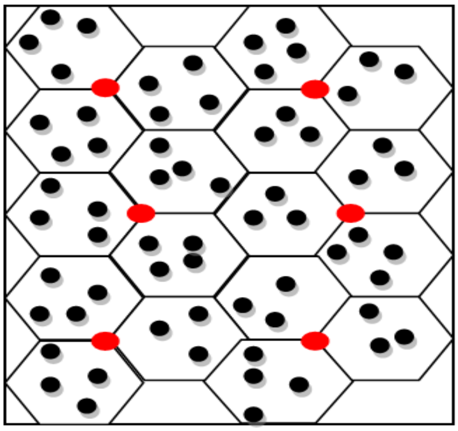

Fig.5 Partition logical grids

Sensor nodes ●

Super nodes ●

Data forwarding and diffusion in EEHS has 3 major steps, namely New Event Data Announcement phase, Request Query from Sinks phase and Data Diffusion phase. As a super node detects a stimulus occurred in its grid, it propagates a data announcement message to all the super nodes using location aware flooding (Phase 1). The super node that detects a stimulus becomes the source node. Each data announcement message contains a message header. Each header of the data announcement message consists of 4 fields, including: sequence number of the message; the coordinate of the source node; received node list which indicates nodes that already received the announcement message; and the path, which is the itinerary of the message. By using that information we can avoid redundancy of the data transmission and thus minimize the energy consumption. The detail format of the massage header and how to use the message header to avoid redundant data transmission will be described in the following sections. When a sink wants to get the data from the source node, it will send a request query to the super node in the grid which it is located and then this super node will forward the request query to the source node (Phase 2). The path for sending request query is defined bases on the path field of the message header. When the source receives the request query for information data it sends a reply message packet to the mobile sink along the reserve path (Phase 3). When sink moves, depends on the new location of the sink, the path will be reused or rebuilt. If the sinks move close to the old path, it is not necessary to establish a new path. It not, a new path will be set up.

Phase 1: New Event Data Diffusion :

When a super node detects a event, it propagates a data announcement message to all super nodes in the network using location aware flooding. The basic idea behind location aware flooding is to reduce redundant transmission by including the node IDs in the packet header. To avoid keeping data announcement message at each super node indefinitely, a source includes a time out parameter in data-announcement message. If this timeout expires and the super node does not receive any further data announcement message, it clears the information of the stimulus and the target's location to release the cache. The format of the packet header is described as follows :

a) Packet Header Format: The format of the packets used in location aware flooding is shown in figure 4. It consists of the Seq. Num field; Source id field; Rev Node List field as well as Path field. Seq. No. field is sequence number; the number of the transmission of the packet until the super node receives. Source id contains the grid ids of the source. Rec. node list field consists of the list of the grid ids of the nodes that have already received the packet. The Path field is the path that the packet traveled from source. It includes the grid ids of nodes in the data forwarding path. Based on this path, a sink can easily send a query request to the source and receive the data from source.

SeqNum	*SourceID*	*RevNodeList*	*Path*

SeqNum: Sequence number of the message
SourceID: ID of source node
RevNodeList: Node list received message
Path: Itinerary of the message

Fig 4. Header format

b) Location Aware Flooding:

Location aware flooding uses node ids to improve the energy efficiency of data declaration diffusion in wireless sensor networks. When a recipient super node receives the packet, it first checks to see if all its neighbors are already in the Rec. node list and Source id. This is done by comparing the receive node list of the packet and the grid id of the source with the neighbor list of the node. If this test is positive, the super node does not broadcast the packet. If not, the super node will do following things: Firstly, increases the sequence number 1. Secondly, adds all neighbor ids in its neighbors table but not in the receive node list to receive node list field in the header. Thirdly, adds its own id to the path field. Finally, it forwards the packet to its neighbors that is not in the receive node list. the operation of location aware flooding for an example configuration. When super node detects a stimulus, it will broadcast a register packet to all its neighbors, including super node. If a super node receives the same packet from more than one super node, it will store all the header of all packets for path recovery and just forward one identical packet to its neighbors that is not in the receive node list.

Phase 2: Request Query from Sinks :

When a sink receive the data declaration, if it wants the data from the source, it will send a query request to the super node in which grid it is located. And then, the super node will transmit the request query to the source. The path of the request query is defined based on the Path field in the packet header.

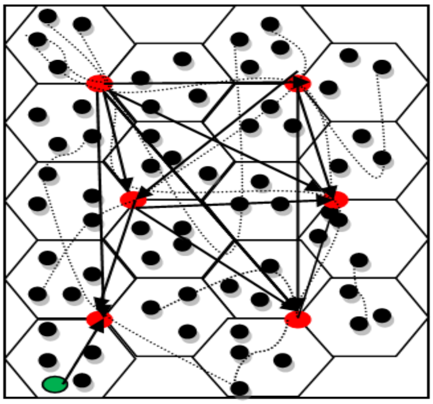

Fig 6. Flooding without location aware

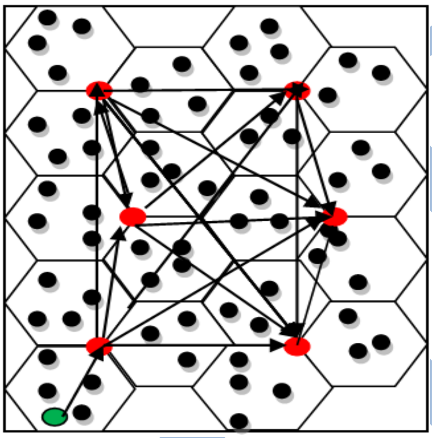

Fig 7. Location aware flooding

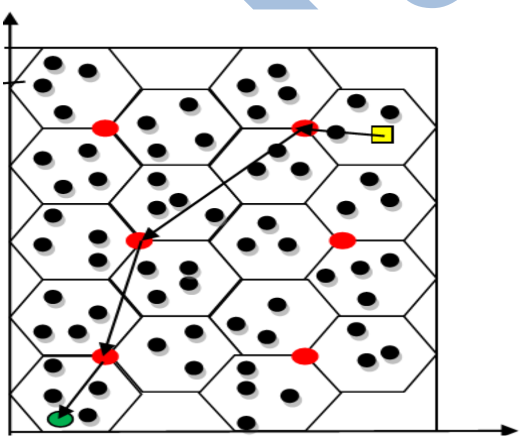

Fig 8 sink sends a query req. to the source

Phase 3: Data Diffusion :

The source starts generating and transmits data to a sink as it receives the request query. When the source receives the request query from the sink, it will send data in the reverse path.

D. Sink Mobility Handling :

In this section, we describe how a sink can keep receiving updated data from the source when it moves within he sensor networks. The mobile sink will periodically checks its current location to know which grid it is located in. If it is still in the same grid since the last check, the sink does nothing. It broadcasts a polling message, and the super node receiving this message will reply with a polling-rec. message that include its location. In Figure 8, the mobile sink receives these messages and will choose the closet super node. If the mobile sink moves a distance of two hops from the old path, the mobile sink will rediscover a new path by sending request to the super node in the same grid.

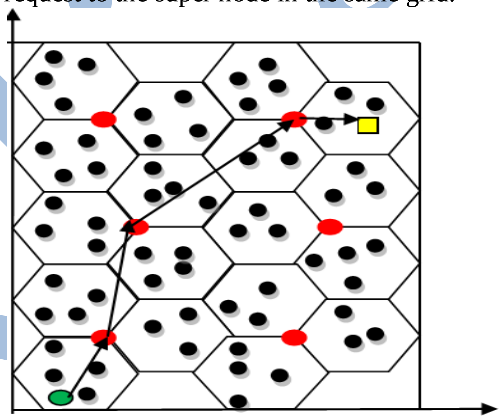

Fig 9 data fusion from source to sink

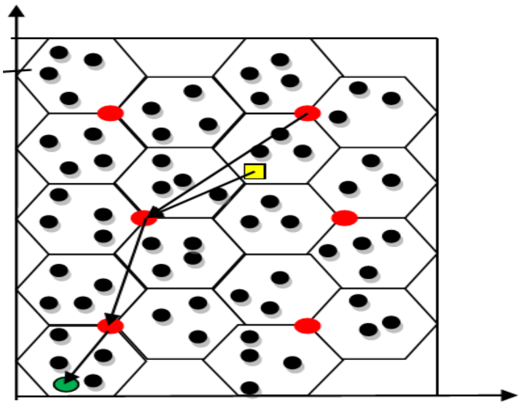

Fig 10. Sink moves in grid

V. CONCLUSION:

In this paper, we proposed an energy-efficient hexagonal grid based using super nodes (EEHS) fusion for data transmission to a mobile sink. The proposed protocol is location-based and grid based approach to maintain effective data fusion between sources and mobile sinks. EEHS consumes less energy and has a longer network lifetime compared with other approaches. We have used a uniform hexagonal grid grid in our approach to optimize the efficiency of super nodes and sensor nodes. Second, the size of the virtual grid should be used for various applications in the network.

Third, it is important to develop techniques that can dynamically reconfigure the virtual grid in a distributed manner after node failures, wear-out, and battery depletion. Finally, as part of future work, the energy savings need to be evaluated on physical hardware to demonstrate the usefulness of EEHS.

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