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EFFICIENT ENERGY SAVING ALGORITHM BY MODERN CLUSTER HEAD SELECTION IN WIRELESS SENSOR NETWORK

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ABSTRACT

Recent technological advances in communications have enabled the development of low-cost, low-power, small in size, and multifunctional sensor nodes in a wireless sensor network. In wireless sensor networks, large numbers of nodes are deployed over the area of interest which has direct relation to the cost of the network. Since the radio transmission and reception consumes a lot of energy, one of the important issues in wireless sensor network is the inherent limited battery power because of which energy of sensor nodes gets drained off. Thus minimizing energy consumption and maximizing network lifetime is important in the design of applications and protocols of sensor networks. In this paper, we have proposed a new algorithm "EFFICIENT ENERGY SAVING ALGORITHM BY MODERN CLUSTER HEAD SELECTION IN WIRELESS SENSOR NETWORK". The proposed algorithm uses Gaussian elimination method for selecting the cluster heads. It considers the current and residual energy of sensor nodes along with the distance and also estimates the number of rounds in which a node can be cluster-head. Our goal is to confront an emerging technology and solve the limited energy problem by using proposed algorithm and increase the network lifetime for the betterment of the wireless sensor networks.

KEYWORDS: Energy Saving, Gaussian Elimination Method, WSN

INTRODUCTION

Wireless Sensor Networks

A wireless sensor network (WSN) consists of spatially distributed autonomous sensors to monitor physical or environmental conditions. These nodes sense the various environmental changes e.g. temperature, sound, vibration, pressure and report them to the base station over a suitable path. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance. The nodes communicate wirelessly with each other and a particular environment may consist of hundreds or even thousands of nodes. The WSN consists of two main components [1]:

- Sensor nodes
- Base station

The block diagram of a wireless sensor node is presented in Figure 1 It is made up four basic components: a sensing unit, a processing unit, a transceiver unit and a power unit.

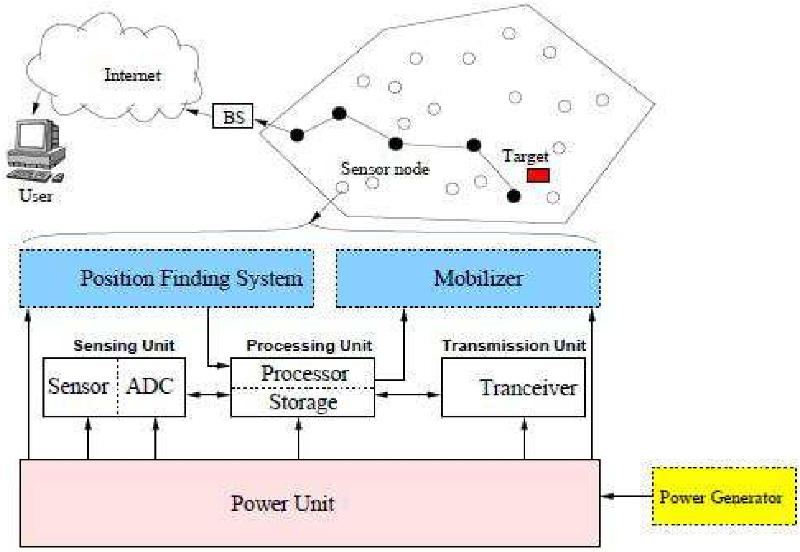


Figure 1: The Components of a Sensor Node [1]

- **Sensor Nodes**

The sensing unit is used to sense the various parameters. It consists of a sensor that is used to sense the various parameters for data transmission. Processing unit is used to process the sensed data. At every node the received data is first processed and then sent to the next node. It also consists of a transceiver unit by which data is sent or received by the node. And most importantly it consists of a small battery that is used to power these devices.

- **Base Station**

A Base Station links the sensor network to another network. Deployment of base station in a WSN is very important because in the end the whole data is given to the base station from the nodes. Sometimes they are also referred to as sinks. Base stations have enhanced capabilities over simple sensor nodes and they can do complex data processing. Due to this base stations can be considered as workstation class processors which have enough memory, energy, storage and computational power to perform its tasks well.

Energy Concern

Sensor nodes are generally small, light and cheap. Also the size of the battery is limited. Normally AA batteries store 2.2 to 2.5Ah at 1.5 V. Now as these sensor nodes are usually placed in remote regions e.g. mountains, forests etc, one cannot replace these batteries again and again. Hence these batteries should be durable and long lived. But the size of the battery cannot be changed so as to keep the node compact, hence different routing protocols and algorithm should be developed that would increase the lifetime and efficiency. Thus energy saving becomes one of the most important parameters of wireless sensor networks.

In proposed algorithm, we use a different method for clustering and routing. Cluster head selection is done by using- Gaussian elimination method. The method is performed only once in the start of the simulation.

Equilateral triangular node deployment is used which has efficient coverage and minimum overlapping area thus reducing the overall cost of the network. Nodes transmit data in the multi hop fashion in given TDMA slots. Hence, energy is saved efficiently and network lifetime is increased further in our proposed algorithm.

RELATED WORK

Sensor Node Deployment

The table below shows the effective area coverage by various arrangements of the sensor nodes.

Table 1: [7]

Grid Type	Efficient Coverage Area Ratio	Efficient Coverage Area Required for Deployment of Sensors S_{EAC} (m^2)
Square	0.634	10.28
Triangle	0.818	8.88
Hexagon	0.901	19.81

LEACH (Low Energy Adaptive Cluster Hierarchy) [8] consists of two phases: set-up phase and steady-state phase. In set-up phase cluster heads selection, cluster formation and TDMA scheduling are performed. In steady phase, nodes sends data to cluster head and cluster head aggregates the data. Aggregated data is sent to base station. After a certain time interval, re- clustering is done. New cluster heads are selected so as to maintain uniform energy distribution among sensor nodes. Role of cluster head is rotated to all the sensor nodes to make the network load balance. In LEACH number of cluster heads can be different in each round.

HEED [4] (hybrid energy efficient distributed clustering) does not select cluster head randomly. Only high residual energy nodes are selected as cluster head. Also probability of nodes within each other's range becoming cluster head is reduced. Probability of cluster head selection can be adjusted to ensure inter-cluster head connectivity for given transmission range.

In EECR [3] (Energy efficient clustering routing algorithm), during the first round the base station splits the network into sub-clusters and then those into smaller clusters, till the desired number of clusters is attained. The base selects a cluster head for each cluster according to the location information of their nodes. In Leach cluster head is selected randomly in each round whereas in EECR the cluster head is selected based on weight of node which includes remaining energy of node, no of neighbor nodes and also total no. of times in which that node has been the cluster head. Thus energy dissipation in network can be made even. Energy consumption is reduced by 20% as compared to LEACH and therefore life span of network can be increased.

ANCAEE [2](A novel Clustering algorithm for Energy Efficiency) is cluster based algorithm consist of round which involve CHs selection, cluster formation and transmission of data to base station. In this algorithm, the sensor field is partitioned first and cluster head is selected depending on probability. Data sensed at a node is sent to cluster head using a single hop & from cluster head a multi hop pattern is used to transmit data. Because of this a lot of energy can be saved instead of direct transmission & extends network lifetime.

PROPOSED ALGORITHM: EFFICIENT ENERGY SAVING ALGORITHM BY MODERN CLUSTER HEAD SELECTION IN WIRELESS SENSOR NETWORKS

To provide energy efficiency and for extending the network lifetime, most of the protocols are based on clusters. These clusters also consist of a cluster head (CH). Nodes in every cluster send data to the CH and from cluster head the data is further sent to the base station directly or via multi-hop routing. In the various algorithms, node with higher energy is selected as the CH at the start. However, the proposed algorithm uses a unique mechanism to select a node as the cluster head. It considers the current and the estimated future residual energy of the nodes, along with the number of rounds that can be cluster heads, in order to maximize the network lifetime. This is achieved by using the **Gaussian elimination method** to calculate the nodes which can be the cluster head and for how many rounds it can be the cluster head.

The base station is assumed to be located at a fixed position and has unlimited energy. Depending on the distance from the CH to BS, energy requirement will change. If the distance is large then more energy will be needed and vice versa. The whole area is divided into various numbers of clusters and from every cluster a CH is selected.

Sensor Node Deployment

Equilateral triangular sensor node deployment is used in proposed algorithm. On studying various node deployment methods, we found that efficient coverage of the area of interest is achieved on deployment of nodes in triangular fashion. Hence equilateral triangular node deployment over the other available deployment is preferred for increasing the network lifetime and achieving better efficiency.

Cluster Head Selection

In this protocol, in order to elect a cluster head the Gaussian elimination method is used. CHs are selected in such a way that there is minimum consumption of energy in the cluster. Clustering is performed only once at the initial stage and hence the protocol can avoid the time and energy consumed for re-clustering. The BS uses the Gaussian elimination method in order to compute the energy consumed by a node if it becomes a cluster head at the very next round by considering all possible combinations. Gaussian elimination process is basically carried out in 2 steps.

- Forward elimination technique
- Backward elimination technique

The forward elimination technique is used to find the rank of the system by use of elementary row operations. In the second phase solution of the system above is found. This can be explained by using a simple example as given below:

Let us assume that, matrix M represent the energy consumed by every node in the cluster m_{ij} denotes the energy consumed by node i if node j is the cluster head. and k is the total number of nodes in a cluster. Additionally, n_i denotes the residual energy of node i, while x_i expresses the times that node i can become a cluster head. In this way, matrices N and X are formed, so that $A{\cdot}X = B$, as shown below:

$$\begin{bmatrix} m11 & m12 & m13 & m14 & \cdots & m1k \\ m21 & m22 & m23 & m24 & \cdots & m2k \\ m31 & m32 & m33 & m34 & \cdots & m3k \\ m41 & m42 & m43 & m44 & \cdots & m4k \\ . & . & . & . & & . \\ . & . & . & . & \cdots & . \\ mk1 & mk2 & mk3 & mk4 & \cdots & mkk \end{bmatrix} \begin{bmatrix} x1 \\ x2 \\ x3 \\ x4 \\ . \\ . \\ xk \end{bmatrix} = \begin{bmatrix} n1 \\ n2 \\ n3 \\ n4 \\ . \\ . \\ nk \end{bmatrix}$$

Proposed Algorithm

Following assumptions are made at the start in the development of the wireless sensor model

- Base station is located far away from the sensor
- All nodes have same initial energy.
- All nodes are immobile
- It is assumed that the node always have the data to transmit.

Set-Up Phase

INITIALISATION

Numbers of sensor nodes are ‘m’

Equilateral triangular topology is used for sensor deployment.

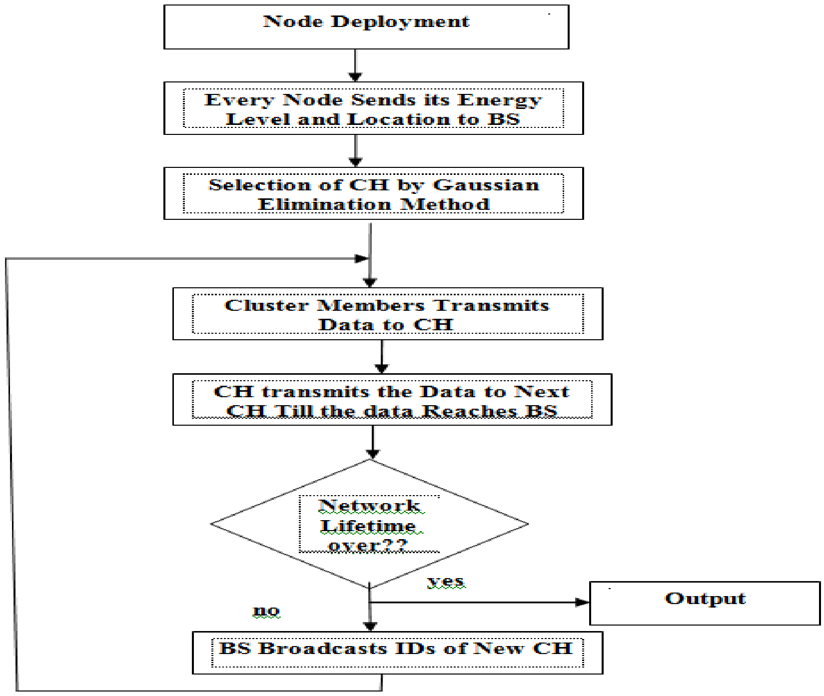
Cluster Head Selection

- The BS requests the nodes to advertise themselves.
- Each node broadcasts a message to advertise its energy level and location to its neighbors. Along with it, each node also sends its unique ID number.
- Based on this exchanged information, each node sets up a neighbor information table that records the energy level and the positions of its neighbors and sends this table along with its corresponding information to its neighbors.
- This step is repeated until the information of all the nodes in the network is sent to the BS, allowing the BS to have a global knowledge of the network. At this step, all the nodes are cluster head candidates.
- As soon as the node advertisement is completed, the BS runs the Gaussian elimination algorithm and computes the appropriate number of rounds that the nodes can be cluster heads, trying to maximize the network lifetime.
- The BS broadcasts the unique IDs of the newly selected cluster heads, and their cluster members and the nodes use this information to form and enter a cluster. Therefore, each node has the knowledge of the number of times that it can be a cluster head and the number of times that it cannot.

Data Transmission

- The data transmission starts.
- The transmission power of every node is adjusted to the minimum necessary to reach its next hop neighbor.
- Every lower level cluster head transmits the data to the upper level cluster heads until the data reaches the base station.
- This process is carried out till the sensor nodes lifetime.

Flowchart



SIMULATION RESULTS AND DISCUSSIONS

Simulation Parameters

Table 2

No of Nodes	Initial Energy	Sensor Field Area	Base Station Position	Distance of Base Station From Closest Node	Round Time
100	2J	100 × 100 m2	(130,60)	100m	5sec

The proposed algorithm and the LEACH protocol is implemented in NS2 with the above parameters. The Figure 2 below shows the sensor node deployment of the proposed algorithm. Deployment of nodes is not done in random manner. Instead of that, equilateral triangular grid is used for sensor node deployment so as to reduce data redundancy.

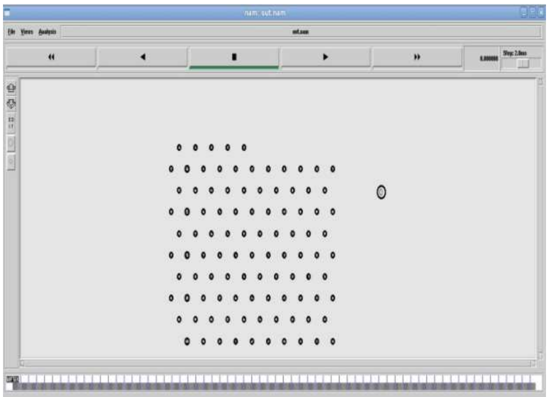


Figure 2: Node Deployment of the Proposed Algorithm

Figure 2 shows the clustering process of the proposed algorithm. During the process all nodes are turned to green color indicating that the clustering process is going on. The base station uses the Gaussian elimination method so as to select the cluster heads. Once the calculation is done, it sends the unique node id to the cluster head. This unique id is sent after every round interval and therefore at the beginning of every round interval all nodes are turned to green color. Figure 3 shows the cluster heads and cluster members in the LEACH protocol. The red color sensor node is used to denote the cluster members and the blue color node denotes the cluster head. The distribution of cluster head is not at all even. Similarly, Figure 4 shows the cluster heads and cluster member of the proposed algorithm. Due to even distribution of cluster heads, cluster member always send data to their nearest cluster head thus reducing energy consumption.

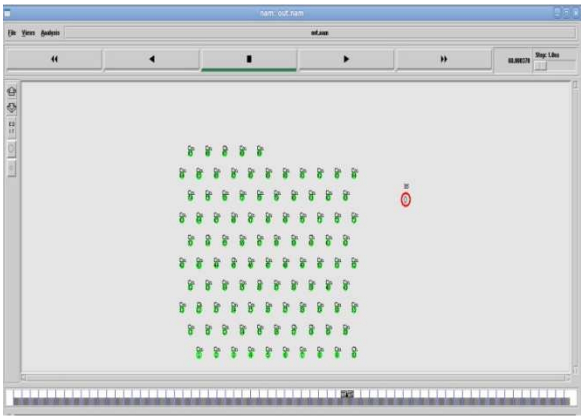


Figure 3: Clustering Process of the Proposed Algorithm

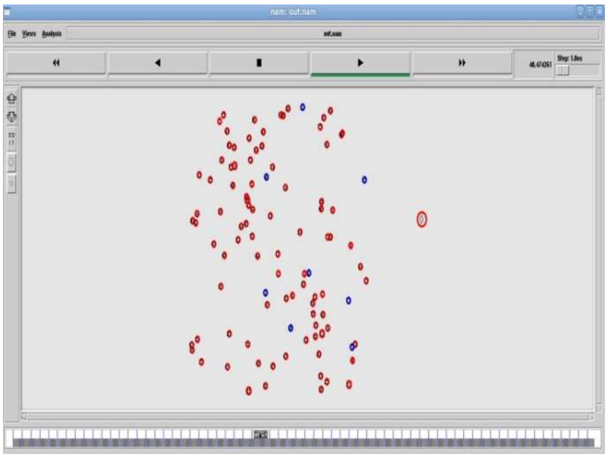


Figure 4: Cluster Head Selection of LEACH

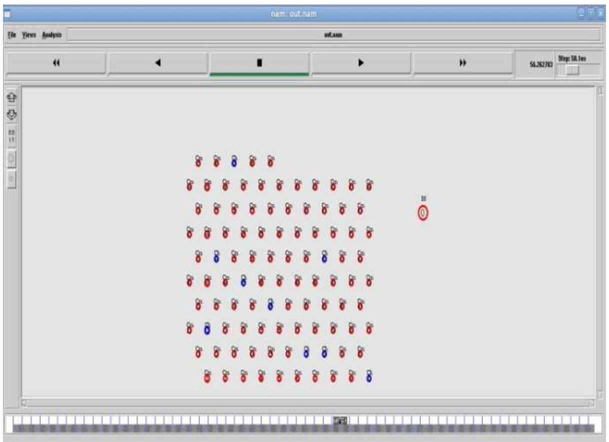


Figure 5: Cluster Head Selection of the Proposed Algorithm

Comparison of LEACH protocol and the proposed algorithm is shown for Average energy dissipation vs Network lifetime in Figure 5 Energy saving can be easily determined from the following graphs right from the start of the simulation. At 60th round, almost 1J of energy is utilized in LEACH, but the proposed algorithm uses only 0.7J of energy. Also it can be observed that for LEACH, the Average energy dissipation almost becomes 1.9J at 100th round whereas for the proposed algorithm, it takes about 125 rounds. Thus, it can be clearly seen from Figure 5 that performance of the proposed algorithm is much better than LEACH.

Figure 6: Average Energy Dissipation (Joules) vs Network Lifetime (Rounds) for LEACH and Proposed Algorithm

Similarly Figure 6 shows the graph of Nodes alive (number) vs Network lifetime in rounds for LEACH and proposed algorithm. Once again the proposed algorithm shows better performance than LEACH protocol. From the graph below, at the 60th round, there are about 60 nodes alive for the LEACH protocol whereas the proposed algorithm still has 100 nodes alive and functioning properly. More precisely, in the case of LEACH, all the network nodes are depleted by the end of the 110th round. On the other hand, for proposed algorithm, the last remaining node is depleted in the 130th round.

Figure 7: Nodes Alive (Number) vs Network Lifetime (Rounds) for LEACH and the Proposed Algorithm

Advantages of the Proposed Algorithm

- Equilateral triangular deployment gives efficient coverage and thus prolongs network lifetime.
- Multi-hop approach reduces energy consumption of nodes far away from cluster head.
- Gaussian elimination method is used for cluster head selection. This helps in prolonging network lifetime.
- Gaussian elimination method not only considers the residual energy of the nodes but also its location in the cluster for selection of the cluster head. Hence the possibility of selection of a node as a cluster head which is at the edge of cluster is removed.

- Gaussian elimination algorithm performs clustering only once at the initial stage which saves time and energy consumption for re- clustering.
- As TDMA schedule is set up by the cluster-head and it is transmitted to the nodes in the cluster there are no collisions among data messages.
- The radio components of the nodes are turned off during transmit time of the other nodes which reduces energy consumption.

Limitation of the proposed algorithm is in multi hop approach the area near the sink is burdened with heavy traffic, thus becoming hotspot. Because of this the sensor nodes in the hotspot are prone to drain their energy and die faster than other nodes, which will further cause problems in data forwarding to the base station.

Future Scope

Proposed algorithm can evolve into a protocol by forming "super-clusters" out of the cluster head nodes and having a "super-cluster head" that processes the data from all the cluster head nodes in the super cluster. These changes will make the proposed algorithm suitable for a wider range of wireless sensor networks. This paper considers only static nodes making them dynamic or mobile would further increase its application and give whole new dimension to the network.

As discussed in this paper Energy saving in batteries is important. The concept of WiTricity can be used as it can be easily used to transmit power to the remote areas. Various primary stations can be constructed and these stations would have a particular area under their range. There may be large number of sensor nodes under this particular area. PowerbyProxi uses coils to transmit and receive power between a power transmitter (PTx) and power receiver (PRx). Depending on their specific power requirements of the electrical devices, this power controller regulates the power flow to the device from the receiving PRx coil. Furthermore RF antennas need to be tuned to maximize the signal strength and increase efficiency and hence in Powerby Proxi a patented tuning technology called dynamic harmonization control (DHC) is used. It provides better performance by dynamically varying the frequency in response to environmental and load changes. Also various advantages like better efficiency, reduced receiver size & negligible electromagnetic interference is achieved. Efficiency of around 90% can be achieved by using Proxi Wave technology[6]

CONCLUSIONS

Wireless sensor networks have many applications in our day to day life and it can be used to play an important role for a number of applications. Energy saving is an important issue in wireless sensor networks. In the proposed algorithm, we have proposed Gaussian elimination method for the cluster head selection, which reduces energy consumption and make the wireless sensor networks more efficient and reliable by not only considering the residual energy of the nodes but also its location in the cluster for selection of the cluster head. Gaussian elimination method also computes the number of rounds for which a particular node can become cluster head. Equilateral Triangular deployment is used for the sensor nodes which gives efficient coverage and thus prolongs network lifetime. Further TDMA schedule is set up so as to reduce collision & save energy. Also multi hop routing scheme helps in reducing the energy consumption. Thus the proposed algorithm will help in reducing the overall power consumption and increase the efficiency of the network by saving the energy of the wireless sensor network.

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