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AN ENERGY EFFICIENT PROTOCOL BASED ON HIERARCHICAL ROUTING TECHNIQUE FOR WSN

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ABSTRACT

The area of wireless sensor networks (WSNs) is one of the emerging and fast growing fields in the scientific world. This has brought about developing low cost, low-power and multi-function sensor nodes. However, the major fact that sensor nodes run out of energy quickly has been an issue and many energy efficient routing protocols have been proposed to solve this problem and preserve the longevity of the network. This is the reason why routing techniques in wireless sensor network focus mainly on the accomplishment of power conservation. Most of the recent publications have shown so many protocols mainly designed to minimize energy consumption in sensor networks. This thesis work proposes a hierarchical routing technique which shows energy efficiency. Our technique selects cluster head with highest residual energy in each communication round of transmission and also takes into account, the shortest distance to the base station from the cluster heads. Simulation results show that hierarchical routing technique with different level of hierarchy prolongs the lifetime of the network compared to other clustering scheme and the energy residual mean value after some communication rounds of simulation increases significantly.

KEYWORDS: Wireless Sensor Network, Hierarchical Routing, Clustering, Energy Efficiency, Network Lifetime

INTRODUCTION

Wireless Sensor Network (WSN) is an upcoming technology which has a wide range of application including infrastructure protection, industrial sensing and diagnostics, environment monitoring, context-aware computing (for example intelligent home and responsive environment) and so on. This kind of network usually consists of a large number of nodes that bring themselves together to form a wireless network. The components of a WSN are sensor nodes, BS and monitored events (that is, an event that is required to be sensed in the environment). A typical sensor node is made of four building blocks: power unit, communication unit, processing unit and sensing unit. The sensing component in a node measures certain physical characteristic like temperature or detects soil moisture of a location in which it is placed. The processing component is responsible for collection and processing captured data from its surrounding. The wireless communication component of a sensor node is responsible for transmission or reception of captured data from one sensor node to another node or to an end user through the cluster head to the base station (BS). The sensor node, its processing and communication component requires energy to function as expected, and the power component, which is of limited amount, is solely

responsible for provision of energy to the three other components. Based on application, the monitored event can either be dynamic or static in its operation. WSNs are usually deployed in an environment to monitor static or dynamic events. The measurement of static events (such as temperature, humidity etc.) is very easy to carry out. On the other hand, dynamic events are typically non-cooperative event is the movement of an unwanted vehicle in a battle field and the movement of whales in the ocean. They are not easy to monitor and they are not stable as they go up and down. Therefore, it is highly difficult to study energy saving schemes for sensing of dynamic event. For example, a forest monitoring application involves static monitoring approach whereas a target tracking application involves a dynamic monitoring approach. Sensor network requires certain protocol for efficient performance. For instance, protocol can come in form of a specific application with a defined order to aggregate data and optimizing energy consumption. This kind of protocol is referred to as hierarchical routing. Moreover, we have also a data centric routing protocol which describes a network environment whereby a sensor node also relies on data centric approach which performs sensing application to locate route path from multiple sources to a single

destination. With this in mind, data from every node in a network can be describe by a list of attribute value pairs called attribute-based addresses, such that a node can expose its availability to the entire sensor network. It is however essential to improve the energy efficiency for wireless sensor networks as the energy designated for sensor nodes is usually extremely limited. And, due to the fact that there is an increase in societal reliance on wireless sensor network technology, we can foresee the complexity of individual networks as well as huge increment in number of networks.

Due to the nature of the WSN, sensor nodes are normally powered by the use of batteries and thereby having a very constrained budget in terms of energy. To effectively maintain the network sensors to have longer lifetimes, all areas of the network should be carefully designed to be energy efficient. Among many methods, clustering the sensor nodes into groups, so that sensors send information to only the cluster heads (CH) and then the CH communicate the aggregated information to the base stations, may be a good method to minimize energy consumption in WSN. Especially for WSN that has a large number of energy-constrained sensors; it is necessary to organized sensors in cluster form to reduce energy consumed when transmitting information from nodes to the base station.

RELATED WORKS

Various methods for minimizing energy consumption in wireless sensor network have been proposed such as by Heinemann et al. [3] who described the LEACH protocol as a hierarchical self-organized cluster based approach for monitoring application. The data collection area of the data is randomly divided into clusters. LEACH uses time division multiple access (TDMA), to transmit data from the sensor nodes to the cluster head. Then CH aggregates the data and transmits it to the base station for processing. One of the features of LEACH is localized coordination and control for the formation and operation of clusters. The cluster head rotate randomly.

In [4] Lindsey et al. came about the proposition of PEGASIS which is an extension of LEACH. It eliminates the overhead of dynamic cluster formation created by LEACH. In this protocol, the nodes transmit to the CH and transmission of data is done by the cluster head, which is selected in a rotational manner, to the BS. PEGASIS protocol is found to save more energy and is more robust in node failure when compared to LEACH.

Muruganathan et al. [5] developed a protocol that creates clusters of the similar size and uses multi-hop

routing between CH and the BS. The cluster head which forward the last hop is selected randomly from the sets of cluster heads to minimize the load of cluster head which are located nearest to the base station.

In [8], Wei Li proposed a geometric programming model to extend the network lifetime of the sensor network by clustering sensor nodes into groups. He developed an iterative method for solving the geometric programming by choosing the optimal location of cluster heads. The optimum mentioned in his proposition refers to minimizing energy consumption based on to inter-sensor network under specific constrained.

Clustering of approaches is useful in the monitoring of habitat and environs. This however, necessitates the use of continuous stream of sensor data. Xinhua Liu et al. [12] propose DDBC (Directed Diffusion Based on Clustering). DDBC is an energy-efficient directed diffusion routing protocol which is based on the reduction of the network topology and gives suppression to the redundancy message in plain flooding in order to minimize energy consumption in wireless sensor network. Ye, Heidemann and Estrin [13] gave a description of a contention based medium access protocol, S-MAC, which minimizes energy consumption in wireless sensor network by using virtual clusters. They developed the common sleep schedule for the clusters and overhearing is avoided by the use of in-channel signaling.

Wei Cheng et al. [14] proposed a novel adaptive, distributed, energy efficient clustering algorithm, AEEC for wireless sensor network. Their approach selects cluster heads based on the node energy related to that of the whole network which can bring about efficiency in heterogonous networks.

PROPOSED ALGORITHM

Our proposed hierarchical routing protocol is based on the principle of clustering algorithm. With data transmission at the network layer being the core area of interest, we have modified the LEACH protocol in terms of hierarchical data transfer with the employment of energy prediction technique for selection of CH via any shortest path to the BS. In the proposed model, clusters are formed geographically. Geographical formation of cluster sizes is based on equal segmentation of area space, depending on the case being considered. Apart from the one cluster formation which makes use of the entire sensors area space, other formation such as two clusters formation and three clusters formation involves equal segregation of area space. The two clusters formation and the three clusters formation are otherwise known as first level and second level hierarchy respectively.

The CH election phase proceeds after the cluster formation phase. The selection of CH(s) within each cluster formed is carried out by electing a node that require less transmission energy (to BS or to the next hop CH nearer to the BS) to be the CH for a particular transmission round. Due to draining activities being constraint on a cluster head during data aggregation and transfer phase, the cluster head is rotated among the sensor nodes of each cluster at every transmission round. A completely new estimation of energy is carried out at the beginning of every transmission round to elect a new CH for the cluster and thereby energy wastage is being reduce to its minimum, and utilization of each nodes energy is being maximized to ensure a prolong network lifetime.

Figures 3.2 and 3.3 illustrate the proposed hierarchical routing technique and the cluster head selection of the protocol respectively. The algorithm in Figure 3.2 consists of four main stages

- i. Geographical formation of cluster.
- ii. Selection of cluster heads in each cluster formed.
- iii. Data aggregation phase which involves the gathering of collected data by the cluster head from the sensor nodes within its cluster.
- iv. Data transmission phase which involves the transfer of all data from the nearest cluster head(s) to the BS.

Also, the Figure 3.3 illustrates the CH selection in the proposed hierarchical routing technique. The CH selection flowchart can be explained also in four main stages:-

- i. The initial energy $E_{in}(n)$ of node is measured
- ii. Also, the distance $d(n)$ from each node to the base station or to the corresponding higher level cluster head is measured.
- iii. Estimation of the energy required by each node for transmission within the cluster not to BS or to higher level CH for two and three cluster formation within a cluster is carried out using the formula: $(E_{amp} * k * d^2)$
- iv. The maximum energy after the subsequent transmission round for each node is estimated and selection of CH is done using the formula: $\max(E_{in}(n) - E_{amp} * k * d^2)$, then after the CH selection is carried out, the next cluster head selection will take place after the current round is completed.

Figure 3.2 Flowchart of the proposed hierarchical routing technique

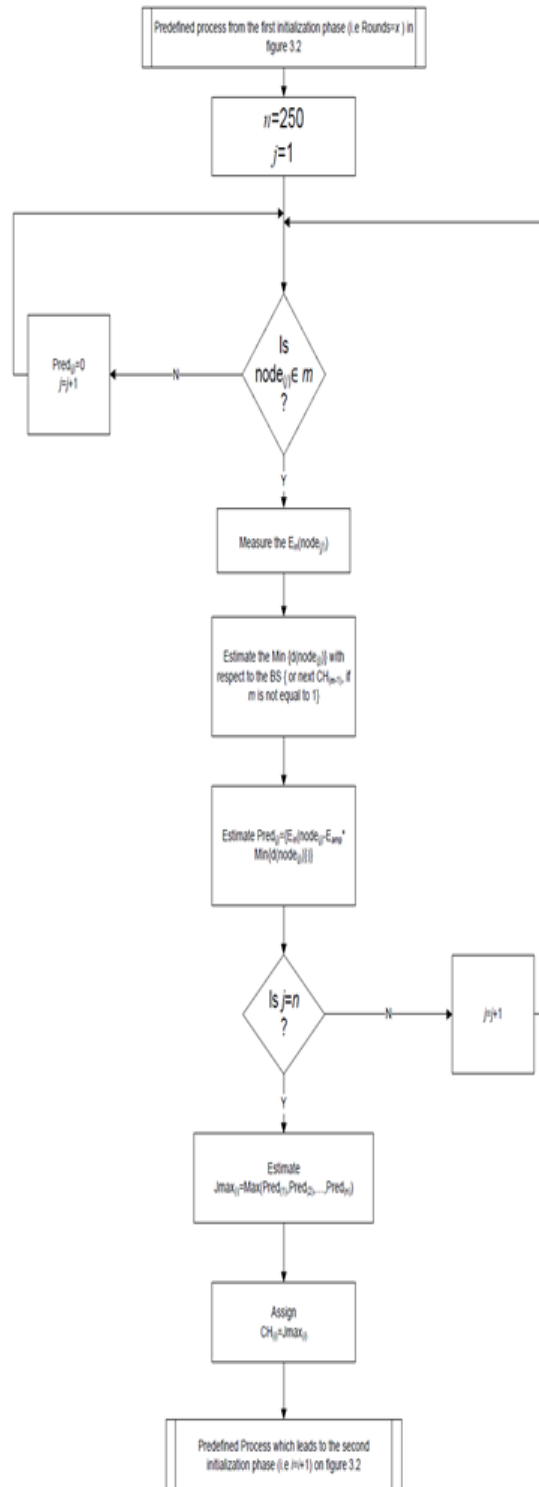
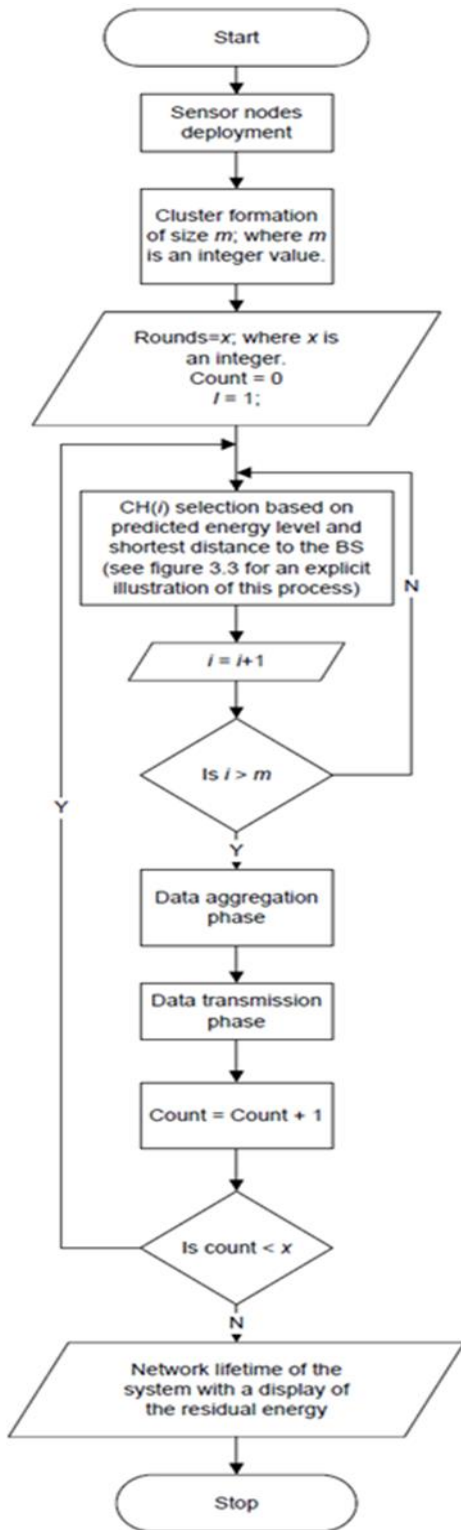


Figure 3.3 Flowchart of CH selections in the proposed hierarchical routing technique



SIMULATION SETUP AND SCENARIOS

In this simulation, a total number of 250 nodes were randomly deployed within a space region on 300 m x 300 m. The figure 4.1 illustrates the simulated environment of the 250 nodes we deployed. The coordinates of X and Y are measured in meters

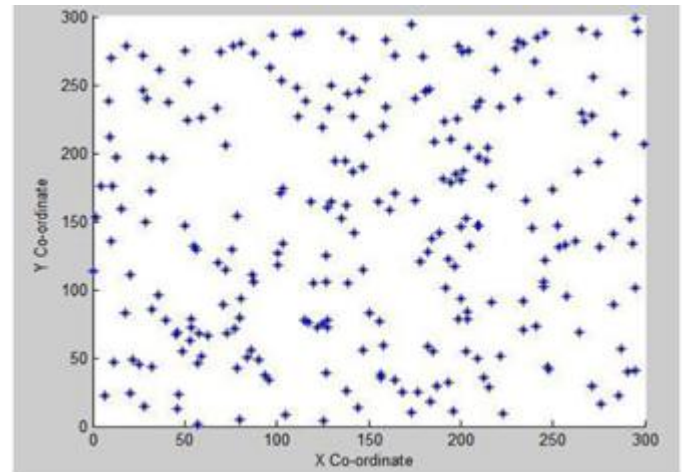


Figure 4.1 250 nodes deployed randomly in a geographical location of X and Y coordinates measured in meters

With the nodes being deployed, some assumptions were made concerning the node features and these are as follows:

- All nodes are homogeneous in nature;
- All nodes start with the same initial energy;
- The base station is situated at the (0,0) origin of the area space;
- Clusters and nodes are static;
- Normal nodes transmit directly to their respective cluster heads within a particular cluster;
- Cluster heads use multi-hop routing to relay data to the data sink;

The parameters used in the simulation are listed in Table 4.1:

Table 4.1: The initial parameters of our implementation

Parameter	Quantity
Total number of nodes, (N)	250
Initial energy of each node (Joules), (E _{in} (n))	200
Packet size (k) in bytes	100
Energy circuitry cost at transmission and reception of a bit of data (E _{elec}) in nano Joule per byte	50
Amplifier coefficient (E _{amp}) in pico Joule per bit	100
Coordinate of base station	(0,0)

The sensor nodes in the network are formed into clusters of different sizes of one, two and three. One indicates a non-hierarchy formation of cluster and, two and three indicate different level of hierarchy one and two respectively for data transmission. Figure 4.2 indicates the non-hierarchical structure of our routing technique. Likewise, Figure 4.3 and 4.4 shows the simulation result of the cluster formation in the proposed technique.

SIMULATION RESULTS

It can be proved that the proposed hierarchical routing technique offers when compared to the non-hierarchical routing. We investigated the advantage of the proposed technique by comparing the time in which the first node dies during the 400 rounds of simulation (network lifetime) to that of the non-hierarchical routing technique.

The network lifetime is shown in Figure 4.5. We observed that the first node dies faster in the non-hierarchical formation since all nodes tend to send captured data via one randomly selected cluster head per round to the base station. The constrained load on the elected cluster heads during the 400 round of simulation drastically reduced the CHs' energy over a short period. Unlike the non-hierarchical formation, the proposed hierarchical routing technique in which cluster hierarchy takes precedence in cluster formation and prediction of minimal transmission energy for selection of cluster head, we observed that this technique offers a better life span for individual nodes and even the entire network. With optimization in energy usage, we observed that the lifetime in our proposed hierarchical technique extends to an impressive range when compared to non-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. Since the sensor nodes in each cluster send data to the cluster head within its cluster range and then the aggregated data is sent to the cluster head closer to the base station, which further aggregates data of its own cluster and that of the incoming data, from cluster head whose distance is farther to the BS, before sending the data to the base station. Thus, a considerable amount of energy is saved which indicate improved network lifetime in the case of first level hierarchy when compared to nonhierarchical technique.

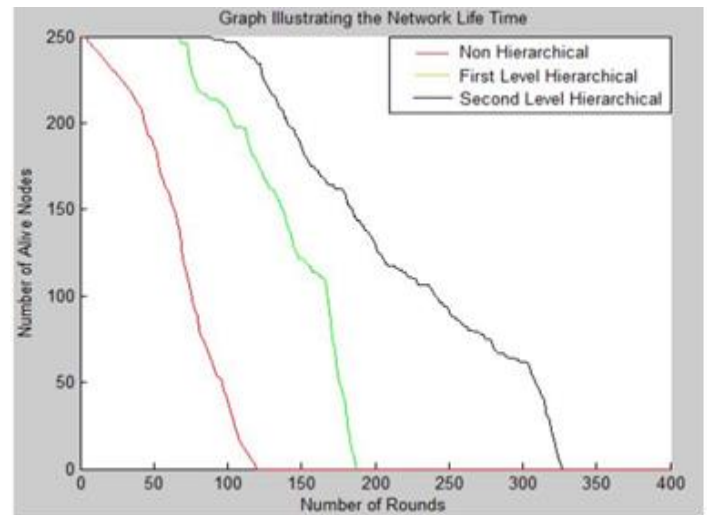


Figure 4.5 Network lifetime graph (number of alive nodes for a particular round of simulation)

CONCLUSION

In this paper, we propose an energy efficient hierarchical routing technique in which cluster heads are elected based on the prediction of transmission energy via a shortest distance to the base station. Our approach applies a geographical formation of sensor nodes into clusters, rotating the role of CH, and optimizing the CH selection by prediction of energy transmission energy in every rounds of simulation, and aggregating data before transmission to the BS. The important features which includes cluster formation and rotation, cluster head election and rotation, and cluster optimization of our proposed hierarchical routing technique in transmitting data to the base station was analyzed and emphasized. Our analysis shows that energy efficiency of WSNs can be further improved by using the hierarchical routing technique. The concept of hierarchical routing technique can be effectively used to designed energy efficient routing protocol in WSN. In our approach, the clusters are formed geographically into different sizes to see how it could affect the network lifetime of WSN.

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