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Grid Based Cluster Head Selection Mechanism for Wireless Sensor Network

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Abstract

Wireless sensor network (WSN) consists of hundred to thousands sensor nodes to gathered the information from physical environment. Different clustering based algorithms have been proposed to improve network lifetime and energy efficiency. Practically it is not feasible to recharge the battery of sensor nodes when they are sensing the data. In such situation energy is crucial resource and it should be improved for life span of WSN. Cluster head (CH) has an important role in hierarchical energy efficient routing protocols because it receives data from nodes and sends towards base station (BS) or sink node. This paper presents a grid based cluster head selection (GBCHS) mechanism by dividing the network field into MXN uniform size partitions that aims to minimize the energy dissipation of sensor nodes and enhancing network lifetime. Simulation experiments have been performed in network simulator (NS2) that show our proposed GBCHS approach outperformed than standard clustering hierarchy LEACH protocol.

Keywords*: cluster head, network lifetime, energy resource, base station, grid construction*

1. Introduction

WSN consists of several sensor nodes with one or many sink nodes that are scattered in a physical environment to sense the events and gathering data. Sensor nodes sense the environment gathering information, integrate the data and send towards BS or sink node. The sink in turn queries the sensor nodes for information [1]. Manage connectivity and detecting nodes or link failures is difficult in unstructured WSN because there is large number of nodes. The sensor nodes are tiny devices with limited constraints and it is not feasible in deployed scenarios to recharging the batteries. Therefore to decrease energy consumption and prolonging the WSN lifetime is main design objective for sensor based applications and mechanisms [2]. Cluster based routing protocols decreases network complexity and give better routing efficiency .That's why these protocols are more attractive in the area of WSN. Based on the role of sensor nodes in cluster based networks can be divided into four different categories.

1) Cluster head (CH): It is coordination of a group of nodes located within the boundaries of the cluster. It receives, compress and aggregate the sensed data by the cluster members and transmit to next hop.
2) Base station (BS): It has high processing capabilities and unlimited source of energy. All the aggregated data processed here and then forward to end user.
3) Relay node (RN): Also called gateway node and it is responsible for relaying sensed or aggregated data by other nodes towards the destination.
4) General node (GN): These are common nodes that sensed the physical environment and forward the data to their cluster heads (CHs).

Minimize energy consumption, routing overheads and collisions are some main advantages of cluster based routing protocols. In clustering mechanism the role of sensor nodes are divided into CH, relay node, general node and BS categories. The two main categories of clustering mechanisms in WSN are static and dynamic. When clusters are formed in static mechanism then they remain same throughout of WSN lifetime but in dynamic the role of CHs are rotated among sensor nodes to prolong the network lifetime and balance the energy consumption. Cluster based routing protocols uses single and multi hop mechanisms. Multi hop communication prolongs energy efficiency and network lifetime so it should be adopted [3]. Due to sensor node's limited constraints adhoc routing protocols are not feasible for WSN

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application. Limited constraints of sensor nodes have posed many research problems for prolonging WSN lifetime.

WSN consist number of nodes with limited memory, processing, power and energy resources. Due to such limited resources monitoring the interested physical environment by numerous sensing devices for a long period of time makes it a challenging task. Saving energy to enhance the network's lifetime is a critical problem in WSN and therefore "how to enhanced and improve the WSN lifetime" is a crucial question. The primary objective of WSN is data collection and transmission. Free space and multipath fading are two types of models in for WSN. There is a nonlinear relationship between each node in terms of the energy consumption of wireless communication. The energy consumption of free space model is much smaller than that of multipath fading model. When sensor node is far away from BS, it may be run out of energy shortly that would lead to quality reduction of network [4].

Dynamic hierarchical routing protocol LEACH [5] consists of several rounds and each single has setup and steady phases. All sensor nodes consist of homogeneous structure. CH is selected in setup phase and then dynamically different clusters are formed. Each cluster has its local CH and sensor nodes. Selected CH sends an advertised message to all nodes and nodes response on that received message. After receiving all the data from nodes CH aggregate and compress them and transfer to sink node. LEACH selects the CH periodically. Random number is generated by each node and the node will be selected as CH if this random number is smaller than predefine threshold value. The predefine value set to zero if this same node has elected again as a CH for same round. In steady phase TDMA is used so that every member node send data to CH when receive its own time slot. The threshold formula for LEACH is shown in eq 1.

$$Tn = \begin{cases} \frac{P}{1-P+\left(r \bmod \frac{1}{P}\right)} & if\ n\ \in G\ otherwise \\ 0 \end{cases} \quad (1)$$

P shows the desired percentage of CHs, r denotes the current round, and G is the set of nodes that have not been elected as CHs in the last 1/p round.

LEACH-B proposed that the protocol needs to ensure that the partition of cluster is balance and uniform to save the energy consumption among nodes and to prolong the lifetime of the network. To accomplish this objective, the number of CHs needs to be dominated and the network needs an optimal CHs. Authors in [6] have proved that WSN will be energy efficient if the network has between 3 and 5 clusters from the total 100 sensor nodes. It means the optimal percentage of CHs range from 3% to 5%. LEACH-B improved the original LEACH algorithm by taking the node's residual energy into consideration and keeping the constant and near optimal number of CHs at each round.

Power efficient Gathering in Sensor Information Systems (PEGASIS) [7] is an improved version of LEACH. It forms a chain of group of sensor nodes and each node transmits and receives data from its neighbor nodes and takes turn being a leader for transmission to the destination. Only one node can send the data to destination at a time. Gathered data is aggregated at the sensor nodes when it moves from node to node. PEGASIS works on two steps to construct the chain. Firstly sensor nodes and BS are self organized with greedy algorithm and secondly after the chain construction BS broadcast the information to all sensor nodes.

Authors proposed [8] cluster based k-means protocol to form the k-clusters of objects based on the euclidean distance. Initially the CHs are selected on the basis of random number as in LEACH to form the initial clusters. Then after the formation of initial clusters, centroid is determined to find the center location of each cluster and the node is selected as a new CH which is closer to centroid. The role of CH is rotated when energy is drain out from certain energy threshold. It prolongs network lifetime and energy efficiency of WSN than proposed schemes [5],[9].

Hybrid Energy-Efficient Distributed clustering (HEED) [9] is another cluster based routing protocol and based on multi hop approach to prolong the energy efficiency and WSN lifetime. Residual energy of nodes and intra communication cost are mainly two parameters have been used in this approach for the selection of CH among sensor nodes. HEED provides

even distribution of CHs and the chances for two nodes within same communication range can be selected as CHs is very low.

Grid routing protocol(GROUP) [10] provides scalability and efficient packets delivery in large region of WSN. It arranges all the nodes dynamically in different regions called clusters and each cluster has its own CH. Virtual grid is made by all selected CHs. One of the sinks proactively and dynamically builds grids for forwarding query messages and data packets. It improved network lifetime and energy efficiency by balance the energy load among sensor nodes as compare to LEACH.

A New Routing Protocol for Efficient and Secure WSN [11] improves network lifetime and energy efficiency . It is round based scheme and network area is divided into a number of squares, each has same number nodes. Squares remain same and do not change in every round. A square is a cluster and all clusters do not change in all rounds. A cluster consists of four cells. CHs are elected in each cell at the start of new round. Data is send towards sink node in multi hop manner. To provide secure communication among nodes, setup server distributes different management keys in each round. It balances the energy consumption among sensor nodes and gives secure communication mechanism for WSN.

In energy efficient clustering scheme (EECS) [12] candidates nodes compete for the ability to elevate to CH for a current round. Each round has fixed time interval and re-clustering occurs at the start of next round. In this approach candidate nodes broadcast their residual energy to neighboring nodes. If a given node does not find a node with more residual energy, it becomes a CH. EECS use different way for cluster formation than LEACH. LEACH performs cluster formulation based on the minimum distance of sensor nodes to their corresponding CH. EECS extends LEACH protocol by dynamic sizing of clusters based on cluster distance from the BS.

Authors in [13] proposed cluster based energy efficient routing protocol (CBERP) for prolonging network lifetime and energy efficiency by combining LEACH and PEGASIS approaches. Clustering procedure is same as in LEACH i.e based on random number CH is selected among sensor nodes while chain is constructed using PEGASIS. All nodes send their energy information to BS for CHs selection. Based on the highest energy level BS selects four CHs. The highest energy level node is considered as first CH and the rest assumed as candidate nodes. When energy level of selected CH is drain down by defined energy limit the next candidate node is selected as new CH. To forward the data to BS greedy algorithm is used to form chain. Table 1 presents the summary of clustering based energy efficient schemes that have discussed in this section.

Table 1. Methodology and Problems of Different Clustering Based Energy Efficient Schemes

Energy Efficient Protocols in WSN	Methodology of CH Election	Issues
LEACH	Probabilistic based	Predefined CHs and residual energy is not considered for CH selection
LEACH-B	Random number and residual energy	High Energy consumption due to single hop.
PEGASIS	Greedy method	Long latency ,no energy and BS location consideration while electing the CH
K-means CH selection	Euclidean	Single hop and clustering overheads
HEED	Residual energy and intra communication cost.	Energy dissipation overheads
GROUP	Distance	Periodically reconstruct data aggregation tree
Routing Protocol for Efficient and Secure WSN	Random number	Overheads due to keys distribution
EECS	Node residual energy	Energy dissipation ,Overheads on nodes due to global information aggregation
CBERP	Residual energy	Overheads and not suitable for large scale WSN

It is difficult for sensor nodes to maintain their energy level uniformly thus it reduces network lifetime and energy efficiency. Because network's lifecycle depends on the alive of nodes so to choose the suitable CHs among sensor node is the main research challenge for clustering protocols. Several proposed cluster based routing protocols for WSN [5],[7],[9],[14] emphasizes on minimizing the routing overheads and energy usage of the sensor nodes but still the issue is unable to prevent completely [15]-[17]. Design of energy ware cluster based mechanism is an key research problem for prolong WSN lifetime and efficiency [18]. The rest of the research paper is organized as follows. Our GBCHS approach is presented in section 2. Research method is shown in section 3. Simulation results and discussions are covered in section 4. Section 5 concludes the paper and suggests for future work.

2. Proposed Method

In this section we present detailed description of our proposed GBCHS, including how to partition the sensing field into uniform size square grids and how to select CH in each grid for prolonging life span of network and energy efficiency. Proposed *mechanism* is divided into two main phases. One is initial clustering and the other one is data transmission. Initial clustering consists of grids construction, CHs selection and TDMA scheduling while packets forwarding from CHs towards destination occurs in data transmission phase. Before going to describe our GBCHS, we highlight the various assumptions for WSN that are as follows.

i. All nodes are deployed randomly and remain static.
ii. Sensor nodes have same initial energy level.
iii. BS has location information of all sensor nodes.
iv. CHs are responsible to send their members data towards BS.
v. All nodes will use the same radio channel for communication with each other.
vi. All the nodes communicate via a shared bidirectional wireless channel.

The algorithm of our proposed GBCHS is discussed in detail as follows:

Step 1: Suppose that n number of sensor nodes is randomly deployed in network sensing field. At the start of simulation round, every sensor node send its location information to BS and proposed scheme initiates the procedure to dynamically divide the entire network field into K uniform size square grids based on number of deployed nodes and network size. BS structures the sensor field into equal size of rows and columns in order to form uniform size grids. All constructed grids are of same size and each one is considered as a single cluster. To control the communication within grids and reduces energy dissipation among sensor nodes, one node is selected as CH to forward the aggregated data towards sink node or BS.The process of grid construction and clusters formation is executed only once time in entire lifetime of WSN in order to minimize the energy consumption and re-clustering overheads.

Step 2: After the construction of uniform sized square grids, our proposed GBCHS initiate the CHs election procedure within grids. It prolongs network lifetime and energy efficiency because only few nodes come for election process due to grid construction.

Step 3: BS determines the centre point for each grid and all sensor nodes determine their distance from it. Based on the minimum distance from grid centre, GBCHS assigned a priority ID to all nodes and arrange them in linear fashion. Finally, in each grid the node is selected as a CH whose distance is very closest to centre point.

Step 4: In order to receive and aggregate the data from sensor nodes, all selected CHs announce their local TDMA schedule. Each sensor node sends its sense data towards CH when it receives time slot.

Step 5: Several proposed energy efficient schemes consist of rounds and periodically performed re-clustering mechanism to rotate the role of CHs among sensor nodes for balancing the energy consumption. But due to re-clustering phase, such approaches degrade network lifetime and increasing communication overheads. In our proposed GBCHS, we rotate the role of CH by using round robin method.

Step 6: Each CH has given preset time period and when it expires, BS elects the next node as new CH that has highest priority i.e relatively closer to grid centre. In this way equally energy consumption is distributed among sensor nodes. To synchronize the communication

among sensor nodes, proposed scheme updates the TDMA schedule every time when it elects new CH and all nodes are informed.

Step 7: Energy is highly consumed in single hop as compare to multi hop communication. So distance is the one of main factor that reduces node's energy rapidly and degrades life span of WSN. Therefore to overcome this issue, GBCHS adopt multi hop communication mode for data forwarding towards BS.

Step 8: Whenever CH needs to send data then determine the nodes around its surrounding. It finds the distance with BS and closest surrounding CH. Based on the minimum distance, data is forward towards destination i.e either through closest next hop or directly to BS.

3. Research Method

In this section we present our simulation model that has been used in different experiments by using well known tool network simulator (NS2) [19]. We randomly deployed 100 sensor nodes within sensor field of 100 X 100 dimensions. Energy model assumed as being used in [5] and a considered free space radio propagation model. The system parameters that have been used in experiments are shown in Table 2. We compared our proposed GBCHS with LEACH protocol with respect to number of alive sensor nodes, total network remaining energy and network throughput performance parameters.

Table 2. System Parameters

Parameter	Value
Network area	100*100m
Nodes	100
Initial energy	5J
Deployment	Randomly
Data packet size	512 bytes
Position	Static
Channel Type	Wireless
Communication	Bi directional
Base station energy	100
Energy Model	Battery
Transport layer protocol	UDP
Simulation time	600sec

4. Results and Discussion

In this section we used different parameters to evaluate the performance of our proposed GHCHS approach with standard hierarchy clustering LEACH protocol. The simulation results of our performed experiments are shown as follows.

4.1. Number of Alive Sensor Nodes

Network lifetime is an important factor to evaluate the performance of cluster based energy efficient scheme. The node can sense and send data towards its destination until it is alive and stable. We performed experiment to determine the number of stable nodes on regular interval basis i.e at the end of 100 seconds and Figure 1 shows that our proposed GBCHS *mechanism* gives better percentage of alive nodes as compare to LEACH because of distributing the CHs in uniformly way and avoid the re-clustering process to rotate the role of CHs among sensor nodes thus increasing network stability period and life span of network. During simulation experiment, we considered node as dead and unstable when its energy level reaches to 0J.

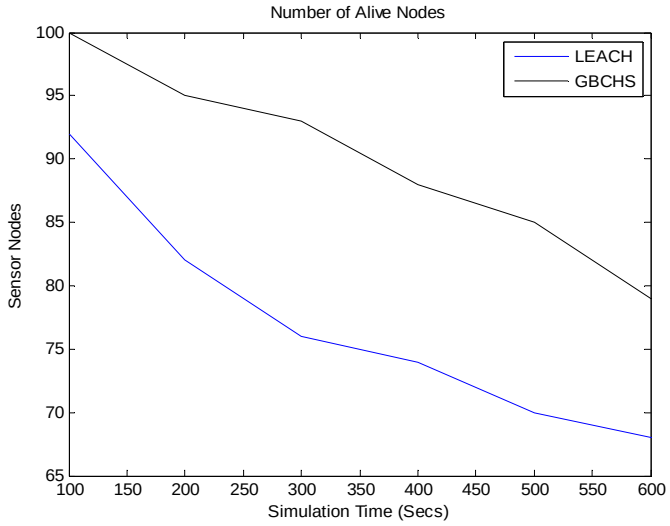

Figure 1. Number of alive sensor nodes over simulation time

4.2 Network Remaining Energy

Energy is very restricted and main resource in WSN. Therefore to minimize the energy consumption among sensor nodes is one of the main objectives for designing cluster based schemes. We performed simulation experiment for monitoring the status of total network remaining energy at the end of regular time intervals and it is proven in Figure 2 that proposed GBCHS *mechanism* gives better outcome to balance the energy usage between sensor nodes as compare to LEACH protocol.

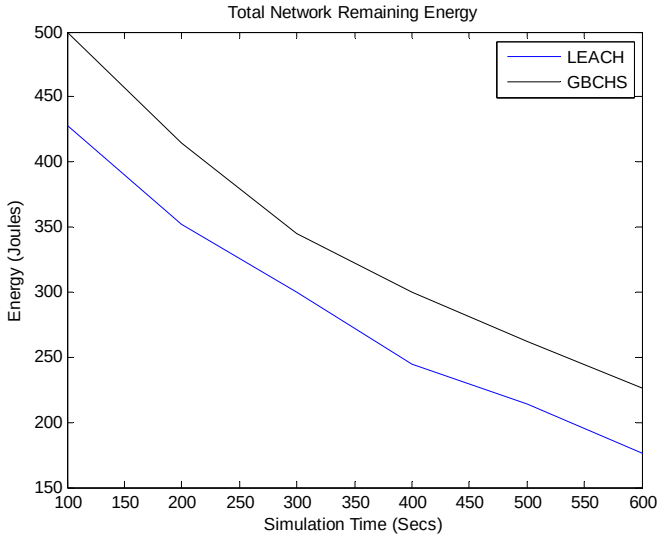

Figure 2. Network remaining energy over simulation time

4.3 Network Throughput

Network throughput means how many data packets have been send by CHs towards destination i.e sink node or BS. In single hop, CHs directly send their aggregated data to sink node and due to distance factor they consume energy rapidly thus mostly data packets are dropped. To increase the network throughput, our proposed GBCHS *mechanism* has adopted

multi hop communication and data is transferring by closest CH to sink node. Figure 3 shows that proposed approach gives better data delivery rate at destination end as compare to LEACH.

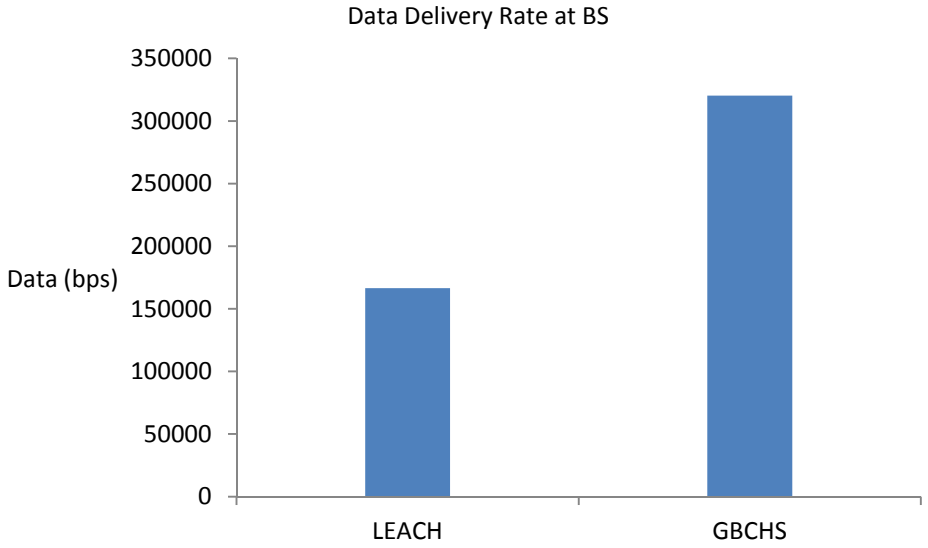

Figure 3. Number of sending packets towards BS

5. Conclusion

Energy dissipation is main factor in WSN for prolonging lifetime. Clustering techniques are mainly used to effectively utilize the energy resource. GBCHS divides the network field into uniform square sized grids and each grid is considered as a single cluster. One node is selected as CH in order to aggregate the member's data and forward towards BS. Role of CH is rotated among sensor nodes by round robin fashion inside each grid to balance the energy consumption. Our proposed scheme has eliminated re-clustering procedure after the end of regular interval thus it reduces communication overheads and energy consumption. Furthermore based on minimum distance, multi hop route is adopted for data forwarding towards destination. Simulation results show that proposed GBCHS mechanism outperformed than standard LEACH protocol in terms of different parameters. In future work, we will further improve the performance of GBCHS mechanism by grouping the sensor nodes to form energy aware and balanced clusters.

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