I-SEP: An Improved Routing Protocol for Heterogeneous WSN for IoT based Environmental Monitoring

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***Abstract*— Wireless Sensor Networks (WSN) is a virtual layer in the paradigm of the Internet of Things (IoT). It inter-relates information associated with the physical domain to the IoT drove computational systems. WSN provides ubiquitous access to location, the status of different entities of the environment, and data acquisition for long-term IoT monitoring. Since energy is a major constraint in the design process of a WSN, recent advances have led to project various energy-efficient protocols. Routing of data involves energy expenditure in considerable amount. In recent times, various heuristic clustering protocols have been discussed to solve the purpose. This article is an improvement of the existing Stable Election Protocol (SEP) that implements a threshold-based cluster head selection for a heterogeneous network. The threshold maintains uniform energy distribution between member and cluster head nodes. The sensor nodes are also categorized into three different types called normal, intermediate and advanced depending on the initial energy supply to distribute the network load evenly. The simulation result shows that the proposed scheme outperforms SEP and DEEC protocols with an improvement of 300% in network lifetime and 56% in throughput.**

***Index Terms*— WSN, Heterogeneous Network, CH selection, Network lifetime.**

I. Introduction

OVER the last few years, the IoT paradigm has evolved as one of the biggest technological advances of modern science. With the evolving era of WiFi and 4G-LTE wireless access of Internet [1] [2], IoT enabled devices like computer, tablets, mobile phones are able to access information about the environment and other objects without human intervention. The two key enablers of IoT are Radio frequency identification (RFID) and WSN.

A WSN constitutes spatially dispersed sensor nodes meant to record and monitor various physical and environmental conditions with low-cost data acquisition. The sensor nodes are usually energy deprived in nature which leads to the formulation of innovative techniques to limit any unnecessary energy dissipation mounting to shortening of lifetime [3]. The source nodes consume a lot of energy in communicating data directly to BS. Hence they have to depend on intermediate nodes to operate. A comparative study of routing protocols [4][5][6] indicates different methods to enhance network lifetime. Khalil et al. [7] have designed a dynamic clustering scheme to reduce energy consumption while transferring information thereby maintaining a trade-off between stability period and lifetime of the network. The method assumes only single-hop data transfer which may not be feasible for a large scale network in an IoT system. Dynamic clustering used in [8] is based on multi-hop communication, where sensors transfer data via intermediate nodes to sink, but reducing the energy at node level is still a problem.

Clustering algorithms have emerged as the most energy-efficient communication protocol that groups the sensor nodes in clusters. Each cluster is headed by a cluster head (CH) responsible for data collection from sensing nodes. The CH fuses the data to remove any redundancy and then transfers to the sink node or BS. Hence election of CH should be done judiciously to maintain proper network balance for energy management. The existing routing methods that select CHs optimally may not be suitable for large scale environments where WSN is integrated with IoT.

Any ad-hoc system can be either heterogeneous or homogeneous. The network where sensor nodes are supplied with equal amount of energy termed as homogeneous, is shown in Fig. 1(a). Heterogeneous networks as shown in Fig. 1(b) and (c) have uneven initial energy distribution. A group of nodes called advanced nodes has higher energy in comparison to normal nodes. The proposed network model introduces intermediate nodes, along with normal and intermediate nodes, that have energy in between normal and advanced nodes. When all sensors in the network start with a constant energy level, the nodes die out randomly within a short span of time. Heterogeneous network structures are gaining importance because it delivers better network performance without demanding much increase in cost [9].

One of the challenging IoT application domains is environmental monitoring, where the sensors are deployed in

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harsh operating conditions [10] [11]. Fig. 2 depicts a scenario where sensor nodes are placed over soil, air, and water to deliver feasible or even optimal solution to monitor moisture, humidity, pH level, temperature.

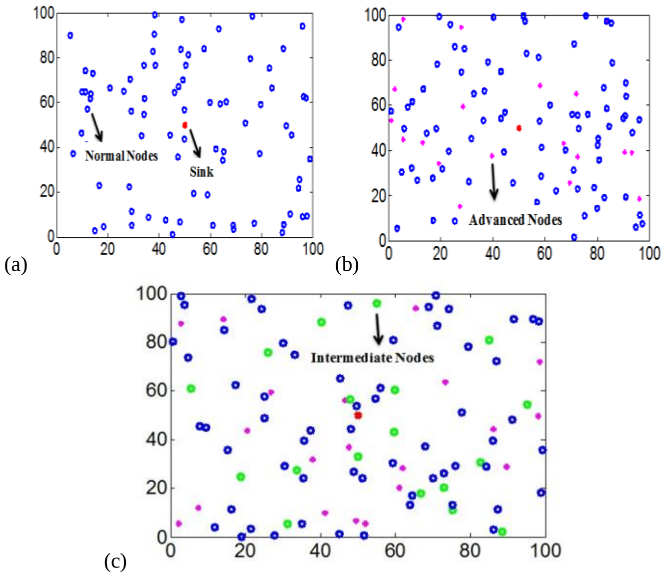

Fig. 1. (a) Homogenous (b) Heterogeneous (c) Proposed Network Model

After deployment, the sensors are expected to keep sensing the environment for a longer period and have no scope of recharging the node battery. Furthermore, the cost and difficulty of accessing the field physically for deployment and maintenance [1] become a challenging task. The WSN platform should offer low-cost nodes with long unattended service time and minimal maintenance to overcome these issues. This is possible only if the network comprises sensors with two or more initial energy levels, which is one of the important criteria considered in the proposed method. Hence it can be inferred that heterogeneous networks perform better when applied in the IoT environment.

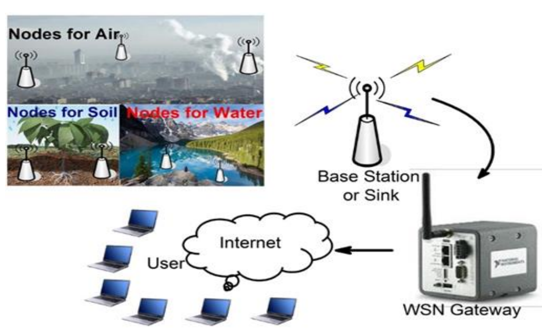

Fig. 2. Environmental Monitoring using WSN

LEACH (Low Energy Adaptive Clustering Hierarchy) is a fully distributed routing algorithm based on TDMA designed for homogeneous networks [12]. SEP (Stable election protocol) is a variant of LEACH where certain populations of nodes (advanced nodes) have some additional energy than other nodes (normal) within the same network [9]. This article discusses an extension of SEP that intends to maximize the network lifetime and throughput by introducing a threshold level in the CH selection process that can be applied in a WSN based IoT network.

Starting with the introduction, a brief analysis of related work is presented in the next section. Section III enlightens the network model and the proposed scheme is provided in section IV. Section V discusses simulation results with issue related analysis. And finally, the conclusion is drawn.

II. RELATED WORK

Any clustering algorithm functions by segmenting the field into clusters headed by a CH. The member nodes, ie, non-CH nodes communicate their data to CH, where the data is processed and aggregated to remove redundancy and sent to the BS. As energy consumption is distributed evenly throughout the network, the overall energy consumption is said to be reduced [13].

LEACH is an energy constrained protocol [14]. The initial CH selection is done randomly such that every node has the chance of becoming CH once in every 1/p epoch [15]. In subsequent rounds, a random number is generated in the range [0,1] and only if the number is less than threshold T_n, formulated by (1), the node functions as CH [16]. The next CH is chosen from the set of non-CH nodes G.

$$T_n = \begin{cases} \dfrac{p}{1 - p(r \bmod \frac{1}{p})}; \; for \ n \in G \\ 0; \; Otherwise \end{cases} \tag{1}$$

After the cluster formation stage, all the elected CHs broadcast a TDMA schedule for non-CH nodes. The sensing nodes transmit the data during the specific allotted time slots. Once the transmission process completes, the frame repeats. Although LEACH is a distributed protocol, it may not be beneficial for large-scale application due to energy constraint.

In a heterogeneous network [9] of n nodes, a fraction of nodes has the extra energy of factor α that are termed advanced nodes. The SEP algorithm focuses on the weighted election probabilities of each node for the election of CHs according to their respective energies. It ensures a more extended stability period with better performance than that of LEACH protocol. The DEEC protocol [17] was proposed for networks with different energy level, where the selection of CH can be decided by both initial as well as residual energy [18]. An enhanced SEP was proposed in [19] that deployed three categories of sensors based on energy levels; named normal, intermediate and advanced nodes. Due to the three-tier node scenario, the network lifetime is enhanced; however, the quantity of CHs in each cluster could not be controlled.

EEHC is an energy-efficient heterogeneous clustering scheme that elects CHs considering the weights of each sensor [20]. The residual energy of each node decides the set of probable CHs in the heterogeneous network. MATLAB results indicate enhanced network lifetime in comparison to LEACH. However, no result analysis is done with any heterogeneous algorithms. Threshold sensitive SEP (T-SEP) is a reactive protocol introduced in [21], where data is transmitted by sensors only when the explicit threshold is reached. Three level heterogeneous nodes were deployed to study the lifetime and stability period of the network. Another modification of SEP for fog-supported WSN discussed in [22] maintains a balanced energy dissipation to prolong the network lifetime. Both types of nodes have equal probabilities to be elected as CHs. As the CHs are chosen judiciously, the node death rate decreases in comparison to LEACH-DCHS [12] and other modifications of SEP.

I-LEACH was proposed in [23] to introduce threshold based CH selection, where the LEACH protocol was modified to obtain better results for IoT based applications. The simulation result showed better performance for different scenarios in comparison to energy efficient routing protocols like LEACH, EECS [24], CPCHSA [25] and Mod-LEACH [26]. However, the algorithm was designed only for homogeneous networks and cannot be implemented for heterogeneous scenarios. To overcome high system complexity CREEP scheme was proposed in [27] that selects numerous CHs to improve the network lifetime by modifying threshold value in a 2-level heterogeneous WSN. Unbalanced energy consumption near CHs limit the network lifetime; particle swarm optimization based CH selection was proposed in [28] that enhances lifetime by identifying energy holes. The approach assumes homogenous network where nodes die out randomly.

In SEP routing algorithm, the election of new CH with the formation of new clusters is done regularly for each round. This in return leads to unnecessary energy utilization generated due to routing overhead which will affect the performance of IoT devices [29] connected to the sensor network. According to the classical SEP algorithm, a CH in the current round will not be able to participate in the CH election process in the next round [27]. However, there can be cases where a CH has not utilized an ample amount of energy in the preliminary round and is eligible for the CH election process in the next round. It can also happen that a sensor with a comparatively lesser amount of energy gets elected as CH in the subsequent selection process [26] that leads to the untimely death of the network. Also, new CH requires new cluster formation in each round, which consumes the node power in sending messages like ADV (advertisement) and ACK (acknowledgment) to CHs back and forth. The above limitation in SEP motivates to investigate and establish an efficient CH replacement method.

The key contributions of the proposed work are:

i. The article aims to enhance the fundamental SEP algorithm by incorporating a unique threshold strategy for CH selection.
ii. The proposed method aims to reduce extra power consumption by avoiding unnecessary clusters and CHs formation in each round.
iii. After CH selection, the proposed algorithm assigns a high level of energy to the node. For the subsequent rounds, when the node again becomes a sensing node, the low level of energy will be assigned. This variation of energy level for different nodes will be beneficial for maintaining proper energy distribution in the network.

III. System Model

Considering energy efficiency and energy balancing [28] as the most vital parameter in the design process of any routing algorithm in WSN, an advanced technique to route data in a heterogeneous network is introduced. To control the energy dissipation, three-level heterogeneity with respect to initial node energy is considered. All the nodes are static in nature. Advance nodes have the maximum, and normal nodes have the lowest level of energy. Intermediate nodes are the ones with higher energy than normal nodes and lower than advanced nodes. Let b be the section of nodes that are assigned an intermediate energy level with β times more power than normal ones, where $\beta=\alpha/2$.

E_0 represents the initial energy given to normal nodes. The advanced and intermediate nodes have $E_0(1+\alpha)$ and $E_0(1+\beta)$ energies respectively. Hence, the total energy of each type of node can be summed up as:

$$E_N = nE_0(1-a-b) \tag{2}$$

$$E_I = nbE_0(1+\beta) \tag{3}$$

$$E_A = naE_0(1+\alpha) \tag{4}$$

Where, E_N, E_I, and E_A are the energies for normal, intermediate and advanced nodes respectively. Therefore, the overall energy of the three types of nodes written as

$$\begin{aligned} E_{Total} &= nE_0(1-a-b) + nbE_0(1+\beta) + naE_0(1+\alpha) \\ &= nE_0(1+a\alpha+b\beta) \end{aligned} \tag{5}$$

The CH election process is similar to that of LEACH and SEP. The threshold value for CH selection is formulated for each type of node by considering their probabilities. Let G_1, G_2 and G_3 represent the set of nodes in each category that had not performed as CH in former epochs and r represents the current round. Considering $p_{(N)}$, $p_{(I)}$ and $p_{(A)}$ as the probabilities of normal, intermediate and advanced nodes to be elected as CHs respectively. For normal nodes,

$$p_{(\mathrm{N})} = \frac{p}{1+a\alpha+b\beta} \tag{6}$$

$$T_{(\mathrm{n}_N)} = \begin{cases} \dfrac{p_{(N)}}{1-p_{(N)}(r \bmod 1/p_{(N)})}; if\ \mathrm{n}_N \in G_1 \\ 0;\ \text{Otherwise} \end{cases} \tag{7}$$

For intermediate nodes,

$$p_{(\mathrm{I})} = \frac{\mathrm{p}(1+\beta)}{1+a\alpha+b\beta} \tag{8}$$

$$T_{(\mathrm{n}_I)} = \begin{cases} \dfrac{p_{(\mathrm{I})}}{1-p_{(\mathrm{I})}(r \bmod 1/p_{(\mathrm{I})})};\ \text{if}\ \mathrm{n}_I \in G_2 \\ 0;\ \text{Otherwise} \end{cases} \tag{9}$$

For advance nodes, $p_{(\mathrm{A})} = \dfrac{\mathrm{p}(1+\alpha)}{1+a\alpha+b\beta}$ (10)

$$T_{(\mathrm{n}_A)} = \begin{cases} \dfrac{p_{(\mathrm{A})}}{1-p_{(\mathrm{A})}(r \bmod 1/p_{(\mathrm{A})})};\ \text{if}\ \mathrm{n}_A \in G_3 \\ 0;\ Otherwise \end{cases} \tag{11}$$

Now, from equation (6), (8) and (10), we can find the average total CHs per round as:

$$n(1-a-b)\,p_{(N)} + nap_{(\mathrm{A})} + nb_{(I)} = np \tag{12}$$

It can be inferred from (12) that the resultant of CHs in a heterogeneous environment is equal to that in case of LEACH protocol. However, the energy dissipation is controlled in a better way owing to the heterogeneous energy level [21].

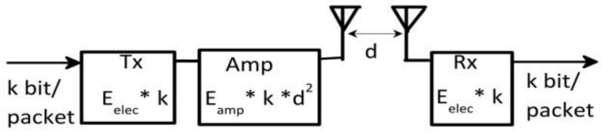

Fig. 3. The first-order radio communication system

The communication in the heterogeneous network follows the model shown in Fig. 3 [30]. If *d* (Euclidean distance between sending and receiving nodes) is less than or equal to a reference distance d_0 (where $d_0 = \sqrt{E_{fs}/E_{mp}}$) then energy dissipation is calculated using multi-path fading model otherwise free-space model is used. Assuming symmetrical communication channel where the energy expended by a sensing node in transmitting *'k'* bits per packet can be given as in [31] [32]:

$$E_{Tx}(k,d) = E_{Tx\_elec}(k) + E_{Tx\_mp}(k,d) \tag{13}$$

$$E_{Tx}(k,d) = \begin{cases} E_{elec} \times k + E_{fs} \times k \times \mathrm{d}^2, d \le d_0 \\ E_{elec} \times k + E_{mp} \times k \times \mathrm{d}^4, d > d_0 \end{cases} \tag{14}$$

E_{mp} and E_{fs} are the amplifier parameters of transmission for multi-path fading model and free-space model respectively [33]. If the transmitter or receiver expends E_{elec} amount of energy per bit, then to receive a packet of *k* bits, a sensor node expends $E_{Rx}(k)$ energy given as:

$$E_{Rx}(k) = E_{Rx\_elec}(k) + kE_{elec} \tag{15}$$

The energy dissipation is estimated in each round for the calculation of threshold boundary for CH election. The proposed scheme aims to estimate a threshold energy value to be maintained by all types of nodes to preserve energy for the network longevity.

IV. Proposed Work

Once the CH is selected, the sensing nodes join the CH according to the information in the ADV message sent by them. Hence for each round, the CHs and clusters keep changing. In case, some CHs (either normal, intermediate or advanced) especially those near to the BS, need not use much of its energy in transmitting data packets. These CHs can continue to transmit with the same group of member nodes in the next round also. But according to conventional SEP, these nodes will not be able to partake in the CH election process for the next *1/p* epochs.

The proposed work introduces a threshold energy value for each type of node in the SEP algorithm, now termed as I-SEP (IoT-SEP). In I-SEP, the threshold energy value decides whether the CH and the corresponding cluster should change or continue transmitting in the next round. After each round, the CH node residual energy is evaluated. If the residual energy is less than the estimated threshold, the CH election process initiates and new clusters are formed. This controls the energy wasted in the unnecessary transfer of routing information for new CH and also reduces the extra energy consumed in new cluster formation.

The energy requirement of a sensing node and a CH node will never be the same. CHs perform extra functions like aggregation and fusion, hence it is desirable that they should be equipped with higher energy level in comparison to those nodes meant for intra-cluster communication. This will additionally save power and packet drop ratio. Hence, the modified algorithm assigns a high energy amplification level only for the selected CH. In the next round, if the CH switches to a normal sensing node, the modified algorithm assigns a low energy level [31][23] to the corresponding node.

With *n* number of total nodes in the network and *C* be the percentage of clusters and *R* is the CH replacement count. P_{kTx} and P_{kRx} are the packet size at transmission and reception.

Let $N=nC$ represents the size of each cluster.

The CH replacement process for new cluster formation also utilizes some energy given as P_{HR} , such that

$$P_{HR} = \left\{ P_{kTx} P_{Tx} + P_{kRx} P_{Rx} (nC - 1) \right\} \times RN \tag{16}$$

Where P_{Tx}= Energy spent in transmitting 1 Byte of data and P_{Rx}= Energy spent in the receiving 1 Byte of data.

The power utilization of each cluster P_{WEC} can be estimated by the multiplying the initial energy supplied to each category of a node with the cluster size, that is,

$$P_{WEC(N)} = E_0 \times nC \tag{17}$$

$$P_{WEC(\mathrm{I})} = E_0 (1+\beta) \times nC \tag{18}$$

$$P_{WEC(\mathrm{A})} = E_0 (1+\alpha) \times nC \tag{19}$$

The power consumption in each cluster *i* for a round can be found by estimating the energy cost of a node in both cases, i.e. when it acts as a sensing node and as a CH. Consequently,

$$\begin{aligned} P_{HR}(i) &= \left\{ (N_i - 1) P_{kTx} P_{Tx} \times P_{kRx} P_{Rx} \right\} + \\ &\quad \left\{ (N_i - 1) P_{kRx} P_{Rx} + (N_i - 1) P_{kTx} P_{Tx} \right\} \\ &= n(5N_i - 3) P_{Tx} \end{aligned} \tag{20}$$

The sensing node expands the nP_{Tx} amount of energy during transmission to the respective CHs. When not transmitting, the nodes move to sleep mode by switching the radio off till the next TDMA slot. The CHs consumes $n(N\text{-}1)P_{Rx}$ energy in the process of data fusion and aggregation. The CH then transmits the fused data to the BS expending $n(N\text{-}1)P_{Tx}$ energy. To estimate the threshold value for CH replacement, the information regarding the number of rounds must be known. $Count_{Rnd}$ represents the total number of iterations in the network which can be calculated for the three types of nodes.

$$Count_{Rnd(N)} = \frac{P_{HR}}{P_{WEC(N)}} \times 100 \tag{22}$$

$$Count_{Rnd(\mathrm{I})} = \frac{P_{HR}}{P_{WEC(\mathrm{I})}} \times 100 \tag{23}$$

$$Count_{Rnd(\mathrm{A})} = \frac{P_{HR}}{P_{WEC(\mathrm{A})}} \times 100 \tag{24}$$

From equation (21) and (22-24), the threshold power level can be calculated as:

$$P_{Th(N)} = Count_{Rnd(N)} (P_{kTx} + P_{kRx}) P_{Tx} \tag{25}$$

$$P_{Th(\mathrm{I})} = Count_{Rnd(\mathrm{I})} (P_{kTx} + P_{kRx}) P_{Tx} \tag{26}$$

$$P_{Th(\mathrm{A})} = Count_{Rnd(\mathrm{A})} (P_{kTx} + P_{kRx}) P_{Tx} \tag{27}$$

$P_{Th(N)}$, $P_{Th(I)}$ and $P_{Th(A)}$ are the threshold values for normal, intermediate and advanced node respectively. The introduction of a threshold value of CH replacement for each type of node in the modified SEP algorithm improves WSN lifetime by minimizing the total network energy. The algorithm for the proposed algorithm I-SEP is included in Table I.

TABLE I
I-SEP ALGORITHM

P_{Th}: Threshold for CH election
E_{Res}: Residual energy of existing CH
CH: CH counter
AF: Amplification factor
G_i: Set of non-CH nodes

begin
    for r=1 to r_{max} **do**
        CH==0;
        calculate $p_{(N)}$,$p_{(I)}$,$p_{(A)}$ by using Eqs. (7),(9),(11);
        calculate $T_{(nN)}$, $T_{(nI)}$,$T_{(nA)}$ by using Eqs. (6),(8),(10);
        CH=*CH*+1;
            if node==*CH* **then**
                AF=high;
            else
                AF=low;
            end if
    for i = 1 to n **do**
        update E_{Res} for each node by using Eqs. (14-15);
        calculate $P_{Th(N)}$, $P_{Th(I)}$, $P_{Th(A)}$ by using Eqs. (25-27);
            if ($E_{Res} < P_{Th(N)}$ & $E_{Res} < P_{Th(I)}$ & $E_{Res} < P_{Th(A)}$) **then**
                $n_i \in G_i$ is selected as new CH;
            else
                previous CH is retained for next round;
            end if
    end for
    end for
end

V. Simulation Result & Discussions

Simulations were carried out in MATLAB with 100 sensor nodes deployed in a network of 100×100 m^2. The BS is positioned at the center with unlimited energy. The network parameters used for simulation are enlisted in Table II. To analyze the behavior of the proposed model in comparison to SEP [9] and DEEC [17] that follows two level heterogeneity, the values of 'a' and 'α' are varied while 'b' maintains a constant value of 0.3. For the first instance α = 1, a = 0.1, for second case α = 2, and a = 0.1, for third case α = 1, a = 0.2 and last case α = 2, a = 0.2.

TABLE II
SIMULATION PARAMETERS

Parameters	Value
P_{Tx}, P_{Rx} (The total energy of the network)	50J
E_{mp} (Energy dissipation: receiving)	0.0013pJ/bit/m^4
E_{fs} (Energy dissipation: free space model)	10pJ/bit/m^2
E_{amp} (Energy dissipation: power amplifier)	100pJ/bit/m^2
E_{DA} (Energy dissipation: aggregation)	5nJ/bit
d_0 (Reference distance)	87 meters
k (Packet size)	4000 bits

The efficiency of any routing algorithm can be analyzed by estimating the number of data packets communicated to the sink node or BS with minimum packet drop ratio. This is called network throughput. With 10% advanced nodes in the network, the throughput and network lifetime are analyzed for SEP and DEEC as shown in Fig. 4 and 5 respectively. It can be found the throughput, increases considerably for I-SEP as compared to both protocols. This improvement results due to the limitation in data transmission for the proposed I-SEP.

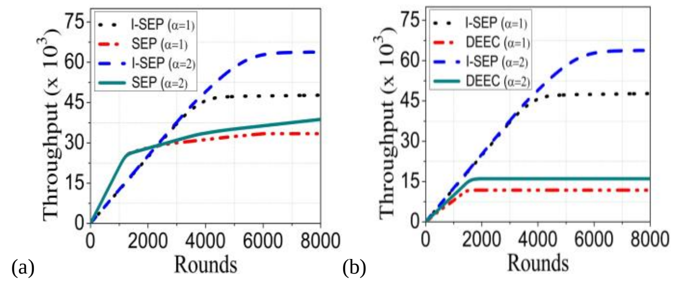

Fig. 4. Throughput for **a = 0.1** in comparison to (a) SEP (b) DEEC

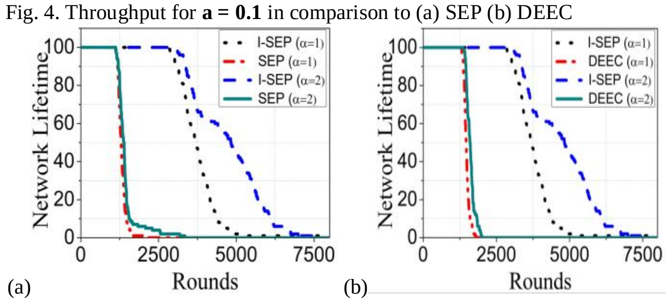

Fig. 5. Network Lifetime for **a = 0.1** in comparison to (a) SEP (b) DEEC

The efficient threshold based CH replacement saves energy owing to the dual power level assignment for CH node and sensing nodes. Introducing a threshold to retain the CH with high residual energy helps to conserve energy for each category of nodes. The nodes are thereby able to communicate more data over a longer period of time. When α is kept constant at 1, the throughput of I-SEP increased by 50% and 240% as that of SEP and DEEC respectively. Similarly for α changed to 2, the maximum throughput further increases by 56% and 300% in comparison to SEP and DEEC respectively.

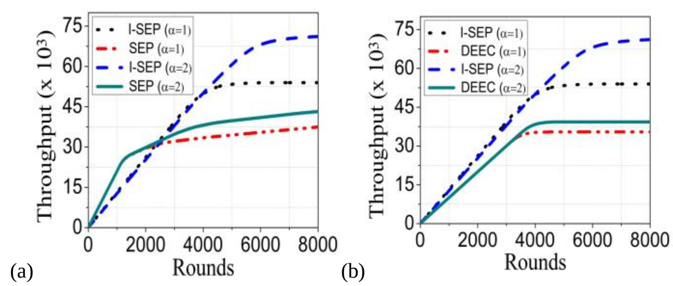

Fig. 6. Throughput for **a = 0.2** in comparison to (a) SEP (b) DEEC

Fig. 6 shows the throughput achieved for SEP, I-SEP, and DEEC for the case when the percentage of advanced nodes is increased to 20%. With more number of advanced nodes, the number of CHs from this category of nodes also increases which indicate more data transfer. Hence, the maximum packets send to BS for I-SEP increases considerably by 53% and 67% than SEP for α value of 1 and 2 respectively. On a similar manner, when compared to DEEC, the rise is 32% and 80% for α=1 and α=2 respectively.

The instant node starts sensing in the network until the death of the last node is termed as stability period [17]. In subsequent rounds, the sensor nodes deplete energy and die eventually. Owing to the availability of sensors with additional levels of energy, I-SEP performs better in context of lifetime than SEP. Since the transmission rate is less in I-SEP, so energy consumption will be less resulting in extended network lifetime.

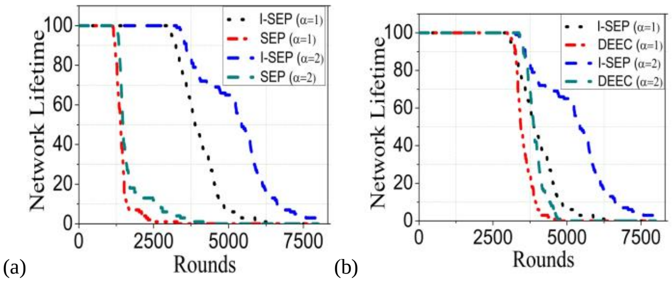

Fig. 7. Network Lifetime for **a = 0.2** in comparison to (a) SEP (b) DEEC

Also, I-SEP considers three categories of nodes whereas SEP and DEEC have only two types of nodes based on initial energy. This heterogeneity in energy level contributes to extend the network longevity to more number of rounds as shown in Fig. 5 and 7. The lifetime metrics in terms of Last Node Dead (LND) and First Node Dead (FND) for different values of α and a is shown in Table III.

TABLE III
LIFETIME METRICS

a	Protocol	α	FND	LND
0.1	SEP	1	1028	2023
		2	1125	3348
	DEEC	1	1308	1809
		2	1371	2002
	I-SEP	1	2846	5287
		2	2876	7600
0.2	SEP	1	1141	3289
		2	1259	4161
	DEEC	1	2997	4579
		2	3388	4938
	I-SEP	1	2997	6258
		2	3268	<8000

Since the energy requirement for CH and sensing nodes are not the same, I-SEP assigns different power levels for these categories of nodes. From the table data, it is clear that by increasing the advanced nodes count, the stability period and network lifetime can be increased, owing to the segregation of nodes into different power levels. The average number of nodes dead in each category is shown in Fig. 8.

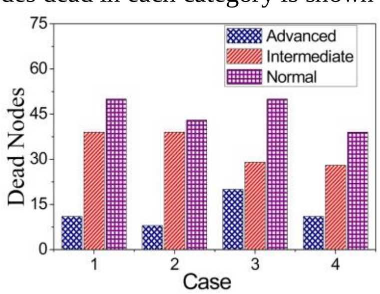

Fig. 8. Dead Nodes in I-SEP

Since the highest energy level is supplied to advanced nodes, the number of dead nodes is less in this category as compared to intermediate and normal nodes. With time, the normal nodes tend to die out at a faster rate. Henceforth, the intermediate and advanced nodes get elected as CH that stretches the lifetime to more number of rounds and increases the CH count as shown in Fig. 9.

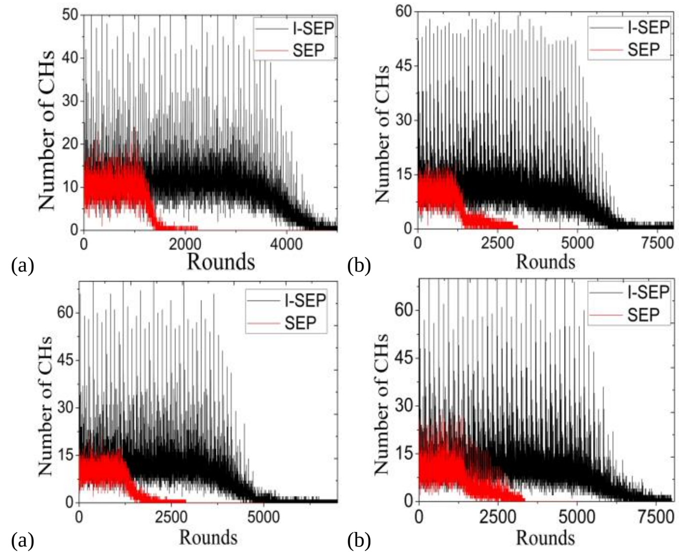

Fig. 9. CH count (a) Case 1 (b) Case 2 (c) Case 3 (d) Case 4

CHs are responsible for aggregating and routing of data to the BS. Fig. 9 shows the CH formation in each round. In all the cases, the CH count is much higher for I-SEP than SEP which indicates more data transfer to BS resulting in increased throughput. When 10% of total nodes are advanced nodes, the CH count for I-SEP reaches almost 50 and 60 in each round for α value of 1 and 2 respectively as compared to only 20 for SEP. The strength starts decreasing beyond 5000 rounds for α=1, and 6000 rounds for α=2 which indicates an enhancement in network lifespan. Similarly, for a network with 20% advanced nodes, CH count reaches 70 to 80 for I-SEP as compared to 20 to 25 for SEP. The CH strength decreases beyond 6000 rounds for α=1, and 7000 rounds for α=2. The increased CH count is a result of heterogeneity. Since the network has nodes of three different level of energy and CHs are chosen from each type of node for equal energy distribution, the overall network energy depletes at a slower rate. As a result, CHs continue sending data packets to BS for more rounds, thereby enhancing network performances.

VI. Conclusions and Future scope

Stability period, network lifetime and throughput are the key factors in the design of a routing protocol for WSN. To evaluate the proposed modified algorithm, extensive simulations have been conducted to confirm the advantages of implementing the protocol practically. A distributed routing algorithm is illustrated that will be well suited for a heterogeneous network where sensors are deployed with more than one energy level. The proposed algorithm is a modification of SEP, and well suited for IoT based environmental monitoring. The simulation result shows I-SEP outperforms protocols like SEP and DEEC in terms of lifetime and throughput for various values of node density. The protocol also switches energy levels between CH nodes and member nodes, which also contribute to saving energy of the network. Implementing the modified algorithm for a mobile network where nodes move from one point to another with a constant speed can be explored in the future.

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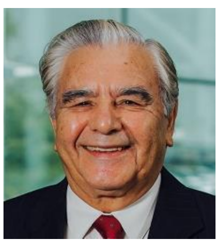

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