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# Routing Protocol for Wireless Sensor Networks Powered by Ambient Energy Harvesting

M.A. Mohamed, M.M. Abdel-Razzak, A.K. Tawfeec

**Abstract**—Energy and Clustering are the most important effective Elements in wireless sensor networks (WSNs) that must be used as efficiently as possible. The sensor node aggregate data from environment and send to base station. Lifetime; stability period; saving energy; deployment of nodes; fault tolerance and latency become the main challenges in WSNs result of its wide range of applications. This paper proposed routing algorithm using solar powered nodes in heterogeneous wireless sensor networks to reach energy efficient clustering concept. It is shown via simulations that the proposed protocol has better network stability period, network lifetime, total remaining energy, and throughput compared to other well-known protocols including LEACH, Teen, DEEC, and SEP with more effective and stability data packet messages.

**Index Terms**—Wireless Sensor Networks (WSNs), Low Energy Adaptive Clustering Hierarchy (LEACH), Stable Election Protocol (SEP), Threshold sensitive Energy Efficient Sensor Network (TEEN), Distributed Energy Efficient Clustering (DEEC)..

## 1 Introduction

Wireless sensor network has reached in last years the most fields like [1, 2]: environment monitoring (hazard monitoring & habitat monitoring), military applications (remote sensing, battle field monitoring and object protection), home intelligence (remote metering and smart home), medical monitoring and industrial process control. WSN consist of (autonomous battery powered sensor nodes), which can monitor or detect physical parameters, e.g. temperature; pressure; sound; light, etc. Sensor nodes are limited on receive data from the environment; transmit; compute; store; board processing, and sense. These sensors monitor the physical phenomenon and produce analog signals based on the spotted phenomenon. Each sensor node executes three primary operations: (i) communicating it within and out of network; (ii) sensing the event, and (iii) processing the data obtained, as required. Wireless sensor nodes sense and transmit their aggregate data to base station (BS) or the sink placed on center of the grid for valuation. Wireless sensor Node structure [3-5]: (i) Sensing unit sensor and analog-to-digital converter (ADC); (ii) Power unit (battery); (iii) Communication unit; Radio, and (iv) Process unit (memory and microprocessor/microcontroller).

The main problems in WSNs in Routing are the capability of computing; storage; battery; storage of sensor node is limited, and data processing. How to reduce energy consumption and how to prolonging the network lifetime is the key problem. That is the main cause to perform the network with clustering protocols [6, 7], these algorithms proposed for the energy of wireless sensor nodes wasted when BS receive redundant information from this wireless sensor node. Designers must strictly consider which are of specific importance in WSNs [8-10]: (i) Quality of Service (QoS)[11], (ii) Real-Time Operation, (iii) Election of Clusters and Cluster heads; (iv) Cluster management (Synchronization); (v) Repair method; (vi) Data gathering, and (vii) Cost of Clustering. Some important Clustering parameter [12]: (i) Nodes and cluster head (CH) mobility: Various published approaches supposed the sensor nodes to be fixed, such networks are stable thus it is easy to preserve intracluster and intercluster Communication [8]. But in case of wireless sensor node mobility all we need to re-elect the CH periodically and preserve cluster organization continually; (ii) Type of nodes: there are two types homogenous or heterogeneous based on clustering approaches [13,14]. In Homogenous network all sensor nodes have same operations and in Heterogeneous network some sensor node are equipped with complex hardware and higher capabilities; (iii) Cluster-head election: different published approaches assume various criteria for selection of CH; (v) cluster count : can be variable or fix depending on which clustering technique is applied[12,14]; (iv) Cluster formation process: there is two types centralized or distributed earlier approaches [15].But these days as time efficiency is important distributed approach is followed; and (vi) Communication among nodes: In clustering two type of communication can occur intercluster communication or intracluster communication both can be moreover two type single hop and multihop. Earlier clustering approaches supposed the communication between its CH and nodes to be single hop but nowadays different approaches are published which equip multihop communication in intracluster.

The design challenges [16-20]: (i) Coverage Area; (ii) Node/Link Heterogeneity; (iii) Node Deployment; (iv) Transmission Media; (v) Data Reporting Method; (vi) scalability; (vii) Data Aggregation (viii) Power Consumption; (ix) Connectivity; (x) Node Dynamics; (xi) Fault Tolerance, and (xii) Node Capabilities.

There are two types of network clustering approaches. At First, clustering algorithms used on homogeneous networks, where initial energy is the same for all nodes like Low Energy Adaptive Clustering Hierarchy (LEACH) [21] used the probabilistic mode to elect the CH and the probability of choosing the CH decides after how many rounds a wireless sensor node can be again CH. Secondly, clustering algorithms used on heterogeneous networks, where a little sensor nodes have high initial energy over others like stable election protocol (SEP) [22]. Which network divided into two types of nodes having different initial energy level normal and advanced nodes. The probabilistic mode of elect the cluster heads is based on their energies. This prolongs the lifetime of the network and improves the stability period.

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Different enhanced versions of SEP routing algorithm were proposed like ZSEP [23], ECRSEP [24] etc. ESEP used three levels of heterogeneity using the normal, intermediate and advanced sensor nodes where increasing initial energies respectively. ZSEP divided network form to zones which like clusters so that energies in each cluster can be done and suitable distribution of the sensor nodes these make ZSEP better than the SEP but weakness of these algorithms thorough SEP of not take on the effect of residual energies on the cluster head selection probabilities for various type of sensor nodes. Distributed energy efficient clustering (DEEC) [25] protocol used concept of set eye on the effect of average energy and residual energy of the WSN to elect CHs with existing heterogeneity in the network sensor nodes. These prolong the lifetime of the network and improve stability period. DDEEC [26] is developed routing algorithm from DEEC applied same approach for estimate average energy of network and CH election algorithm based on residual energy. DDEEC introduce threshold residual energy and took the concept of when energy level of two types of sensor nodes (normal and advanced) reach to the limit of threshold residual energy in this state advance and normal nodes have the same probability to elect as CH. Threshold Sensitive Energy Efficient Sensor Network (TEEN) [27] protocol which categorized as reactive protocol proposed method to reduce the transmission time as the processing of data in sensor nodes expend energy less than transmission. In this scheme, every round the cluster head broadcasts to its member's soft and hard threshold. A sensor node transmits only when sensed value (sv) is more than hard threshold and difference among sensed current value (cv) and previous sensed value is more than soft threshold.

Rasheed et al. [28] proposed Energy-efficient whole Removing Mechanism technique (E-HORM) to remove energy holes. In this approach, they used awake and sleepmechanism for nodes to keep energy. In this technique finds the maximum distance nodes to calculate the max of energy for data transmission. Authors consider it as a threshold energy Eth. Every wireless sensor node first checks its energy level for data transmission. If the energy level of sensor node is less than Eth, it cannot transmit data.

The rest of the paper is organized as follows. (2) Presents the proposed algorithms, (3) introduces the results and discussions, (4) provides the main conclusions and future works.

## 2 PROPOSED ALGORITHM

### 2.1 Mathematical model

The total initial energy for normal, advanced and super nodes calculated as:

$$E_{normal} = N(1-m)E_0 \quad (1)$$

$$E_{advanced} = Nm(1-m_0)E_0(1+a) \quad (2)$$

$$E_{super} = Nmm_0E_0(1+b) \quad (3)$$

The total initial energy for three level heterogeneity networks calculated as:

$$E_{total} = E_{normal} + E_{advanced} + E_{super} \quad (4)$$

$$E_{total} = N(1-m)E_0 + Nm(1-m_0)E_0(1+a) + Nmm_0E_0(1+b)$$

A homogenous wireless sensor network after some rounds turns into heterogeneous due to the residual energy for nodes in network become different as compared to each other. Therefore, a protocol treats heterogeneity more important than homogenous protocol. Our proposed algorithm implements the same method for estimating the energy in the network as in DEEC. Since the probabilities calculated depend on the average energy at round r in the network. This average energy estimated as:

$$\bar{E}(r) = 1/N\, E_{total}(1 - r/R) \quad (5)$$

Total rounds for network life time calculated as:

$$R = E_{total}/E_{round} \quad (6)$$

Where $E_{round}$ energy dissipated during a single round in a network and calculated as:

$$E_{round} = L(2NE_{elec} + NE_{DA} + kE_{amp}d_{toBS}^4 + NE_{fs}d_{toCH}^2) \quad (7)$$

Where k is number of clusters, $d_{toBS}$ average distance between CH and BS, $d_{toCH}$ is average distance between cluster head and cluster member. Now:

$$d_{toCH} = M/\sqrt{2\pi k}, d_{toBS} = 0.765\, M/2 \quad (8)$$

Calculating the derivative of $E_{round}$ with respect to k to zero we get optimal number of clusters as:

$$k_{opt} = \sqrt{\frac{N}{2\pi}}\frac{M}{d_{toBS}^2}\sqrt{\frac{E_{fs}}{E_{amp}}} \quad (9)$$

Now we can detect the energy dissipated per single round by substituting Eq.8 and Eq.9 in Eq.7.Every round at the start, nodes decided to be cluster head or not depend on threshold value. This threshold value calculated as:

$$T(S_i) = \begin{cases} \frac{P_i}{1-P_i(\mathrm{mod}\,(r,\frac{1}{P_i}))} & \text{if} S_i \in G \\ 0 & \text{otherwise} \end{cases} \quad (10)$$

Where Pi is the desired percentage of cluster heads, r is the current round number and G is set of nodes haven't been cluster head in the last 1/prounds.In heterogeneity each type of nodes (normal, advanced and super nodes) have different probability. This probability calculated as:

$$P_i = \begin{cases} \frac{P_{opt}E_i(r)}{(1+m.(a+m_0.b))\bar{E}(r)} & \text{if} S_i \text{isnormalnode} \\ \frac{P_{opt}(1+a)E_i(r)}{(1+m.(a+m_0.b))\bar{E}(r)} & \text{if} S_i \text{isadvancednode} \\ \frac{P_{opt}(1+b)E_i(r)}{(1+m.(a+m_0.b))\bar{E}(r)} & \text{if} S_i \text{issupernode} \end{cases} \quad (11)$$

Threshold for CH selection is calculated for each type as:

$$T(S_i) = \begin{cases} \frac{P_i}{1-P_i\left(mod\left(r,\frac{1}{P_i}\right)\right)} & \text{if } S_i \in G \\ \frac{P_i}{1-P_i\left(mod\left(r,\frac{1}{P_i}\right)\right)} & \text{if } S_i \in G'' \\ \frac{P_i}{1-P_i\left(mod\left(r,\frac{1}{P_i}\right)\right)} & \text{if } S_i \in G''' \\ 0 & \text{otherwise} \end{cases} \quad (12)$$

$G$ Is the set of normal nodes haven't become CH at last $1/P_i$ rounds of the epoch where $S_i$ is normal node. $G''$ Is the set of advanced nodes haven't become CH at last $1/P_i$ rounds of the epoch where $S_i$ is advanced node. $G'''$ Is the set of super nodes haven't become CH at last $1/P_i$ rounds of the epoch where $S_i$ is super node. $1/P_i$. Thus, the probabilistic threshold value of cluster head depends on initial energy, residual energy and type of a sensor node. The CHs act as local control center to organize and manage the data transmission in their cluster. CHs transmit TDMA schedule to the sensor nodes in their cluster. That makes no collision during the transmission of data messages. CHs permit radio component of each non CH sensor node to be turnoff at all-time except among transmission time, thus minimize energy consumption for each sensor node in the network, Fig.1.

### 2.2 Energy Model

In our proposed scheme we are using on some nodes the concept of rechargeable batteries by solar energy. Every time the battery level of those nodes chosen as cluster heads reaches to the critical point it will transmit signal to BS for low energy level. BS transmit signal to those nodes to open the charging circuit. Charging circuit will open in CHs and charge the battery by solar energy. It's flow diagram in Fig .3.

## 3 Experimental Results

In this section implementation of all present routing protocols simulation results for LEACH; ILEACH; SEP; ISEP; TEEN; ITEEN; DEEC; IDEEC; DDEEC, and the proposed algorithm using MATLAB 2014a. Network consist of 100 node randomly deployed in 100 m *100 m area with unlimited power base station is centered in the field. For simplicity, ignore the effect caused by interference and signal collision in the wireless channel. The metrics used for the evaluation Routing protocols performance are: (i) stability period and network lifetime, (ii) number of packets sent to the BS, and (iii) Network remaining energy. Assuming $m = 0.5$, $m_0 = 0.4$ a=1.5, and b=3 for this we consider a network contain 50 normal nodes, 30 advanced nodes and 20 super nodes. Advanced nodes having 1.5 times more energy than normal nodes, super nodes have 3 times more energy than normal nodes and other parameters see Table 1.

### 3.1 Stability Period and Life Time of the Network

See Table 2. First node dies, the last node dies stability period and life time duration for all present algorithms and implemented in Fig.2 & Fig.6. It's clearly proposed algorithm have longer life time and stability period.

### 3.2 Network Remaining Energy

Fig.4 shows total remaining energy over time with rounds. Here total initial energy is 102.5J for proposed algorithm and 87.5J for DEEC and SEP protocols and 50J for LEACH and TEEN therefore LEACH and TEEN are homogenous routing protocols and all nodes in network have same probability to become cluster head. SEP assumes that in real environment sensor nodes having different energy level, therefore SEP and DEEC use two types of sensor nodes normal nodes and advanced nodes but difference between them in DEEC protocol all nodes use residual and initial energy level to select the CH. Fig.7 shows the enhancement percentage for proposed algorithm over LEACH, SEP, TEEN and DEEC see Table 3. Energy in proposed algorithm is depleting in very slow rate.

### 3.3 Number of Packets Sent to the Base Station

Successful data delivery at Base Station is an important factor to analyze quality of routing protocol. Fig.5 shows the comparison of all present protocols for number of packets that are sent to BS. Result shows that more number of packets is sent to BS in comparison with other routing protocols, as heterogeneity-awareness make it having more probability of becoming the CHs, due to more residual energy so more number of packets will be sent to the BS. Thus, the proposed algorithm sends more effective data packets to the base station.

## 4 Conclusion

Efficient route discovery and Energy optimization are challenging issues in WSNs. Different techniques proposed Clustering technique is one of them, and this work is devoted to estimate the efficiency of different clustering methods. For this purpose, we increased the level of WSNs heterogeneity, through the addition of super node, some nodes using the concept of rechargeable batteries by solar energy, having energy more than advanced nodes; normal nodes, and respective probabilities. Residual energy and initial energy is the main concept to elect CH from sensor nodes. The performance of four traditional techniques (LEACH; SEP; TEEN, and DEEC); five modified techniques (Improved-LEACH; Improved-SEP; Improved-TEEN; Improved-DEEC, and Developed-DEEC), as well as a proposed technique, was evaluated using five matrices: stability period; network lifetime; number of packets sent to BS, throughput and total remaining energy. As a result of the extensive experimental results, it was found that the proposed routing protocol is superior to all other discussed nine techniques.

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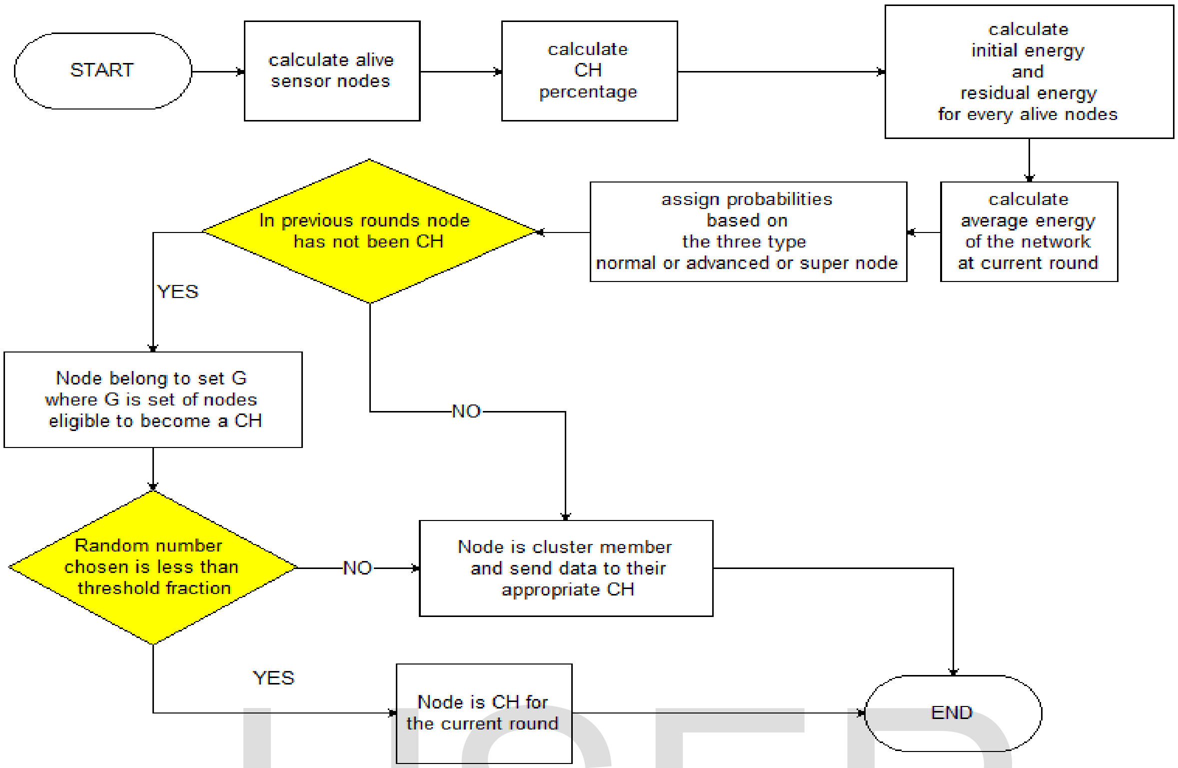


Fig. 1.Flow chart for proposed algorithm.

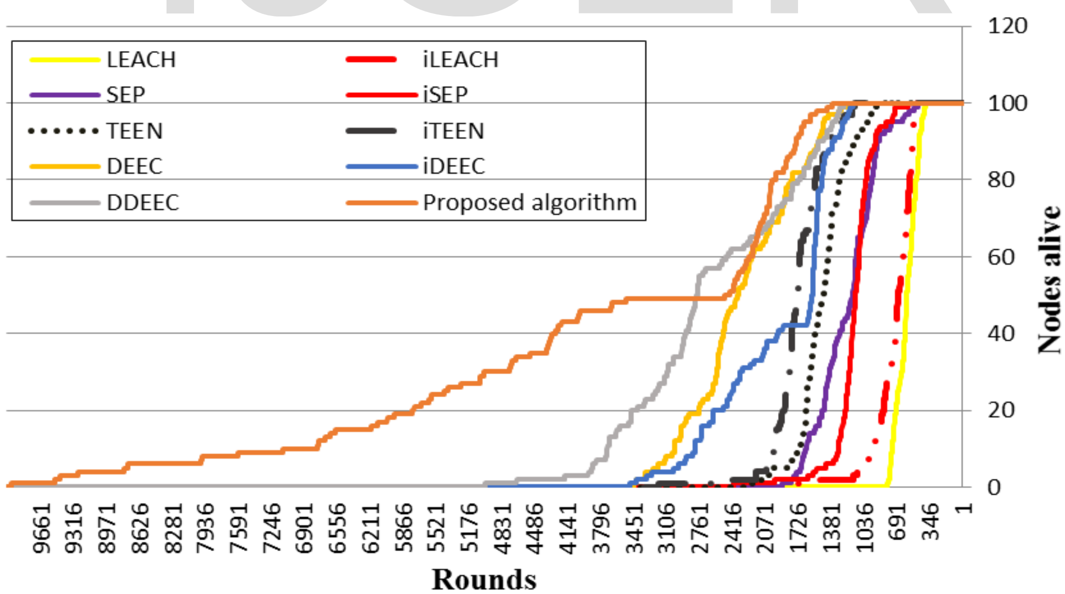


Fig. 2. Nodes alive during rounds.

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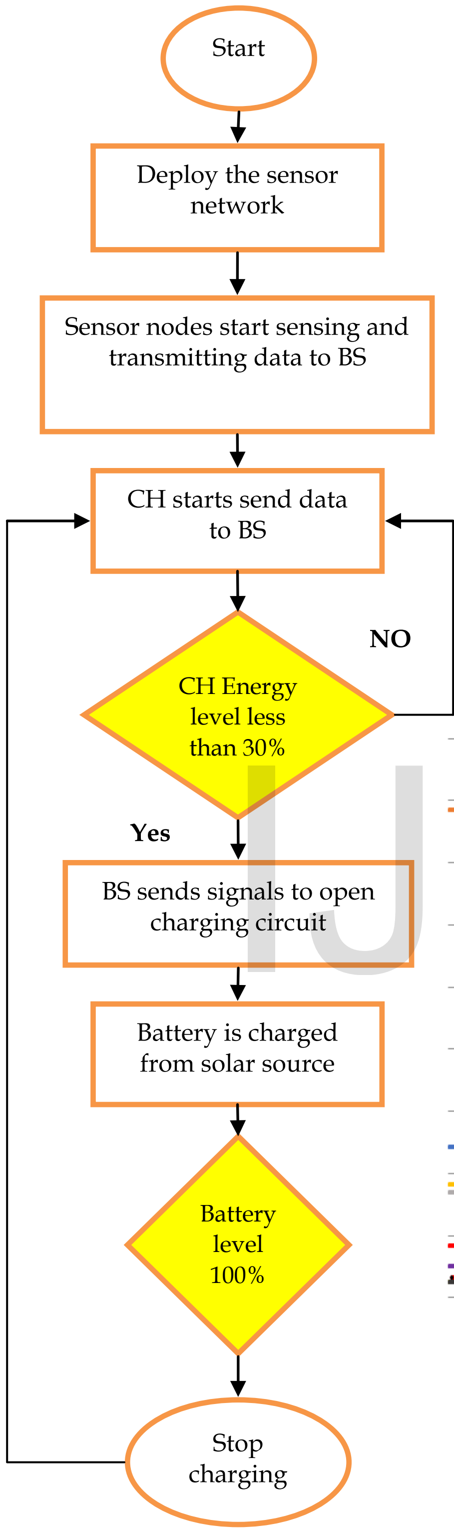


Fig. 3. Energy model.

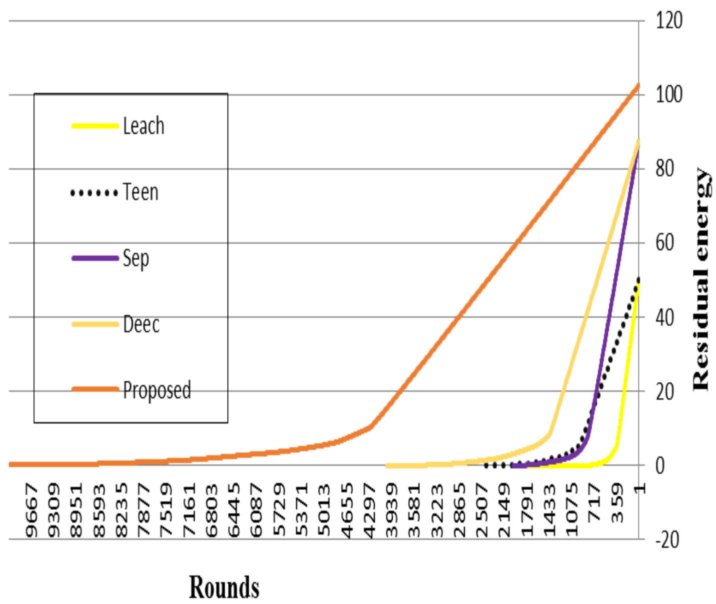


Fig. 4. Total remaining energy every round.

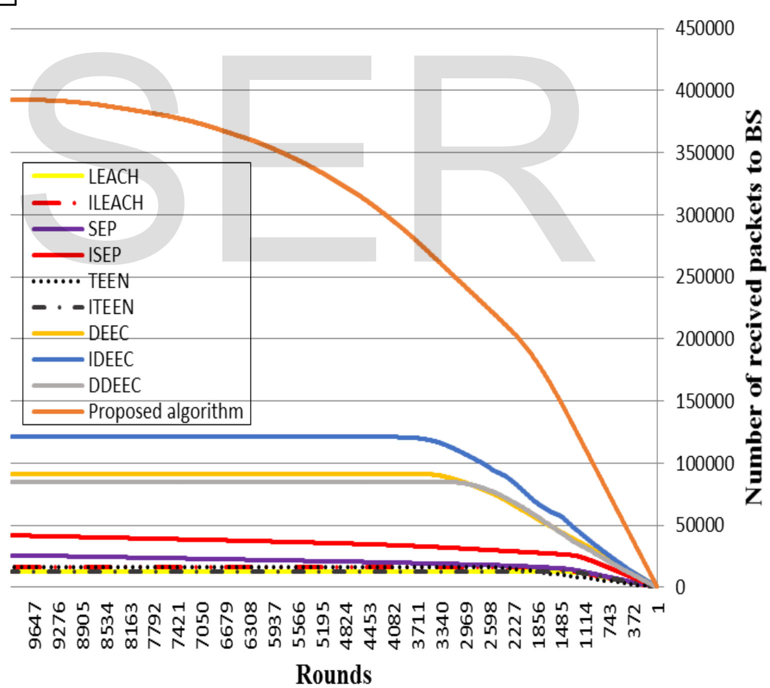


Fig. 5. Data packets sent to BS over rounds.

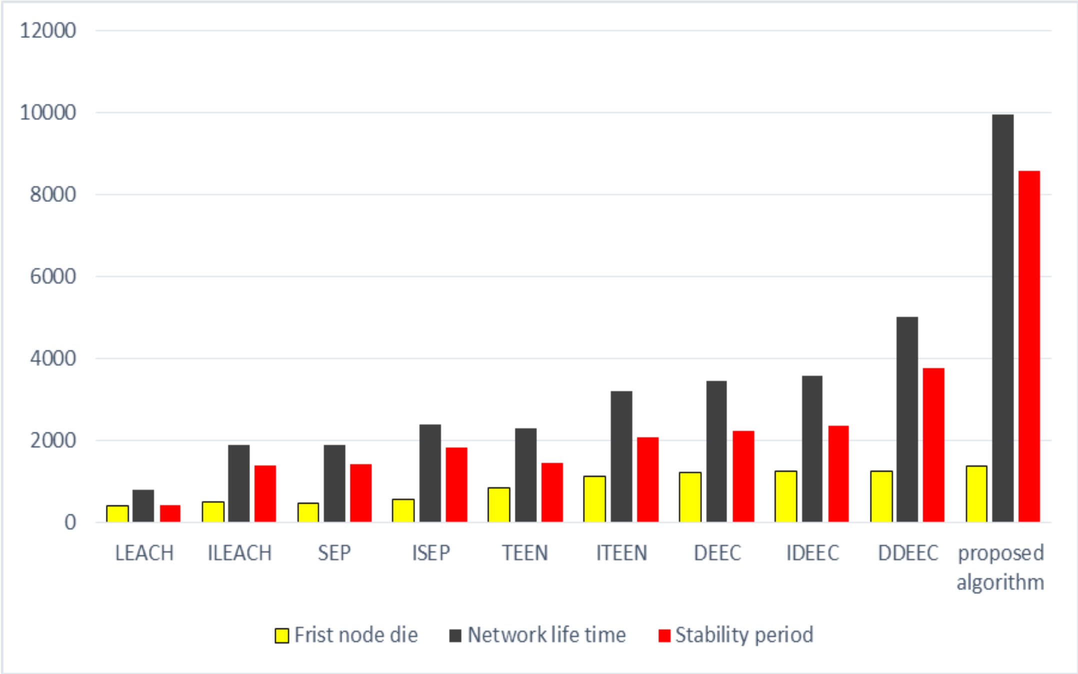


Fig. 6.Stability period, network life time & first node die for all present routing protocols



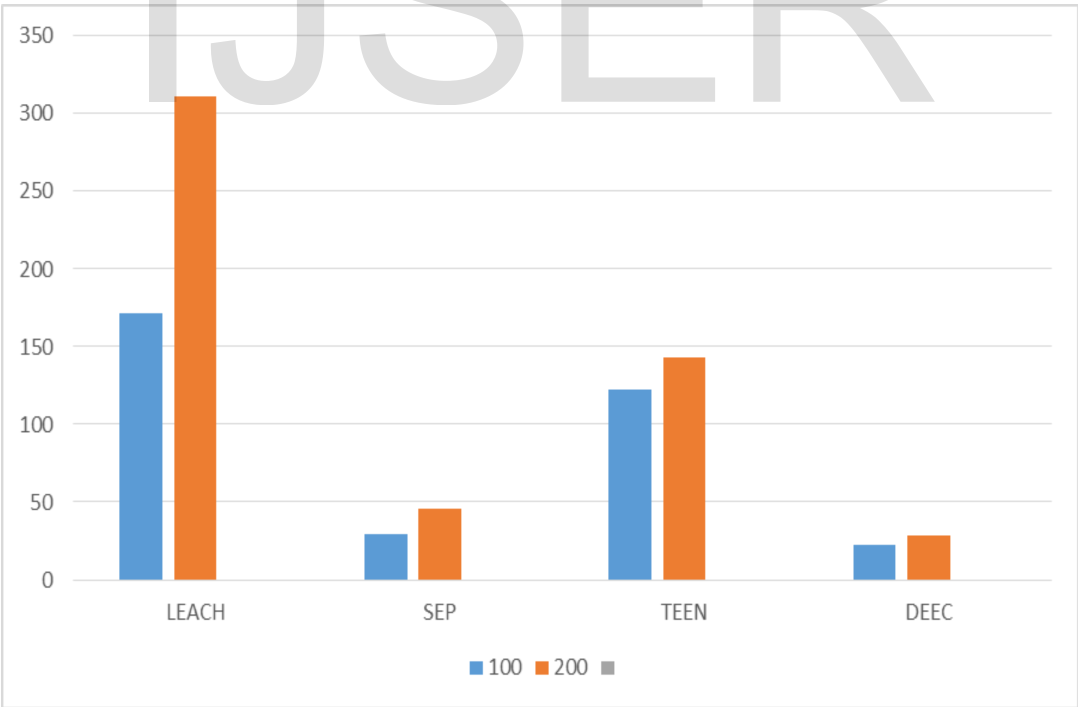


Fig. 7.Enhancement percentage for proposed protocol over other routing protocols

| Parameters | Value |
|---|---|
| Network field | 100m*100m |
| Number of nodes | 100 |
| Initial energy of normal nodes $E_0$ | 0.5j |
| Message size | 4000 Bit |
| $E_{elec}$ (receiver energy per node(ERX)= transmitter energy per node (ETX)) | 50nJ/bit |
| $E_{fs}$(amplification energy when d is less than $d_0$) | 10nj/bit/$m^2$ |
| $E_{amp}$(amplification energy when d is greater than $d_0$) | 0.0013pJ/bit/$m^4$ |
| $E_{DA}$ (Data Aggregation Energy) | 5nJ/bit/signal |
| $d_0$( Threshold Distance) | 70m |
| $P_{opt}$ | 0.1 |
| maximum number of rounds (r) | 10000 |

*Table 1 Simulation Parameters*

| Protocol | Frist node die | Network Life time | Stability Period |
|---|---|---|---|
| LEACH | 385 | 792 | 407 |
| ILEACH | 484 | 1877 | 1393 |
| SEP | 467 | 1888 | 1421 |
| ISEP | 566 | 2399 | 1833 |
| TEEN | 829 | 2288 | 1459 |
| ITEEN | 1125 | 3184 | 2059 |
| DEEC | 1219 | 3441 | 2222 |
| IDEEC | 1238 | 3575 | 2337 |
| DDEEC | 1252 | 4999 | 3747 |
| Proposed algorithm | 1368 | 9958 | 8590 |

*Table 2 Routing algorithms stability period*

| Protocols | 100 round | 200 round |
|---|---|---|
| LEACH | 171.74208% | 311.05% |
| SEP | 29.620057% | 45.88% |
| TEEN | 122.14% | 143.5% |
| DEEC | 22.586165% | 28.85% |

*Table 3 Enhancement percentages for proposed protocol over other routing protocols at 100 round and 200 rounds*


- *M.A. Mohamed received the Ph.D. degree in Electronics and Communications Engineering from the Faculty of Engineering-Mansoura University-Egypt by 2006. E-mail: mazim12@yahoo.com*
- *M.M. Abdel-Razzak received the Ph.D. degree in Electronics and Communications Engineering from the Faculty of Engineering-Mansoura University-Egypt. E-mail: mabdelrazzak@hotmail.com*
- *A.K. Tawfeec M.Sc. Student in Electronics and Communications Department, Faculty of Engineering-Mansoura University-Egypt. E-mail: khairtahmed@yahoo.com*