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GEECA: Grid Based Energy Efficient Clustering Algorithm for Mobile Wireless Sensor Networks

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Abstract: Energy Efficiency is the critical need of Mobile Wireless Sensor Network (MWSN) due to the limitation in the size of the device and the disability to replace the battery of the nodes. In this paper, a Grid Based Energy Efficient Clustering Algorithm for Mobile Wireless Sensor Networks (GEECA) is proposed to select the Cluster Heads (CHs) thereby minimizing the energy consumption. The simulation results are compared with a prevailing clustering algorithm, which reveals that the proposed algorithm outperforms the existing algorithm.
Keywords: MWSNs, Clustering, Grid, Mobility, Energy Efficiency.

INTRODUCTION

Mobile Wireless Sensor Networks [1] is a network of mobile sensor nodes is deployed randomly in a specific area to monitor the physical and environmental conditions. Energy efficiency is a key issue as the nodes consume energy while communicating with each other. Clustering is an Energy Efficient technique used to minimize the energy consumption during the delivery of packets from a Sensor node to the Base.

In this paper, a Grid Based Energy Efficient Algorithm for Mobile Wireless Sensor Networks (GEECA) is proposed to minimize the energy consumption while electing a Cluster Head (CH). The weight is calculated for each node based on the degree, energy, distance and mobility. The node with maximum weight is elected as a Cluster Head.

The rest of the paper is organized as follows: Section II deals with the Related work followed by, the network model and problem specification in section III. Section IV and V describes the proposed algorithm and the experimental results. Section VI concludes the paper.

Related work

Researchers have proposed several algorithms for Cluster Head selection in MWSN where Clustering technique is used to communicate within the network, but still there exist various challenges for Cluster Head Election process. Fuzzy-TOPSIS based Cluster Head selection in Mobile Wireless Sensor Network proposed by Bilal Muhammad Khan, *et. al.* [2] mainly focuses residual energy, node energy consumption rate, and number of neighbor nodes, average distance between neighboring nodes and distance from the sink. A threshold based intra-cluster and inter-cluster multi-hop communication mechanism is used to decrease energy consumption. Finally, after every round completion, the sink moves its position by using sink predictable mobility with an octagonal trajectory

Eid Rehman, *et al.* proposed an Energy Efficient Secure Trust Based Clustering Algorithm for Mobile Wireless Sensor Network [3] which focuses on calculating the weight of each node to deal with secure selection using minimum energy consumption. The weight of node is calculated based on the trust metric (behaviors of sensor node) which promotes a secure decision of a CH selection which will never be a malicious one. The trust metric prevents from selecting a malicious node as a CH. Other metrics include waiting time, connectivity degree, and distance among nodes. The selection of CHs is completed utilizing weights of member nodes.

Fire Fly Optimization Algorithm based Clustering by Preventing Residual Nodes in Mobile Wireless Sensor Networks proposed by Ramandeep Kaur, *et al.* [4] provides an efficient clustering for avoidance of residual nodes and prevents occurrence of dead nodes with usage of mobile nodes. Firefly Optimization is used for prevention of residual nodes and efficient clustering. It uses distance and light intensity parameters for clustering. GSA algorithm used for finding best path for data transmission with less energy consumption. Mobile nodes are used and occurrence of dead nodes is prevented on basis of distance and light intensity parameters. Nodes which are at minimum distance are brighter than farthest nodes. Minimum distance nodes join nearest cluster and prevent formation of remaining nodes and outperforms better in terms of network lifetime, energy consumption, end to end delay and throughput and number of dead nodes.

An Improved Cluster Head Selection Algorithm for Mobile Wireless Sensor Networks proposed by Kavita Gupta, *et al* [5]. The cluster head is primarily selected on basis of the residual energy of the node during the communication. Node with highest remaining energy will be elected as new cluster head. The unique contribution of this research work is a process when the existing cluster head moves out of the cluster range and cluster remains unattended. The results obtained are reflecting a significant improvement in the life time of the network and it was further discovered that the ratio of unattended clusters has reduced potentially.

In EEDBC-M: Enhancement of Leach-Mobile protocol with Energy Efficient Density-based Clustering for Mobile Sensor Networks (MSNs) proposed by R.U. Anita *et al* [6] DBSCAN algorithm is used for cluster formation that are significantly more effective in discovering clusters of arbitrary shape. Then cluster head selection process is according to a node residual energy, Mobility and density such as node closeness to its neighbors. It also achieves quite uniform cluster head allocation across the network.

The critical look at the literature presented above highlights the fact that there exists lot of clustering based mechanisms but very few are suitable for MWSN. Moreover the best of our knowledge, none of these have suggested an algorithm addressing issues such as electing a Cluster Head with minimum energy consumption, minimum distance to the Base Station, minimum Mobility and maximum Degree based on the weight of the node [7-9]. Hence an improved design of CH selection algorithm is being proposed in next section.

Proposed work

Enhanced Energy Efficient Clustering Algorithm (EEECA) [10], an energy efficient algorithm which minimizes the energy consumption and thereby maximize the lifetime for the MWSN. EEECA algorithm was designed for the nodes which change the mobility with time. The algorithm focused mainly on four metrics, namely the Degree, Energy consumption, Distance between the node and the Base Station and the Mobility of a node. The weight of each node is calculated and the node with minimum weight is considered as the Cluster Head.

Issues in EEECA

EEECA finds a Cluster Head based on the weight calculated using four metrics namely Degree, Energy Consumption, Distance between node and the Base Station and the Mobility of the node. The Node with minimum weight is elected as Cluster Head for 100 nodes. It is an overhead for the Cluster Head as it has to send and receive messages from and to the Cluster Members as the size of the Cluster is large. The energy of the Cluster Head drains and the node is subjected to deplete energy and lead to the death of the node.

GCEEA Algorithm

The proposed algorithm Grid Based Energy Efficient Algorithm (GEECA) uniformly partitions the sensing field into four equal sized square grids. The algorithm selects a Cluster Head in each grid based on the weight calculated from four metrics, Degree of the node, Energy Consumption of the Node, Mobility of the node and the Distance between the Base Station and the node. The algorithm also elects a new Cluster Head when the Cluster Head leaves the Grid area due to mobility.

GEECA highlights mainly on the various assumptions for Mobile Wireless Sensor Networks that are as follows.

- All nodes are deployed randomly and are in mobility.
- Sensor nodes have same initial energy level.
- The location of BS is in the center of the sensing field.
- All the Cluster Members send data to the CH which is forwarded to the Base Station.
- All nodes will use the same radio channel for communication with each other.
- All the nodes communicate via a shared bidirectional wireless channel.

Algorithm

Step 1: Partition the sensing area into four uniformly sized Grids.

Step 2: Deploy the nodes randomly in the sensing area.

Step 3: For each node i = 1 to N in each Grid

- Calculate the Distance *Dis_BS(i)* between the node and the Base Station.
- Calculate the Degree *Degree(i)* of each node.
- Calculate the Energy consumption *Ec(i)* of each node. The Energy consumption includes energy consumed during the transmission and reception of data.
- Calculate the Average Mobility *Mob(i)* of the node.
- Calculate the weight of each node based on the Distance, Energy, Degree and Mobility.
- Node with minimum weight is elected as CH.

Step 4: The Cluster Heads are newly elected whenever the Cluster Head leaves the Grid area.

MWSN parameters and definitions

The Mobile Wireless Sensor Network can be defined by a graph *G = (V, E)* where *V* represents the Sensor Nodes and *E = {(u,v)***:***V/D(u,v)<=R}* represents the wireless connection between two nodes *u* and *v*. *R* represents the Transmission Range and *D(u,v)* represents the Euclidean Distance between node *u* and *v*.

Table I defines the parameters and their definitions in MWSN.

Table-1: Parameters and their definitions in MWSN

Parameters	Definitions
N	Number of nodes
M(i)	Mobility level of *u*
Ec(i)	Energy consumed by the node *u*
DisBS(i)	Distance between the node *u* and the Base Station
Deg(i)	Degree of node *u*
Weight(i)	Weight of the node *u*
Mob(i)	Mobility of *u*

Simulations and results

The algorithm is implemented using MATLAB 7.0.1 tool. The number of nodes N varies from 10 to 100. The simulation is carried out in a space of 100m x 100m and the Transmission Range of 40 m. The size of the message is 4000 bits. The initial Energy EI is 1.5J, Eelec=50nJ/bit, ϵ_{amp}=100pJ/bit/m^2. The BS coordinates are (50, 50).

EEECA VS GEECA

The proposed algorithm GEECA is compared with the recent algorithm EEECA (Enhanced Energy Efficient Clustering Algorithm for Mobile Wireless Sensor Networks). This algorithm selects a node with minimum weight as the Cluster Head. Table 2 represents the comparison of average energy consumption of EEECA and GEECA at Grid 1. Fig.1 represents that the average energy consumption of GEECA at Grid 1 is lesser than EEECA.

Table-2: Comparison of average energy consumption of EEECA Vs GEECA at Grid 1

Time (Sec)	Energy (Joules)	
	EEECA	GEECA_Grid -1
10	0.001073105	0.000711333
20	0.001436611	0.00064505
30	0.001682869	0.00049025

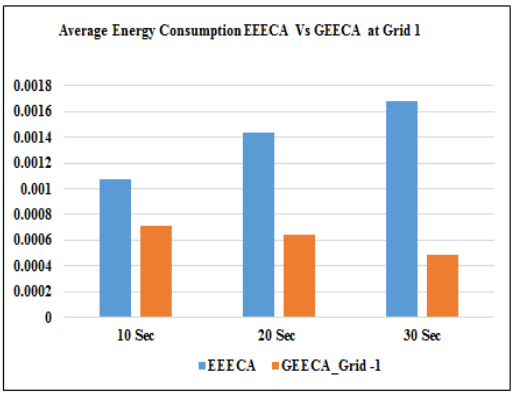

Fig-1: Energy Consumption EEECA Vs GEECA_Grid-1

Table 3 represents the comparison of average energy consumption of EEECA and GEECA at Grid 2. Fig.2 represents that the average energy consumption of GEECA at Grid 2 is lesser than EEECA.

Table-3: Comparison of average energy consumption of EEECA vs GEECA at Grid 2

Time(Sec)	Energy (Joules)	
	EEECA	GEECA_Grid - 2
10 Sec	0.001073105	0.00089207
20 Sec	0.001436611	0.00088414
30 Sec	0.001682869	0.0007945

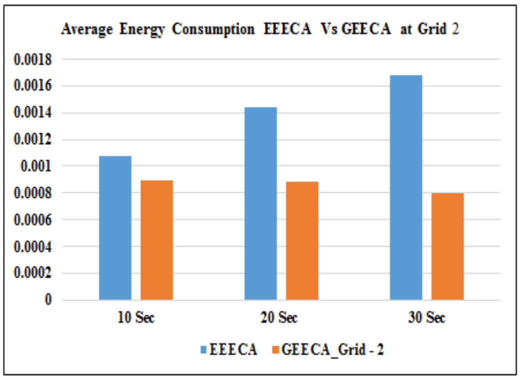

Fig-2: Energy Consumption EEECA Vs GEECA_Grid-2

Table 4 represents the comparison of average energy consumption of EEECA and GEECA at Grid 3.

Fig.3 represents that the average energy consumption of GEECA at Grid 3 is lesser than EEECA.

Table-4: Comparison of average energy consumption of EEECA Vs GEECA at Grid 3

Time (Sec)	Energy(Joules)	
	EEECA	GEECA_Grid – 3
10	0.001073105	0.00073558
20	0.001436611	0.00083135
30	0.001682869	0.00076567

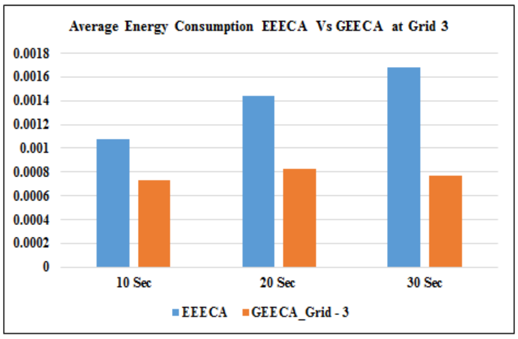

Fig-3: Energy Consumption EEECA Vs GEECA_Grid-3

Table 5 represents the comparison of average energy consumption of EEECA and GEECA at Grid 4.

Fig. 4 represents that the average energy consumption of GEECA at Grid 4 is lesser than EEECA.

Table-5: Comparison of average energy consumption of EEECA Vs GEECA at Grid 3

Time (Sec)	Energy (Joules)	
	EEECA	GEECA_Grid – 4
10	0.001073105	0.000980333
20	0.001436611	0.00112564
30	0.001682869	0.000881

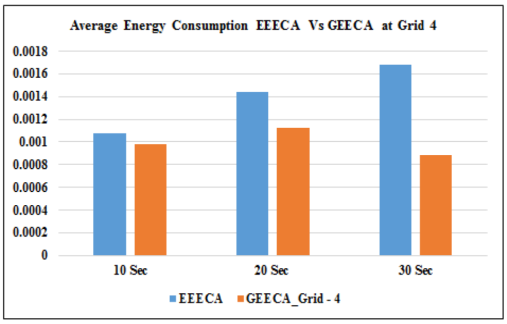

Fig-4: Energy Consumption EEECA Vs GEECA_Grid-4

Table 6 represents the comparison of energy consumption with mobility based on time in EEECA and GEECA at Grid 1. Fig.5 depicts the energy consumption of EEECA and GEECA during mobility for duration of 10 Seconds, 20 Seconds and 30 Seconds in Grid 1. The Figure shows that the energy consumption at 10 Seconds, 20 Seconds and 30 Seconds is lesser in GEECA at Grid 1 than EEECA as the migration of nodes to Grid 1 is very low compared to the migration of nodes from Grid 1 to Grid2, Grid3 and Grid4.

Table-6: Comparison of energy consumption with mobility based on time at Grid 1

Mobility	Energy (Joules)					
	10 Sec		20 Sec		30 Sec	
	EEECA	GEECA - Grid 1	EEECA	GEECA - Grid 1	EEECA	GEECA - Grid 1
0.989949	0.000439	0.000439	0.000439	0.000429	0.000439	0.000439
1.08423	0.000439	0.000439	0.000439	0.000429	0.000439	0.000439
1.131371	0.000451	0.000439	0.000451	0.000439	0.000451	0.000451
1.178511	0.000451	0.000439	0.000451	0.000439	0.000451	0.000451
1.225652	0.000465	0.000439	0.000465	0.000439	0.000465	0.000451

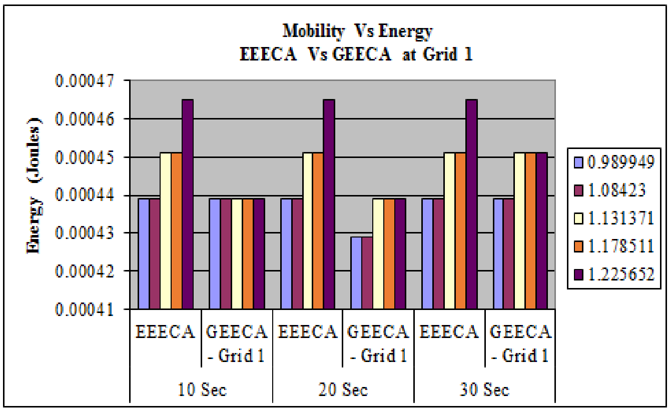

Fig-5: Energy Consumption Vs Mobility at Grid-1 based on Time

Table 7 represents the comparison of energy consumption with mobility based on time in EEECA and GEECA at Grid 2. Fig.6 depicts the energy consumption of EEECA and GEECA during mobility for duration of 10 Seconds, 20 Seconds and 30 Seconds in Grid 2. The Figure represent that the energy consumption is reduced at 20 Seconds and 30 Seconds in GEECA at Grid 2 as the migration of nodes from other Grids to Grid 2 is very less.

Table-7: Comparison of energy consumption with mobility based on time at Grid 2

Mobility	Energy (Joules)					
	10 Sec		20 Sec		30 Sec	
	EEECA	GEECA - Grid 2	EEECA	GEECA - Grid2	EEECA	GEECA - Grid 2
0.989949	0.000439	0.000439	0.000439	0.000439	0.000439	0.000439
1.08423	0.000439	0.000439	0.000439	0.000439	0.000439	0.000439
1.131371	0.000451	0.000451	0.000451	0.000439	0.000451	0.000439
1.178511	0.000451	0.000451	0.000451	0.000439	0.000451	0.000451
1.225652	0.000465	0.000465	0.000465	0.000439	0.000465	0.000451

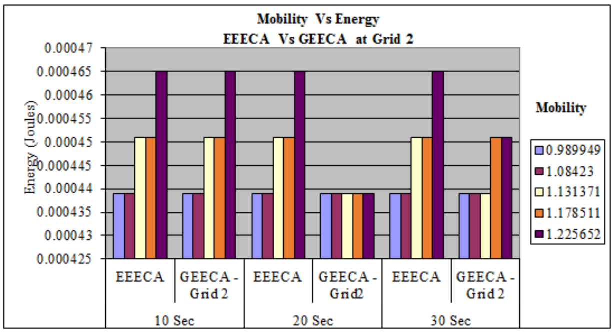

Fig-6: Energy Consumption Vs Mobility at Grid-2 based on Time

Table 8 represents the comparison of energy consumption with mobility based on time in EEECA and GEECA at Grid 3. Fig.7 depicts the energy consumption of EEECA and GEECA during mobility for duration of 10 Seconds, 20 Seconds and 30 Seconds in Grid 3. The Figure shows that the energy consumption at 20 Seconds and 30 Seconds remains the same in GEECA at Grid 3 which is slightly lesser than EEECA. The energy consumption at 20 Seconds and 30 Seconds in GEECA at Grid 3 does not show much variation compared to EEECA as the number nodes entering Grid 3 increases due the migration of nodes from Grid 1and the nodes from Grid 3 are migrated to Grid 4.

Table-8: Comparison of energy consumption with mobility based on time at Grid 3

Mobility	Energy (Joules)					
	10 Sec		20 Sec		30 Sec	
	EEECA	GEECA - Grid 3	EEECA	GEECA - Grid 3	EEECA	GEECA - Grid 3
0.989949	0.000439	0.000439	0.000439	0.000429	0.000439	0.000429
1.08423	0.000439	0.000439	0.000439	0.000439	0.000439	0.000439
1.131371	0.000451	0.000451	0.000451	0.000439	0.000451	0.000439
1.178511	0.000451	0.000451	0.000451	0.000451	0.000451	0.000451
1.225652	0.000465	0.000465	0.000465	0.000451	0.000465	0.000451

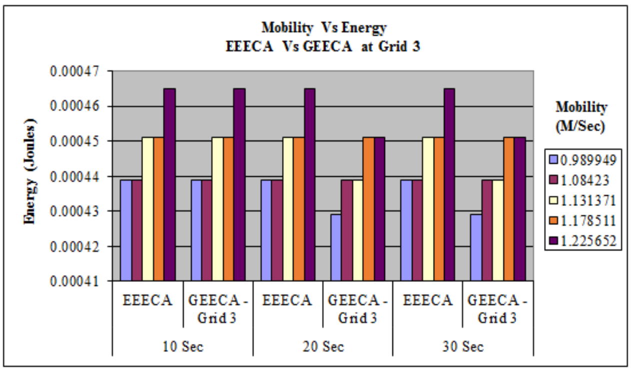

Fig-7: Energy Consumption Vs Mobility at Grid-3 based on Time

Table 9 represents the comparison of energy consumption with mobility based on time in EEECA and GEECA at Grid 4. Fig.8 depicts the energy consumption of EEECA and GEECA during mobility for duration of 10 Seconds, 20 Seconds and 30 Seconds in Grid 4. The energy consumption is reduced during 20 seconds and 30 seconds in GEECA at Grid 4 than EEECA as the migration of nodes from Grid 1, Grid2 and Grid 3 to Grid 4 is increased due to mobility and a set of nodes from Grid 4 is migrated out of the simulation area.

Table-9: Comparison of energy consumption with mobility based on time at Grid 4

Mobility	Energy (Joules)					
	10 Sec		20 Sec		30 Sec	
	EEECA	GEECA - Grid 4	EEECA	GEECA - Grid 4	EEECA	GEECA - Grid 4
0.989949	0.000439	0.000439	0.000439	0.000429	0.000439	0.000429
1.08423	0.000439	0.000439	0.000439	0.000429	0.000439	0.000429
1.131371	0.000451	0.000451	0.000451	0.000439	0.000451	0.000439
1.178511	0.000451	0.000451	0.000451	0.000439	0.000451	0.000451
1.225652	0.000465	0.000465	0.000465	0.000439	0.000465	0.000451

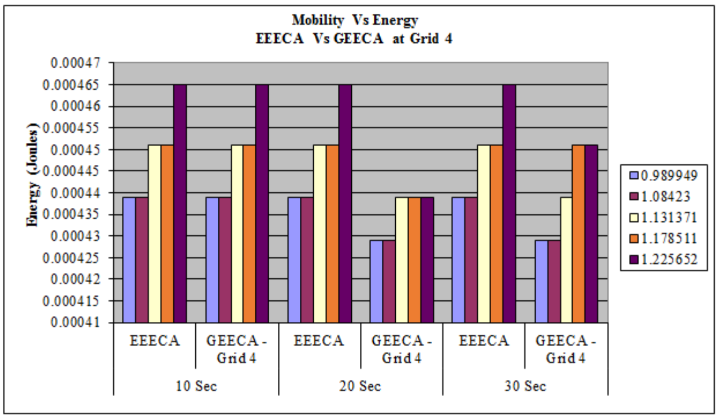

Fig-8: Energy Consumption Vs Mobility at Grid-4 based on Time

CONCLUSION

In this paper, Grid Based Energy Efficient Algorithm for Mobile Wireless Sensor Networks (GEECA) is proposed for reducing the energy consumption. Simulation results showed that the proposed contribution GEECA is more efficient in saving energy and reducing the energy consumption thereby increasing the lifetime of the nodes.

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