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Original Article

An Improved Routing Protocol for Heterogeneous Wireless Sensor Networks

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Abstract *- In these recent years, loT has graded the forecast of agriculture and automation. A loT, which mostly comprises different technologies. The wireless sensor network is one such big technology. Nodes communicate with each other through the nodes, which are spatially arranged. The communication between nodes is wireless, and the data is sent to the Base Station. Communication is established between the nodes through the concept of routing protocols. We have different routing algorithms for different networks. LEACH, DEEC and more are the routing protocols used for homogenous networks, and SEP (stable election protocol) is one of the routing algorithms used in heterogeneous networks. The importance of these protocols comes from not only the communication but also the need to be energy efficient and less power consumptive. We implemented the routing algorithm SEP to observe its constituents like power consumption, energy usage, data transmission, and the number of dead nodes. By observing the factors of SEP, as it is not much effective protocol and thus implemented the improved or advanced protocol of SEP that is Improved version-SEP. I-SEP is an algorithm for the Stable Election Protocol, which is an improved algorithm. In this improved version of SEP, we have the concept of cluster head formation. It means the group of nodes elects the single node as head and transfers their data to the head. It's the most efficient use of energy as the nodes need not waste energy in transmitting the information as the transmission is the duty of Cluster Heads. In the I-SEP protocol, the number of not live nodes decreases as it is less power-consumptive. So, its use over the SEP is more helpful in the longevity of nodes and networks. We need to implement the protocol for the purpose of the high network lifetime and the best use of its energy. Implementation was done in MATLAB. We studied the existing algorithm SEP, and after finding the difficulties and drawbacks in the factors, we implemented I-SEP.*

Keywords *- Base Station (BS), Cluster Head (CH), SEP, I-SEP, WSN.*

1. Introduction

The network comprises a sizable number of locally deployed sensor nodes. The battery power prevents their replacement. Other nodes utilise these sensor nodes for data processing, communication, and sensing. In remote locations and inhospitable conditions, WSN is crucial. [1][2]. Energy has a crucial function in WSN. Energy consumption from the source to the destination occurs during data transmission. Therefore, this algorithm employs these protocols. Because of this, clustering-based protocols are now a reality. [3].

LEACH came into existence. In this approach, energy efficiency can be increased by random selection of Cluster Heads [4].LEACH doesn't work for a heterogenous network, DEEC came into existence which works for the heterogenous network [8]. It is a two-level and multilevel heterogeneous network. The enhancement of SEP in [5] sensor nodes is categorised into three levels based on normal, intermediate, and advanced nodes. T-SEP [13] is threshold SEP data transmission that takes place only when it reaches the threshold value. The election of a new Cluster Head and generation of clusters are done inSEP algorithm[7] automatically.SEP is the heterogeneous protocol where CH is selected based on the weighted election probability of nodes with remaining energy.[9]

2. System Model

The I-SEP consumes more energy during transmission than in sensing the data and is performed only when a certain threshold is achieved. It contains three heterogeneity levels.

They are Normal nodes, Intermediate nodes, and Advanced nodes.

All nodes are considered static in this situation. The initial node energy is taken into account. Advance nodes have the most energy, whereas regular nodes have the least. The intermediate nodes sit between lower-energy nodes, such as regular nodes, and higher-energy nodes with advanced capabilities.

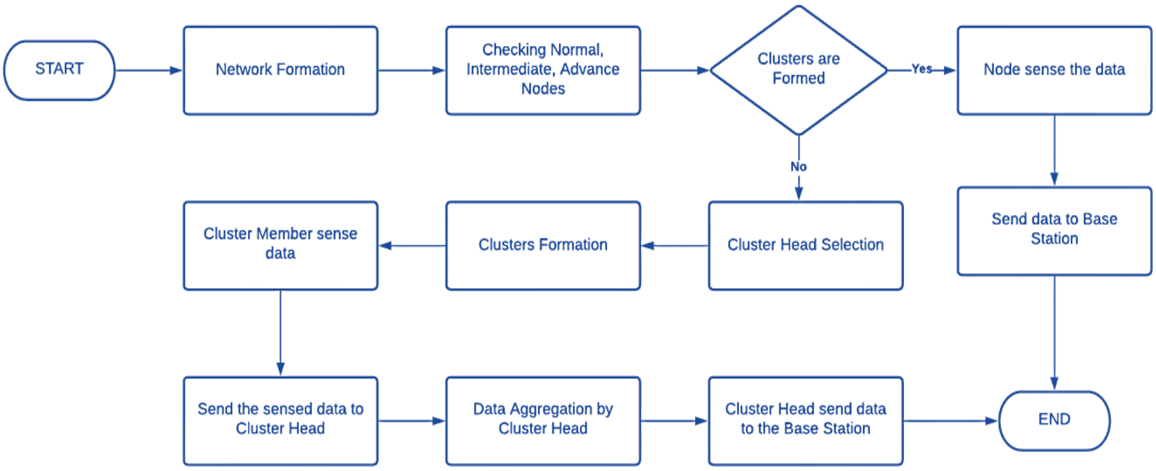

Fig. 1 System Model

To ensure that energy consumption is distributed equally, every node turn as CH. In the CH election, the selection used is a random process. After the formation of clusters, a time window is assigned to its cluster members in respective time and can send the data.

To control the amount of transmission data, CHs broadcast HT and ST to the participants in the I-SEP routing protocol. Nodes only send sensed data to CH in a round when the current value is larger/greater than the value of HT. A subsequent internal variable called Sensed Value stores the discovered property (SV). Nodes constantly detect the value of their attribute; it is only transmitted if the subsequent value deviates from the SV by an amount equal to or greater than the ST. The ST lowers data transfer frequency by discarding attributes with small changes. The value of ST is changed to accommodate user needs. Lowering the ST improves network accuracy while consuming more energy. It is necessary to modify the trade-off between.
There are different steps in the procedure of the implementation of I-SEP. They are:

2.1. Stage 1: Channel Detection

Each node conducts a channel detection process and lists the accessible channels during the channel detection step. For instance, node I finds the subset of S called the S(i) accessible channel list.

2.2. Stage 2: CH Election

The priority number sent by node one is a random value between 0 and 1. If the chosen node has a lower value than the threshold value T(n), then the associated node selected has the CH node.

If N G1 0, T(N) = p/(1-p*(rmod(1/p))). Alternatively ………..(1)

where "p" denotes the proportion of nodes, who will take part in selecting the CH among all nodes. R stands for the most recent round. The letter "G" in the equation above denotes that nodes only take part in a CH selection if they did not participate in the previous 1/p rounds. Where G is the group of nodes that didn't participate in the 1/p round before.

2.3. Stage 3: Cluster Formation

After the node is selected as the CH node, it will send an advertisement message to each pertinent node. After receiving this message from the CH and sending back a joint message, the other nodes determine whether to join CH for the current round based on the signal strength received.

2.4. Stage 4*: Transmission of data*

Nodes constantly monitor their surroundings. Cluster members receive HT and ST from CHs. In the transmission of data step of the TEEN routing protocol, nodes transfer data to CHs in their designated time slot while adhering to the HT and ST constraints.

Stages 1–4 are re-started after a round time.

CH random election is one of the I-SEP routing protocol's drawbacks. The election of CH is uncontrolled, with a high level of randomness. The I-SEP routing optimisation technique (Advanced-TEEN) protocol is presented in this research. First, determine the noise in the electromagnetic environment based on the requirement of applications, which define the channels and bandwidth accessible. A-TEEN uses the number of unoccupied channels as more weight in the chance of each node becoming a CH. The node that detects the idlest channels has a better chance of becoming CH.

With = /2, let c stand for the subset of nodes that have been given an intermediate energy level and have more power than regular nodes. E0 stands for the energy that is provided by the ordinal nodes. The energies E0(1 +) and E0(1 +) are respectively present in advanced and intermediate nodes. As a result, the total energy of each node is represented as

EN equals nE0(1 a c)........... (2)

EI = ncE0(1 + β) ....(3)

EA = naE0(1 + α) EI, EN, and EA are the intermediate, standard, and advanced node energies. As a consequence, E Total = nE0(1 a c) + nbE0(1 +) + naE0(1 +) represents the total energy of the three node types. ....(5)

Let G1, G2, and G3 are the number of nodes that are not performed as a CH in past 'p' rounds.

For normal nodes:

$$p_{(N)} = \frac{p}{1 + a\alpha + c\beta} \quad \dots\dots\dots(6)$$

$$T(nN) = \{\frac{p(N)}{1-p(N)\left(\frac{rmod1}{p(N)}\right)},\ if\ nN \in$$

$$G10,\ Otherwise \dots\dots\dots(7)$$

For intermediate nodes:

$$p_{(I)} = \frac{p(1+\beta)}{1 + a\alpha + c\beta} \quad \dots\dots\dots(8)$$

$$T(nI) = \{\frac{p(I)}{1-p(I)\left(\frac{rmod1}{p(I)}\right)},\ if\ nI \in$$

$$G20,\ Otherwise \quad \dots\dots\dots(9)$$

For advanced nodes :

$$p_{(A)} = \frac{p(1+\alpha)}{1 + a\alpha + b\beta} \quad \dots\dots\dots(10)$$

$$T(nA) = \{\frac{p(A)}{1-p(A)\left(\frac{rmod1}{p(A)}\right)},\ if\ nA \in$$

$$G30,\ Otherwise \quad \dots\dots\dots(11)$$

From 6,8 10 Equ. The total CH average is calculated as

$$n(1 - a - c)p_{(N)} + nap_{(A)} + nc_{(I)} = np \quad \dots\dots\dots(12)$$

In a heterogeneous network, communication follows the model presented in Fig. The energy dissipation will be computed using the multipath fading model if d, Which is the Euclidean distance between receiving and sending nodes which should be less than or equal to d0, then the reference distance.$d_0 = \sqrt{Efs/Emp}$.

In all other cases, the free-space model is used. Assume that a sensing node calculates the energy used to transmit "k" bits per packet over a symmetrical communication channel.

$$ETx(k,d) = \{Eelec \times k + Efs \times k \times d2,\ d \le d0\ \ Eelec \times k + Emp \times k \times d4,\ d > d0$$

Emp and Efs are the transmission parameters of multipath and free space models, respectively. If a transmitter expends Eelec amount of energy per bit, a sensor node must expend ERx(k) energy to receive the packet of k bits, which is given as

$E_{Rx}(k) = E_{Rx\_elec}(k) + kE_{elec.}$

Some of the most important aspects are listed below:

1) Time-sensitive data is delivered to the user almost instantly.
2) Nodes continue to sense indefinitely, but transmission is not done frequently, resulting in substantially lower energy use than proactive networks.
3) Because characteristics are communicated at cluster change time, the user can adjust them according to their needs.

3. Implementation

3.1. Implementation of a WSN

A three-level heterogeneity, intermediate, Normal, and advanced nodes are implemented in a Matlab code to simulate a wireless sensor network. The WSN's centre is where the BS, which has endless energy, is located. A node's chance of becoming a CH is assigned a value of 0.1. At first, each node is given a type of "N". The nodes are classified into various categories and given varying energy levels based on the likelihood and other parameters m and n. Table 1 contains a list of the common parameters utilised for the implementation. The standard distance for transmission of information is calculated as do=sqrt(Efs/Emp);, Where Efs is free space energy and Emp is amplification energy.

The sink is not a part of the sensors in the network. So, it is considered an extra node and the values are assigned accordingly. To suffice for the extra load a cluster head faces for data aggregation, an amplification factor 'G' is introduced. When the whole amplification energy is used, the node can no longer be a cluster head.

3.2. Election of Cluster Heads

A cluster head is chosen using probability and threshold computation. The energy required for data transport to the base station is computed using the distance between the node and the sink.

The protocol is reactive; the data is transferred only when the sensed value has breached the threshold.

3.3. Associated Cluster Head

A normal node cannot withhold the data transfer energy if it is far away from the base station. So, a bridge is required when this condition occurs. For this purpose, a normal node with enough energy is selected, and the distance between the node and the nearest CH is calculated. Also, the distance between the normal node and sink is calculated. If the distance is greater, this node can act as an associated cluster head for the normal node situated away from the base station.

4. Simulation Results and Discussions

All the Simulations were completed in MATLAB, Version R2013a. Here, n = 100 indicates the sensor nodes were arranged in a network with parameters Xm=100m2, Ym=100m2, i.e., 100×100 m2. The Base Station is positioned in the middle possessing limitless energy. The network parameters utilised are recorded in the below table.

4.1. Network Parameters

Table 1. Network Parameters

PARAMETERS	VALUES
Emp (Receiving energy dissipated)	0.0013pJ/bit/m4
Efs (Free space model Energy dissipated)	10pJ/bit/m2
Do (Reference distance)	87 meters
Eda (Energy Dissipation: Aggregation)	5nJ/bit
K (Packet size)	4000 bits

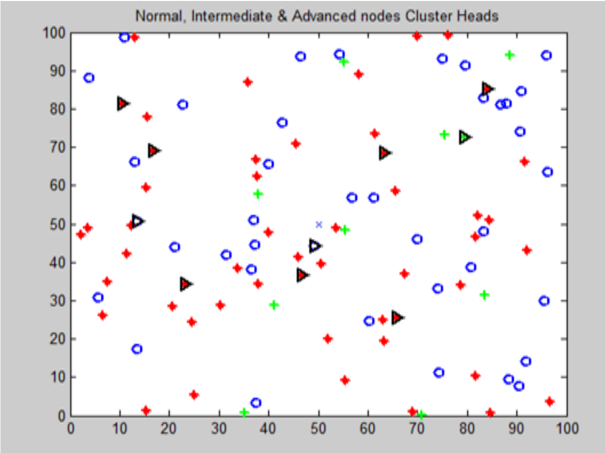

Fig. 1(a) Proposed Network Model

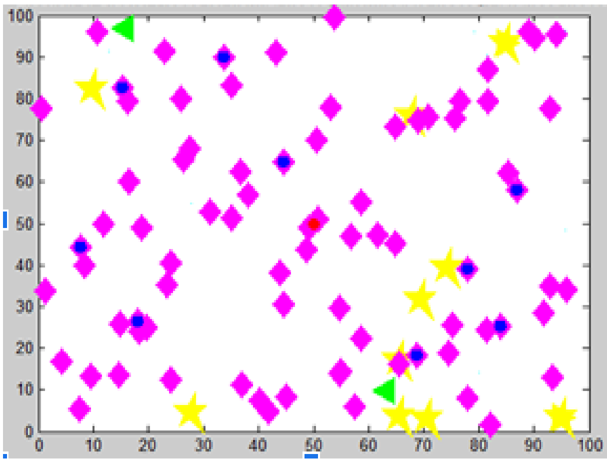

Fig. 1(b) SEP Network Model

In contrast to SEP, the suggested model behaves differently, as seen in Fig. 1(a). Two levels of heterogeneity emerge, with values of "a" and "fluctuating, while "c" maintains a constant value of 0.5. At first, = 1, a = 0.1, and rmax = 8000. (maximum number of rounds). Here, blue denotes a normal node, red is an intermediate node, green is an advanced node, and black denotes a cluster head in the form of a triangle. The behaviour of the model in comparison to I-SEP, which follows two levels of heterogeneity, is shown in Fig. 1(b). While the values of "a" and "are altered, "c" retains a specific value of 0.5. For the following example, a = 0.1, = 1, rmax = 3999 rounds, xm = 100, ym = 100.Here, the pink colour indicates Normal Nodes, the Yellow colour indicates Advanced Nodes, and the Green colour in a Triangle shape represents a CH. The red-coloured node in the middle is the Sink node, with the highest energy.

4.2. Dead Nodes

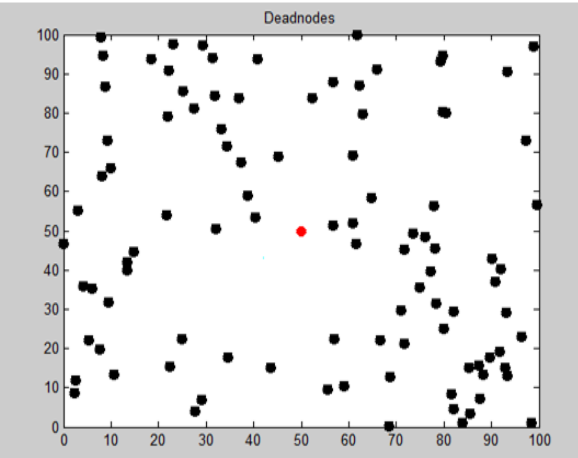

Fig. 2(a) Dead nodes in I-SEP

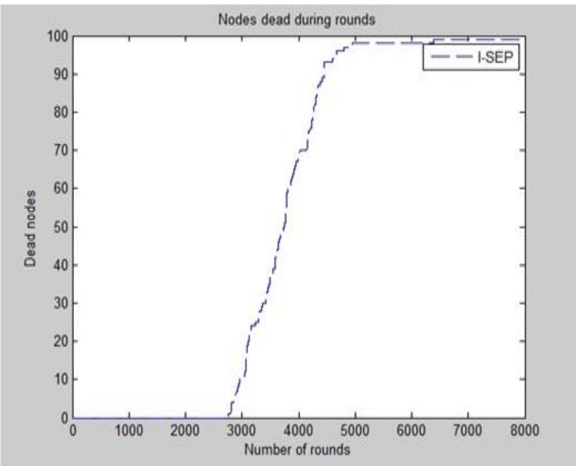

Fig. 2(b) Dead nodes in I-SEP

Fig. 2(a) Indicates Dead nodes in I-SEP; the red-colored node at the center in Fig. 2(a) is the base station with unlimited energy. As a large amount of energy is applied to the advanced nodes, the number of dead nodes is extremely low when contrasted with normal and intermediate nodes. Meanwhile, the normal nodes are dead at a quicker rate. In this manner, the advanced nodes and intermediate are chosen as Cluster Heads, increasing the lifetime to a large no. of rounds and incrementing the Cluster head count. As the dead nodes are increased, the amount of alive nodes decreases, as in Fig.3. Here, the number of rounds' r' is 8000. With b=0.5 , a=0.1, α =1.

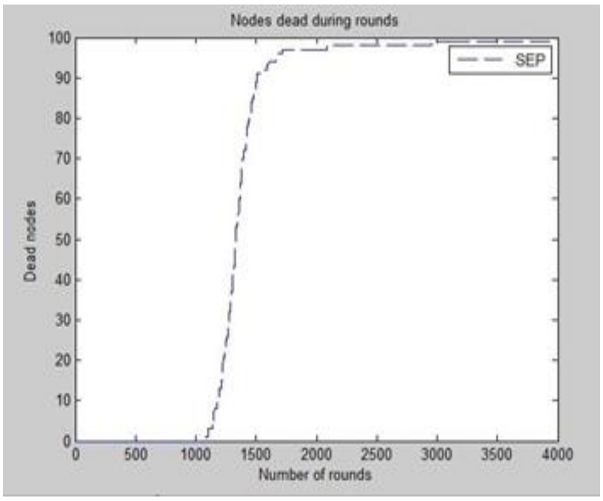

Fig. 2(c) Dead nodes in SEP

Fig. 2(c) Indicates Dead nodes in SEP; the red-coloured node at the centre is the base station with unlimited energy. As a large amount of energy is applied to the advanced nodes, the number of dead nodes is extremely low when contrasted with normal and intermediate nodes. Meanwhile, the normal nodes are dead at a quicker rate. In this manner, the intermediate and advanced nodes are chosen as Cluster Heads, increasing the lifetime to a large no. of rounds and incrementing the Cluster head count. As the dead nodes are increased, the number of alive nodes decreases, as in Fig.8. Here, the number of rounds' r' is 3999. With b=0.5 , a=0.1, α =1.

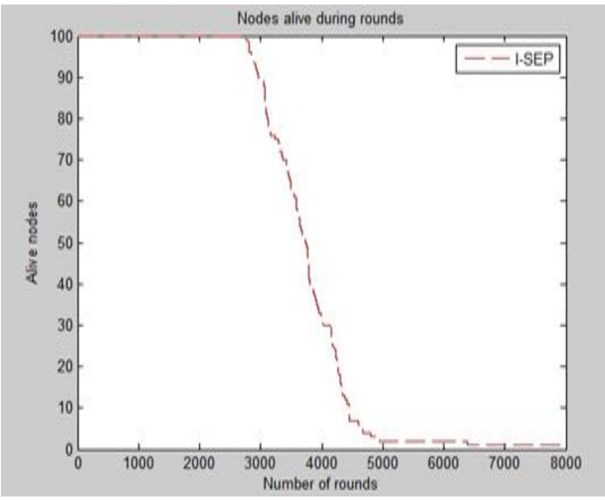

Fig. 3(a) Alive nodes for rmax=8000 in i-sep

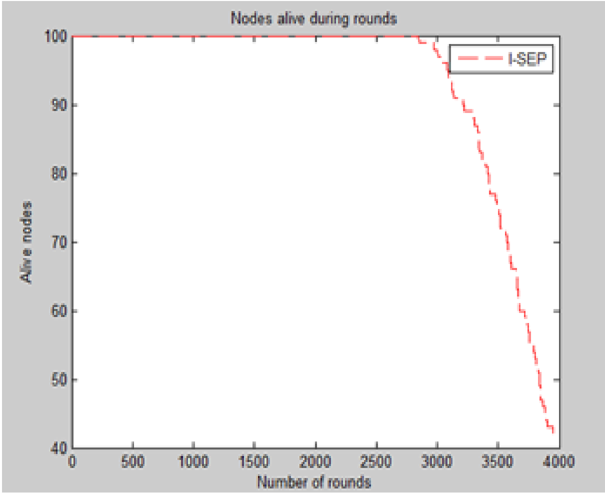

Fig. 3(b) Alive nodes for rmax=4000 in i-sep

Fig. 3(a) Indicates the decrease in the amount of not dead nodes since the iteration of the loop increases. Here, when the number of dead nodes increments, the number of alive nodes decreases. Here, the number of rounds 'r' taken is r= 8000, and the maximum number of rounds' rmax' is 8000. With the dimensions of 100 x 100m2. Similarly, in Fig.3(b), the rmax is decreased by 4000; the only difference is that the graphs can be seen clearly as the maximum number of rounds increases.

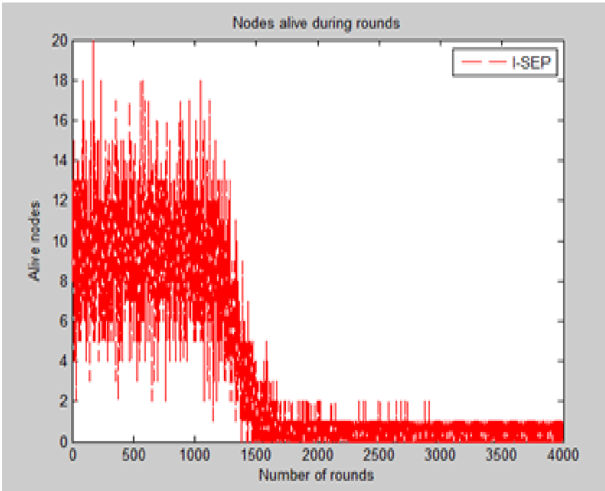

Fig. 3(c) Alive nodes in SEP

Fig. 3(c) Indicates the decrease in the amount of not dead nodes since the iteration of the loop increases. Here, when the number of dead nodes increments, the number of alive nodes decreases. Here, the number of rounds 'r' taken is r =3999, and the maximum number of rounds' rmax' is 3999. With the dimensions of 100 x 100m2. As we observe the difference between the I-SEP and SEP, it shows that the distortions are more in SEP. So, we prefer using I-SEP.

5. Throughput

Fig. 4(a) Indicates Throughput for a = 0.1 in I-SEP. The maximum number of rounds taken is 8000. throughput is the key factor for constructing a routing protocol in a wireless sensor network. Throughput is the amount of information a node can receive and transfer to the BS within the specified period. So this can be done by introducing a threshold limit within a CH selection process. The throughput increments for Improved SEP in contrast with the SEP Protocol.

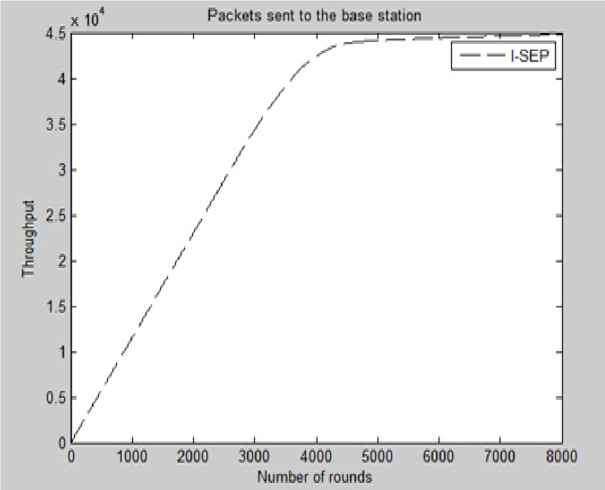

Fig. 4(a) Throughput for rmax=8000

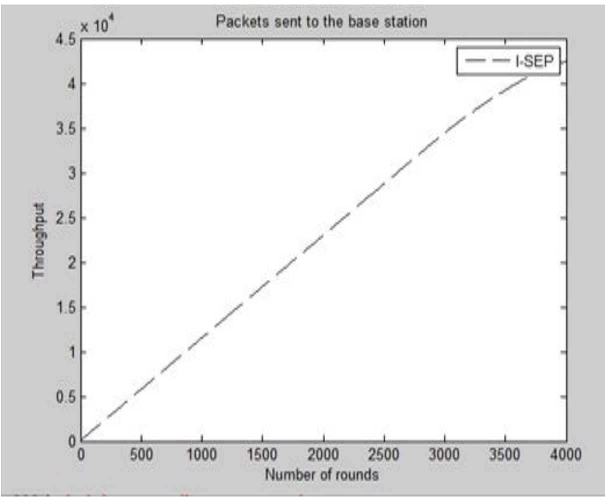

Fig. 4(b)Throughput for rmax=4000

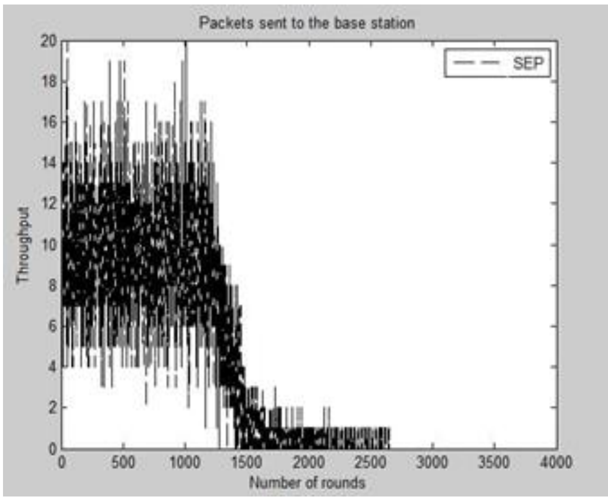

Fig. 4(c) Throughput in SEP

By inserting a threshold value to stay in the Cluster Head, having enormous residual energy assists in preserving energy individually. These nodes will help in communicating the information for more time. When we put α = 1, the throughput for I-SEP increments 50 percent in contrast to SEP 4(c). As the number of rounds increases, the graph can be seen clearly. The efficiency for all routing algorithms is analysed by determining the amount of data packets linked to the sink node / Base Station having a much less packet ratio. It is known as "network throughput". The 10 percent of advanced nodes within the network, network lifetime, and throughput were analysed in SEP.

Fig. 5 Shows the I-SEP Protocol with n = 100 sensor nodes inserted within a network with the parameters Xm=100m2, Ym=100m2, i.e., 100×100 m2. The sink node is positioned in the middle with unlimited energy. A very large number of rounds taken were rmax=4000, the value of b=0.5. The Network parameters taken were the same as in table 1.

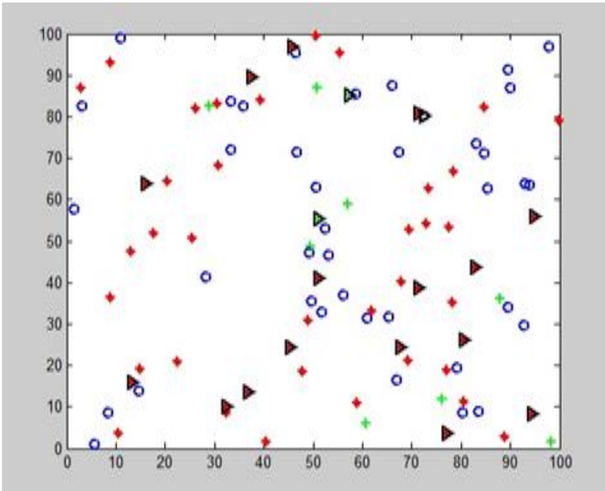

Fig. 5 Advanced, intermediate and normal nodes in I-SEP

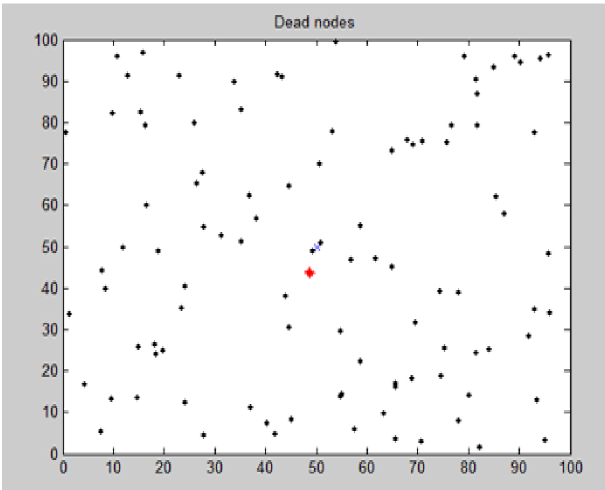

Fig. 6(a) Dead nodes in I-SEP for rmax=4000

Fig. 6(a) Indicates Dead nodes in I-SEP; the red-coloured node at the centre in Fig. 6(a) is the base station with unlimited energy. As a large amount of energy is applied to the advanced node, the amount of dead nodes are extremely low In this case when contrasted with normal and intermediate nodes. Meanwhile, the normal nodes are dead at a quicker rate. In this manner, the intermediate and advanced nodes are chosen as Cluster Heads, increasing the lifespan to a large no. of rounds and incrementing the Cluster head count. As the dead nodes are increased, the amount of alive nodes decreases, as in Fig. 3(b). Here, the number of rounds' r' is 4000. With b=0.5,a=0.1,α=1

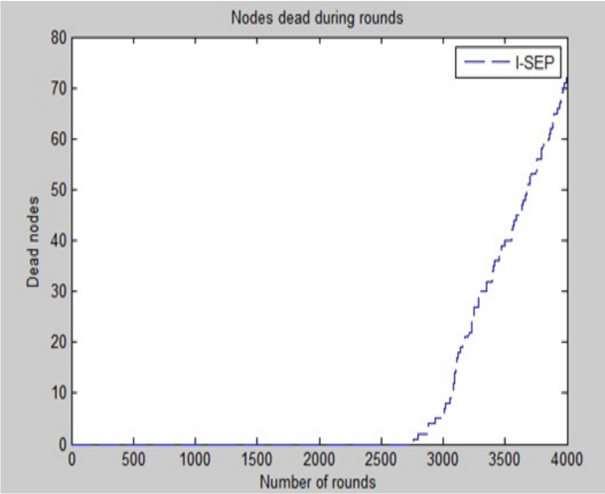

Fig. 6(b) Dead nodes in I-SEP for rmax=4000

5.1. Comparing the 2 Protocols of Sep and I- Sep:

- I-SEP indicates that it is far good compared to SEP.
- I-SEP has a stability period way more when compared to SEP and also all other protocols
- I-SEP shows greater throughput than SEP.
- The lifetime of the network lifetime is more in comparison with SEP.
- Throughput decreases compared to SEP because we are implementing a threshold-based data release approach.

6. Conclusion

Stability period, network lifetime, and throughput were the main elements for constructing an efficient routing protocol, I-SEP, in a heterogeneous WSN. To evaluate the I-SEP algorithm, considerable simulations are performed to ensure the benefits of developing the I-SEP in real-time. This algorithm is shown in a way that best suits a heterogeneous network having the sensors possessing more than a single energy level (Normal, Advanced, Intermediate). This I-SEP protocol is an improved version of the Stable Election Protocol (SEP), which suits the best in the Internet of Things. All the operations and results prove that the I-SEP protocol beats all the other protocols, like the Stable Election Protocol, based on lifetime and throughput for other values of node density. This I-SEP distributes the energy levels among the Cluster Heads and the other nodes, enabling energy conservation within a network. Thus, In comparison with SEP, the proposed protocol I-SEP, because of the three (Normal, Advanced, Intermediate) levels having heterogeneous behaviour, with a reactive routing network protocol, leads to the growth in the stability period & the network life.

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