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HBO based Optimized Sink Mobility in Heterogeneous Wireless Sensor Network

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Abstract:
Wireless sensors are used extensively for numerous applications ranging from civilian, military, habitat, health and different monitoring applications to take required actions to avoid any heavy damage to the humanity. The sensor employed in these applications connect with each other to form a network termed as Wireless Sensor Network (WSN). Due to the limited battery resources of sensor nodes, it becomes a hardcore requirement to conserve the battery to operate the network for longer duration. Sink mobility in the network helps to reduce the energy consumption of nodes that are involved in communication. In this paper, HBO (Honey Bee Optimization) based optimized sink mobility is introduced that helps in data collection from the network in a way that network lifetime is enhanced significantly. The proposed work is done in heterogeneous WSN in three steps; firstly, the Cluster Head (CH) selection is done based on energy and inter-cluster distance; secondly, the sink is moved by determining the optimized location of energy enriched CH. Lastly, the CHs where sink has not moved, transmit data to the sink in multi hop fashion. Simulation show that the proposed technique enhances the network performance in terms of network lifetime and stability period as compared to the state-of-art techniques; EECS, iMBEENISH, BEENISH etc.

Keywords: Wireless Sensor Network, Honey Bee Optimization, Sink mobility, clustering, CH selection

I. INTRODUCTION

Recent years have brought tremendously growing technology in the form of Wireless Sensor Network (WSN). It generally consists of various nodes that are connected with each other wirelessly and transmit data to the sink [1].
Sinks are considered resource-rich, i.e., energy, processing power and memory are not considered a limitation for their prolonged functioning and operations. Sensor nodes are instead usually quite constrained in terms of battery power, storage, and computational capabilities.

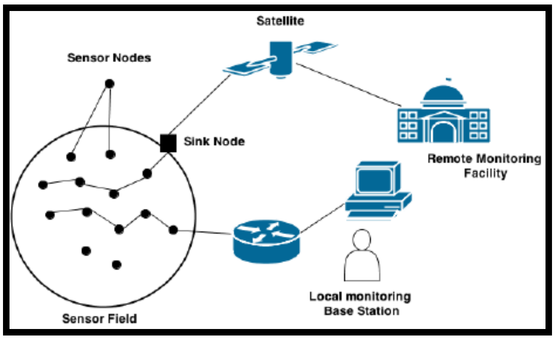

Fig. 1 Architecture of WSN [1]

The architecture of WSN is shown in Fig.1. The sensor nodes deployed in the remote areas are forwarding data to the sink and then it is sent to the remote station for any rescue operations.
WSN consists of various sensors such as temperature, infrared, magnetic, vibrational sensors. These sensor nodes can find their utilization in many applications. Basically these applications can be classified into two main categories [3].

a. Tracking: Different individuals including animals or any objects can be tracked they categorize the particular applications into different sectors of human life.
b. Continuous Monitoring: In this, the applications include health care monitoring, environmental monitoring that may focus on temperature, humidity, flood detection and seismic and structural monitoring etc.

Routing is very essential for the battery preservation of sensor nodes. If the network is to be made energy efficient data aggregation, nodes are partitioned into a number of groups which are called as clusters.

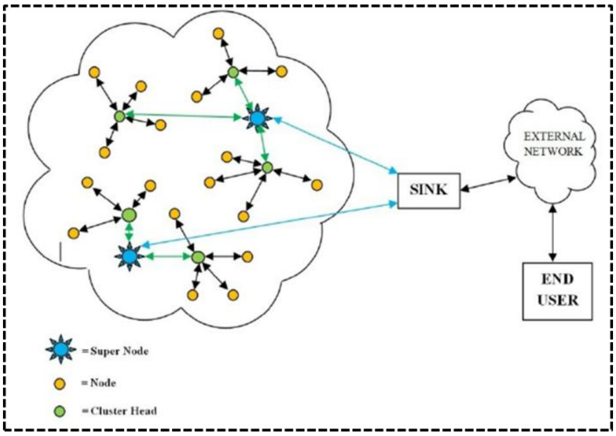

Fig. 2 Clustering in WSN

CH supervises the data collection along with data aggregation. As shown in Fig. 2, it then forwards the collected data to the Base Station. This clustering scheme leads to the enhancement of the life time of network by avoiding unbalancing of energy load in the whole network.
The organization of the remaining work is as follows. Section II represents the related work and section III represents the problem definition. Section IV introduces the Honey Bee Optimization and thereafter discusses the results and simulation. Thereafter, conclusion is presented. Then references are listed.

II. RELATED WORK

A plethora of research has worked toward saving the energy of nodes. Heterogeneous WSN has outperformed homogeneous WSN due to its load-balanced nature. It is to be noted that homogeneity in sensor network does not exist ideally. So, introduction of heterogeneity in the network not only enhances stability but also improves the network performance tremendously. The first heterogeneous protocol was SEP that gave the concept of two level energy nodes; normal and advanced. It could not be applied for multi-level due to which it failed. Then there was observed improvement in DEEC [3] which introduced the factor of energy ratio i.e. ratio of residual energy and average energy of the nodes. However, it made the advanced nodes suffering from penalized effect as it kept on making advanced nodes as Cluster Heads more frequently irrespective of their energy stock. DDEEC [4] worked in improving the DEEC protocol by declaring a threshold value, which decides the criteria of selection of Cluster Heads by treating all nodes equally. However, this algorithm worked only for two levels of heterogeneity. After the development of two levels routing protocols, EEHC [5] introduced three levels of heterogeneity comprising of normal nodes, advanced nodes and super nodes. The performance evaluation of EEHC has shown the improvement of the LEACH [6] protocol. However, results shows that EEHC suffered from the drawback that it could not handle the penalizing effect as happened in DEEC protocol. EDDEEC [7] worked in the same fashion as done by DDEEC but on the three levels. It introduced the threshold concept to avoid the penalizing of high energy rich nodes. BEENISH [8] worked for the four levels of heterogeneity by introducing the ultra-nodes along with normal, advanced and super nodes.

BEENISH has drawback that at the same level of energies, of ultra-super nodes, super nodes and advance nodes then CH selection criteria keep on penalizing the ultra-super nodes, super nodes and advance nodes node to be CH. This penalizing effect happened in case of three-level heterogeneity in EDEEC and in two-level heterogeneity in DEEC which was removed by EDDEEC and DDEEC respectively. So, removing this penalizing effect at four-level heterogeneity designs a new protocol i.e. I-BEENISH [9]. Mobility is introduced on the basis of maximizing the stop time for the sink. When sink moves it doesn't collect data, but when it stops it collects data. So, the maximization function is used in i-MBEENISH [9] protocol which drives its functioning.

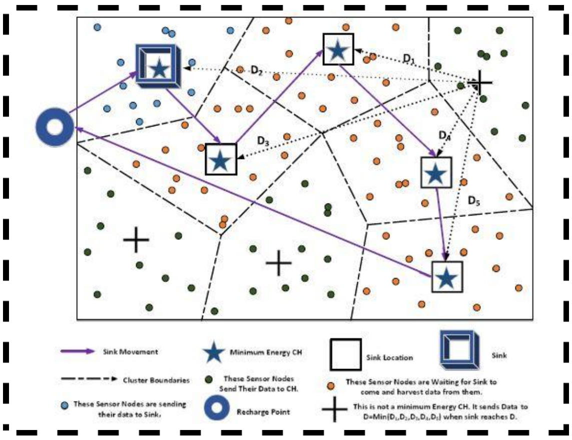

Fig. 2 Sink mobility Scenario []

III. Problem Definition

It has been observed in the literature that the main concern of many of the researchers working towards energy saving is making the clustering energy efficient. CH selection is very important parameter that has given a special attention in heterogeneous protocols. The sink mobility helps in collecting the data from the network without suffering from the delay and the energy hole problems. Numerous optimization problems have been introduced so far, but finding the optimized sink mobility is NP-hard problem. iMBEENISH only maximizes the stop time for the sink so that it can collect maximum data during its functioning. However, the various parameters were ignored. EECS worked towards the enhancement of lifetime of the network and to increase the packet delivered to mobile sink in the network. In order to select CH, the various factors were considered viz., residual energy of the node, distance, and the data overhead. Finite state machines and Markov model are used to realize the role of sensor nodes. It suffered from the inclusion of only few parameters for CH selection.

IV. Introduction to HBO

There are various optimization techniques which are incorporated in WSN to enhance the network lifetime by working on some specific parameters. Some tend to optimize the routing path or some optimize the Cluster Head selection in the clustering strategies of WSN.

Honey bee colony extends themselves over long distances in multiple directions in order to achieve large number of food sources. The foraging process starts in a colony by sending the scout bees to search for the promising flower patches. There is a random movement of scout bees from one patch to another.

When the scout bees return to the hive, they found a patch which is measured above a certain quality threshold and deposit their pollen or nectar and then they move to the dance floor to perform the waggle dance. The waggle dance is for colony communication and it contains the information of flower patch i.e. the direction in which the patch is found, distance of flower patch from hive and its quality fitness. This information is useful for sending the bees to the flower patches without using maps. The waggle dance enables the colony to determine the fitness of various patches according to the food quality and amount of energy required to harvest it. After the waggle dance, the scout bee moves back towards to the flower patch with other bees i.e. follower bees that were waiting inside hive. Then more follower bees are sent to the more promising patches which allow the colony to gather the food more efficiently and quickly. The bees monitor the food level while harvesting from the flower patch. This is important to decide the next waggle dance when they return to hive.

Honey Bees algorithm performs random search along with the neighborhood search for both functional and combinatorial optimizations. The main aim of this algorithm is to find an optimal solution by the honey bees' natural foraging behavior. Here, various parameters are1 required in general i.e. scout bees (n), selected sites in visited sites (m), stopping criteria, best sites in selected sites (e), initial patch size that includes the size of the network and its neighborhood, bees for selected sites, bees for (m-e) sites.

Bees are randomly placed in a space and then the evaluation of bee's fitness is done. Now, the bees with highest fit nesses are the selected bees and the bees that visit the sites are selected for the neighborhood search. Now for the selected sites, recruit bees and evaluate fitness's. Fittest bees from each patch are selected.

V. Proposed Work

The proposed technique follows three steps as shown in Fig. 3.

a) In first step, the CH selection is done on the basis of residual energy and inter-cluster distance. However, in iMBEENISH only residual factor was taken into consideration. The incorporating inter-cluster distance factor selects CH in a way that the inter-cluster distance between two clusters is low and which makes it easy for a sink to collect data from two respective CHs by travelling at very few distance. It is to be noted that when sink moves it doesn't collect data. It only gathers data when it rests at a particular position.

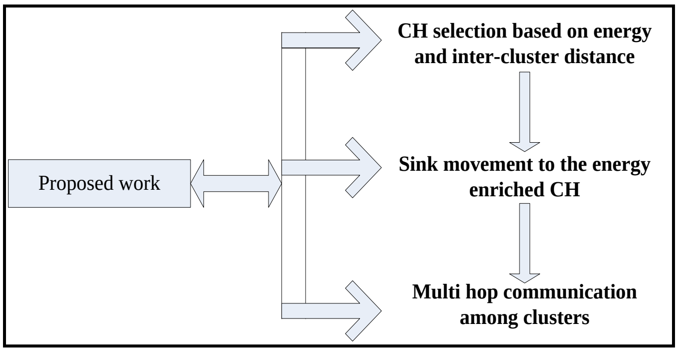

Fig. 3 Proposed work

b) In second step, HBO is applied for the sink mobility that considers the CHs with least energy and moves towards it. While applying HBO, the following fitness function is employed.

$$Fitness\ Function = \alpha \times f1 + \beta \times f2 \quad (1)$$

$$f1 = \sum_{j=1}^{m} \frac{1}{m} (||CH_j - Sink||) \quad (2)$$

$$f2 = \sum_{j=1}^{m} (E_{CH(j)}) \quad (3)$$

$$\alpha + \beta = 1 \quad (4)$$

In the above equations (1-4), α and β are the weight variables, f1 and f2 are two fitness parameters which integrate fitness function together. In f1, $||CH_j - Sink||$ represents the Euclidean distance of *j* number of CHs from the sink and m represents the no. of CHs. In f2, $E_{CH(j)}$ represents the energy of *j* number of CHs.

The objective is to minimize the fitness function as we want to move sink towards the minimum distance located CH with minimum residual energy. The reason behind sink movement towards minimum energy is the fact that least energy CH will die first so the approach is to collect data from that CH on the priority basis.

c) Thereafter, rest of the CHs forms a chain as shown in Fig. 4 to forward data to the sink. Such multi hop communication helps in the data delivery to the sink in very less delay.

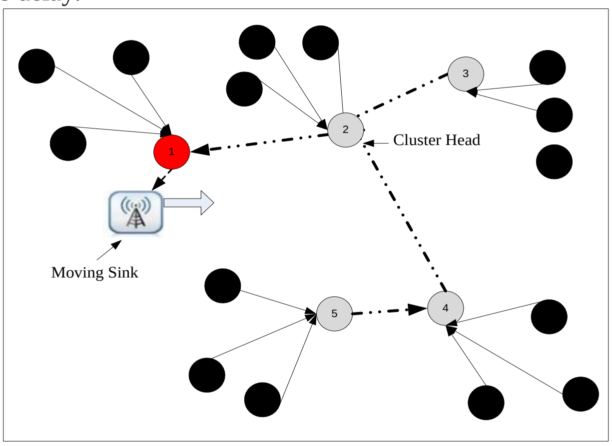

Fig. 4 Data transmission scenario

VI. Results and Simulation

Simulations are performed in MATLAB Software version 2016a. The simulation parameters for the proposed technique are given in Table 1.

The performance of proposed technique is compared on the basis of following parameters.

a) **Stability Period:** It is defined as number of rounds covered till the first node is dead.

b) **Network Lifetime:** It is defined as the number of rounds covered until 10% of the network are dead.

c) **Network's remaining energy:** It is the parameter that tells the status of network energy with the passage of rounds.

d) **Throughput:** It is defined as the number of successful packets delivered to the sink.

The simulation parameters taken for the simulation analysis of proposed protocol is given as following. It is to be noted that sink is moving in nature, rest all nodes are stationary.

Table 1 Simulation parameters

Parameter	Value
Network size	(100, 100) m^2
Node Number	100
Initial energy (Quantity)	In Joules 0.5
Types of heterogeneity	Four; Normal, Advanced, Super and Ultra-nodes
E_{elc}	50nJ/bit
E_{efs}	10pJ/bit/m^2
E_{mp}	0.0013pJ/bit/m^4
d_0	87m
E_{da}	5nJ/bit/signal
Data packet size	4000bits

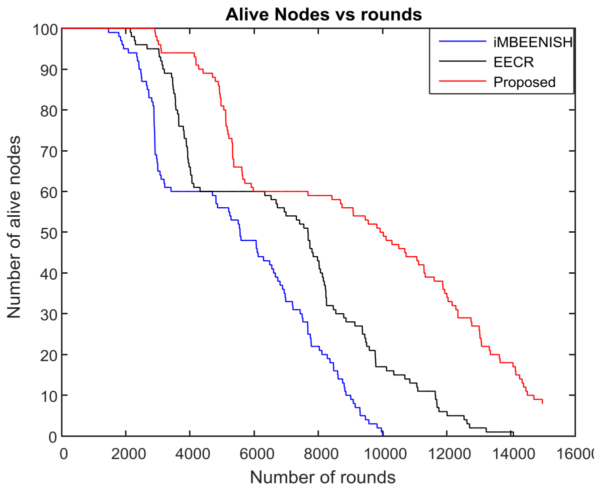

Fig. 5 Alive nodes vs rounds

It is found that the stability period of the proposed protocol is 2908 rounds whereas it was just 2142 and 1461 rounds in case of EECR and iMBEENISH, respectively as shown in Fig. 4. The percentage improvement by the proposed protocol is 35.76% and 99% as compared to EECR and IMBEENISH protocols, respectively. The reason for the improvement is the CH selection is the residual energy and inter-cluster distance which helps in energy conservation of nodes.

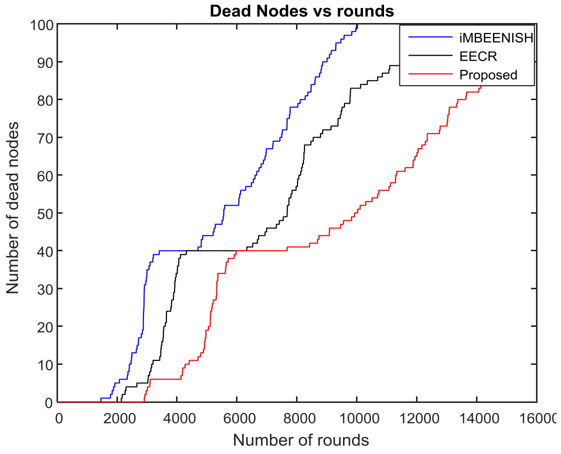

Fig. 6 Dead nodes vs rounds

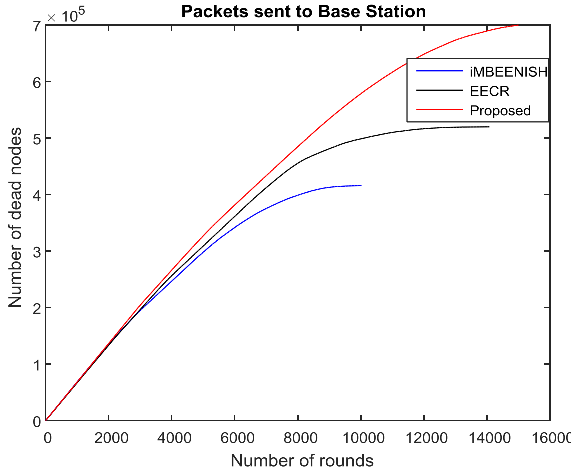

Fig. 7 Throughput

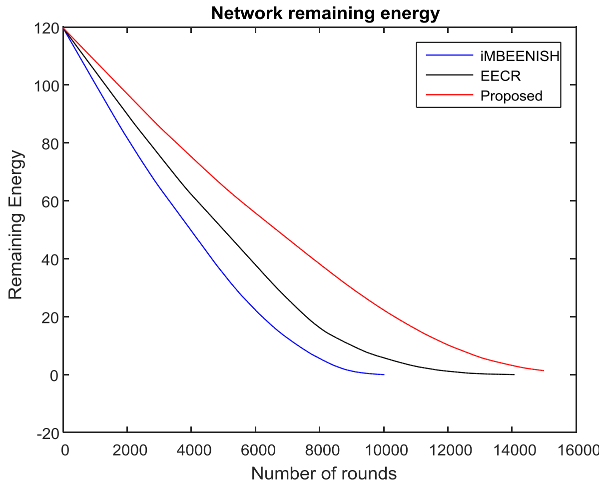

Fig. 8 Network's remaining energy

The graph of dead nodes vs round is shown in Fig. 5. The network lifetime in proposed protocol is observed to be 14515 rounds whereas it was just 11645 rounds in case of EECR and 8860 rounds in case of iMBEENISH protocol. The throughput is observed to be performing way better than the other protocols as shown in Fig. 6. It is due to the muli-hop transmission in the left out CHs so as to transfer the data from the nodes to the sink.

The network's remaining energy of the network is shown in Fig. 5. The proposed protocol improved the network performance as compared to other protocols in a way that the energy is conserved using HBO optimization technique.

Table 2 Performance comparison

Parameters/ Protocols	Stability Period	HND	Network Lifetime
iMBEENISH	1461	5558	8860
EECR	2142	7674	11645
Proposed	2908	9926	14515

Table 3 Percentage improvement by proposed protocol

Parameters/ Protocols	Stability Period	HND	Network Lifetime
iMBEENISH	99.0	78.5	63.82
EECR	35.76	29.34	24.64

The aggregated improvement is reported in Table 2 and Table 3. It can be observed that the protocol has outperformed the other two protocols under the aforementioned performance metrics.

VII. Conclusion

The main objective of the monitoring applications of WSNs is the collect information from the target area regularly. The energy saving is one of the most important concern that is dealt by many of the researchers these days. In this paper, a novel routing technique is proposed that optimizes sink mobility using HBO along with selection of CH i.e., done by using node's residual energy and inter-cluster distance. Furthermore, the multi hop communication is adopted to decrease the effective distance among the CHs and the sink. Simulation are performed in MATLAB and results show that proposed technique enhances stability period by 35.76% and 99% and network lifetime by 24.64% and 63.82% as compared to EECS and iMBEENISH protocols, respectively.

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