TRANSMISSION EFFICIENT PROTOCOL USING POPULATION-BASED META-HEURISTIC TECHNIQUE WITH MOBILE SINK FOR LIFETIME ENHANCEMENT OF HETEROGENEOUS WIRELESS SENSOR NETWORKS

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ABSTRACT

Wireless sensor Networks are small sized devices which work on the small batteries which cannot be recharged again, due to this optimization of battery resources are the most important design criteria for wireless sensor networks A hybrid algorithm incorporating social insect colony and double cluster head approach, with improved Mobile Balanced Energy Efficient Network Integrated is proposed to improve the intra and inter cluster organization of the existing four level heterogeneous wireless sensor networks. The social insect colony algorithm reduces the energy loss due to long distance transmission within the cluster by introducing layered multi hop transmission. The double cluster head approach helps in load balancing. The burden of the cluster head is shared by the vice cluster head which will reduce the energy loss in cluster heads due to long distance transmissions. The proposed algorithm increases the life time, throughput and stability of the network by reducing the energy losses due to long distance transmissions.

Keywords: *Mobile Sin, Heterogeneous, Social Insect Colony Clustering, Routing, Energy Efficient, BEENISH, Ibeenish, Imbeenish*

1. INTRODUCTION

Wireless sensor network is a collection of nodes powered by a limited battery supply. These nodes are used for sensing data in places, remote and inaccessible by humans. These nodes form a network and transfer the sensed data to the base station by co-ordinating with each other. These nodes are independent and can survive without any centralised coordination in most scenarios. These nodes undergo energy losses due to various factors such as energy spent on sensing, processing, transmission and reception of data [1] [2]. Since these nodes' batteries cannot be recharged, it is important to conserve their energy and extend their lifetime. The sensor nodes also should coordinate with each other so that they can route data efficiently and also reduce the redundancy in data transferred by aggregating similar data from nearby nodes. The standard communication and routing algorithms fail to work efficiently with the wireless sensor networks as they are independent, de-centralized and do not have sophisticated hardware and framework support to incorporate the conventional algorithms. Though they are similar to MANETs, WSNs have strict energy constraint [3][4][5]which is not in the case of MANET as its mobile devices are rechargeable. This led to the development of algorithms unique for wireless sensor networks. These algorithms are designed to reduce the energy consumption by establishing protocols for sensing, aggregation, transmission and routing of data. Several of these algorithms are discussed in the next section. The Objectivity of the proposed work is to enhance the lifetime of heterogeneous wireless sensor network by optimising the battery usage of the nodes with the implementation of the hybrid proposed work in the network.

2. LITERATURE REVIEW

One of the first fully featured clustering and routing algorithm for wireless sensor networks was 'Low energy adaptive cluster hierarchy' (LEACH) [6]. LEACH overcame the drawbacks of direct transmission and multi hop routing by introducing clustering of nodes. This established a better path for data transfer from node to base station via the cluster head. Clustering also helped in reducing the

redundancy of data transferred by aggregating the data of nodes within the cluster, at the cluster head. The absence of redundancy had helped in the conservation of node energy as the no of packets to be transferred is less, thereby extending the lifetime of the network. Though many clustering algorithm existed before LEACH, the dynamic selection of cluster head based on probability and dynamic cluster formation made LEACH popular. The leach used random unique IDs and a probabilistic method to elect cluster heads which prevented the nodes from a single location being selected as cluster head, thereby making the network stable. The LEACH had its fair share of disadvantages. The algorithm did not consider heterogeneity among nodes. It assumed that all nodes are of equal energy. But, this is not always true as few nodes might be deployed with higher energy and/or at later stage of the network to extend the network lifetime. The 'stable election protocol' [7] (SEP) overcame the drawbacks of LEACH by introducing a 2 level heterogeneity. It categorized nodes into normal and advanced nodes based on the initial energy of the nodes.

It had similar cluster head selection and clustering approach as that of LEACH except for that the different types of nodes had different election probability. The advanced nodes had more probability of getting selected as cluster heads and also were more frequently selected when compared to the normal nodes. This was done to prevent the normal nodes from getting elected as cluster heads frequently and dying out while the advanced nodes lived longer. The network stability was prioritized over the life of individual nodes. The SEP performed better than the LEACH in heterogeneous scenario. The 'threshold sensitive stable election protocol' [8] (TSEP) is improvised over the SEP. TSEP considers 3 level of heterogeneity – normal, intermediate and advanced nodes. The advanced nodes have the highest election probability as cluster head, followed by intermediate nodes. The normal nodes have the least probability to be elected as cluster heads and were least frequently selected as the cluster heads.

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The BEENISH [9] Balanced Energy Efficient Network Integrated Super Heterogeneous Protocol is a 4 level heterogeneous protocol. The nodes are categorized into normal, advanced, super and ultra-super nodes. The protocol considers the type of heterogeneity and also the residual energy of the node for the election of cluster heads. The BEENISH protocol performs better than the previous protocols in terms of network lifetime and throughput. The major drawback of this protocol is that the probability of the selection of super or ultra-super nodes is the same even after they lose most of their energy and are less energetic than the normal nodes, which leads to quicker death of high energy nodes. The iBEENISH [10] improved Balanced Energy Efficient Network Integrated Super Heterogeneous protocol is an improvisation over the BEENISH protocol. It has the same 4 level heterogeneity as that of the BEENISH protocol and also considers type of heterogeneity and the residual energy for cluster head election just like BEEENISH. The iBEENISH is different from BEENISH in the fact that the probability of election as cluster head for high energy nodes is reduced once their energy becomes less than a pre-defined fraction of energy of normal nodes. This prevents the low energy nodes from being frequently elected as cluster heads.   The iBEENISH has more network lifetime and throughput than the BEENISH protocol. The Sink mobility aware energy-efficient network integrated

super heterogeneous protocol [11] introduces a mobile sink approach in the existing BEENISH and iBEENISH protocols leading to mobile BEENISH and improved mobile BEENISH. The MBEENISH and iMBEENISH protocols have similar methods for cluster head election, cluster formation and data transmission methods as their counter parts BEENISH and iBEENISH with only difference being the additional mobile sink. The protocols find low energy cluster heads and fix their coordinates as sink locations. For each round the mobile sink visits these sink locations and collect the data from these cluster heads. The cluster heads whose locations are not sink locations transmit their data to the nearest sink location when the mobile sink visits that location. After the collection of data the sink returns to its original location. The MBEENISH and the iMBEENISH protocols have drastically increased network lifetime and throughput when compared with the BEENISH and iBEENISH protocols.

The social insect colony [12] is a meta-heuristic protocol inspired from the organizational behaviour of social insects like bees and ants [13][14]. The nodes are given a unique ID. The nodes make a random back off based on their unique ID and residual energy. A node after its back off time announces itself as cluster head and the nodes within a pre-determined range become their cluster member and turn off their clocks. If a node is not a member after its back off time it again announces itself as cluster head and the nodes within the pre-determined range become the cluster members. This continues until all nodes are part of a cluster. The clusters are then divided into concentric layers and each node is given a layer number based on the layer to which it belongs. The nodes in the outer layer find a parent in the inner layer. The parent in the inner layer receives data from all its children, aggregates them along with its own data and sends to its parent. This continues till the data reaches the cluster head in layer zero which transmit the data to the base station.

In paper [15], double clustering approach for load balancing is discussed. This paper proposes the election of a vice cluster head after the cluster formation. This is done so that the burden of the main cluster head is reduced. Conventionally the main cluster head is over burdened with data reception, aggregation and transmission to base station. In the double cluster head approach the load is balanced between the main and the vice cluster head as the main cluster head receives and aggregates the data, while the vice cluster head does the long distance transmission to the base station. The vice cluster head is decided among the nodes, based on a cost function which takes into consideration, the distance of the node from the cluster head and also the residual energy of the node. The node with the highest cost value is chosen as the vice cluster head. The cluster head thus selected receives the aggregated data from the main cluster head and transmits to the base station[16]

3. FIRST ORDER RADIO DISSIPATION MODEL

The first order radio model as discussed in [1] gives the standard for energy dissipation due to various losses which is given in figure 1 below:
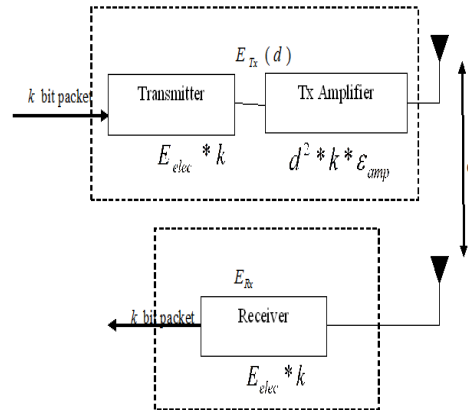

Figure 1: The First Order Radio Model.

The energy spent in data transmission is given by equation (1):

$$E_{tx} = \begin{cases} E_{elec} * L + E_{fs} * L * d^2 & when\ d < d_0 \\ E_{elec} * L + E_{amp} * L * d^4 & when\ d \geq d_0 \end{cases} \quad (1)$$

The energy spent in data reception is given by equation (2):

$$E_{rx} = E_{elec} * L + E_{da} * L \quad (2)$$

The L is the number of bits per packet, the d is the distance of propagation of the transmitted signal and d_0 is the threshold distance. The various energy dissipation parameters and their costs are given in table I below:

TABLE I. Energy Cost Parameters

Parameter	Value
E_0 (initial energy)	0.5 J
L (Message size)	4000 bits
E_{elec} (energy for Tx and Rx)	50 nJ/bit
E_{fs}	10 pJ/bit/m2

E_{amp}	0.0013 pJ/bit/m4
E_{DA} (aggregation cost)	5 nJ/bit/signal
d_0 (threshold distance)	70 m

4. FOUR LEVEL HETEROGENEITY MODEL

In the four level heterogeneity model the nodes are divided into ultra-super, super, advanced and normal nodes based on their initial energy [17]. The energy of ultra-super, super and advanced nodes are increased by a factor of u, b, a respectively. If E0 is the initial energy of a normal node, the initial energy of advanced nodes is given by E0*(1+a), the initial energy of super nodes is given by E0*(1+b) and the initial energy of ultra-super nodes is given by E0*(1+u). The ratio of number of advanced nodes to total number of nodes is m, the ratio of number of super to advanced nodes is m0 and the ratio of number of ultra-super nodes to super nodes is m1.[18][19]

5. PROPOSED ALGORITHM

The proposed algorithm incorporates the social insect colony algorithm in the iMBEENISH to improvise the intra-cluster organization. The proposed algorithm also incorporates the double cluster head approach to reduce the over-burdening of the cluster head by balancing the load between main and the vice cluster head. The algorithm begins with the deployment of node in the field and assignment of unique ID. The nodes are divided into 4 types: ultra-super, super, advanced and normal based on their initial energy. After deployment, the protocol begins with the calculation of the average energy of the network which is given by equation (3).

$$\overline{E}(r) = \frac{1}{N}E_{total}\left(1 - \frac{r}{R}\right) \qquad (3)$$

Where N is the number of nodes in the network, E_{total} is the total energy of the network, r is the current round number and R is the optimal number of rounds. The optimal number of rounds is given by equation (4).

$$R = \frac{E_{total}}{E_{round}} \qquad (4)$$

Where E_{round} is the total energy consumed during one round and is given by equation (5).

$$E_{round} = L(2NE_{elec} + NE_{DA} + k\varepsilon_{mp}d_{toBS}^4 + N\varepsilon_{fs}d_{toCH}^2)$$
.
$\qquad (5)$

L is the number of bits per message, d_{toBS} is the optimal distance from a cluster head to base station, d_{toCH} is the optimal distance from a node to a cluster head and k is the optimal number of cluster head which is given by (6) & (7).

$$d_{toBS} = 0.765\frac{M}{2}$$
$$d_{toCH} = \frac{M}{\sqrt{2\pi k}} \qquad (6)$$

$$k = \frac{\sqrt{n}}{\sqrt{2\pi}}\sqrt{\frac{E_{fs}}{E_{amp}}}\frac{M}{d_{toBS}^2} \qquad (7)$$

M is the dimension of the sensor field.

Once the optimum values are calculated, the probability P_i of each node to be elected as cluster head is given by equation (8).

$$p_i = \begin{cases} \dfrac{p_{opt}E_i(r)}{(1+m(a+m_0(-a+b+m_1(-b+u))))\overline{E}(r)} \\ \dfrac{p_{opt}(1+a)E_i(r)}{(1+m(a+m_0(-a+b+m_1(-b+u))))\overline{E}(r)} \\ \dfrac{p_{opt}(1+b)E_i(r)}{(1+m(a+m_0(-a+b+m_1(-b+u))))\overline{E}(r)} \quad -- \\ \dfrac{p_{opt}(1+u)E_i(r)}{(1+m(a+m_0(-a+b+m_1(-b+u))))\overline{E}(r)} \\ \dfrac{c\times(1+u)p_{opt}E_i(r)}{(1+m(a+m_0(-a+b+m_1(-b+u))))\overline{E}(r)} \end{cases}$$
$\qquad (8)$

The first four probability equations are of the normal, advanced, super and ultra-super nodes respectively. The fifth equation is for the high energy nodes whose energy has fallen below threshold energy $T_{absolute}$. $T_{absolute} = Z*E_0$ and $E_0 = 0.71$.

After the probability calculation, the threshold T_i is calculated as given by equation (9) below:

$$T(s_i) = \begin{cases} \dfrac{p_i}{1-p_i\left(r.\bmod\dfrac{1}{p_i}\right)} & s_i \in G \\ 0 \end{cases} \qquad (9)$$

If the unique ID of the node is less than the threshold, then the node is elected as CH. Once

CHs are elected, the other nodes become the cluster member of the closest CH. The clusters formed are divided into concentric layers.

The layer radii are given by equation (10) & (11).

$$b_k = \begin{cases} 0 & k \leq 0 \\ \bar{b}_{k-1} + r_{com} \end{cases} \qquad (10)$$

Otherwise

$$\bar{b}_{k-1} = \sqrt{\frac{b_{k-1}^2 + b_{k-2}^2}{2}} \qquad (11)$$

Where b_k is the radius of the kth layer. r_{com} is the radius of communication, which is chosen initially. After dividing the cluster into concentric layers, each node is given a layer number LN based on the layer to which it belongs. The cluster head is in the inner most layer with the layer number zero. The nodes in the outer layer select a parent in the inner layer by transmitting an LCP for a range of r_{com}. If no parents are found in that region, the radius of communication is increased and LCP is again sent. Once a parent in the inner layer accepts the LCP it transmits an acknowledgement. Thus a parent-child link is established. The nodes transmit their sensed data to their parent. The parent aggregates data from all its children with its own data and transmit to its parent. This continues until all the packets reach the cluster head.
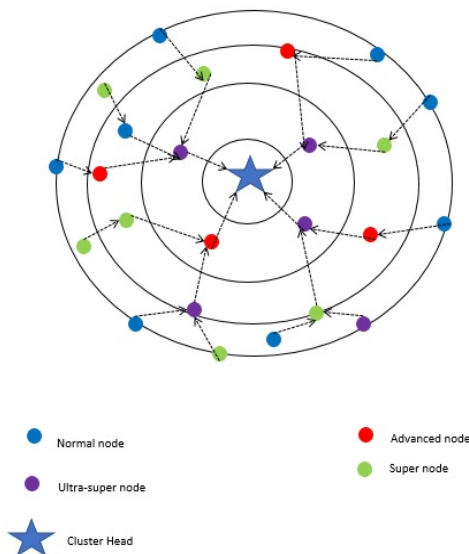
Figure 2. Intra-Cluster Organization

Figure 2 depicts the intra cluster organization of nodes pictorially, where the data is transmitted from child to parent until it reaches CH.

The 5 cluster heads with least energy are chosen as sink locations. The mobile sink visits these locations and receives the data from the cluster heads. The cluster heads whose coordinates are not sink locations elect a vice cluster head. This helps in load balancing as the vice cluster head reduces the burden of main cluster head by doing the long distance transmission. The vice cluster head is elected from the cluster members based on the cost function given by equation (12) below:

$$Cost = \varepsilon \left(\frac{res\_energy}{max\_res\_energy} \right) + (1-\varepsilon) \left(1 - \frac{dist}{max\_dist} \right) \qquad (12)$$

Where 'res_energy' is the residual energy of node under consideration, max_res_energy is the residual energy of the node with maximum energy, dist is the distance from the node to cluster head, max_dist is the distance from the farthest node in cluster to the cluster head and ε is the weightage parameter, which can be modified. The node with the highest cost will be elected as the vice cluster head. The vice cluster head receives the data from main cluster head and transmits to the mobile sink when it arrives at the nearest sink location [20][21][22].
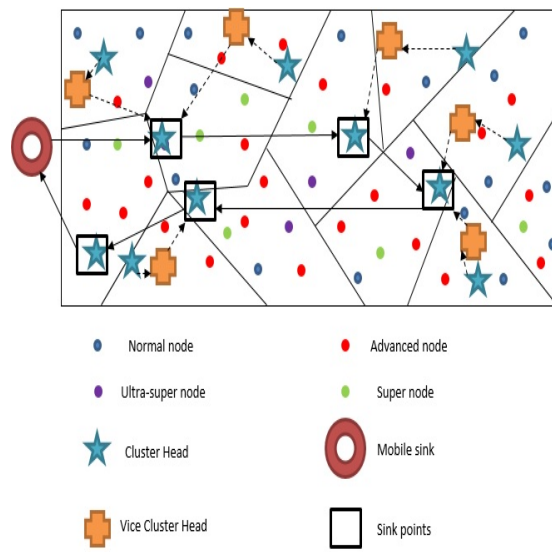

Normal node   Advanced node
Ultra-super node   Super node
Cluster Head   Mobile sink
Vice Cluster Head   Sink points

Figure.3. Network Topology

Normal node   Advanced node
Super node
Ultra-super node
Cluster Head

Figure 3 shows the path of the mobile sink. The sink visits the nearest unvisited sink location. Once it receives data from that location, it visits the next nearest unvisited location. [23] This repeats until all the sink locations are visited. The mobile sink then reaches its original location. Figure 3 also shows vice cluster heads elected in cluster whose cluster heads are not in sink location. The vice cluster head transmits to sink when it arrives at nearest sink location. Once the sink returns to its original location the next round starts with the election of CHs. This continues until the last node is dead [24].

6. SIMULATION RESULTS.

The algorithm was designed in matlab 2013a and was simulated for scenarios 100x100 m^2 area with 100 nodes and 200x200 m^2 area with 200 nodes. For the simulations we consider the energy factors a=2, b=2.5 and u=3. The ratios of node heterogeneity are m=0.6, m0= 0.5 and m1 =0.3. The radius of communication r_{com} is 1.5m and the weightage parameter ε is chosen as 0.5.

The graphs in figure 4 and figure 5 shows the number of alive nodes vs. round number plot for 100x100 with 100 nodes and 200x200 with 200nodes.

The graphs show that the proposed algorithm out performs the existing algorithms in terms of first node death, second stability period and last node death in both the scenarios. The results from the graph are summarised in the table II below.
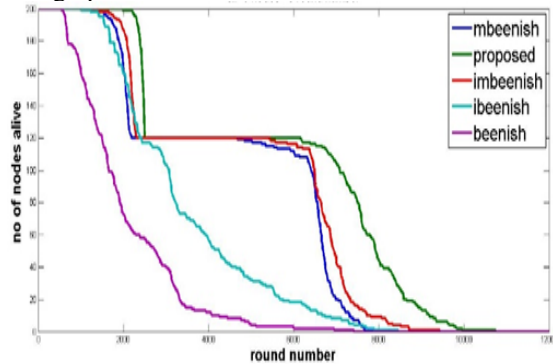

Figure.4.Alive Nodes vs. Round Number for 100x100 With 100 Nodes

TABLE II.   Stability Periods (Number Of Rounds) Of Protocol

Protocol	100 X 100 with 100 nodes Stability periods		200 X 200 with 200 nodes Stability periods	
	First	Second	First	Second
BEENISH	700	NIL	542	NIL
iBEENISH	1175	NIL	997	NIL
MBEENISH	1915	4230	1331	2487
iMBEENISH	2069	4431	1344	3112
PROPOSED	2129	4562	1980	3655

It can be observed from the table that the proposed algorithm has the highest first and second stability period in both scenarios. The following two bar graphs show the throughput of the algorithms for both scenarios.
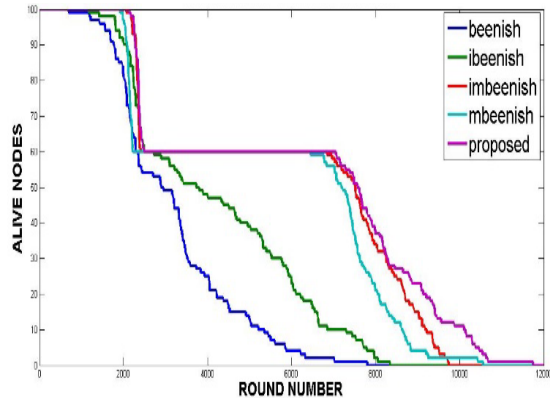

Figure.5. Alive nodes vs. Round Number For 200x200 With 200 Nodes
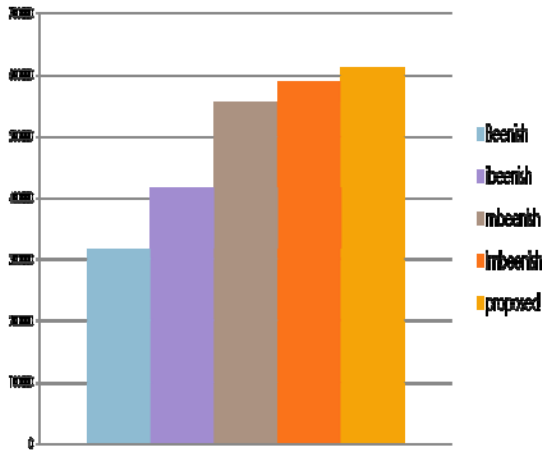
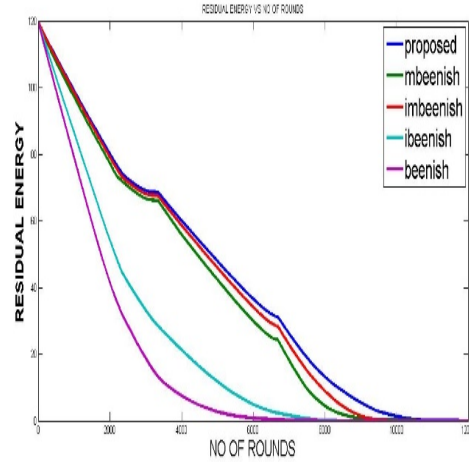*Figure 6. Throughput (packets to BS) Of Algorithms For 100x100 With 100 Node*

Figure 7. Throughput (Packets To BS) Of Algorithms For 200x200 With 200 Nodes

The figure 6 and figure 7 show that the proposed algorithm has the highest throughput in both scenarios. The table III below summarizes the two figures.

The proposed algorithm outperforms the existing algorithm in terms of throughput for both scenarios. Figures 8 and 9 show the residual energy of networks after each round for 100X100 with 100 nodes and 200X200 with 200 nodes scenario respectively.
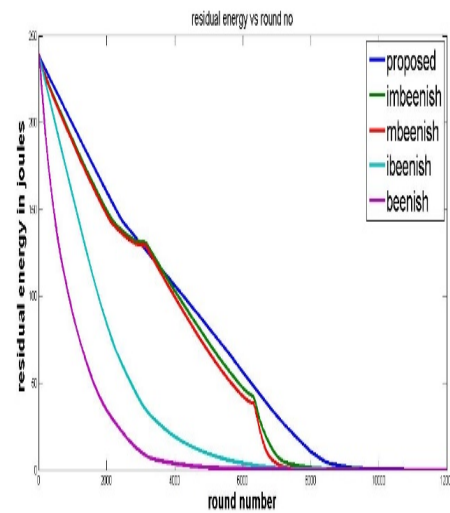

Figure 8 .Residual Energy vs. No Of Rounds For 100X100 With 100 Nodes Scenario

TABLE IV. Throughput Of Algorithms For Both Scenarios

Protocol	100 X 100 with 100 nodes	200 X 200 with 200 nodes
BEENISH	316051	397547
iBEENISH	417501	671486
MBEENISH	556389	954763
iMBEENISH	589620	1000759
PROPOSED	612896	1140014

Figure 9. Residual Energy vs No Of Rounds For 200X200 with 200 Nodes Scenario

It can be observed from figure 8 and 9 that the proposed algorithm has highest residual energy for a given round always in case of 100 X 100 with 100 nodes scenario and for 94.16% of the network lifetime for the 200X 200 with 200 nodes scenario.
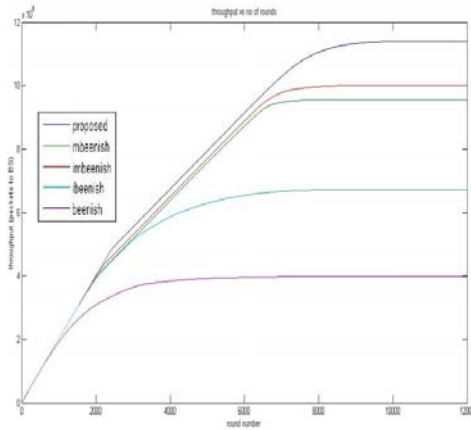
Throughput of the Network

Figure 10. Throughput vs. Number Of Rounds For Area 100×100 m2 With 100 Nodes
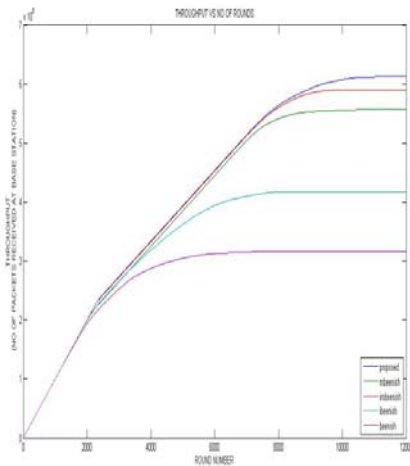

Figure 11. Throughput vs. Number Of Rounds For Area 100×100 m2 With 100 Nodes.
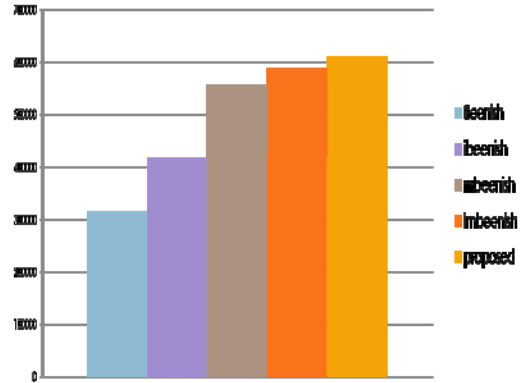

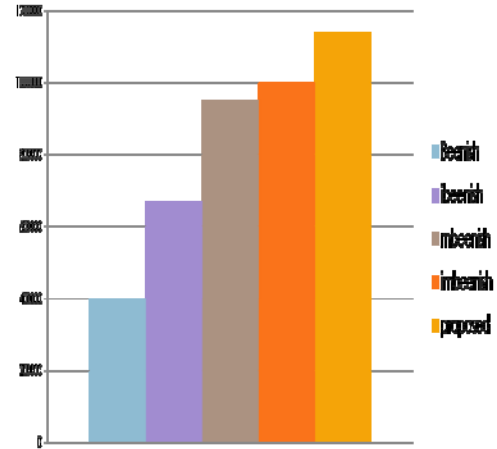*Figure 12. Throughput vs. Number of Rounds for Area 200×200 m2 With 200 Nodes*

Figure 13. Throughput vs. Number Of Rounds For Area 200×200 m2 With 200 Nodes

Table IV. Throughput After 12000 Rounds.

Protocol	100x100 with 100 nodes	200x200 with 200 nodes
BEENISH	316051	397547
iBEENISH	417501	671486
MBEENISH	556389	954763
iMBEENISH	589620	1000759
PROPOSED	612896	1140014

Form figure10, figure11, figure12, figure13 and Table IV it can be observed that the proposed algorithm has 10.1 % more throughput when compared to MBEENISH [11] and 3.9% more throughput when compared to iMBEENISH [11] in 100 x 100 with 100 nodes scenario.

The proposed algorithm has 19.4 % more throughput when compared to MBEENISH [11] and 13.9% more throughput when compared to iMBEENISH [11] in 200 x 200 with 200 nodes scenario.

The analysis of throughput of the network for these different areas shows that the proposed algorithm performs best among all the other protocols. Increasing the area of region decreases the rate of residual energy dissipation in the proposed algorithm while in the previous protocols, the rate of residual energy dissipation increases with increase in area

7. CONCLUSION

The proposed algorithm overcomes the drawbacks of the existing algorithms by incorporating social insect colony algorithm and double cluster head approach for intra cluster organization and load balancing respectively.   The proposed algorithm has 11.1 % more primary stability period when compared with MBEENISH and 2.8 % more primary stability period when compared with iMBEENISH. The proposed algorithm has 7.8 % more secondary stability period when compared with MBEENISH and 2.9 % more secondary stability period when compared with iMBEENISH. The analysis of the network lifetime for the two different scenarios show that the proposed algorithm has higher primary and secondary stability periods than BEENISH [4], iBEENISH [5], MBEENISH and iMBEENISH [6] protocols.

The proposed algorithm has 10.1 % more throughput when compared to MBEENISH [6] and 3.9% more throughput when compared to iMBEENISH [6] in 100 x 100 with 100 nodes scenario. The proposed algorithm has 19.4 % more throughput when compared to MBEENISH [6] and 13.9% more throughput when compared to iMBEENISH [6] in 200 x 200.with 200 nodes scenario. The analysis of throughput of the network for these different areas shows that the proposed algorithm performs best among all the other protocols

From these comparisons it can be concluded that the proposed algorithm is better than the existing algorithm in terms of network lifetime, stability and throughput. Future scope of this work could be more hybrid metaheuristic techniques and higher heterogeneity in the sensor network.

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