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A Radical Study of Energy Efficient Hierarchical Cluster-Based Routing Protocols for WSN

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Abstract: For many decades, researchers and vendors are continually developing and designing sensors and wireless network devices for countless applications. These low power wireless sensor network devices have designed to gather and propagate data for applications such as environment, industry, habitat, patient monitoring, and many more to excel humankind—however, these devices also inherent many challenges and drawbacks due to the default hardware design. Subsequently, to mitigate limitations and enhance the capability, authors and researchers have investigated and conferred that minor optimization in modeling or routing techniques gradually elevates the performance of WSN. One of the primary concerns which remain on top of the Domain for discussion is *energy conservation* in WSN devices. Our primary goal is to *analyze and design* a cluster-based routing protocol for WSN, An efficient way to elevate the network performance. Finally, the emanate results showcase that the performance of the proposed protocol is much more optimized and favorable when combined with soft-computing tactics when compared to the conventional paradigm.

Keywords: *LEACH; PEGASIS*; *SEP; DEEC; BIHP; MGEAR; TDEEC; ZSEP; SPEED; T-SEP; B-SEP; PDFND; NDUD; Energy Hole;*

1. Introduction

WSN is a self-sustain[1], infrastructure-less, spatially distributed low power, sensor network with a centralized sink connect through many MOTE, mote diagram, as shown in Figure 1. Lossy[2] networks consisted of mote hardware for gathering and propagating the required data from the surrounding environment. To operate these sensor networks over a long period or to cater to useful information from the sensor field, researchers and scholars have been looking into creatures or beautiful nature to solve many human complex issues. We study how a network from homogeneity to heterogeneity is beneficial. The cost of transmitting 1kb data over a distance of 100 meters is approximately 3 joules. By contrast, a general-purpose processor with 100MIPS/W power could efficiently execute 8 million instructions for the same amount of energy (1) DPM and DVS are the main two power-saving mechanisms. We are also inclined to technique seeded from biological behavior, one of the sources called the BFO paradigm (Bacteria forging optimization)[3]. As per the conventional methods, such as LEACH[4], PEGASIS[5], SEP[6], BIHP[3] are simulated and compared to compute a better result.

Motivation1: To enhance reliability and performance[7], we incorporated an evolutionary technique for selecting cluster-Head in a conventional routing protocol. The behavior of the BIHP[3] protocol in a homogenous environment is inconsistent as compared to SEP for the assumed parameter, but much better than LEACH and PEGASIS when executed[3]. Also, to tackle the real-time problem of low power devices and to prolong the overall network lifetime SEP Stable Election Protocol showcases better results when blended with BFO.

Motivation2: Another dimension that highlights the scope of the future in WSN or smart management is viral nowadays, called SDN[8][9] (Software Defined Network)[10]. It is computing—typically composed of the controller and switches that overcome the inherent weakness of the traditional network. This novel architecture model was first introduced by Luo[11]to Bridge the gaps of WSN using SDN. This Blended SDN structure offers a scalable and potential approach through programming aspects. Since fortunate to decouples the control plane

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from the data plane to work independently. The envisage of making this device conferred flexibility and soar potential for the traditional networks[10].
Challenge: due to the constrained environment in WSN, SDN architecture is not easy to implement, whereas the Inherent nature of SDN articulates the adaptation of centralized computing in WSN, a tradeoff between QoS and power consumption.

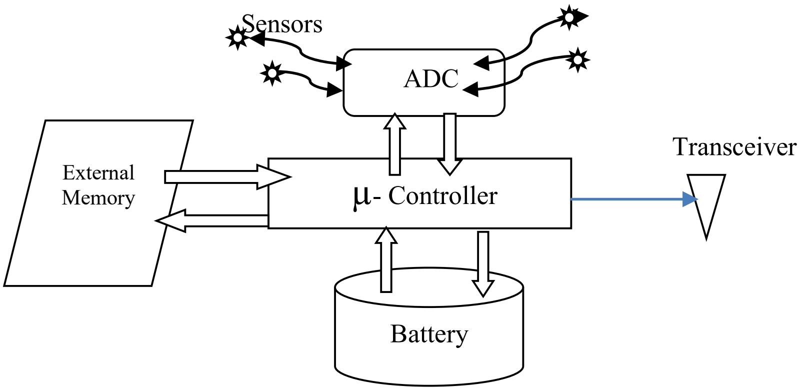


Figure 1. MOTE (Sensor)

Solution: To tackle the above challenges, we required a few adoptions to envisage QoS. 1) Simply ignore all the above problems or merely improve upon the excellent hardware configuration, but this leads to a higher cost network. 2) Develop Low power lossy network for layer 3 Protocol such as RIME or RPL operate by building and maintaining the DODAG graph[12], or WSN. 3)Develop a less-overhead architecture that effortlessly merges into WSN using SDN and IPV6[12][13] to conferred high potential or flexibility through programming[8]. POX is one of the open-source Python-based controllers for the SDN network, resulted in high potential, compared from NOX. Another such centralized device that is currently more popular is known as the RYU controller. Compared to POX[8], RYU is a component-based controller that can easily handle using python programmable language for designing a new customized controller application[8].

2. Motivation and Previous Work

Energy conservation and maintaining the longevity of the network are the two prime objects of the wireless sensor network. In this article we analyze hierarchical cluster-based routing protocols for homogeneous and heterogeneous network such as LEACH[4], PEGASIS[5], SEP[14], DEEC[15], MGEAR[16], ZSEP[17], SPEED[18], TDEEC, TSEP[19], BSEP. Cluster-based data collection is the conventional way of saving energy or load balancing techniques as compared to the direct method of communication. In LEACH[4], the authors presented a hierarchical cluster-based routing technique to minimize global energy usage and balance the load among nodes. It's wholly distributed and doesn't require control details from the base station. Their simulation exhibits that the LEACH protocol outperforms Eight times as compared to the direct method and last node death took place three times later, which improves the stability period of the network, LEACH setup and flowchart as shown in Figure 2-3.

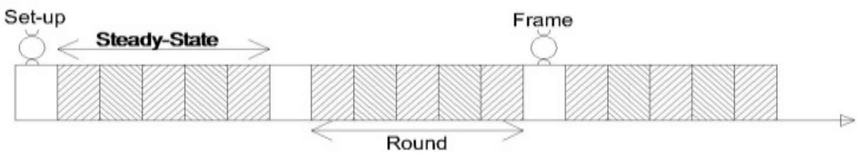


Figure 2. Setup and steady-state in LEACH

The key features of the LEACH protocol are 1) Local coordination, 2) Randomization of C.H. and Clusters, 3) Data aggregation, avoiding duplicate data.

In LEACH routing protocol, Cluster Head selection criteria are at a certain probability for a given time.

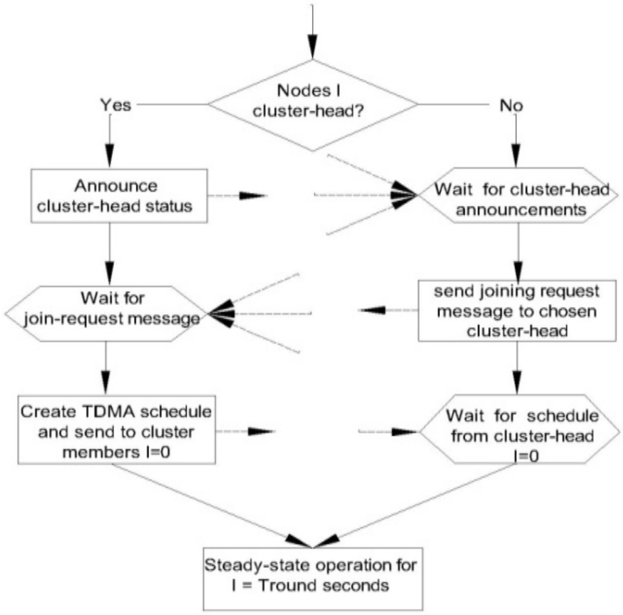


Figure 3. LEACH Flowchart

In PEGASIS[5], authors presented optimal chain based routing to have more improvement than Direct and LEACH protocol results compared in Table 1, where each node set to communicate with its nearest neighbor to transmit the data to the destination. Using this scheme allows nodes to spend less energy as compared to other protocols per round. This scheme is also known as a token passing approach, as shown in Figure 4, PEGASIS Token Passing.

C1→C2→C3←C4←C5←C6

|

BS

Figure 4. Token Passing[20]

Table 1. Shown the No. of rounds 1%, 20%, 50% and100% nodes die.

Energy J/node	Protocol	1%	50%	100%
0.50	DIRECT	28	40	61
	LEACH	339	461	576
	PEGASIS	675	1362	1544
1.00	DIRECT	56	80	122
	LEACH	690	911	1077
	PEGASIS	1346	2720	3076

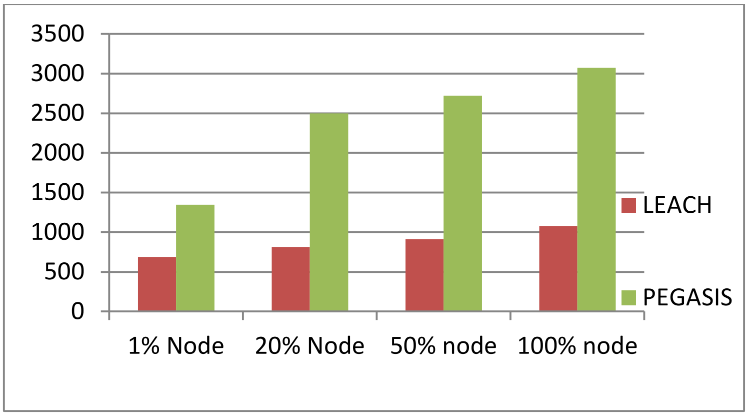


Figure 5. Performance result of LEACH Vs. PEGASIS with initial energy 1 J/node.

The simulation shows that the number of rounds when 1% to 100% nodes die using 0.5 or 1.0 Energy J/nodes, simulation performed for 50mX50m network where PEGASIS outperforms three times better than LEACH shown in Figure 5. In this routing, every node transmits forming a greedy chain to its close neighbor and reaches the destination B.S., hence limit the energy consumption and outperformed by removing the overhead of Cluster formation as compared to the LEACH routing spend per round. In our simulation in the next section, showcase that the PEGASIS has better results than LEACH by about three times by saving energy in each stage. However, this scheme inherent the delay for far-away nodes hence might not be suitable when required fast communications.

In SEP [http://csr.bu.edu/sep][14] routing protocol, the authors presented the impact of advance node over the homogeneous network, as shown in Figure 6 Sensor Field, where every node discriminated between 2-level energy called heterogeneous network. C.H. selection is on the criteria of initial energy and weighted election probabilities of each node. The sensitivity of the stability period is varying on these values of m and alpha. However, performance doesn't depend on this independent value instead of their products [m x α], as shown in the Figure 7 Stability region. Simulation exhibited that SEP protocol outperforms then LEACH and Fair when [m x α=0.2] SEP Performance increased by 18 percent, and when [m x α=0.9] SEP performance increased by 33%. Although improvement is due to the advanced nodes which are uniformly distributed, and elected Cluster head to consume extra energy judiciously. P_{adv} and $P_{nrm}$are the weighted election probability of the advance nodes and normal nodes given by equation 1-4, Where $P_{opt}$is replaced by $T(S_{nrm})$, and $T(S_{adv})$ known as the threshold for advance node and the normal node, which guaranteed well-distributed energy consumption and an optimum number of cluster head is given by k_{opt} given by equation 3. The idea of SEP protocol is to increase the time interval between the F.N. Death until the L.N. Death, known as the stability period. The author examined, unlike[21], that SEP doesn't require prior knowledge of node energy at every round intends to curb the complexity of the algorithm. In addition to global awareness of node, SEP is also dynamic since no prior distribution of sensor node is required, unlike[22]. In paper [23] SEP using opinion dynamics SEP based routing in

$$P_{nrm} = \frac{P_{opt}}{1+\alpha.m} \quad (1)$$

$$p_{adv} = \frac{P_{opt}}{1+\alpha.m} X(1+\alpha) \quad (2)$$

$$k_{opt} = \sqrt{\frac{n}{2\pi}}\frac{M}{d_{toBS}} = \sqrt{\frac{n}{2\pi}}\frac{2}{0.765} \quad (3)$$

$$p_{opt} = \frac{k_{opt}}{n} \quad (4)$$

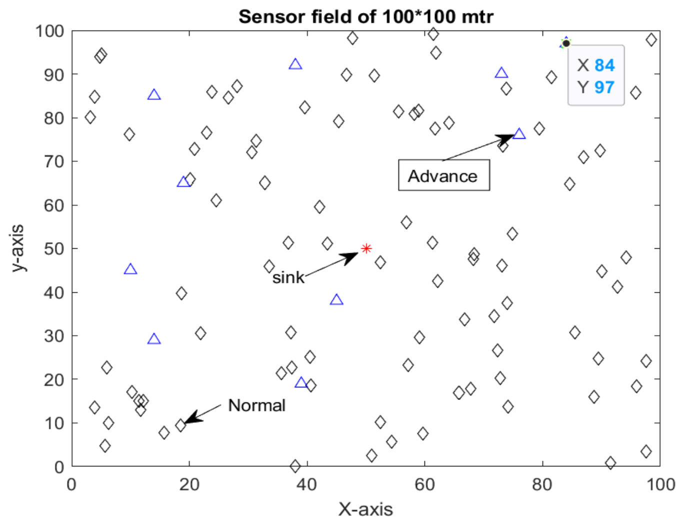


Figure 6. Sensor Field

In this paper [22], Enrique examined the performance and energy consumption issues in the sensor field. It has assumed that the two types of sensors deployed randomly, One with a single layer and others with an additional power source. However, this ecosystem also quantifies an additional number of clusters and respective cluster heads, where sensor lifetime depends on the varying parameter such as distance and size.

Considering all the parameters and constraints, Results show that an appropriate number of cluster head should be between 4 and 10. Moreover, the exact number can vary according to the size of the sensing field. Now let E_{nrm} and E_{avd} are the energy of the sensor nodes for normal and advance nodes, respectively, as shown in equation 5.

$$\frac{E_{nrm}}{K_3+(K_4+A_2E[S^{\propto}]C_s(\frac{n}{q})} = \frac{E_{adv}}{K_1+(K_2+A_1E[d^{\propto}])C_o(q)} \tag{5}$$

From this, we get the relation of normal E_{nrm} and overlay E_{adv} as follow:-

$$\frac{E_{nrm}}{E_{adv}} = \frac{K_1+(K_2+A_1E[d^{\propto}])C_o(q)}{K_3+(K_4+A_2E[S^{\propto}]C_s(\frac{n}{q})} \tag{6}$$

Where $E[d^{\alpha}]$ depends upon the number of nodes q in the sensor field, if perfect scheduling has achieved at the MAC layer, then the value of C_0 (q) $=C_s$ (n/q) = 1.

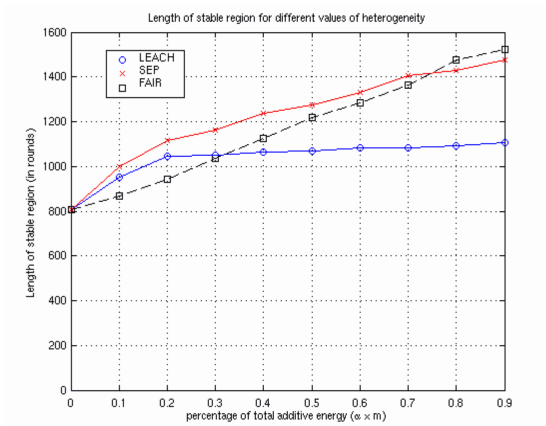


Figure 7. SEP Stability Regions[14]

Another clustering technique protocol designed for the heterogeneous environment is called DEEC[15]. Distributed energy-efficient cluster algorithms describe the critical technique to maximize energy conservation in sensor nodes. Allow long network lifetime and increase scalability. The probability criteria for selecting the cluster head can be defined as the ratio of residual Energy E_i over average energy in the nodes.

The chances of nodes to become C.H. depend upon the energy level at the begging or node with high residual energy referred to as reference energy, which each node should spend during the round. Nodes are defined with much more power to avoid situations for the entire nodes to die simultaneously. In the DEEC[15] protocol, authors choose different nodes denoted by $n_{ito\ to}$ depend upon residual energy to select the cluster head. The Average power to each round r of the network can be given by equation 7.

$$\acute{E}(\boldsymbol{r}) = \frac{1}{N}\sum_{i=1}^{N} \boldsymbol{E_i(r)} \tag{7}$$

To computer average energy at round r from equation 7, all nodes must have the prior knowledge of (T.E.) total energy of each node. Now suppose $p_i=1/n_i$, denoted as the average probability of the node during n_i to become cluster head. Using E.I. and ÉI, the author has computed the equation 8.

$$\boldsymbol{p_i = p_{opt}}\left[\boldsymbol{1} - \frac{\acute{E}(\boldsymbol{r}) - \boldsymbol{E_i(r)}}{\acute{E}(\boldsymbol{r})}\right] \tag{8}$$

Choosing the p_i to be p_{opt} regard as p_{opt}N, it is an optimal C.H. to achieve at each Round and where all these nodes die approximately the same time.

$$\boldsymbol{p_i = p_{opt}}\frac{\boldsymbol{E(r)}}{\acute{E}(\boldsymbol{r})} \tag{9}$$

Which sure that the average total number of C.H. as equation 10

$$\sum_{i=1}^{N} \boldsymbol{P_i} = \sum_{i=1}^{N} \boldsymbol{p_{opt}}\frac{\boldsymbol{E_i(r)}}{\acute{E}(\boldsymbol{r})} = \boldsymbol{Np_{opt}} \tag{10}$$

Also, setting the probability threshold given by T $(\boldsymbol{s_i})$ in equation 11, where G is the eligible set of nodes at round r to become C.H. and if node s_i has not elected as the C.H. in the last rounds, then it opt for a random number $0<s_{i\ Value}<1$ since the value is less than T (s_i) node with "s_i value" elected as a cluster head for that round r_i.

$$\boldsymbol{T(S_i)} = \begin{cases} \dfrac{\boldsymbol{p_i}}{\boldsymbol{1 - p_i(r mod \frac{1}{p_i})}} & \boldsymbol{if\ S_i \in G} \\ \boldsymbol{0} & \boldsymbol{Otherwise} \end{cases} \tag{11}$$

To maintain two-level heterogeneity, reference energy P_{opt} change for P_{normal} node and $P_{advance}$ node to equation12. To achieve multi-level heterogeneous networks same can be extended with equations 13 and 14.

$$\boldsymbol{p_i} = \begin{cases} \dfrac{\boldsymbol{p_{opt}E_i(r)}}{\boldsymbol{(1+am)}\acute{E}(\boldsymbol{r})} & \boldsymbol{if\ S_i \in normal\ nodes} \\ \dfrac{\boldsymbol{p_{opt}(1+a)E_i(r)}}{\boldsymbol{(1+am)}\acute{E}(\boldsymbol{r})} & \boldsymbol{is\ S_i \in\ Advance\ nodes} \end{cases} \tag{12}$$

From eq(10)

$$\boldsymbol{p(s_i)} = \frac{\boldsymbol{P_{opt}N(1+a_i)}}{\boldsymbol{N+\sum_{i=1}^{N} a_i}} \tag{13}$$

$$\boldsymbol{p_i} = \frac{\boldsymbol{P_{opt}N(1+a)E_i(r)}}{\boldsymbol{(N+\sum_{i=1}^{n} a_i\,)}\acute{E}(\boldsymbol{r})} \tag{14}$$

Note: as stated above, p_i is inversely proportional to n_i $[\boldsymbol{n_i} = \frac{\boldsymbol{1}}{\boldsymbol{p_i}}]$

In [16]M-GEAR, Gateway-based Energy-aware multi-hop routing protocol, as shown in Figure 8, the author divided the sensor field into four logical parts and deployed the Base Station out of the sensor field rather than the gateway node in the center. Multi-hop or direct communication decision took place; based on the distance between node and Base Station or gateway, if the distance is less than the threshold distance, then the optimal solution for the node is to communicate directly to the base station else find the shortest path to reach the destination where cluster head is selected based on probability. The performance of the M-GEAR protocol is compared with LEACH, Result showcase that the proposed technique outperforms in terms of

longevity of the network and energy conservation. In this [16]paper author highlights two significant drawbacks of the multi-level hierarchical routing protocol.
1) Energy Transmission of relay C.H. is high if it is far away from BS.
2) Border Nodes or distant nodes from the Sink become C.H. required high power or energy to reach to the destination, so such nodes die soon as compared to the node near to the Base Station.

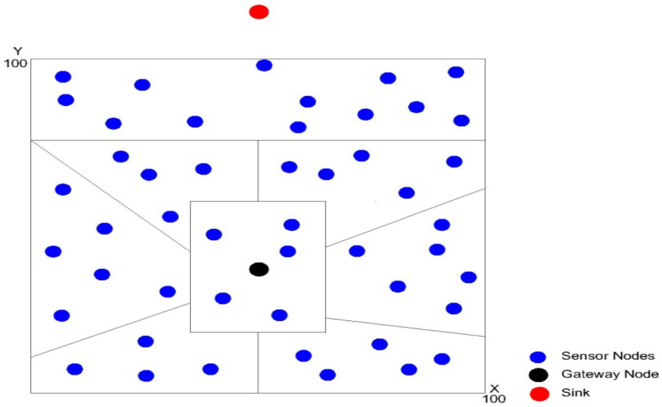


Figure 8. M-Gear sensor Field

The author discusses the Node data Table 2, consisting of node Id, residual Energy, location of the nodes, and distance to the Base station.

Table 2 Node data table[12]

Node Id	Residual Energy J	Location of Nodes (X, Y)	Node Distance from B.S.	Node Distance from center
Node_1	0.5	69, 90	Near	Far
Node_2	0.5	49, 52	Far	Near
Node_3	0.5	10,30	Far	Near
. . .				
Node (n-1).	0.5	59,90	Near	Far
Node_n.	0.5	(89,95)	Near	Far

In ZSEP[17] hybrid routing protocol, the main objectives are to achieve throughput and stability period in the network. However, in this Semi hierarchal technique, nodes are segregated based on the criteria of distance$_{tosink}$. Sensor nodes far away from the destination node communicated using a clustering technique similar to SEP. In contrast, the remaining node near to the Sink doesn't require participating in the cluster

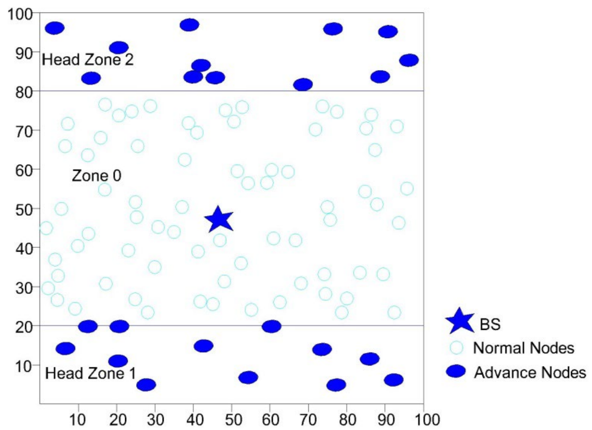


Figure 9. Network Architecture Z-SEP

In this protocol, authors specifically target the uneven Distribution of the nodes supply, suppose if the majority of the nodes are deployed randomly far from the B.S., then the network required more energy for transmission; thus, it reduces the network stability and throughput. Address problems can be resolve by dividing the entire network into zones, where normal nodes are deployed near B.S., and advance nodes are set near the corner of the field equipped with higher power forming clusters since more energy is required for far away nodes to reach Base Station. Terminology such as epoch: describe which node is eligible to become C.H. in the current round. Data Aggregation: Sensing nodes near to each other may share similar information called redundancy, to remove similar information, data aggregation help in suppressing redundancy.
Network lifetime: is defined as the total time from the begging of the network until the death of the last sensor node.
Throughput: it is defined as the total rate of data sent from the Node to B.S. and vice versa.
Instability Period: it is the time interval between the deaths of the 1st node until the nth node inside the network.

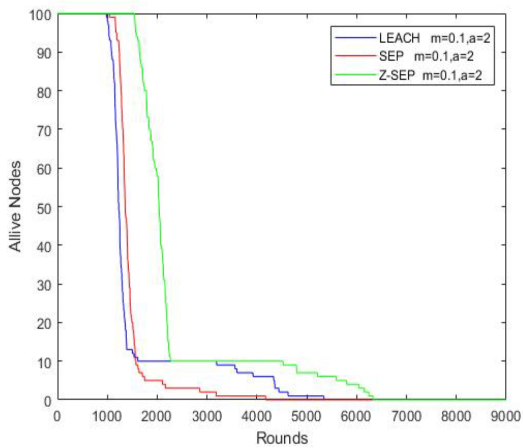


Figure 10. Performance result of LEACH SEP and ZSEP with initial energy 0.5 Joules/ (node)

Stability Period: it is the time interval before the death of the 1st node inside the network. As described in Figure 9, entire networks in partitioned into three zones Named Zone 0, head zone 1, and Head Zone 2, respectively. For Zone 0, Deployment is done with a normal node lying between the coordinates 20<y≤80, similarly for Head Zone 1 and Head Zone2 coordinates are 0<y≤20 and

$80<y\leq100$ deployed advance nodes. Results showcase that the just by placing node according to their energy level Z-SEP outperforms 50% compared to LEACH and SEP.

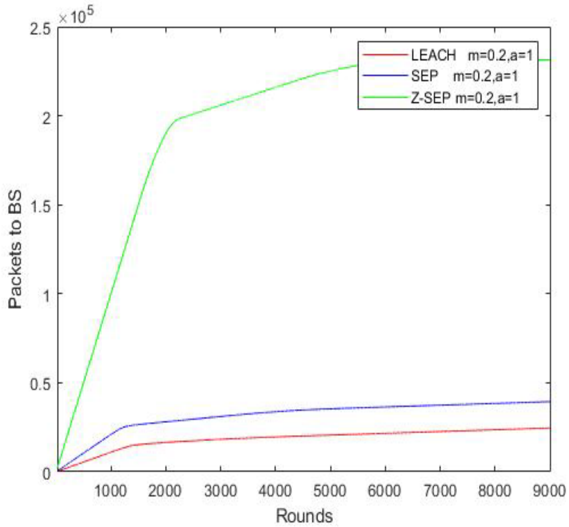


Figure 11. Performance results of Packets to Base Station vs. Round

In Energy Efficient SPEED[18] demonstrate the approach for routing by considering residual energy and based on weight function where $\alpha = \beta=1$ as in equation 15, emanated as

$$f = \max (En .\alpha + \beta.Sp*\varphi (De)) \tag{15}$$

En is the residual energy of the jth node, and Sp is the relay speed defined in equation 17. Delay, Speed, and Energy, also known for the stateless routing protocol. However, the results showcase that the energy graph of enhanced SPEED routing protocol is much better than the original SPEED routing protocol. Like M-GEAR, this protocol also adheres to node neighbor-table consisting of variables such as neighbor-id, position, single-hop delay, and Expire time, as shown in Table 3 [Neighbor Table] used for exchanging position information using beacon signal.

Table 3. Neighbor Table

Node	neighbor-id	Position(X,Y)	single hop delay(D)	Expire Time
1	Node i	X1, Y1	X1	Timeout 1
2	Node i+1	X2, Y2	X2	Timeout 2
3	Node i+3	X3, Y3	X3	Timeout 3
4	Node i+n	X.N., Y.N.	X4	Timeout N

Energy mode is given by equation 16, where C.E. is the energy utilized, and E is the initial level of energy.

$$E_j = \frac{E_o - CE_j}{E_o} \tag{16}$$

$$RS = (|L - L\_next| / SingleHopDelay) \tag{17}$$

R.S. denotes relay speed, L is defined as the distance between sensor nodes at Neighbor subset Nsi to the Destination node I, L_next is the distance from the destination node to the next node forming the Forwarding set candidate set shown in Figure 12 [18].

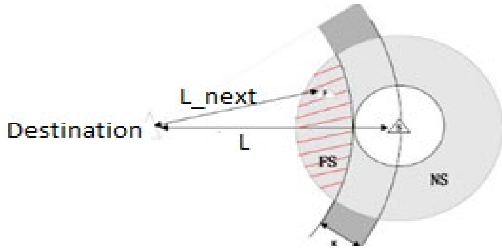


Figure 12. Distance between a node and Destination L and L_next.

In E-DEEC[24]author proposed three types of nodes focusing on prolonging the network lifetime based on heterogeneity and providing a more stable period of the network. The simulation results showcase that the E-DEEC outperforms compared to SEP protocol in messages and stability.

E-DEEC emanate from DEEC[15]introduces another supernode with more energy compared to advance nodes, in turn, elevate heterogeneity. Total energy for multi-level heterogeneity can explicitly be given by equation 18[25][26].

$$\mathbf{Em_{total}} = \sum_{j=1}^{n} \mathbf{E_0} * (\mathbf{1} + \mathbf{a_j}) \tag{18}$$

Simulation parameter listed in Table 4 used for the scenario when sensor nodes deployed randomly in 100m X 100 m

Table 4. E-DEEC Parameters

Field	100 m X 100 m	Random Deployment
Sensor node	100	Heterogeneity level 3
Normal nodes	50%	0.5 J
Advance node	20%	1.5xTime more energy than normal nodes
Super Nodes	30%	3xTime more energy than normal nodes
do	70 m	Threshold Distance
Popt	0.1	Desired % of CH
Message Size	4KB	Packet
Eelec	50 nJ/B	Operation Energy/Radio dissipation
Efs	10nJ/B/m^2	
Eamp	0.001PJ/B/m^4	

Sensor field. However, the Sink always remains at the center for receiving. In this [24]paper, the authors have assumed that the node always has data to send. However, all sensor nodes are equipped with similar processing and communication capabilities but don't aware of location since GPS is not attached also discriminates initial energy among nodes. Traditional LEACH nodes organize themselves into clusters with one local base station to receive data from its member. These local Base stations, also known as Cluster Head, where data fusion for data compression is done[4]. These results showcase that the E-DEEC has improved the stability and lifetime of the network. However, the instability period is more in the case of SEP when scrutinizing and compare to E-DEEC shown in Table 5.

Table 5. Comparison of SEP v/s E-DEEC

Protocol	Death of 1st node	Stability Period	Instability Period	Last node death
SEP	1200 r	less	High	6000 r
E-DEEC	1500 r	High	less	4100 r

Note: r= number of rounds.

In T-SEP[19], Threshold Sensitive Stable Election Protocol has designed with two main aspects:

1) Its a Reactive routing protocol that means the transmission is carried out when specific threshold criteria reached.

2) Three-level heterogeneity nodes with different energy levels.

However, the average C.H. selection is like LEACH[4], SEP[14], ESEP[27]. At the beginning of each routing, C.H. broadcasts the following parameter, as shown in Table 6. One of the significant drawbacks of using this scheme is that

Table 6. Broadcasting Parameter of CH

CH Broadcast	Parameter	Detail
R.T.	Reporting Time	Time is required by each node to send the report.
(A)	Attributes	Information on Physical Parameter
(H.T.)	Hard Threshold	The node switches on and transmits data when the absolute value reaches ≥H.T.
(S.T.)	Soft Threshold	Smallest sensed value at which node transmits

it doesn't provide any prior information to the system about node death, so it may not be useful for those applications where data required regularly. Performance evaluation is done using MATLAB for comparison of following protocols which showcase that in term of throughput, E-SEP has a better result, however in term of stability period and network lifetime T-SEP outperform.

Table 7. Comparison of LEACH vs. SEP vs. ESEP vs. TEEN vs. T-SEP

Protocols	Stability Period	Network lifetime	Throughput
LEACH	Low	Less	< SEP
SEP	>LEACH	>LEACH	<ESEP
E-SEP	> SEP	>TEEN	>TSEP
TEEN	>ESEP	>SEP	< TSEP
T-SEP	>TEEN	>TEEN	<ESEP

3. Other Energy-Efficient Method

Mishra et al. [28]present a method to resolve the problem of energy dissipation due to uneven Deployment of WSN, using

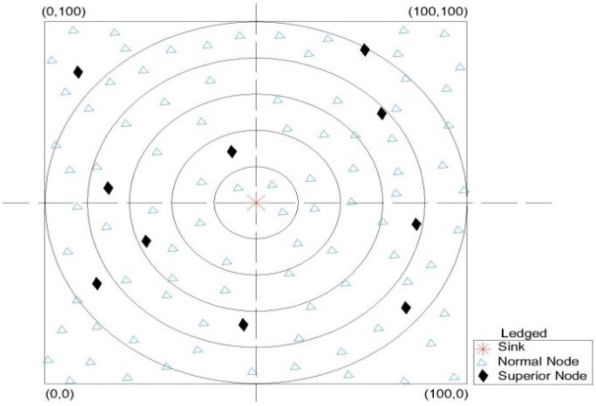


Figure 13. Corona NDS Design

PDF (Probability Distribution Function) based on NDS (non-uniform deployment strategy) caters better coverage. It hence increases network lifetime. Further author adduces that for better energy consumption, node density between adjcorona should be proportional to each other. Li et al. work in this paper[29] adduce many-to-one communication later solve the "energy hole" problem would arise for nodes near to the Sink, due to relay for more traffic as compared to nodes sitting away from the Sink. However, the "energy-hole" problem was also introduced by author olariu et al. in this paper[30], where the energy model and distance to sink relation are given by equation 19 and 20, respectively.

$$\boldsymbol{E_{model} = d^{\propto} + C} \tag{19}$$

Note: the value of $\propto$ $\boldsymbol{power\ attentuation}$ ≥2, C is technology constant, and d is the transmission distance.

$$\boldsymbol{f(\forall\ sensor_{distance\ to\ sink}) = \begin{cases} min\left\{T_{X}, < \left(\frac{2C}{\propto - 2}\right)^{\frac{1}{\propto}}\right\}, & Direct\ communication \\ otherwise\ , & Indirect\ communication \end{cases}} \tag{20}$$

Case I. To avoid uneven energy utilization author choose $\propto > \mathbf{2}$
Hence doesn't lead to an energy hole inside the network.
Case II. $\propto = \mathbf{2}$Author proves negative results mean no way or no routing method can help to prevent the energy hole inside the network leads to uneven depletion of power among the nodes also lead to node uncertainty.
In this paper [28], the Distribution of nodes in each corona would be calculated by equation 20 and 21, respectively, where N.D. (Node Distribution) has shown in Table 8. And the network is divided into a number of circles with width W, as shown in Figure 13. Note Wi =(√i + 1 − √ i) R where the value of R can be Ri = √ iR also network filed divided into a concentric circle can be given by equation 22.

Table 8. Node Distributions ∀ $\boldsymbol{corona}$

Layer L(a_i)	1	2	3	4	5
Pi	0.51	0.25	0.12	0.07	0.05
Ti	51	25	12	7	5

$$\text{Ti} = \text{Pi} \times \text{Total} \tag{21}$$

$$\text{Area}_{\text{Last}} = \frac{\boldsymbol{H^2}}{\boldsymbol{4\ xR}} \tag{22}$$

Similarly, the last circle radius is given by equation 23.

$R_{last} = \sqrt{}$ last R. (23)

However, the outermost circle radius have given by H/2 and using equation 24

$Ri = \sqrt{}$ iR. (24)

The proposed strategy PBNDS when compared with other competent schemes such as PDFND[31], NDUD[32], NDGD[33], and PDFBNDS. It has been observed for strategies NDUD and NDGD; each corona doesn't appear to consume equal energy at the same time. Hence more energy is consumed in layer one than layer two and so on. Therefore nodes in corona 1 die sooner lead to unstable energy consumption. In the proposed method PBNDS, the death node in the network for each round is approximately the same and better coverage in all the layers of corona when compare with PDFND. The proposed scheme with NDS provides almost equal energy balance in WSN, which means all nodes exhaust their energy at the same time hence avoid the energy hole problem altogether, as shown in Figure 14 [Average energy consumption in each layer][28].

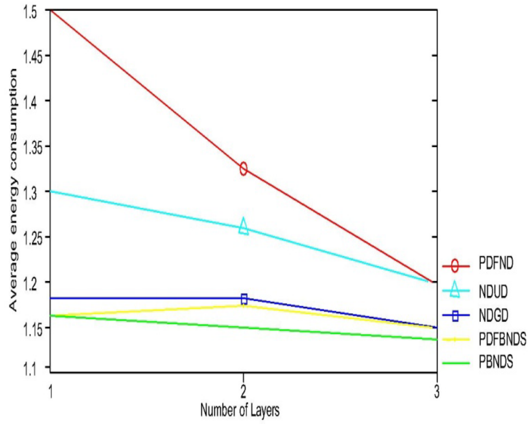


Figure 14. Energy Consumption [22]

Objective-1: To analyze and compare the performance of various cluster energy-efficient routing protocols in WSN. In this section, we have reached the old routing protocols with Stable Election Protocols, along with extensions of SEP. It has been observed that energy dissipation could be controlled up to some limit due to heterogeneity in ESEP and Performance results for a 100x100m network with initial energy 1J/node compared using Matlab.

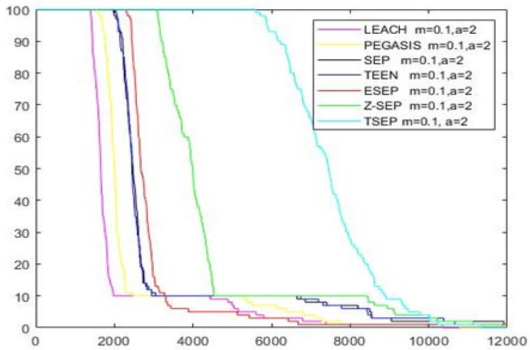


Figure 15. Alive nodes vs. Rounds performance result for 100x100 m network with initial energy 1 J/node.

Table 9. Comparison Number of Dead Node Per Round

ROUTING PROTOCOL	1% Node	20% Node	50% node	100% node
SEP	1682	2285	2617	4231
DEEC	2590	2981	4382	7263
TEEN	3746	4431	5182	11231
ZSEP	3113	3387	4156	12200
TSEP	4817	6034	7512	12001

Our desired goal is to compare the traditional routing protocol with the ESEP, ZSEP, and TSEP. All nodes keep on sensing the environment continuously.

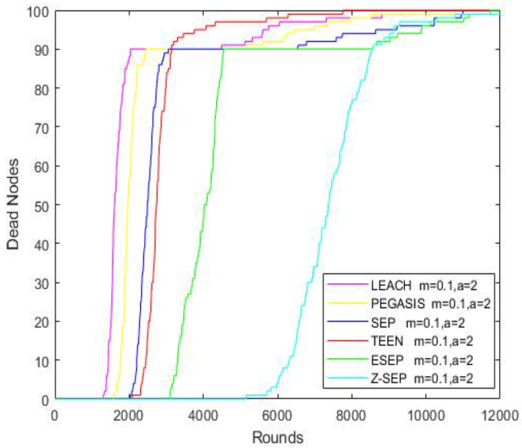


Figure 16. Dead nodes vs. Rounds performance result for 100x100 m network with initial energy 1 Joules/(node)

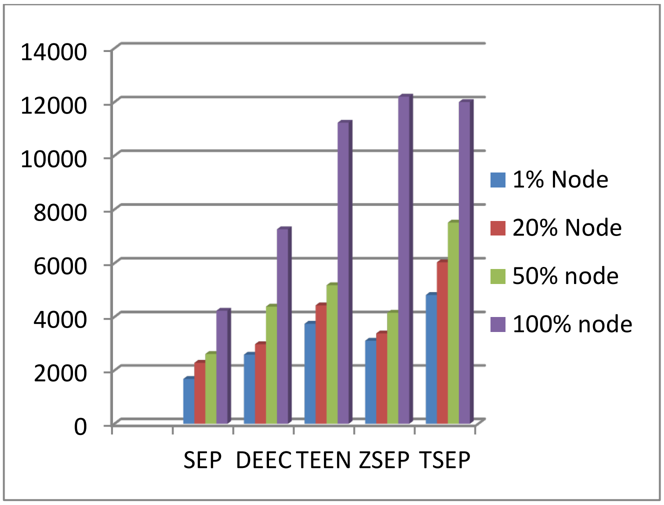


Figure 17. Shows the number of rounds and node dies for 100x100 m sensor field for 1%, 20%, 50%, and 100%.

4. Proposed Model

In this study, we adduce a model of energy to prolong the stability period and QoS for wireless sensor networks. Although we have analyzed many clustering techniques caters unique two tire message delivery process to sink, resulting in less traffic generation in the network as compared to chain based multi-hop routing[5][3]. This paper targets the two main objectives, to analyze and to achieve performance.

Objective-2: Our desired goal is to design an energy efficient routing technique using clustering for WSN.

Primarily aims for energy efficiency, load balancing, network longevity, less energy consumption, PDF-based NDS node Deployment. These standard protocols envisage a high stability period and pinpoint many techniques to reduce energy consumption. Moreover, it was found that there is a sharp thrashing of the sensors node due to the uneven depletion of energy, called energy-hole near the Sink. Additionally, these protocols are also prone to many intruder attacks because these protocols have no security layer inherent by default. In this network, the decision of the sensor nodes to become cluster heads depends upon cost function as discussed in the next session, and the ratio of residual energy and average energy of the nodes aggregates member's data and sends it to the Sink [34].

In this strategy, sensors are deployed randomly and segregation based on Z-SEP[17]. We were even aware of the location of the Sink at the location (50m, 50m) and Sensor field100m X 100m area of size. The probability of selecting C.H. is high in the region with more number of nodes away from to the Sink since transmission energy is directly proportional to the square of the distance[35], hence for transmission required less energy as compared to the node far from the Sink. This technique helps us to improve energy conservation graph and also to result into better network coverage than classical protocols[5][14][24][15][17][3][16][5][5-7]. We assumed that the Sink is not limited to the power source and remains fixed at position X, Y. For the first scenario, later, the same can be performed for different positions of the Sink. In the next section, we discuss classical SEP using soft computing to take full advantage of heterogeneity.

We discuss SEP, an Energy-aware protocol that has increased the network duration until the first node death called stability period in the previous section, crucial for the applications where the feedback from the motes[36]should remain consistent Time duration. Typically required nodes are enabled with more energy than normal nodes, which is an identical scenario of heterogeneous networks[37]. SEP is a weighted selection probability based on some threshold value for a sensor node to be elected as Cluster head. In this paper, we proposed an overview of Heterogeneous models[37]like SEP, consider m percentage of nodes equipped with more energy than the remaining sensors in the network. Sensor nodes have fitted with a two-levels Energy, Advance node and normal node. The node comprises α time normal nodes called an Advance node, and the rest (1-m) × n are normal nodes. Where value m is the fraction of advance level node, and n are normal nodes.

The nodes in the sensor field during simulation in Matlab, assume a parameter ($m = 0.2$, $\alpha = 1$) of 100m×100m sensor field; setting can be computed from equations[1-3] the optimal number of clusters per round, kopt. "^" sign nodes are advanced nodes, and "diamond" are normal nodes in the sensor field, * is the location of the Sink. The NODE choice has been made using random selection since all nodes Hold a similar energy level to become a cluster head with a probability Popt on average (n × Popt) node become Cluster Head per Round. We also checked that Cluster Head in the current round cannot become C.H. in the same epoch, the non-cluster nodes reside to the set G, and to conserve an even number of cluster heads per round, the probability of nodes reside in G to become a cluster head raise after each round in the self-same epoch. Random number less than a threshold[19] T(S) node fit to become a cluster head in the current round [39]. However, r is the current round number. Nodes G are pending set to become cluster heads increases in every round in the self-same epoch were equal to 1 in the last round. Clustering is excellent in the Sense that energy consumption is equally balanced over all sensors, and the total energy consumption is also less.

According to the radio energy dissipation model, with an L bit packet transmitted over a distance d, which is given by equation 26.

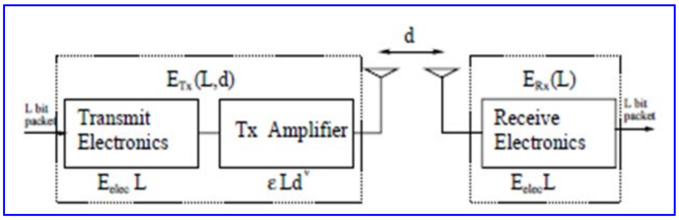


Figure 18. Transmitters and Receiver[40]

$$\boldsymbol{T\,(S)} = \begin{cases} \dfrac{\boldsymbol{p_{opt}}}{\boldsymbol{1-P_{opt}*\left(r\,mod\,\frac{1}{P_{opt}}\right)}} & \boldsymbol{ifs\ \in\ G} \\ \boldsymbol{0} & \boldsymbol{otherwise} \end{cases} \tag{25}$$

E_{TX} (d,L) = L*Eelec + L*ε_{fs}d2, if d< do
E_{TX} (d,L)=L*Eelec + L*ε_{mp}d4, if d≥do (26)

E_{elec} is the energy released per bit to power the Tx or Rx circuit, $\mathcal{E}_{fs}$ and $\mathcal{E}_{mp}$ depend on the transmitter amplifier model

$$\boldsymbol{do} = \sqrt{\frac{\mathcal{E}_{fs}}{\mathcal{E}_{mp}}} \tag{27}$$

equating two expressions at d = d0, we have received an L−bit message the radio expends

$$E_{Rx} = L \cdot Eelec. \tag{28}$$

The energy required during a round is:
K is the total Cluster, EDA is data aggregation[41] cost of a bit per signal,

$$\boldsymbol{E_{CH} = L.E_{elec}\left(\frac{n}{k}-1\right) + L.E_{DA\frac{n}{k}} + L.E_{elec} + L.\mathcal{E}_{fs}d^2_{toBS}} \tag{29}$$

d_{toBS} is the distance between the cluster head and the Sink. The energy used in a non-cluster head node is equal to:

$$\boldsymbol{E_{nonCH} = L.E_{elec} + L.\in_{fs}.d^2_{toCH}} \tag{30}$$

Where d_{toCH} is the distance from cluster member and its cluster head in the Sensor Network.

$$\boldsymbol{d_1toCH^t\,2] = \iint x^t\,2 + y^t 2\ \rho(x.y)dxdy = M^t\,2/(2.\pi.K)} \tag{31}$$

[ρ(x,y)is the node distribution.
In Cluster, total energy dissipated per round can be given by:

$$\mathrm{E_{Cluster}} \approx \mathrm{E_{CH}} + \frac{\mathrm{n}}{\mathrm{K}}\mathrm{E_{nonCH}} \tag{32}$$

In-network total energy dissipated can be computed by

$$\boldsymbol{E_{tot} = L.(2nE_{elec} + nE_{DA} + \in_{fs}(K.d^2_{toBS} + n\frac{M^2}{2\pi k})))} \tag{33}$$

$$\boldsymbol{Kopt} = \sqrt{\frac{n}{2\pi}\frac{M}{d_{toBS}}} = \sqrt{\frac{n}{2\pi}\frac{2}{0.765}} \tag{34}$$

E_{tot} differentiated concerning k and equating to zero; constructed clusters as formed;
The average distance between the Sink and the cluster head is defined in equation 35.

$$\boldsymbol{E[d_{toBS}] = \int_A \sqrt{x^2 + y^2}\,\frac{1}{A}dA = 0.765\frac{M}{2}} \tag{35}$$

The probability of any sensor node to become a C.H., p_{opt}, can be computed as follows

$$\mathbf{Popt} = \frac{\mathbf{K_{opt}}}{\mathbf{n}} \tag{36}$$

We have used and define the following parameters for the performance investigation of the routing protocol in the sensor network first, and we used the Stability Period metrics.

The cost function J_{CC} can use as shown in equation 38 and fitness function (F.F.) to find the optimal Cluster head is based on maximum residual energy and the minimum distance between C.H. and members, as shown below.

$$\mathbf{FF(x)} = \sum_{\mathbf{i=1}}^{\mathbf{x}} \boldsymbol{\alpha}_{\mathbf{i}} \mathbf{f}_{\mathbf{i}} \tag{37}$$

Where $\boldsymbol{\alpha}_i \in [0,1]$ $and\ for\ [i = 1\ to\ Rmax]$

$$f_i \begin{cases} \dfrac{1}{no\ of\ CH}\ x \sum_{i=1}^{no\ of\ CH} \left[\dfrac{\sum_{i=1}^{no\ of\ members} dist(CH, Members)}{no\ of\ members}\right] \\ + \\ \dfrac{E_{residual}}{Total\ Energy\ of\ nodes\ _{range}} \\ + \\ \dfrac{Avg\ Cluster\ Members\ _{cluster}}{Total\ number\ of\ nodes} \end{cases}$$

Table 10. Parameter for Simulation

Parameter	Value
Network Field	100,100
Numbers of Nodes	100
Internal Energy of Normal Nodes	0.6 J
Initial Energy of Advance node	1
Message size	39 K.B.
threshold distance	79
M	0.2
a	0.5-1.0
M	% of advance node
cost function J(i, j,k,l)	0.02
p	2
s	10
Nc	10
Ns	4
Sr	s/2
J_{last}	J(i, j,k,l)
N_{re} Reproduction number	4
N_{ed}	2
P_{ed}	0.25
Operation	Energy Dissipation
Tx/Rx electronics	E_{elec}=50nJ/bit
Data Aggregation	E_{DA}=5nJ/bit/Signal

It is the interval when the network executes its operation until the death of the first sensor node and calculated in terms of Round higher the number of counts higher the stability period of the system, referred to as stable region or steady-state. In contrast, we can define instability in the sensor filed as the time taken by all the nodes to remain in the sensor filed until all nodes are dead in the network. It also is defined as an unstable region. The Next significant metrics used for comparing the routing protocol is the Network lifetime. Network_life_time = Stability_Period + Instability_Period.

This measure shows the total number of nodes (advanced, normal) alive, i.e., the nodes having energy greater than zero, and lastly, throughput. It is the total actual data sent over the

Table 11. Comparison of popular routing protocol

ROUTING Protocol	LEACH	PEGASIS	SEP	DEEC	MGEAR	Z-SEP	EE-SPEED	E- DEEC	T-SEP
Criteria for cluster head	selects cluster heads periodically and drains energy uniformly	Logical chain-forming	electing cluster heads in a distributed fashion	Probability ratio between residual and average energy of each node.	C.H.s are selected based on a probability	Zone base cluster formation for advance node and Direct Communication for normal nodes	Node with maximum Residual energy using weigh function: Delay, Energy, and speed.	C.H.'s are selected based on the ratio between residual energy and average energy of the node	C.H. selection is done as traditional Sep and also based on the Threshold level.
Energy Level of the nodes	Single –level	Single –level	2- Level	2- level	Single –level	2- level	Single Level	3- level	3 level
Network Type	Homogeneous	Homogeneous	Heterogeneous	Heterogeneous	Homogeneous	Heterogeneous	Homogeneous	Heterogeneous	Heterogeneous
Data-Centric	no	no	yes	yes	yes	yes	Location-based	no	no
Hierarchical	yes	yes	yes	no	Semi	yes	yes	yes	yes
Location-Based	no	no	no	no	yes	no	yes	no	no
Query-based	no	no	no	no	no	no	yes	no	no
Data Aggregation	yes	yes	yes	yes	no	yes	no	yes	yes
Power usages	high	max	medium	medium	limited	medium	high	medium	medium
Scalability	medium	low	medium	medium	limited	medium	limited	high	medium
QoS	no	no	no	no	no	yes	yes	yes	no
Security	no	no	no	no	no	no	no	no	no

Network from nodes to their Cluster-Heads and also from Cluster Heads to the base station. One by one, all the above metrics are evaluated. We have discussed the different energy levels of heterogeneity and mimic BFO[42] algorithms. In this paper[43]author estimates the harmonic components. We also compare the performance of these protocols by changing the base station position and find that the B-ZSEP shows a higher performance when the Sink is located at the center of the network or located in corners. The parameters used in the simulations have been mentioned in Table 10 [Parameters for the simulation]; we have modified some values of the parameters in this paper and find the results accordingly because parameter plays a significant role in the performance of the Wireless Sensor Network. The first parameter used in the table is the size of the sensor field, i.e., 100x100 m; the second parameter in this sequence is the number of nodes which is according to the need of application or user-dependent if we want to sense the large area number of Sensor Nodes also increase, we keep the initial energy of the Normal node to 0.6 J and size of Packet in the network is 3500. Whereas E_{elec}, E_{amps}, E_{fs}, E_{DA} remains the same and do set to 79 m in When we consider this parameter for the evaluation of the performance of the network, we find that the network supported for a more extended period, which is a crucial factor for the time-critical application in WSN. In this paper, we have reported the performance of WSN at different levels of heterogeneity (three-Level) called B-SEP routing Protocol in comparison with B-ESEP, B-ZSEP, B-TSEP where B is the BFO algorithm used in the extension of SEP as demonstrated[3],

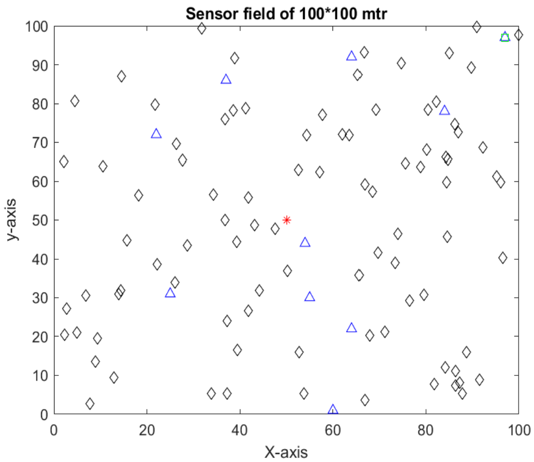


Figure 19. Sensor Field for Simulation

The BFO calculated in the following way: First, sum the distance squares from each node to the C.H. for one Cluster. Then this value for all the clusters should be summed over:
For Case I (a=0.5 and m =0.1), SEP is based on weighted election probabilities of each node to become a cluster head

According to the remaining energy in each node; Comparison between types of SEP using BFO:
(a) Nodes dead per round.
(b) Total data packets transmitted to C.H. over rounds.
(c) Total data packets sent to B.S. over rounds.
(d) The total number of the existing node.

Figure 22-23 shows a comparison of the routing protocol. Here we can easily find that the performance of routing protocols increases when we have applied Bacteria foraging optimization[44].

The cost function:

$$J(i, j,k,l) = J(i, j+1,k,l) + Jcc(\theta i(j+1,k,l)P(j+1,k,l)$$

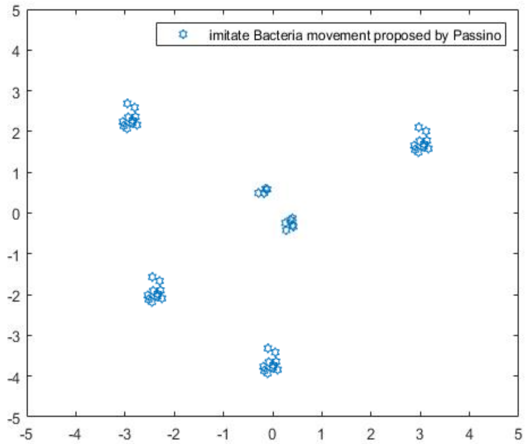


Figure 20. Bacteria Movement in search of higher energy and less distance from Sink in a sensor field of 100x100 m

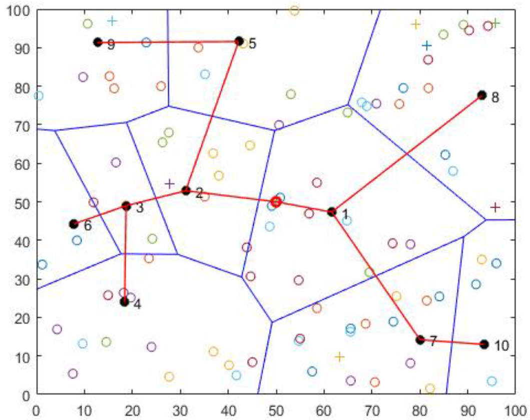


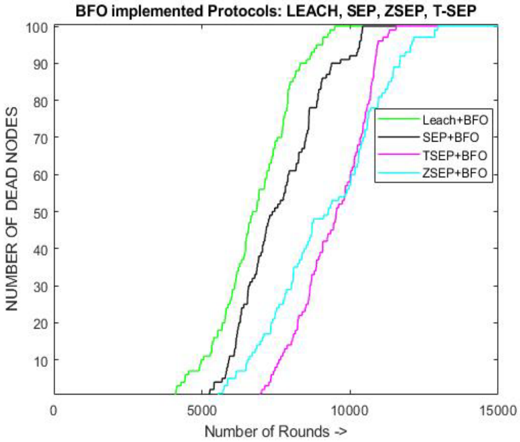
Figure 21. Intercluster chain routing

We performed the comparison of B-SEP, B-ZSEP, B-ZSEP, and B-TSEP based on the Number of Dead nodes, Total Number of Packets sends to the Cluster Head, and Total Number of Packets Send to the Base Station. We observed that the BFO technique[45] applied to original SEP or other hierarchy routing protocols.

Table 11. Comparison of Proposed Protocols for Number of Dead Node Per Round

ROUTING PROTOCOL	1% Node	20% Node	50% node	100% node
B-SEP	4137	4743	6391	9462
B-ESEP	4901	5569	7725	11467
B-ZSEP	5818	7051	8997	12940
B-TSEP	6141	6632	8110	10341

Subsequently improves the performance of the network in terms of Stability, Packet transfer to Base Station, and Cluster Head. E-SEP performs best for time-dependent applications in a heterogeneous environment; it increases the stability period and network lifetime of the network[46]. Figure 22 indicates the significant improvement in the numbers of data packets received at the base station and cluster Head in Case of B-ESEP over B-SEP. Results showcase



that 11% more data packets were sent to the B.S. and the C.H.'s in Case of BTSEP over B-SEP. Figure 22. shows the number of rounds and node dies for 100x100 m sensor field for 1%, 20%, 50%, and 100%.

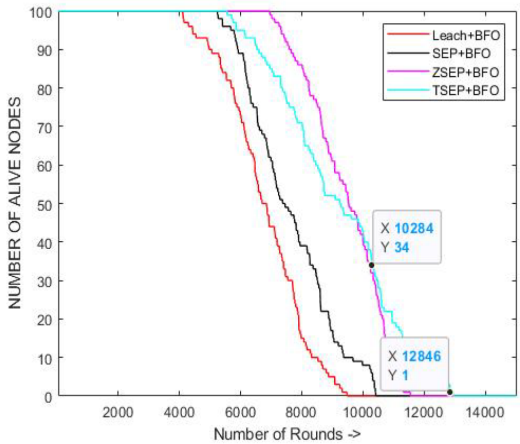


Figure 23. Performance result for 100x100 m network with initial energy .5 Joules/(node)

5. Conclusion

In this paper, we have analyzed and compared hierarchal routing protocols as our objective-1 discussed in section 3. In section IV, we have proposed nature-inspired algorithms to these routing techniques. The simulation result of TSEP and ESEP Protocols with conventional routing protocol portrayed better performance. On the other side, demography exhibits that the performance of bacteria foraging optimization techniques on Leach, Hybrid (Leach & Pegasus), SEP (Stable Election Protocol), and Enhance-SEP routing protocol prolongs the network stability period in current clustering protocols used in this paper. We have examined that the stability period of original SEP is almost around 1100 rounds when the first node is dead and the last node dead after 2400 rounds, while for B-SEP, it is after 1149 rounds and the last node dead after 2573 rounds. Similar for B-ESEP, it is 1383, and the last node remains till 2891 rounds, as shown in Table 11[COMPARISON OF NUMBER OF DEAD NODE PER ROUND]. By this means, we have improved the stability of up to 5 and 15%, respectively. We must understand the cost metrics for the sensor deployed in the field, so, to maintain the cost in our network, we don't undergo a higher value of m and a perhaps fruitful for many WSNs applications[9].

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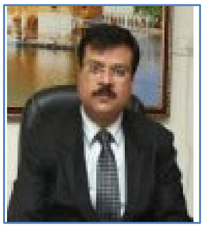

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