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TDTCGE: Two Dimensional Technique Based On Center of Gravity and Energy Center in Wireless Sensor Network

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ABSTRACT

in this paper, an algorithm is proposed based on clustering to reduce energy consumption in sensor networks. TDTCGE algorithm (Two Dimensional Technique Based on Center of Gravity and Energy) is a new technique to select the optimal CH (Cluster Head), in which CH selection is based on finding center of gravity and energy center in each cluster considering distance and energy parameters. An optimal function is created which improves CH efficiency in compare of previous similar techniques. Simulation results show the rounds that first node dies (FND) and the last node dies (LND) are greatly increased. Moreover, network lifetime increasing with low energy consumption in the network .this technique optimize network performance in compare to such algorithms like Low Energy Adaptive Clustering Hierarchy (LEACH) , Stable Election Protocol (SEP), Clustering to Reduce Energy Consumption in WSN (CRCWSN), Low Energy Adaptive Clustering Hierarchy with Sliding Window and Dynamic Number of Nodes (LEACH-SWDN),Clustered Routing Protocol (ERP), Energy-Aware Evolutionary Routing Protocol (EAERP),
KEYWORDS:—Wireless sensor network, Grid, Center of gravity, Energy center, Network lifetime

INTRODUCTION

Sensor network is a series of sensors gathering information from their peripheral environment and sends it to (Base Station) BS or sink [1, 2].

WSNs, due to the numerous benefits that their utilization offers, support an ever growing variety of applications [4]

They are widely used in medicine, military, fire extinguishing, agriculture etc. to gather information and monitoring the peripheral environment [2, 3].

Because of the capacity limitation, computing capability and low-energy batteries, one of the most important issues in sensor networks is optimal energy consumption [6].

In widespread environments, low-energy sensors are not able to connect directly to BS because of far distance of BS [7] or destroying of them cause to reduce efficiency and network life time. In some scenarios such as fire detection and intrusion, it is very critical to make all nodes alive to the greatest extent possible, since destroying of each node will decrease network efficiency. Because of this, a factor called (First Node Dies) FND is defined in which gives an estimated value for destroying the first node [9]. In contrast, there are other scenarios in which the network is able to respond even when there is one or more node/s, and here, the LND factor denotes an estimated value for destroying the last node [10].One of the most effective factors for increasing FND and LND and consequently the lifetime of network are routing protocols and network clustering. There are some classifications in sensor networks. One type of them is based on single-hop and multi-hop. In single-hop routing, (Cluster Head) CH sends information to BS in one time but in multi-hop routing, information will be sent to BS after one time or more from the middle node [9].

Another classification is based on being flat and hierarchy. In flat routing, each node sends its information to BS and there is no middle node but in hierarchical routing, the network will convert to a series of clusters based on clustering algorithm and each cluster includes a CH whose nodes give information to CH and CH will send them to BS after gathering operation for decreasing the size of information [7, 12, 13]. Today, most of algorithms are based on hierarchical routing. Ensuring the required reliability and energy efficiency is an essential issue in WSNs [5].

In this paper, we show energy consumption will decrease due to CH is calculated based on a formula related to the center of gravity and energy center. In this way, the node which is either in more suitable position with respect to BS or is more energetic than other nodes has been elected as the CH. So, the amount of energy stored will be increased. the simulation results show that our proposed algorithm will relatively increase the lifetime of network in compare to mentioned similar algorithms.

RELATED WORKS

The first related/presented hierarchically algorithm is called LEACH (Low Energy Adaptive Clustering Hierarchy) which is the foundation of most algorithms of clustering routing.[6, 12] In LEACH algorithm, each round includes two phases called setup and steady. In setup phase, clusters and CHs are shaped, using threshold intensity. Based on this, each node produces a random number between [0, 1]. If the produced number is lower than P(n), then that node introduces itself as CH; otherwise it is considered as a normal node in the round [24].

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

p: the probability of becoming CH – r: current round – G: a set of nodes which have not become CH in the 1/p current round.

One of the performed optimizations on LEACH is LEACH-SWDN algorithm [17] in which selection of CH is based on residual energy of each node. There is a moving window for making the number of CH(s) sustainable with two parameters 1- initial energy of each node and 2- The average energy of nodes which are never been CH which includes two phases of setup and steady.

$$P_i(t) = \begin{cases} \frac{p}{n-p\left(r \mod \frac{n}{p}\right)} \frac{e_{ic}}{e_{im}}, & c_i(t) = 1 \\ 0 \quad , & c_i(t) = 0 \end{cases} \quad (2)$$

e_{im} Is the initial energy of each node and e_{ic} is the current residual energy of each node i. This algorithm can relatively improve LEACH and increase lifetime of the network.

In algorithm Stable Election Protocol (SEP), the probability function is calculated based on the initial energy of each node in relation to other nodes of the network which is an improvement for LEACH. There are two kinds of nodes in this algorithm, as normal and advanced, in which energy of advanced nodes are more than normal nodes. [18]

$$P_n = \frac{p}{1+\propto * m} \quad (3)$$

$$P_a = \frac{p}{1+\propto * m} * (1+\propto) \quad (4)$$

This guarantees that each normal node will become a CH exactly once every 1/p ∗ (1 + α ∗ m) rounds and each advanced node will become CH each (1/p) ∗ (1 + α ∗ m)/ (1 + α) rounds.

Based on the probability function of LEACH, each of them is separately evaluated for becoming CH called T_n and T_a.This algorithm increases lifetime of the network until the first node would die (FND).

Algorithm Evolutionary based clustered Routing Protocol (ERP) is an algorithm based on EA (Evolutionary Algorithms) using meta-heuristic [19]. At the start of each round, a dynamic clustering will be implemented including setup and steady. For selecting CH in ERP, a population has been used in which each individual includes a list of nodes. Based on formula 1 [11], it gives a value to each node. Then it updates the numbers in the list of individuals in which CHs takes 1, normal nodes takes 0 and dead nodes takes number -1. Then, a fitness function will be determined in order to improve finding clusters based on evolutionary algorithms' rules. The fitness function is based on the distance of information transfer and for this purpose, two kinds of distance are considered: inter distance and intra distance.

Intra distance is calculated based on the following formula:

$$C = \sum_{i=1}^{\mathrm{CHs}} \sum_{\forall n \in c_i} d(n, \mathrm{CH_i}) \quad (5)$$

CHs are number of clusters, c_i is the cluster which ch belongs to that, and n is any node except CH which has the lowest distance with CH_i in c_i cluster.

Inter distance is the lowest Euclidian distance between each pair of CH_i.

$$d_m = \min \{d(\mathrm{CH_i}, \mathrm{CH_j})\} \quad (6)$$

In this way, fitness function is a function which can meet the following conditions simultaneously and minimizesf_1, f_2

$$f_1 = \frac{C}{d_m} \quad (7)$$

$$f_2 = Number\ of\ \mathrm{CH} \quad (8)$$

$$F = W * f_1 + (1 - W) * f_2 \quad (9)$$

So, ERP algorithm can reduce amount of energy consumed and also, average residual energy in final rounds has been increased in compare of algorithms such as SEP, LEACH-SWDN and LEACH.

Based on the model considered in ERP, a model called Energy-Aware evolutionary routing protocol (EAERP) has been developed [20]. Similar to ERP, initial population will be organized based on LEACH model in (1). Then evolutionary operators such as election, recombination and mutation are applied on it in order to increase the quality of CH.

Here a complete solution of cluster routine is considered as an individual with N genes, each of which has energy -1, 0 and 1.

∀i€{1,……n} and ∀j€{1,……n}

$$I_j^i = \begin{cases} 1 & if\ E(n_j) > 0\ and \quad n_j = \mathrm{CH} \\ 0 & if\ E(n_j) > 0\ and \quad n_j = non - \mathrm{CH} \\ -1 & otherwise \end{cases} \quad (10)$$

This algorithm has also decreased amount of energy consumed and energy-saving has been increased.

The CRCWSN algorithm [23], based on genetics, includes rounds in which each round has two phases of setup and steady. During setup phase, clustering is done in grid form and in steady phase, data transfer is done. In this algorithm binary coding system is used to show normal nodes and CH nodes. Selection of CH is based on the distance of each node from center of gravity and initial energy of each node. Genetic algorithm uses a population consisting of bit strands streams called chromosome (initial population), and applies a fitness function on that population in each round. This would be continued until optimal solution will be reached. The fitness function used in CRCWSN is based on Heinzelman model [8,23].

Amount of consumed energy of total network is equal to:

$$E = E1 + E2 + E3 + E4$$

E1: Energy for sending information from each normal node to CH

E2: Energy consumed by CH for receiving information from normal nodes

E3: Energy for gathering information in CH

E4: Energy required for sending information from CH to BS

Through re-clustering, CRCWSN algorithm can increase the lifetime of network, decrease the energy consumed of network and improve LEACH and other previous methods.

CENTER OF GRAVITY

Center of gravity is the average point of the object weight in a way that the object has balance or free turning around that point [21].

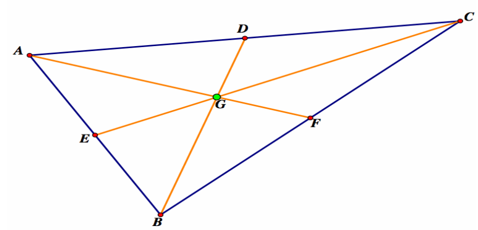

Figure1: Center of gravity

If we want to find center of gravity between two points on x axis, center of gravity will be venter of that line and it is calculated by [22,15]:

$$X_{gc} = \frac{x_1 m_1 + x_2 m_2}{m_1 + m_2} \quad (11)$$

$$Y_{gc} = \frac{y_1 m_1 + y_2 m_2}{m_1 + m_2} \quad (12)$$

If there are m objects with masses m_1, m_2, m_3 … and coordinates (x_1, y_1) ,(x_2, y_2) ,(x_3, y_3)… then the value of x and y for center of gravity is:

$$X_{gc} = \frac{x_1 m_1 + x_2 m_2 + x_3 m_3 + \cdots}{m_1 + m_2 + m_3 + \cdots} \quad (13)$$

$$Y_{gc} = \frac{y_1 m_1 + y_2 m_2 + y_3 m_3 + \cdots}{m_1 + m_2 + m_3 + \cdots} \quad (14)$$

ENERGY CENTER

In order to calculate center of energy [16], the formula of center of gravity has been used but here, we considered mass of each node as 1. So we have:

$$X_{ec} = \frac{x_1 m_1 + x_2 m_2 + x_3 m_3 + \cdots}{c} \quad (15)$$

$$Y_{ec} = \frac{y_1 m_1 + y_2 m_2 + y_3 m_3 + \cdots}{c} \quad (16)$$

And C is the number of nodes.

NETWORK MODEL

1- All sensors and BS are motionless and it is not possible to add or remove any sensor or BS after deployment [14].
2- Initial energy of nodes is different.
3- Each sensor knows spatial position of its own, BS and other node. Therefore there is a need to GPS [14].

ENERGY MODEL

Consumed energy or energy of sending a message is equal to:

$$\begin{cases} E_t = n(E_e + \in_{fs} d^2) & d < d_c \\ E_t = n(E_e + \in_{mp} d^4) & d \geq d_c \end{cases} \quad (17)$$

in this model, each node, to transmit n bits of data in d distance from itself ,consumes E_t.

E_e is energy of sender or receiver of network circuit and $\in fs$ and $\in mp$ are free space parameter and multi-routine remove parameter.

Consumed energy for receiving n bit is equal to:

$$E_r = nE_e \quad (18)$$

SETUP PHASE

In this phase, the network is converted to grids or identical parts. Then CH will be determined for each grid:
Firstly, we find center of gravity and center of energy in each cluster. While each sensor is aware of its own position and BS and other nodes, center of gravity and center of energy is calculated as follow.
Determining center of gravity:
1- If a grid only includes a node (sensor), then that node participates in grid computation which is nearer to BS.
2- If a grid includes two nodes, then center of gravity is center of that line.
3- If we have more than two nodes in a grid, then we will use formula 13 and 14 [19, 20].
Determining energy center:
1- If a grid includes only a node, then we will use it in grid computation which is nearer to BS.
2- If we have more than a node in a grid, then we will use following formula [19, 20]:

$$Ec = \begin{cases} X = \frac{\sum_{i=1}^{n} x_i}{c} \\ Y = \frac{(\sum_{i=1}^{n} y_i)}{c} \end{cases} \quad (19)$$

x_i is the coordinate of x axis and y_i is the coordinate of y axis for each node and c is number of sensors in each grid.
Determining CH:
After finding center of gravity and center of energy in each grid, if distance of energy center from BS is lower than distance of center of gravity from BS, then more energetic node is elected as CH Otherwise, the node which is nearer to the center of gravity is elected as CH**.**

STEADY PHASE

In this phase, data transformation has been done, in each grid the data will be sent from normal node to its CH then the CH will transmit gathered data to BS.

When node is normal, the energy of transferring and receiving is calculated based on formulas (17) and (18). But when node is CH. another source of energy will be consumed for accumulating information in addition to transferring and receiving energy, namely accumulation, calculated by:

$$Ea = n * E_{ag} * N_{CH} \qquad (20)$$

In which E_{ag}=5j and N_{CH} is the number of CH nodes and n is number of message bits.

Pseudo code of proposed algorithm is shown in below:

SETUP PHASE

1. Divided network into separated grids
2. Find center of gravity for each grid
   1. if node-count = 1
      a. the node participates in grid computation that is nearer to BS.
   2. ElseIf node-count > 1
      a. allMass =calculate sum of all node's mass in grid
      b. sum (X-coordinate(node) * node-mass)/allMass
      c. sum (Y-coordinate(node) * node-mass)/allMass
3. Find energy center for each grid
   1. if node-count = 1
      a. the node participates in grid computation that is nearer to BS.
   2. ElseIf node-count > 1
      a. sum (X-coordinate(node) * node-mass)/node-count
      b. sum (Y-coordinate(node) * node-mass)/ node-count

4. if Distance(CenterOfGravity,BS)<Distance(EnergyCenter,BS)
   a. elect nearest node to the center of gravity as CH
5. Else
   a. elect most energetic node as CH

STEADY PHASE

Repeat
1. If the node is normal
   a. node-energy = node-energy - consumed energy of sending a message
2 .Else
   a. node-energy = node-energy – aggregation energy- consumed energy of sending a message

Until no node has energy

SIMULATION

Simulation of this algorithm has been performed with MATLAB. Initial energy of each node in our algorithm is considered as a random number between .2 to .5 joule, while in performed simulations in LEACH and LEACH-SWDN, amount of energy for each node is a constant 5j. It can be said that TDTCGE_make better results by using much less energy. Table 1 shows simulation parameters in the proposed method.

Table1: Simulation Parameters

Parameter	Value
Network size	100*100 m
E_e	50nJ/bit
$\in fs$	10pj/bit/m2
$\in mp$	0.0013pj/bit/m4
Nodes number	100
Grids number	9
d_0	87m
L	1000

Grid's count can be determined randomly which is considered as 9 during this implementation, The Outputs of TDTCGE have been compared with LEACH, LEACH-SWDN, SEP, ERP, CRCESW and EAERP and presented.

The simulated network environment is shown in figure 1.red points are energy center, Yellow points are center of gravity and green points are CHs which can be in any point of cluster with this condition that they should be the most optimal node for election as CH based on the above mentioned formulas.

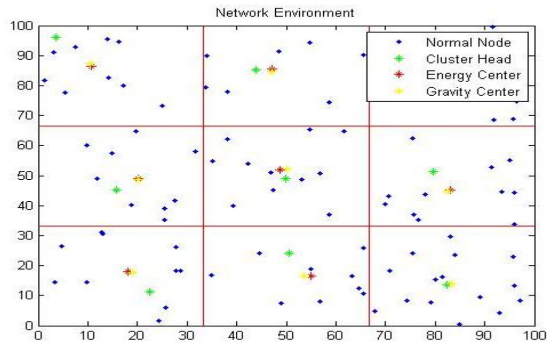

Figure2: Network environment with 100 nodes

We evaluate the results of simulation in several aspects:

CH: Electing the most suitable node as CH for sending data to BS is very important. Because in TDTCGE, CH selection is based on center of gravity and energy center, therefore amount of CH's nearness to these centers shows goodness of CH in energy and distance viewpoint. Figure3 shows nearness amount of center of gravity to CH in each cluster and nearness amount of energy center to CH and it is apparent that distance of CH from these centers is relatively similar.

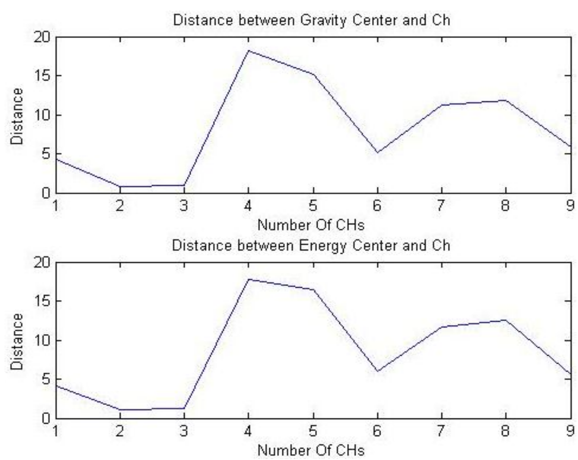

Figure 3: Comparing nearness of center of gravity and energy center to CH

Lifetime: lower energy consumption leads to increase network lifetime and monitoring time. As shown in figure4, network lifetime is increased compared to similar algorithms.

The following diagram (Figure4) shows amount of energy consumed in TDTCGE algorithm and compared algorithms. As shown in the figure, in a network with size 100*100m TDTCGE algorithm has provided a longer lifetime, while the amount of consumed energy is much less than compared algorithms.

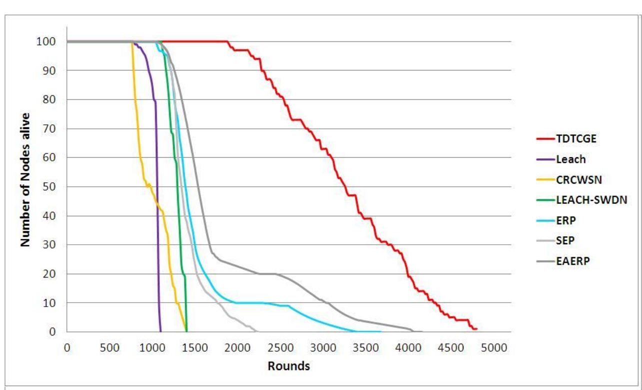

Figure 4: Total number of alive nodes in TDTCGE and LEACH, LEACH-SWDN, CRCWSN, ERP, SEP, EAERP

FND: As described before, FND and LND are two effective factors in network efficiency and increase of them shows an improvement in presented algorithm. In comparison with studied algorithms in this paper, these two factors have been appropriately increased.

In TDTCGE, the FND takes about 1880 rounds while in SEP method, it is 1107 rounds, in LEACH-SWDN, this number is nearly 1100 rounds, in EAERP it is 1076 rounds, in ERP method, it is nearly 1057 rounds and in LEACH and RCWSN, it is 780 rounds.

LND: The last node losing its energy, LND, in TDTCGE is 4800 rounds which is upper than obtained numbers in comparison with other algorithms in this paper. For EAERP method, the amount of LND is 4085 rounds, for ERP method, it is 3673 rounds and in SEP method, it is nearly 2238 rounds, in LEACH-SWDN method, this number is nearly 1490 rounds, in CRCWSN, it is nearly 1400 rounds and in LEACH method, it is nearly 1100 rounds.

Diagrams related to FND and LND is shown in figure5, 6. As shown in diagrams and numbers below, lifetime of the network in TDTCGE has been increased.

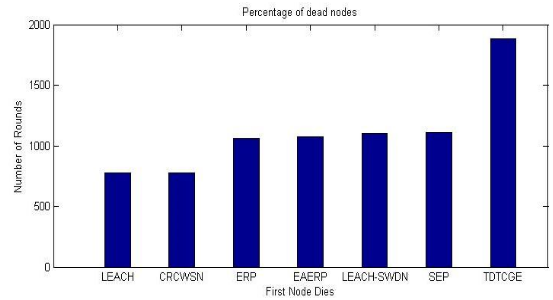

Figure 5: FND in compared algorithms in terms of 100 nodes

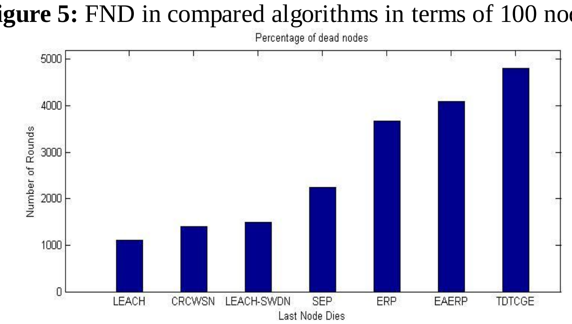

Figure 6: LND in compared algorithms in terms of 100 nodes

Figure7 shows lifetime of TDTCGE algorithm in terms of different number of nodes from 100 to 800 nodes.

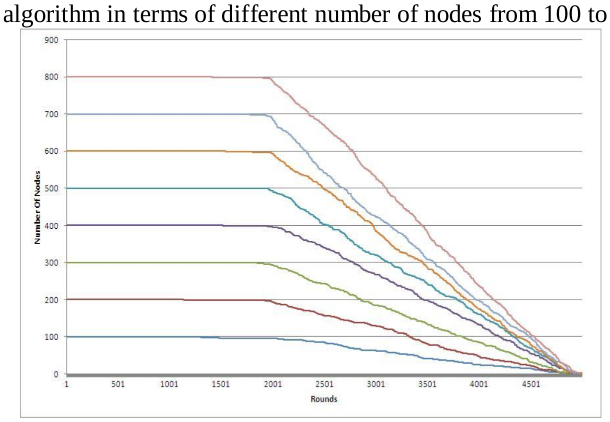

Figure 7: Lifetime of network in terms of 100 to 800 nodes in 100*100m environment

We have compared TDTCGE with initial energy of 5j and LEACH-SWDN algorithm and output of comparison is as below:

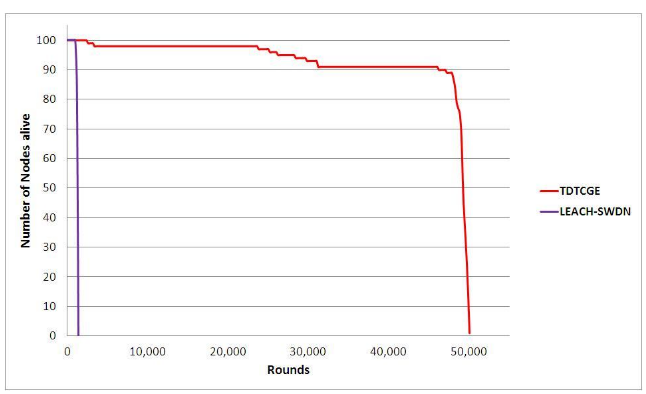

Figure 8: Total number of alive nodes in TDTCGE and LEACH-SWDN with initial energy of 5j

There is another comparison between TDTCGE and EAERP, SEP, in which BS is located at the corner of the area. Since life time of EAERP, SEP is greater than other algorithms in this situation and TDTCGE's lifetime is greater than EAERP, SEP so our proposed algorithm is better than the other algorithms (LEACH‚LEACH_SWDN, CRCWSN, ERP); for this reason , simulation result is not shown here.

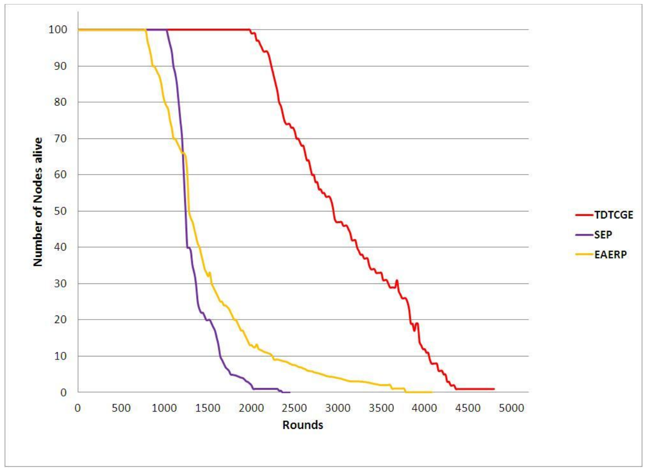

Figure9: Total number of alive nodes in TDTCGE and SEP, EAERP with the BS is located at the corner of area

Following diagram is the proposed algorithm in terms of 100 nodes in an environment with size 100*100m and BS is positioned at 70*70m. In this figure, number of dead nodes in each round and diagram of total energy consumed during the lifetime of the network have been shown.

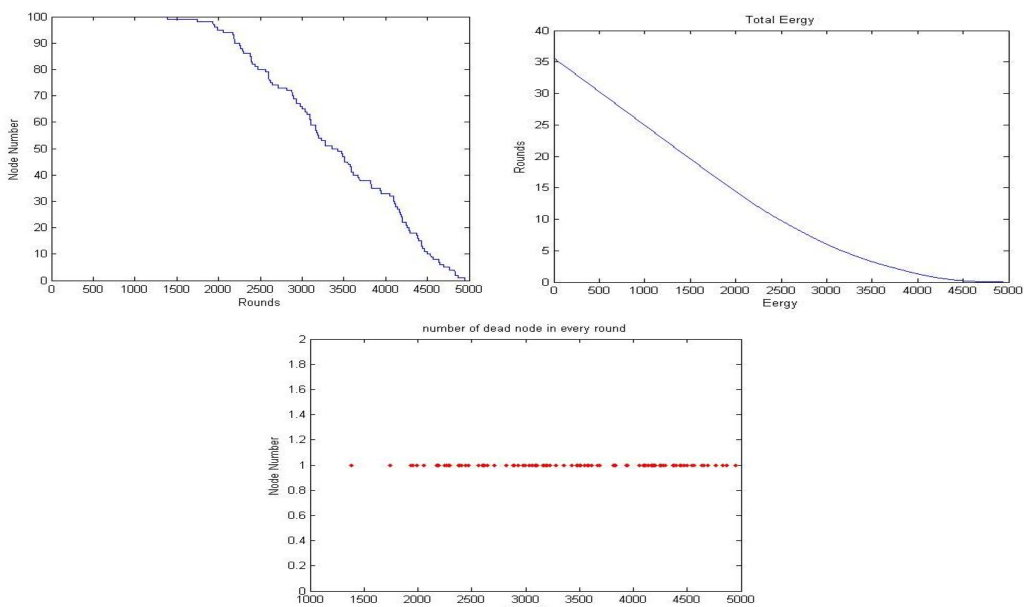

Figure10: Lifetime, number of dead nodes in each round and total amount of energy consumed in terms of 100 nodes

CONCLUSION

In this paper we presented a new technique to elect CH, named TDTCGE .This paper studies the problem of energy consumption and network lifetime in WSN where the challenges include how to decide the most efficient node as CH because Selection of optimum cluster head play an effective role in increasing sensor network's lifetime. We studied some factors like CH election, FND, LND and network lifetime. Comparing this algorithm with LEACH, LEACH-SWDN, CRCWSN, ERP, SEP, EAERP algorithms , showed that in addition of a great increase in performance and network lifetime in TDTCGE, network energy consumption will greatly reduce.

Future research directions can be inspired from the TDTCGE in complex routing. For example, instead of using a single-hop routing method, it is more efficient use a multi-hop routing between the clusters for routing the data to the base station.

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