

Efficiency Improvement in Wireless Sensor Networks using ABC Algorithm for Cluster-based Packet Forwarding

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Abstract

Background/Objectives: The Particle Swarm Optimization (PSO) uses the sleeping mechanism that provided energy optimization in Wireless Sensor Networks (WSN), but failed to provide better energy efficiency. **Methods/Analysis:** This paper proposes an Artificial Bee Colony (ABC) Algorithm, to improve the energy efficiency of WSN by proper Cluster Head (CH) selection. The proposed algorithm helps to form a cluster in a network, in which the nodes are randomly deployed. **Findings:** The selection of CHs is based on the energy of each node which is communicated using ABC algorithm. The energy and time involved in the CH search mechanism are much minimal than the time and energy consumed by PSO algorithm. Thus, the overall network lifetime is enhanced by generating more alive nodes. **Novelty /Improvement:** The performance of the proposed system is validated in terms of Packet delay Ratio (PDR), Throughput and the lifetime of the WSN.

Keywords: Artificial Bee Colony (ABC) Algorithm, Cluster Head Selection, Packet Delay Ratio (PDR), Throughput, Improved Lifetime, Wireless Sensor Networks (WSN)

1. Introduction

Clustered Wireless Sensor Networks (WSN) are the most recent and evolving research domain due to its wide range of applications right from monitoring to controlling a data. Mainly the WSNs are employed for disaster management, Military surveillance and other civilian tasks meant for obtaining data from remote areas. In traditional WSN, the sensor nodes are powered by conventional batteries which get dried up before completing the designated work. So rechargeable sensor nodes have come up in recent times to improve the longevity of the sensor nodes^{1,2}. The longevity of the sensor node will extend the lifetime of a WSN and this, in turn, will help in our critical application areas where other modes of communications are impossible³.

The main advantages of the WSN include –

- Cheap Hardware
- Works in harsh environment

- Miniaturized products
- Easy installation
- Can be tagged with GPS
- Real time monitoring

The energy harvesting sensor nodes are helpful in obtaining the energy from an energy source to sustain the life of the network. The advanced programming tools help to program the WSN to work as desired for any real time application. The WSN can be programmed using any of the simulation tools like NS, OPNET, NetSim, TinyOS making the WSN easy to handle.

The network can operate efficiently when their nodes work as clusters, then as individual nodes. The cluster based packet forwarding is more prevalent in Wireless Sensor Networks, (WSNs), nowadays. The WSN use clusters to have good access or control over each and every node in a network.

The cluster-based data transfer enables the WSN to

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utilize the right node at the right time. The performance goals are required to be met by the WSNs due to the complexity of various sensing networks. So clustering becomes significant to promote the efficient use of deployed nodes in a network. The major advantages of clustered WSN are -

- Data aggregation at cluster heads
- Easier data access through CH
- Proper allocation of sensor nodes
- Efficient route Management

The Particle Swarm Optimization (PSO) algorithm which is already explored, achieves minimum intra-cluster distance. The operation of the algorithm works similar to the food searching pattern of the flock birds. PSO algorithm uses a centralized control algorithm that is implemented at the base station. The Cluster Head (CH) is elected with respect to the energy supply available at every node of the network. More energy is being spent for CH election. Though PSO achieved the minimum intra-cluster distance, the energy efficiency is not yet improved. The major demerits of the existing system are,

- Reduced Lifetime of the network
- Low Energy efficiency
- Network partition due to energy depletion

Hence, effective measures have to be formulated for getting desired results in the mentioned demerits of the PSO algorithm. To address the above said problems, in this work, a swarm based artificial algorithm is presented, called Artificial Bee Colony (ABC) algorithm so as to increase the network lifetime and energy efficiency. Here the cluster head selection plays the major role. The CH of the network is distributed, unlike the earlier systems, so the energy and time spent on CH selection become minimum.

The main implementation concept of the work is

- Data forwarding is hierarchical, similar to the foraging pattern of honey bees.
- The CH selection is made by considering all the equipotent nodes of the WSN. This makes all the clusters to have balanced energy level⁴.
- The residual energy, number of clusters and nodes and their relative positioning of the nodes are considered for forwarding the data packets with optimal use of energy. These factors help to overcome the demerits of the PSO algorithm.

The staircase water filling algorithm to implement an optimal solution for the constraints that arise due to energy harvesting in wireless communication. The Energy sources and channel condition were taken into consideration in the proposed method. The problem of allocation of energy was dealt by considering both causal Side Information (SI) and full SI of the channel. The main advantages were efficient implementation, increased throughput per slot^{5,6}. Energy Conservation with Assistance of Resourceful Mules (ECARM) to address the energy constraints present in Wireless Sensor Networks (WSNs) using the wireless devices that were used in day to day life. The WSN's energy was saved by using used laptops, Smart phones and tablet PCs, powerful sensors present in the RM's Communication Range. The main advantage of the proposed methodology was low duty cycle ratio and reduced power consumption⁷.

The remaining sections of this paper are arranged as follows. The earlier works associated to energy constraints in wireless sensor networks and the methodologies used to overcome the problems are presented in Section II. The descriptive details of the proposed ABC algorithm for cluster based packet forwarding is given in Section III. The experimental results based on the simulation and their comparative output results are provided in Section IV. Lastly, Section V summarizes and gives the conclusion to the work.

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2. Proposed Method

This section presents the detailed description of the proposed Artificial Bee Colony Algorithm. The main objective of the algorithm is to enhance the efficiency of the WSNs. The work is initialized by assuming a stable base station and multiple clusters are formed around the base station. This energy saving algorithm utilizes the centrally placed base station and produces the cluster head in the distributed manner. The work selects the nodes by considering their distance with reference to the multiple cluster heads⁸. Every time the base finds the node

with sufficient energy, it announces the resulting data to all nodes⁹. [Figure 1].

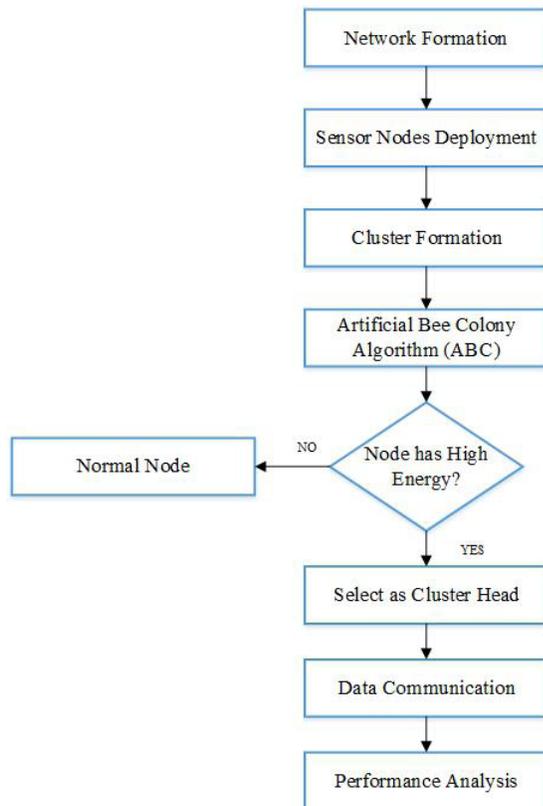


Figure 1. Overall flow of the proposed system.

The overall process of the proposed system is shown in Figure 1, which is composed of the following stages:

- Network formation
- Sensor Nodes deployment
- CH Selection using ABC Algorithm
- Data Communication

2.1 Network Formation

Firstly, the network is formed with the set of nodes with separate paths in a random manner. In this work 50 nodes are generated and are distributed over 500x500 network area. The nodes are generated with the equal energy of 1 Joule each. The network is formed based on the real-time requirement to monitor the specific areas.

2.2 Sensor Nodes Deployment

The deployment of sensor nodes is made in the areas, where the data is to be collected in an application. The Nodes can be deployed either statically or dynamically.

Here we use static deployment of nodes in random. This ensures the sensing field to have wide coverage area and less complex.

2.3 CH Selection using ABC Algorithm

The proposed ABC algorithm is applied to obtain the Cluster Heads from the member nodes of the WSN. The operation step of the ABC algorithm is similar to the working pattern of honeybees in real life. In order to search the Cluster Head, three groups of nodes were formulated, namely,

- Employed Nodes,
- Onlooker Nodes and
- Scout nodes.

All of these nodes search for energy data among these nodes in the distributed network of given dimension^{10,11}. The search is made at every sensor node of the network. The employed nodes search data around the network and shares the information of these data to the onlooker nodes. The onlooker nodes tend to select right data from those found by the employed nodes. The data that has higher energy (fitness) will have a larger chance to be selected by the onlooker nodes than the one of lower energy. The scout nodes are translated from a few employed nodes, which abandon their low energy data and search for new ones.

During the start of the ABC algorithm, many solutions were generated. After subsequent modifications, based on comparisons made, finally, the nodes with higher energy is elected as the Cluster Head based on its fitness value. And this is recorded to be the temporarily best solution of the given network. The fitness value is updated periodically in order to avoid exploiting a single cluster head. The work ensures that the selected cluster head have enough energy to make effective communication. Also, the cluster head selects the right candidate node with an appropriate energy level to perform every packet forward.

The fitness value is updated to provide the quality of communication within the network. The cluster heads in the network are optimally distributed so that many issues of the WSNs were avoided.

The responsibilities of the CH includes –

- Compiling the data collected from various nodes
- Data Forwarding to the base station
- Evaluating the nodes with good energy level

The main benefit of the described algorithm is that the distance between the cluster Heads and cluster nodes are minimum. Thus, it provides a large number of alive nodes than the classical methods (PSO and LEACH)^{12,13}.

2.4 Data Communication

After the appropriate selection of the Cluster Head, data communication is initialized within the network. The two-step data gathering procedure is as follows,

- The data sensed by each node is directed to their respective cluster heads.
- All the data collected by the cluster heads are consolidated and is directed to the base station of the WSN.

The data communication is the vital part of WSN, because of the fact that the WSNs are always employed in the critical application areas such as habitat monitoring, event detection, tracking and management of inventory. So the sensors play a crucial role to forward the data packets to the sink without any fault or delay. The proposed algorithm allows the data communication to be intact without congestion and without any network partitioning. Since the energy levels of each node are constantly monitored, the data packets are routed into the right path and the data are transceiver without error.

3. Performance Analysis

This part presents the performance results of the distributed WSNs with the proposed ABC Algorithm. The performance is measured based on the jitter, delay, and the bandwidth. Through the simulations, it has been observed that the determining criteria of the energy consumption and radio parameters are the distance between the sender nodes and receiver nodes in the WSN.

The results are analyzed and evaluated in terms of,

- Average delay
- Packet Delivery Ratio (PDR)
- Throughput
- Network Lifetime

The performance analysis is made over the Network Simulator NS 2. The size of the sensing network is chosen as 500x500 meters. The algorithm is implemented using 50 sensor nodes were randomly distributed in the network. Firstly every sensor node initiated with a definite amount

of energy and the simulation is performed on every sensor nodes in the network have consumed their energy in whole. In this paper, the whole work is performed in a single network setup. That is, the same number of nodes in the same position is examined in all the experiments presented here.

The minimum separation distances between cluster heads are varied, to find the energy consumption difference in the network. The position of the base station is fixed at the center of the sensing field or monitoring area. (X: 250; Y: 250) The initial energy of all the nodes are set as 1J and the time was taken to simulate is estimated by rounds. The range of communication is defined by the communication radius of the base station, which is set as 50 m. The data packet length is 50 bytes, and the data packet size is 512 bytes.

With the above mentioned experimental setup, various parameters are studied for the comparison of ABC algorithm with that of PSO algorithm. The graphs are produced with a common number of nodes in the network at the x-axis. The results are plotted against the parameter to be compared in the y-axis. The numerical parameters examined are discussed in the following subsections.

3.1 Average Delay

The time taken by the network to generate a message and to transmit the message is termed as the average delay of a network. This parameter is evaluated with respect to existing Particle Swarm Optimization (PSO) Algorithm and the proposed Artificial Bee Colony (ABC) algorithm. The simulation result shown in the Fig 2. Presents a reduced delay of 35.2 ms. this delay is lower than that of PSO, which shows 46.2 ms of average delay.[Figure 2].

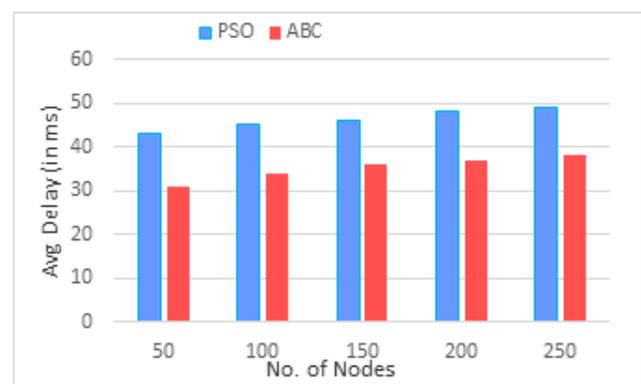


Figure 2. Average delay for existing and proposed system.

3.2 Packet Delivery Ratio (PDR)

Packet delivery ratio of a WSN is defined as the fraction of the sum of the packet received by the network and the sum of packets transmitted by the network is known as. The transmission and reception of data packets from the nodes are evaluated to arrive a solution to prove the efficiency of the WSN.[Figure 3].

$$PDR = \frac{\text{Number of packets received}}{\text{Number of packets transmitted}} * 100$$

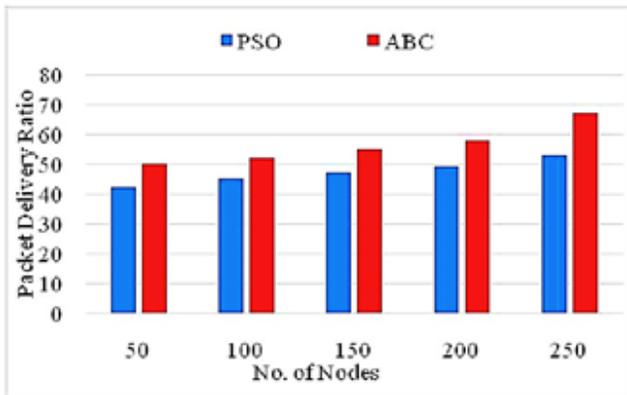


Figure 3. Packet delivery ratio for existing and proposed system.

Figure 3. Provides the comparative results on the PDR for both PSO and ABC algorithms. The numerical result of ABC arrives as 56.4 which is higher than the earlier PSO method which showed the PDR of about 47.2.

3.3 Throughput

The amount of data packets that can be processed in a unit time is called as the throughput of a system. It is the degree of the efficiency of a networking system which is expressed in terms of data transfer rate of suitable and non-repetitive information. Higher the throughput, the faster will be the communication in a network. This parameter is studied by initiating a typical data communication in the network. The results proved the proposed ABC to be superior to that of existing PSO system with values 4.3 and 3.4 respectively. The graphical illustration to show throughputs for ABC and PSO is provided in Figure 4. [Figure 4].

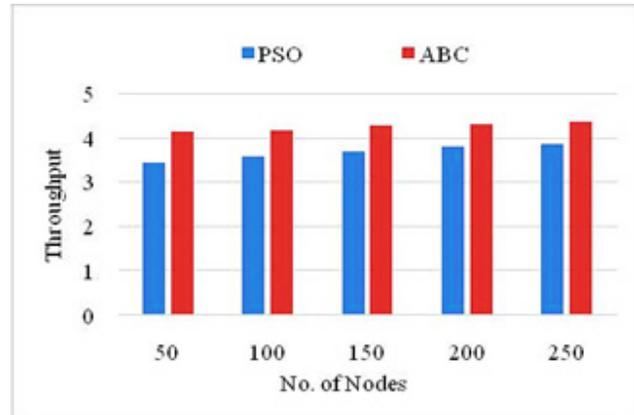


Figure 4. Throughput for existing and proposed system.

3.4 Network Lifetime

The time duration between the start of the data transmission of a network until the formation of a first non-alive node in that network is termed as the Network lifetime. This gives the active time of a network to process a data without loss in functionality of any node. The following Fig 5. Depicts the network lifetime increase in ABC algorithm compared to that of PSO algorithm. [Figure 5].

The network lifetimes of PSO and ABC 231.4 and 282 respectively. The graph displays a relatively stable lifetime, which makes the system robust. Thus, ABC algorithm balances the energy consumption effectively that optimizes the inter-cluster communication and the number of alive nodes.

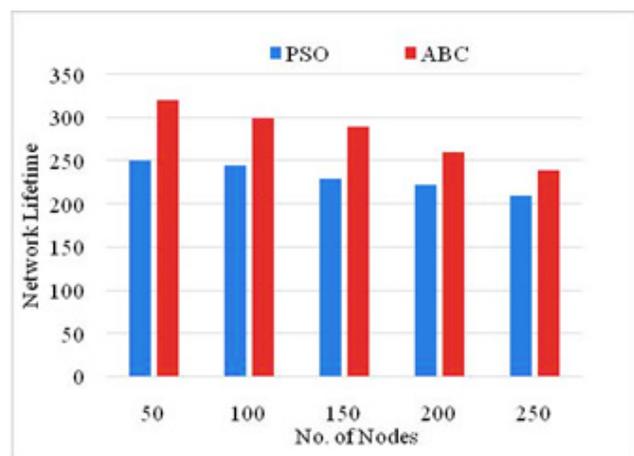


Figure 5. Network lifetime for existing and proposed system.

4. Conclusion

In this work, an energy enhancing ABC algorithm is provided for cluster based packet forwarding in a WSN. The work highlights the need for proper selection of cluster head and the procedure to choose the appropriate node as a cluster head. In the proposed scheme, the sensing nodes are formed into clusters with different roles as an employed node, onlooker node and as a scout node. The CH is selected based on the fitness value of a node. This type of cluster head formation sustains many nodes alive. The merits of the system include lower delay, higher throughput, prolonged network lifetime and hence greater energy efficiency. The simulation results have compared the WSN parameters for PSO and ABC algorithms. The study proved ABC algorithm is energy efficient as well as have longer network lifetime.

5. References

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