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Energy Efficient Routing in Wireless Sensor Networks Using the Weed Optimization

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Abstract: Routing becomes a challenging task in the WSNs when lifetime of the network and throughput is considered as the significant factors to be ensured for any kind of WSN applications. Therefore, this paper concentrates on developing an energy effective conquered protocol for extending the lifetime of the network. In WSN application, energy efficiency is significant in the network as all the sensor nodes engaged in the data collection and transmission are battery-operated nodes. Accordingly, in this research, weed optimization is applied for ensuring the effective communication in the network through the design of the multi-objective function. Rather than concentrating only on the routing application, the cluster head formation is implemented in the network as a significant step for ensuring the efficiency involved in the network. Thus the setup is implemented and the effectiveness of the system is analyzed depends on the performance measures throughput and energy which highlighted the performance efficiently.

Keywords: WSN, routing protocol, optimization, energy efficient, throughput.

1. Introduction

A mobile data collector has been used in Wireless sensor networks (WSNs) for energy-efficient data transmission, especially when sensors are sparsely distributed across a large region [7]–[9]. The mobile collector collects data from each sensor and transfers it to a remote control centre, eliminating the requirement for each sensor to connect directly with the control centre, resulting in significant energy savings in data transmission [2]. The network is made up of sensor nodes (ranging from a few to hundreds or even thousands) that are randomly placed throughout the interest region to collect sensory data and relay it to the sink node (collection point). Several constrained resources affect these nodes, including sensor range, communication range, battery power, storage, and CPU [10] [3]. A monitoring region frequently necessitates the deployment of a high number of sensor nodes, but the sensor nodes' computing, storage, and communication capacities are constrained in order to save money [4]. WSN receives data from its surroundings and communicates it to the digital world, such as computers, providing a bridge between physical and virtual information worlds. WSNs must address two demands in order to complete their tasks: I sensing in the target region and (ii) communication between sensor nodes. Because widespread computing relies on limited power supplies, it's critical to keep them running as long as feasible [5].

There are two types of cluster-based WSNs: (i) those with temporary CHs [11] and (ii) those with permanent CHs [12]. The sensor nodes in the first type have a somewhat equal energy supply and status, and each node has a probability of being chosen as the CH [4]. Multiple constraints, such as end-to-end dependability, latency, and energy efficiency, should be considered while determining QoS routing. Because some of these requirements are incompatible, only soft QoS provisioning is possible. Soft QoS refers to a route that meets the QoS requirements with a probability that is good enough for the purpose [13] [1]. The network working period is separated into rounds in a clustering protocol, and each round is usually broken down into three phases: Cluster Head (CH) selection,

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cluster creation, and data transfer. The CH selection algorithm is in charge of determining the best collection of CHs based on some predetermined criteria. Clusters are normally established by associating each regular node to its nearest CH after picking the best set of CHs. There are two types of data transmission phases: intra-cluster and inter-cluster. Data transmission between member nodes and their respective CH is classified as intra-cluster communication, whilst data transmission between CHs or between a CH and the Base Station (BS) is classified as inter-cluster communication [6].

In this research, the routing protocol based on the weed optimization is performed for which initially, the cluster heads are formed in this network utilizing the FABC algorithm. Then optimal routing path is decided by weed optimization using the multi-objective function in order to allow the data communication through the best routing path that would render an energy-efficient communication in the network.

The structure of the paper is: section 2 demonstrates the review of the existing literature, proposed routing phenomenon in section 3 with the detailed results in section 4 and conclusion in section 5.

2. Literature Review

In this section, the detailed review of the existing methods is presented with the challenges considered for the research. Habib Mostafaei [1] employed a distributed learning automation-based algorithm to perceive compact number of nodes for transferring the data between them with highly secured links. In the process of node selection, the delay time is too short for the network operations in prolonged time. Jaeuk Baek, et al. [2] used a Voronoi diagram-based algorithm to increase the least residual energy of sensors after the data get transmitted. It is used to determine the floating location of UAV at the Voronoi highest point thus the UAV has possible chances to gather the data from the proximate sensors. Ammar Hawbani, et al. [3] presented a Zone Probabilistic Routing protocol to minimize the difficulties in data routing during the data transmission in the wireless sensor network. Zone Probabilistic Routing achieves better efficiency due to the acute control of Routing Distance efficiency and Transmission Distance Efficiency. Tianshu Wanga, et al. [4] developed GA-based energy-efficient clustering and routing algorithm to improve the energy efficiency and the cluster heads consumes lowest average energy whereas the nodes consume lowest energy. Under different conditions, it attains the finest load balancing with respect to variations in the load on the cluster heads. Mohit Sajwan, et al. [5] used hybrid energy-efficient multi-path routing protocol to minimize the energy consumption. It consists of clusters and nodes in which the nodes are designated as cluster heads if it is lead to produce the cluster formation. The time interval between the nodes when transmitting the data is too long.

2.1 Challenges: The challenges of the research include

- Providing reliability for communication links in WSNs is a challenging problem due to leveraging shared error-prone communication medium which causes packet loss [1].
- The sensor node is supplied with limited battery power and it is difficult to provide secondary energy to the nodes. Thus, network failure occurs after more than a certain percentage of the nodes die. Therefore, reducing the energy consumption of sensor nodes and prolonging the network life-cycle is the key challenge for WSNs [4].

- Both the problems of selecting the optimal set of CHs and finding the optimal inter-cluster routing tree have been proved to be Non-deterministic Polynomial (NP)-hard optimization problems [6].

3. Proposed Routing Protocol Using the Weed Optimization in WSNS

In Wireless Sensor Network, the network operation gets affected owing to the sensor nodes unbalanced distribution and high energy utilization. An energy efficient routing algorithm and CH selection is required to ensure the efficiency of energy and extend the lifetime of Network. In this manuscript, to achieve smooth communication in the network, a routing algorithm weed optimization is developed by selecting the optimal routing path. Centralized routing is performed by subjecting the sensor nodes to the cluster heads selection and data clustering. With the help of FABC algorithm, cluster head selection process takes place and the nodes get communicates the sensed data to the CH. Finally, it gets forwarded to the Central Station using the adequate path and the preferable process takes place through weed optimization. The exploitation and explorationissues in choosing CH can be solved by the FABC algorithm. Data clustering techniques shows the energy challenge in retransmitting the data between CH and BS, in which the sliding window method is applied to shorten the repeated transmitted data.

3.1 WSN system model

Figure1 reveals the simplified diagram for the conquered mechanism. In WSN, n be ordinary nodes fitted along to the Central Station which is denoted by N_d . Uniformly distributed actuator nodes with a largecommunication scale of C_j and D_j measures and common ID is labeled for the individual sensor be combined to form a cluster in WSN for transmission. The position of the ordinary nodes is calculated by the accommodate achievements of C_c and D_c for obtaining the normal nodes input case whereas the Central Station is placed in the suitablesituation of $\{0.5C_j, 0.5D_j\}$. Here, I is the entire nodes which is initiated as $\mathrm{CHs}(\mathrm{N}_l)$, where the normal nodes form group as I clusters, the entire normal nodes is $n-\mathrm{I}$. Each cluster has I number of sensor nodes, N_l in CH collects the input from the ordinary nodes N_N also be in contact with the N_d in BS. After placing the metrics in network, the spaceinbetween the normal nodes p^{th} to the q^{th} CH is obtained as g_{pq} and the distance between the q^{th} CH to N_d is represented as d_q. The radio model and the mobility model of the wireless sensor network are mentioned in [25].

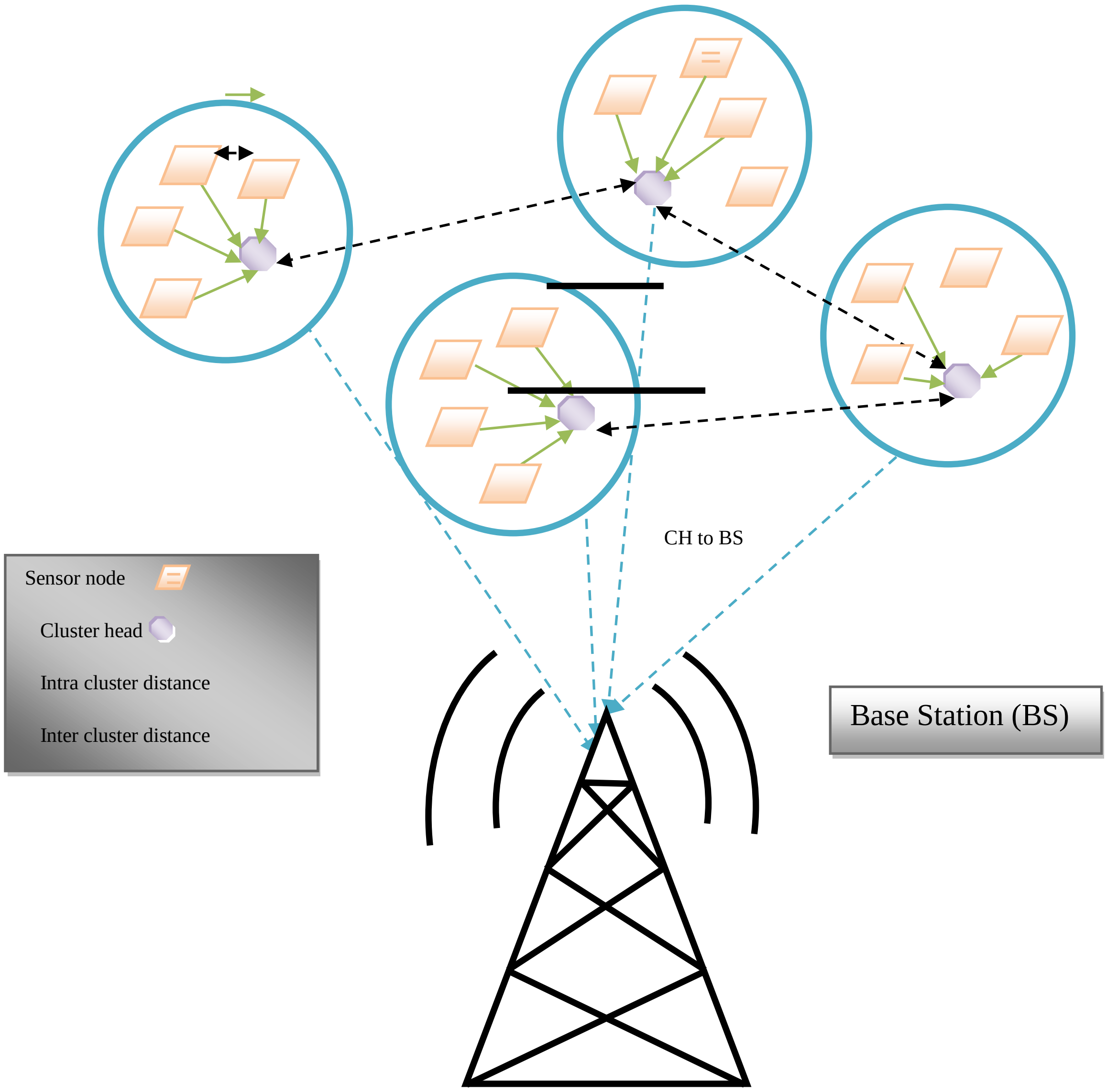


Figure1. System model of WSN

Cluster formation in WSNs

Clusters are developed for every cluster with one Cluster Head and FABC algorithm is utilized in this research to form the suitable clusters in the developed network. The nodes and CHs suitable location enable the important criterion as energy and distance for conserving energy. The loss of energy in Cluster Head is higher than other nodes, when it gathers the information from all the nodes; it is effectively handled by constantly updating the CH. The updating process is monitored by FABC at the termination of every transmission thus it improves the searching behavior. FABC recreates a key partto improve the result research potential in reserved analyzing area by resolving the problems in solution development using the best results obtained in previous stages. FABC is utilized to solve the optimal CH choosing problem by analyzing the shortest path between the CH and BS. The update rule used to find the optimal cluster head on FABC is as follows:

$$S_{p,q}^{\lambda+1} = \left[\alpha_S S_{p,q}^{\lambda} + \frac{1}{2} \alpha_S S_{p,q}^{\lambda-1} + V_{p,q} \left(S_{p,q} - S_{m,q} \right) \right] \tag{1}$$

where, $S_{p,q}^{\lambda}$ is the p^{th} food source of q^{th} value in λ^{th} iteration, $V_{p,q}$ is the random value generated, which ranges between [-1,1], $q \in \{1, 2, 3 \ldots I\}$, and $m \in \{1,2,.....X\}$.Here, α_S demonstrates the order of food derivative in the range of $0 \le \alpha_S \le 1$, $S_{p,q}^{\lambda+1}$ is the derivative version of the order $\alpha_S = 1$ and $S_{p,q}^{\lambda+1}$ is referred as the new solution with respect to the best solution at instance λ and $(\lambda - 1)$.

3.2 Routing protocol for selection of the energy-efficient routing path

In this section, the routing protocol used for selecting the optimal routing path is highlighted with the designed multi-objective function. Let us take a deep insight into the sections.

3.2.1 Solution encoding

The optimal routing path is determined using the proposed weed optimization in the solution encoding process for effective communication. The pathway of data communication is from the source (CH) where it is represented as FN_{CH} to its destination BS via the optimal selected path using the proposed optimization. It improves 1) The path that goes through the minimum distance 2) Delay of nodes and power consumption thereby increasing network life. Alter $i = 1,2,....,I$, between the intermediate nodes involved in the route, where $i \in q$. Figure3 represents the solution vector.

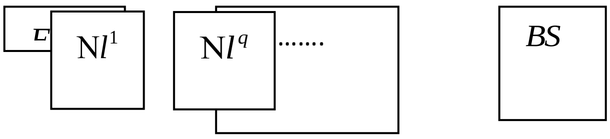


Figure3. Solution vector

3.2.2 Multi-objective function

Based on the Multi-Objective function, the proposed weed optimization prefers the optimal path which depends on the network parameters energy and distance. At last of the communication, the energy levels of the normal nodes and cluster heads are decomposed, so the remaining energies in the nodes and cluster heads are updated, which is designed as follows,

$$\zeta_{\lambda+1}\left(\mathrm{N}_{\mathrm{N}}^{\mathrm{T}}\right) = \zeta_{\lambda}\left(\mathrm{N}_{\mathrm{N}}^{\mathrm{T}}\right) - \zeta_{e}\left(\mathrm{N}_{\mathrm{N}}^{\mathrm{T}}\right) \quad (2)$$

$$\zeta_{\lambda+1}\left(\mathrm{N}_{l}^{\mathrm{T}}\right) = \zeta_{\lambda}\left(\mathrm{N}_{l}^{\mathrm{T}}\right) - \zeta_{e}\left(\mathrm{N}_{l}^{\mathrm{T}}\right) \quad (3)$$

In the sensor node the updated energy is denoted as $\zeta_{\lambda+1}(\mathrm{N}_{\mathrm{N}}^{\mathrm{T}})$ and updated cluster head energy is $\zeta_{\lambda+1}(\mathrm{N}_{l}^{\mathrm{T}})$, the dissipated energy by the receiver with respect to the CH and the member node is $\zeta_{e}(\mathrm{N}_{l}^{\mathrm{T}})$ & $\zeta_{e}(\mathrm{N}_{\mathrm{N}}^{\mathrm{T}})$, where, the initial energies of the CH and member nodes is denoted as $\zeta_{\lambda}(\mathrm{N}_{\mathrm{N}}^{\mathrm{T}})$ & $\zeta_{\lambda}(\mathrm{N}_{l}^{\mathrm{T}})$ respectively.

The intra-cluster distance between the nodes and the corresponding CH is calculated as,

$$\aleph_1(\mathrm{N}_{\mathrm{N}}^{p}, \mathrm{N}_{l}^{q}) = \sqrt{\frac{1}{2|\mathrm{M}_l|} \sum_{\substack{p=1 \\ q \in 1,2,\ldots I}}^{n} (\mathrm{N}_{\mathrm{N}}^{p}, \mathrm{N}_{l}^{q})^2} \quad (4)$$

where the intra-cluster distance between the member node and the cluster head p^{th} and q^{th} is denoted as $\aleph_1(\mathrm{N}_{\mathrm{N}}^{p}, \mathrm{N}_{l}^{q})$.

3.2.3 Optimal path discovery using weed optimization

In this section, a routing protocol named weed optimization is used for declaring the best routes for communication in the network. The loss of energy in the nodes is the major problem in the communication process, which affect the network lifetime. To ensure that, an energy conscious routing protocol is proposed named weed optimization algorithm.

Mathematical design of the proposed weed optimization:

By a general precision, weed is a growing plant by accident. Although, the benefits and uses of weeds is high related to some areas, but it affects the human basic requirements and functions.

To ensure the habitual characteristics of weeds, there are some basic aspects for processing are as follows:

1) Initialization of Predominant population: Initially, reduced number of ovules are dispersed in the exploration field.

2) Procreation: Depending on their fitness value each ovule developed into a flower and further generates ovules for processing. Grain number of grasses reduced from $\mathrm{M}_{\max}$ to $\mathrm{M}_{\min}$ and it is given as:

$$h(x_s) = \frac{\mathrm{M}_{\max}(\max apt - apt(x_s)) + \mathrm{M}_{\min}(apt(x_s) - \min apt)}{\max apt - \min apt} \tag{5}$$

3) Spectral Spread: In normal distribution, the seeds evolved with average planting stage and the standard deviation (SD) which is described by the following equation:

$$\delta_y = \left(\frac{t-y}{t}\right)^2 (\delta_{initial} - \delta_{final}) + \delta_{final} \tag{6}$$

Where the number of maximum iterations is denoted as t, the current standard deviation is δ_y, h is the nonlinear modulation index.

This conversion assures that at each step plunge of a grain decreases nonlinearly within the range, which leads to develop more apt plants and diminish the most unfitted plants, where the transfer mode is shown as from f to designation of F.

4) Competitive deprivation: To maintain constant number of herbs, the grass which has frustrate sturdiness is eliminated if the required number of grasses exceeds the $J_{\max}$ in the colony.

5) This action repeats still it reaches the $J_{\max}$ number of iterations, and eventually the limited colony cost task of the grasses is stored.

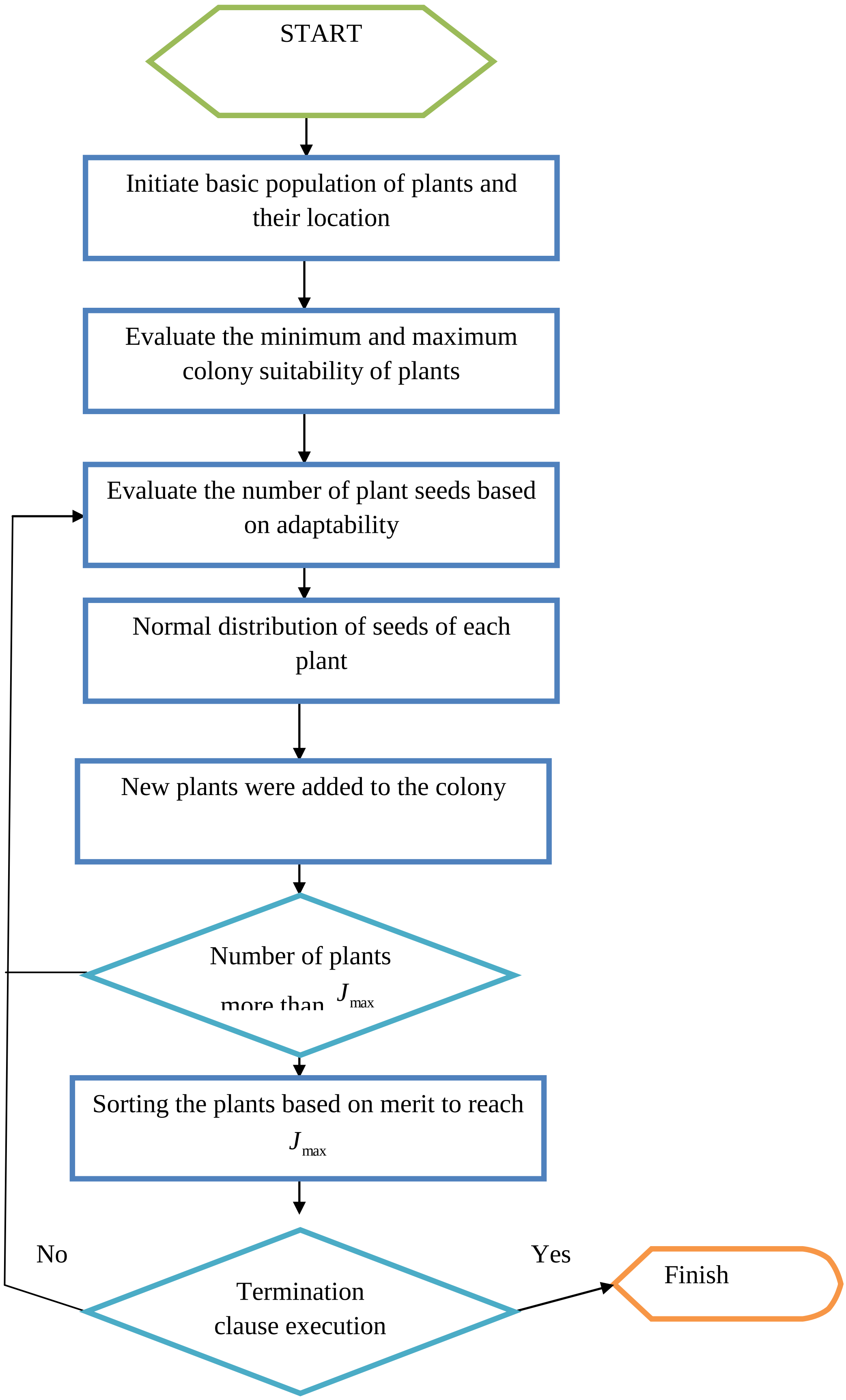


Figure 4. Flowchart of weed algorithm

4. Results and Discussion

This part illuminates the discussion and results of weed optimization routing algorithm for originating an energy-aware routing protocol. To explain the efficiency of the weed optimization, the performance depends on the network energy, throughput, and number of nodes in alive are executed. Moreover, the comparative analysis is done with the conventional methods in order to show the performance of the proposed method.

4.1 Experimental setup

The assumption setup is executed in MATLAB operating in the PC with windows8 OS and 8GB RAM. The nodes are simulated in the MATLAB environment, which engages in collecting the data from the simulation area that is communicated along with the central station through the optimal cluster head selected using the FABC algorithm. The communication between the cluster head and the central station is depends on the selected path using the weed optimization.

4.2 Simulation results

In this section, the network simulation using the proposed weed optimization algorithm is demonstrated. At first, the nodes are dispersed in the sensing environment, for which the FABC algorithm for CH selection is applied for cluster formation. During routing, transmission of data from the CH to the BS, the nodal energy tends to decrease thus, eliminating the size of the nodes in the network. The results obtained from the proposed weed optimization for 100 nodes are illustrated in the figure 5.

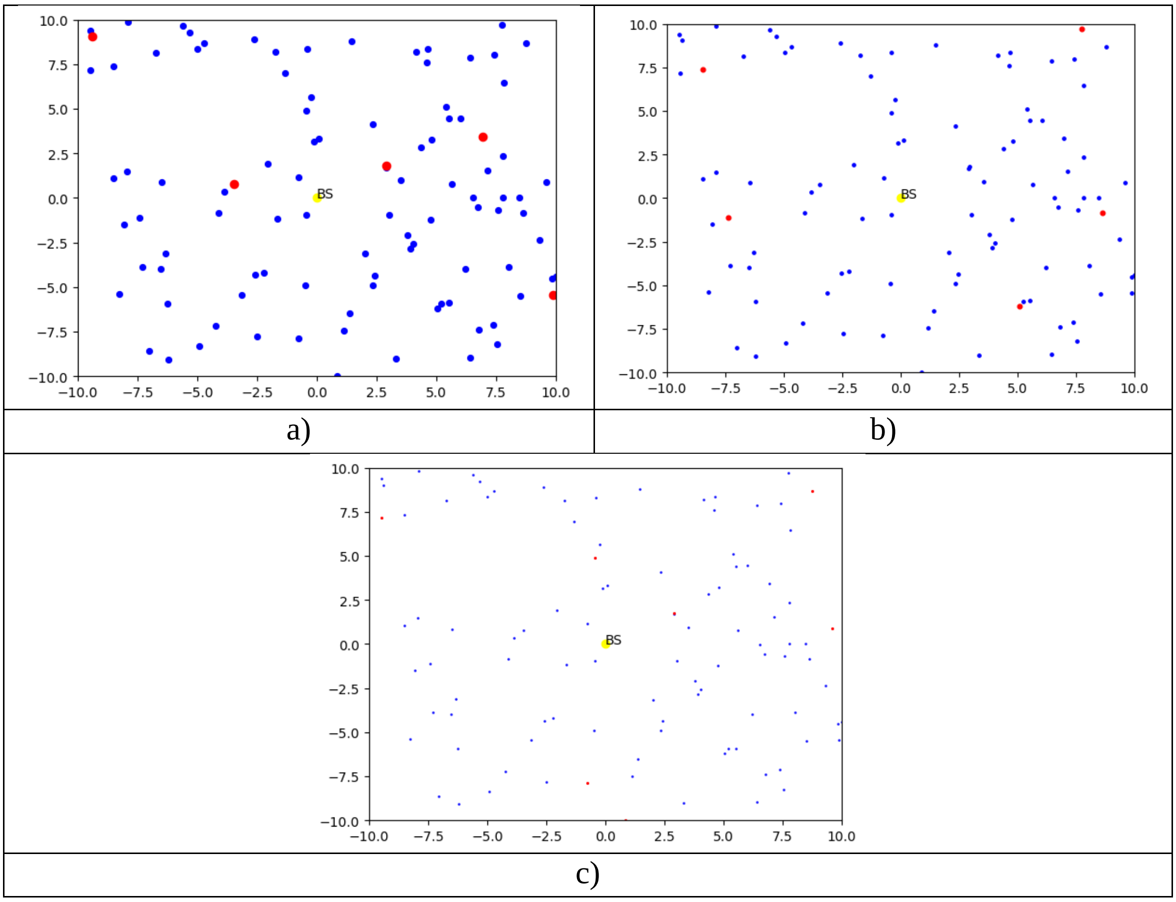


Figure5. Simulation area with 100 nodes, a) Round_60, b) Round_140, c) Round_290

4.3 Comparative methods

The methods used for the comparison includes Fractional Artificial Bee Colony (FABC) + Invasive Weed Optimization (IWO), ABC + Particle Swarm Optimization (PSO), Artificial Bee Colony (ABC) + IWO, Genetic Spider Monkey Optimization (GMSO) + PSO, O-SEED + PSO.

4.4 Performance measures

The metrics used for the analysis of comparative methods with the proposed model are Active nodes, Average energy and Throughput.

4.5 Analysis of the comparative methods

The comparative analysis of the weed routing model with 50 and 100 nodes present in the network which depends on the total number of alive nodes, synthesized network energy in addition the throughput in order to expose the importance of the proposed model.

i) Analysis among 50 nodes:

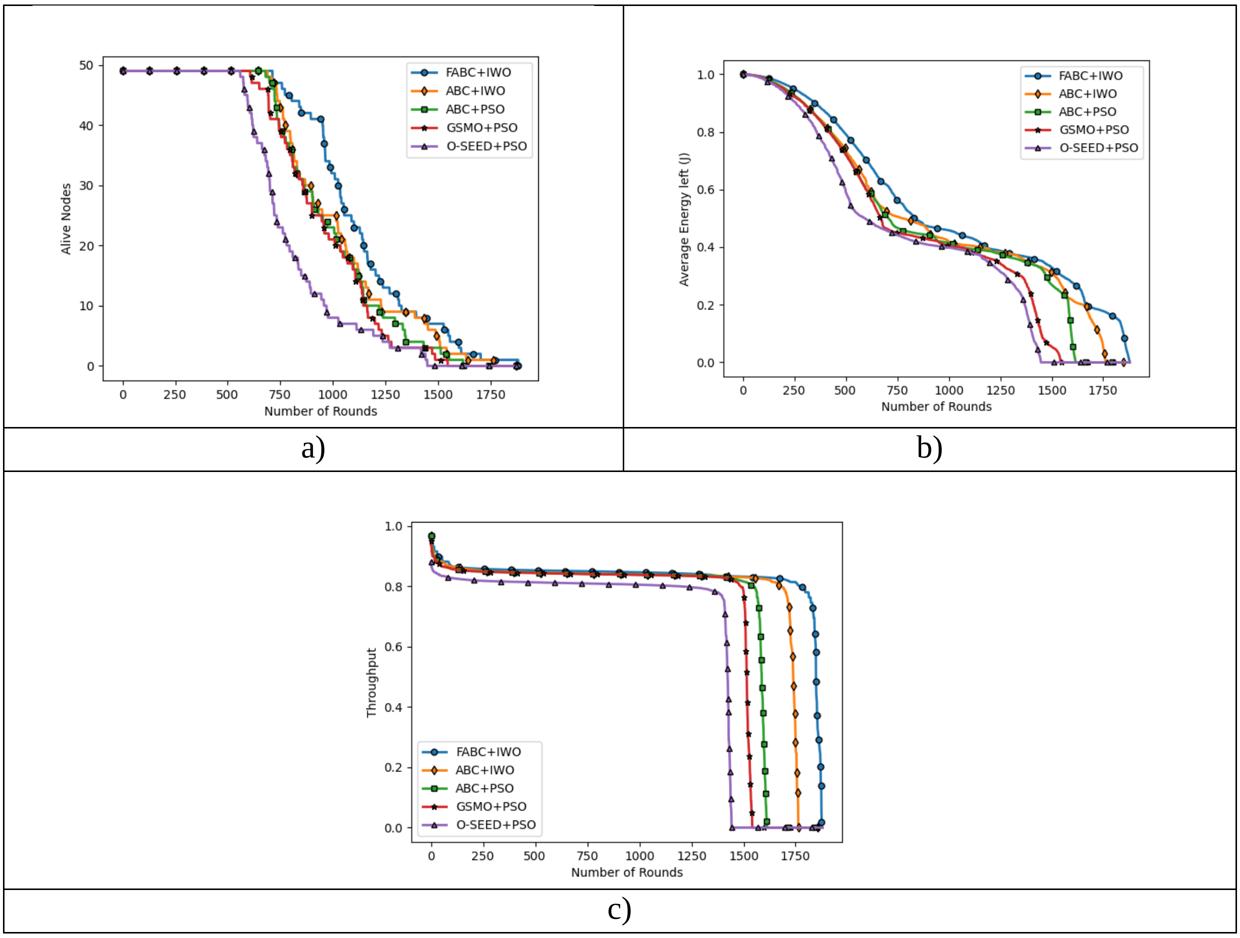
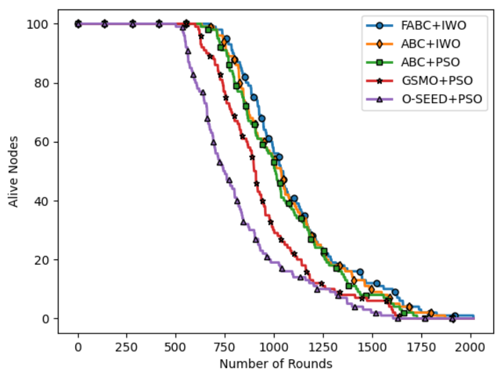


Figure 6. Comparative estimation among 50 nodes, a) alive nodes, b) average energy remaining in the nodes, and c) throughput

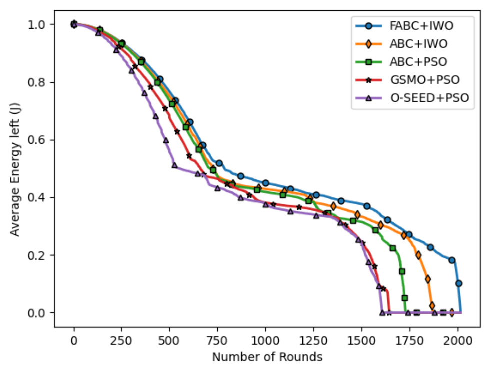
The estimation of the developed method with 50 nodes is shown in figure 6. Then, the comparative estimation in terms of active nodes, network energy and throughput of the conventional and developed methods is illustrated in figure 6 a), b), and c), respectively. At 900 rounds, the active nodes available for the proposed Fractional Artificial Bee Colony (FABC) + Invasive Weed Optimization is 41 and Artificial Bee Colony + IWO, ABC + Particle Swarm Optimization (PSO), Genetic Spider Monkey Optimization (GMSO) + PSO, O-SEED + PSO holds 29, 29, 27 and 12 respectively. At 1400 rounds, the average energy available for the proposed Fractional Artificial Bee Colony (FABC) + Invasive Weed Optimization is 0.3634J and Artificial Bee Colony + IWO, ABC + Particle Swarm Optimization (PSO), Genetic Spider Monkey Optimization (GMSO) + PSO, O-SEED + PSO contains 0.3447J, 0.3421J, 0.2383J and 0.1243J respectively. At 1440 rounds, the analysis of 50 nodes throughput for the proposed Fractional Artificial Bee Colony (FABC) + Invasive Weed Optimization is 0.833bps and Artificial Bee Colony + IWO, ABC + Particle Swarm Optimization (PSO), Genetic Spider Monkey Optimization (GMSO) + PSO, O-SEED + PSO contains 0.831bps, 0.826bps, 0.824bps and 0.095bps respectively.

ii) Analysis among 100 nodes:

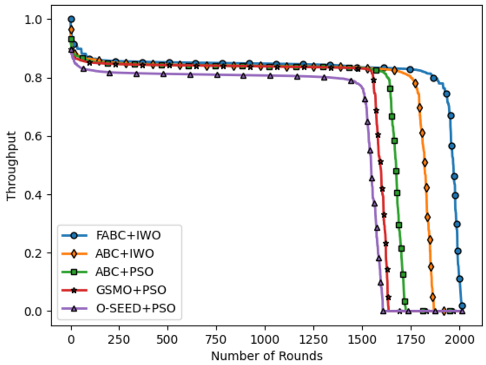
The evaluation of the proposed method with 100 nodes is shown in figure 7. The comparative estimation in terms of active nodes, network energy and throughput of the conventional and developed methods is illustrated in figure 7 a), b), and c), respectively. At 900 rounds, the active nodes available for the proposed Fractional Artificial Bee Colony (FABC) + Invasive Weed Optimization is 75 and Artificial Bee Colony + IWO, ABC + Particle Swarm Optimization (PSO), Genetic Spider Monkey Optimization (GMSO) + PSO, O-SEED + PSO holds 67, 66, 51 and 30respectively. At 1400 rounds, the average energy available for the proposed Fractional Artificial Bee Colony (FABC) + Invasive Weed Optimization is 0.389J and Artificial Bee Colony + IWO, ABC + Particle Swarm Optimization (PSO), Genetic Spider Monkey Optimization (GMSO) + PSO, O-SEED + PSO contains 0.360J, 0.326J, 0.311J and 0.307J respectively. At 1440 rounds, the analysis of 100 nodes throughput for the proposed Fractional Artificial Bee Colony (FABC) + Invasive Weed Optimization is 0.838bps and Artificial Bee Colony + IWO, ABC + Particle Swarm Optimization (PSO), Genetic Spider Monkey Optimization (GMSO) + PSO, O-SEED + PSO contains 0.836bps, 0.834bps, 0.833bps and 0.791bps respectively.



a)



b)



c)

Figure7. Comparative evaluation among 50 nodes based on a) alive nodes, b) average energy remaining in the nodes, and c) throughput

4.6 Comparative discussion

Table 1. Comparative discussion of the conventional and developed methods with 50 nodes at 1000^{th} round

METODS	Alive Nodes		Remaining Energy		Throughput	
	With 50 nodes	With 100 nodes	With 50 nodes	With 100 nodes	With 50 nodes	With 100 nodes
Proposed FABC + IWO	32	57	0.459	0.449	0.846	0.848
ABC + IWO	25	54	0.421	0.429	0.839	0.840
ABC + PSO	23	54	0.415	0.419	0.838	0.839
GMSO + PSO	21	30	0.405	0.381	0.837	0.838
O-SEED + PSO	8	19	0.398	0.378	0.805	0.807

5. Summary

In this research, the requirement of energy efficient network is highlighted through appropriate identification of the cluster heads and optimal conquered path for communication. Through the selection of the CH and path, the network lifetime is extended with higher throughput, which highlights that the WSN shall find a valuable application in any area. The implemented idea is analyzed with the performance metrics, which revealed that at the end of the 1000^{th} round, the throughput acquired is 0.805 and 0.807 for the weed optimization-based routing protocol, when the network is simulated with 50 and 100 nodes, respectively. In future, an effective function with more network parameters, like intercluster and intercluster distances will be considered with a more powerful protocol to acquire the energy efficiency in the network.

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