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LIFETIME MAXIMIZATION OF A MOBILE WSN USING ZRP-FUZZY CLUSTERING PROTOCOL BASED ON ANT-LION OPTIMIZER

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***Abstract*- Wireless sensor network (WSN) require energy-efficient protocols for communication and data fusion to integrate data and extend the lifetime of the network. An efficient clustering algorithm for sensor nodes will optimize the energy efficiency of WSNs. However, the clustering process requires additional overhead, such as selection of cluster head, cluster creation, and deployment. In this paper, cluster head (CH) selection is done using fuzzy logic approach and propose zone routing protocol (ZRP) for mobile WSN clustering scheme named as (ZRP-FCM) protocol which proposed fuzzy logic approach based on three factors of nodes for the selection as CH nodes such as, residual energy, the concentration, and the centrality of the node. also, the Ant-lion optimization (ALO) algorithm is applied in this work to determine the best position of mobility base station (BS) for gathering data, so-known as (ZRP-FMC-ALO) protocol. The performance of the proposed protocol is compared with the famous protocol such as the low energy adaptive clustering hierarchy protocol (LEACH) protocol. Simulations were carried out in MATLAB. The results show that the ZRP-FMC-ALO outperforms ZRP-FMC and LEACH in terms of networks lifetime (FNDs) by 16.19%, 304.5% respectively, (HND) by 14.2%, 184.29% respectively, and in terms of average consumed the ZRP-FMC-ALO outperforms LEACH after 1000 round by 84.9% and outperforms ZRP-FMC after 3000 round by 30.7%) respectively.**

keywords: **WSN, Sink mobility, ZRP, Fuzzy logic, Ant-lion optimization.**

I. INTRODUCTION

A wireless ad-hoc network (WANET) is a decentralized type of wireless network that is built dynamically without using any pre-configured infrastructure. Such a network does not contain a central intermediate or router that is available for forwarding messages among the computing devices. Also, these devices rely on the ad hoc wireless network for their interface cards to support direct communication with each other [1]. WSN can refer to a network of nodes or small devices, which are used for specific physical sensing from the round environment, computing, and transmitting information collected from the monitored domain through wireless links to send and receive information between different sensor nodes, so each sensor acts as a router [2]. The major role of a WSN is to monitor and control the physical parameters in the specific environment. The sensor is battery powered and is mostly designed for long-term deployments without human intervention. The architecture of WSN consists of a sensing unit, processing unit, transceiver, and power supply. Hence, energy efficiency is one of the major design goals for sensor networks [3]. So, Power management represents the prime challenge in sensor networks, especially the sensor nodes are powered by tiny batteries not easy to change or recharge when it is depleted [4]. A great amount of power is consumed during transmission. control of the transmission can be considered one of the most functionalities to reduce power consumption. The transmission depends on how to route the data from node to node which is the task of the network layer of each node. [3], [4], [5]. In this work, energy-efficient WSN clustering protocols based on a zone routing protocol (ZRP) were developed using a fuzzy logic approach for cluster head selection. It is applied by incorporating three-factor such as remaining energy, centrality, and the concentration of the node. The sink mobility pattern is moved in different two ways: The first is in a circular path with different diagonal sizes for the circular shape. The second way is moving BS in a random position inside or outside the field depending on the objective function when the ant-lion algorithm is applied to determine the best position of the BS when any CH energy level became less than the specified threshold. The ant lion algorithm starts to calculate the new position of BS by generating random positions in the selected area, Calculate the fitness of initial ant-lions (the newly generated position) and sort them according to the objective function to optimize network life and average power consumption. The rest of the paper is organized as follows: Related work is delivered in Section II, proposed mobile WSN clustering protocol in Section III, Simulation Environment and Parameters in Section IV, testing and comparison for ZRP-FMC-ALO in Section V, and conclusion in Section VI.

II. Related Work

One of the prime challenges that are facing designers in mobile WSN is battery power limited. In general, which affects the quality and lifetime of the network. To avoid power consumption, the researchers considered a cluster-based approach to transmitting data [6]. In (RARZ) [7] , this protocol divided the network into concentric rings centred on the base station.it is a multi-hop energy-efficient protocol that makes routing decisions depend on the remaining energy of nodes without the need to know the position of the nodes. Each node allocates itself to a specific ring, known by a ring ID. Simulation results show that RARZ in terms of energy consumption, average hop count, and end-to-end delay outperforms ad hoc on-demand distance vector (AODV), the address-light integrated MAC routing protocol (AIMRP). In RF-LEACH [8] , a cluster-based hierarchical routing protocol (HRP) was coined as an energy-efficient load-balanced data gathering protocol (RF-LEACH) which is an extension of LEACH. It used rough fuzzy c means (RFCM), to partition the nodes deployed into a compact of clusters as well as the selection cluster head is based on fuzzy logic. Simulation results show that proposal RF-LEACH extends WSN lifetime and throughput compared against LEACH, fuzzy c mean (FCM-LEACH), and Fuzzy-LEACH. In [9], for the selected cluster head in hierarchical topology control. Initially, proposed cluster head selection based on fuzzy clustering approach according to geographical location for sensor nodes, then improved by PSO, the fitness function considered both the energy depletion and distance factors of WSN. Simulation results show that proposal work extending the network life cycle and reducing the mortality number of nodes. The AD-ZRP [10] is multi-hop and self-configuring, which consists of ZRP that relies on dynamic regions and ACO that work together to improve pathway maintenance and pathway detection through pheromones. The results obtained from the proposed scheme are good in terms of targeting overhead, percentage of data delivery, and avoidance of crowding for dynamic topology environments. While in [11] "Cluster Head selection protocol using Fuzzy Logic" (CHUFL) contains two stages: the first one is (finding the neighborhood phase) each node in this phase sends a packet of information (such as ID, location information), and stores it in the table next to it. Whereas the second stage is (steady-state phase) each round begins with the selection of CH followed by block formation, data collection in CH, and finally, data transmission to the sink station. The simulation result in CHUFL shows an enhancement of about 20 % in-network lifetime (consumed energy) and 72% in the throughput when compared to one of the energy-efficient clustering protocols. In [12] CRT2FLACO "a Type 2 Mamdani Fuzzy Logic System (T2MFLS)" was used in the setup phase to support uncertainties and network load balancing. While in the steady-state phase, all CHs are linked in series using the ACO algorithm and each CH sends its collected data to the leader to reduce transmission

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consumption. Simulation results for the proposed routing protocol show extending the life of WSN. In [13] The temporal fuzzy logic of cluster-based routing has been proposed by introducing two types of the head node, one for gathering data and the other for routing. The results obtained for the proposed protocol show enhancements in some issues such as the QoS, flow control, and congestion control. In [14] The data-collection tour provided by the mobile sink is illustrated similarly to the Problem of an asymmetric Euclidean Traveling Salesman and a separate ant lion optimization algorithm has been proposed to find the optimal path of the mobile sink to collect data and forward it to the base station. The results showed that the proposed algorithm performed better in terms of average round length, accuracy, and convergence rate over the other existing methods. In [15] proposed "The fuzzy cluster head selection algorithm is based on the LEACH protocol" . The results of the proposed algorithm show an increase in network life compared to LEACH by 58.38%. In [16] Bacterial swarm optimization (BSO) is used for energy saving in WSN by determines the optimal route through next an optimal hop node for each gateway based on the lifetime of the gates and the number of hops in the path between the gateway and base station. The results gotten from the proposed algorithm outperform the current algorithms in terms of network lifetime by 50 rounds, power consumption by 15%, and the number of hops by 2 to 5. In [17] Ant Lion Optimization approach(ALOP) has been proposed to solve the positioning base station problem by reducing the communication distance between the base station and cluster head. Moreover, the network lifetime is outperformed by 80% compared with other traditional evolutionary algorithms.

III. The Proposed Mobile WSN Clustering Protocol

To prolong the lifetime of wireless sensor networks, a fuzzy clustering approach for cluster head election based on zone routing protocol was proposed (ZRP-FMC). It is an extension of previous work named (MCHFL-ZRP)[5].To enhance the result for this protocol,ant-lion Optimization was proposed known as (ZRP-FMC-ALO) protocol. It is composed of two phases: the setup phase and the steady-state phase, during the first one, cluster formation was performed, while in the second phase the data was collected.

A. Set Up Phase

During the setup phase, the cluster head was selected using fuzzy logic approach leading to cluster formation. Initially, the WSN area was divided into equal-sized groups (K). The nodes were distributed randomly in the field and the base station moved (mobile) in a specific pattern illustrated in the next section. Initially, the ZRP-FMC protocol work with the mixed environment (fixed nodes and mobile BS). The BS moves in a specific pattern for initiating the setup phase. In each round, BS sends a request packet to all the sensor nodes in its range. After all sensor node receive their packet, each node replay to the BS packet contain) energy level, concentration, and centrality) of the node. As soon as, the BS knows the energy level and position of each node its starts applying fuzzy logic to select the cluster head and announce the CHs ID list. Each node selects a cluster to join as a member of its group. In case When the CH energy became less than the specific energy level, the CH sends a packet to BS contain its new energy level to make BS re-initiate the setup phase to recalculate the new CH list.

ISSN:2222-758X
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B. Steady-State Phase

At this phase, each regular node sends its collected data to its CH and each CH node sends its aggregated data to the next hop CH or the destination (BS) according to the minimum distance from each as in the following Eq. 1.

$$v_{i,j} = \sqrt{(x_j - x_i)^2 + (y_j - y_i)^2} \quad , \forall i \neq j,\ i = 1, ..., n+1 \quad j = 1, ...k \tag{1}$$

Where x_j and y_j are the location of the BS on the x-axis and y-axis respectively. Whilex_i and $y_i$are the location of the CH on the x-axis and y-axis respectively. When the BS sends packet messages to head nodes, then CHS will evaluate the distance between them and BS, if the BS site is within contract communication range, it will send its data directly to BS. When BS moves all other nodes will be switched to sleep mode until BS sends a packet containing its new location and all nodes will update BS position in their routing table and keep sending their data. The steady-state phase is executed in steps (10-14) in the flowchart as shown in Fig. 1.

C. Sink Mobility Pattern

The BS movement in the proposed protocol is in two different methods. The first one, the movement of the sink is on a circular path with different size diameters of the circular shape within the field. The network work has been tested based on the BS movement through a circular path with three different diameters, which are a small, medium, and large circle, where the diameter of the small circle is (22.4 m), while the diameter of the middle circle is equal to twice the small circle and its value (44.8 m) and finally the diameter of the large circle is three times the small circle and its value (67.2 m). it was shown in Fig. 2 The second method: The BS has moved in a random position inside or outside the field when the ant-lion algorithm is applied to determine the best position of the BS when any CH energy level becomes less than the specified threshold. The ant lion algorithm starts to calculate the new position of BS by generating random positions in the selected area, Calculate the fitness of initial ant-lions (the newly generated position) and sort them according to the objective function to improve network lifetime, and the average power consumption.

Steps of Ant Lion Optimization Algorithm [18] :

Ants random movement: ALO algorithm modelled using a random walk phenomenon as shown in Eq. 2. Also, a random function and a cumulative sum function are used to model the movement of the random walk over different iterations as given in Eq. 3.

$$A(i) = [0, cumsum(2r(i_1) - 1);\ cumsum(2r(i_2) - 1);\ ...;\ ...;\ cumsum(2r(i_{iter}) - 1)] \tag{2}$$

$$R(\Delta) = \begin{cases} 1 & if\, rand > 0.5 \\ 0 & otherwise \end{cases} \tag{3}$$

Where A(i) is is the set of walks for the n-th ant, cumsum is the cumulative sum, 'iter' denotes to iterations number, i denotes step size while $R(\Delta)$ is a random function that takes the value "1" if the generated random number is greater than

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0.5, otherwise "0" is assigned. Minmax equation can be done in Eq. 4

$$A_i^t = \frac{(A_{i-a_i}^t) \cdot (A_{i-c_i^t})}{(b_{i-a_i}^t)} + C_i \tag{4}$$

where a_i and b_i indicate the minimum and maximum random walk of the variable i^{th} respectively, c_i and c_i^t are the minimum and maximum value for the i^{th} a variable at t^{th} iteration respectively. Random ant walks affected by the trap designed by Ant-lion in a 2D search space. This behavior is expressed mathematically in Eq. 5.

$$\begin{aligned} c_i^t &= Antlion_j^t + c^t \\ d_i^t &= Antlion_j^t + d^t \end{aligned} \tag{5}$$

where c^t and d^t denotes the minimum and maximum of all variables on iteration-t respectively, c_i^t denotes the minimum and maximum of all variables at iteration-t for ith ant respectively, and $Antlion_j^t$ the position of the selected jth Ant-lion at iteration-t.

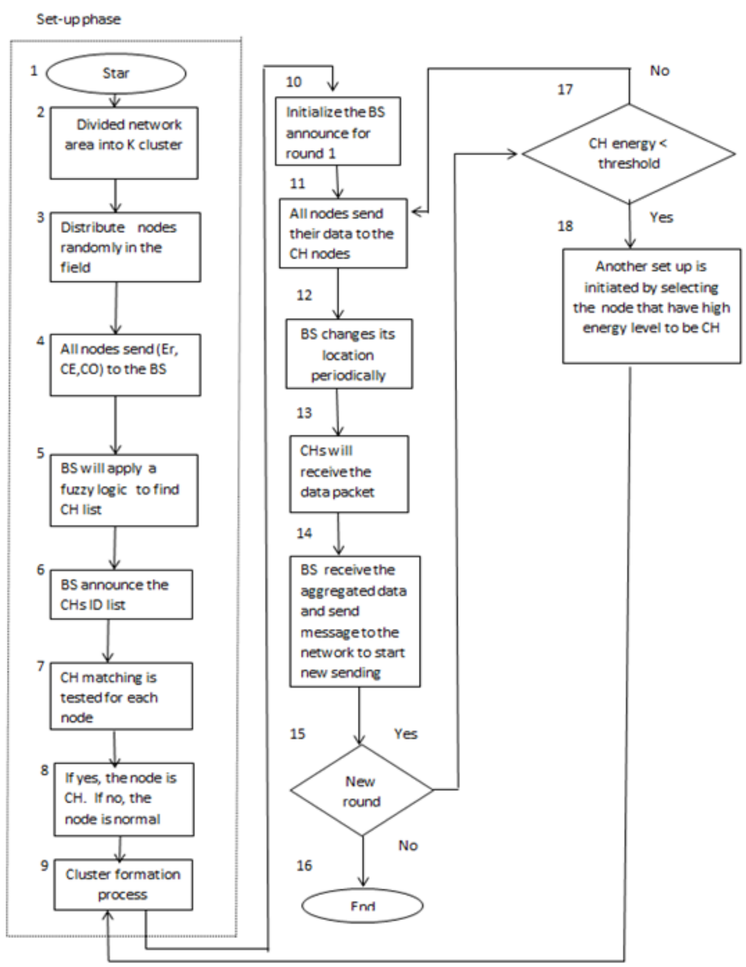

Figure 1: Flowchart summarizing ZRP-FMC operation

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Building Traps: The Ant-lion hunting behavior is modeled using a roulette wheel. Here the ant is assumed to be trapped in any one selected Ant-lion. It is used to choose an Ant-lion from its population with a high fitness value while optimizing for an ant hunt.

Ant traps: Ant lions can build their traps in proportion to their fitness value and release sand out of the center of the hole when they find the ant is inside their traps. This will cause the ant to slide down when it tries to escape from the ant lion.

Catching prey and rebuilding the trap: Ant-lion consumes the ant at the bottom of the pit and will adjust its position to build a new trap to catch new prey. Ant-lion catches the ant when the fitness of the ant is greater than the fitness of the Ant-lion as shown in Eq.6, where f (Ant) and f (Ant-lion) refer to the value of the fitness of the ant and Ant-lion respectively.

$$X_{AL,j}(t) = X_{At,j}(t) \quad if\, fitness(X_{At,j}(t)) > fitness(X_{AL,j}(t)) \tag{6}$$

Where $X_{AL,j}(t)$ is the position of chosen j-th ant-lion at t-th iteration, $X_{At,j}(t)$ is the position of ith ant at t-th iteration. The ant lion algorithm starts to calculate the new position of BS by generating random positions in the selected area, Calculate the fitness of initial ant-lions (the newly generated position) and sort them according to the objective function. Roulette Wheel Selection Algorithm used to select the index of the best position from the sorted group then the random walk function used to random walk around the selected position by Roulette wheel algorithm. The best position selected by the algorithm is called the elite. After the random walk, all position is updated then recalculate the elite. Steps of ant-lion optimization are performed by blocks (18-22) of the flowchart shown in Fig. 3.

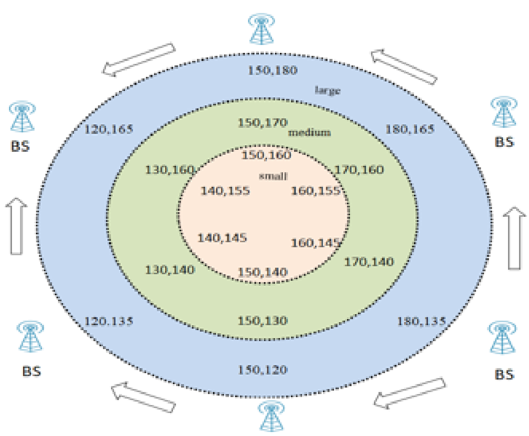

Figure 2: Different Circular Diameters

IV. Simulation Environment and Parameters

The general objective of the simulation showed the effect of the number of clusters and the movement of the sink on the lifetime of the WSN using some metrics such as FND and the amount of power dissipation in the network.

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A. Simulation Environment

proposed work tested using MATLAB R2019a running on Intel ® $Core^{TM}$ i52.7GHz CPU. Network of the proposed protocol used 100 sensor nodes, randomly distributed in $(100*100)m^2$. The initial energy was assumed as 2J of each sensor node. The performance of the proposed protocol compared with ZRP-FMC and LEACH protocol. The results obtained for the proposed algorithm improved the lifespan of WSN greatly. Also, the number of search agents is 40 while the number of generations was set to 500. Table I illustrates the network parameters used in the simulations.

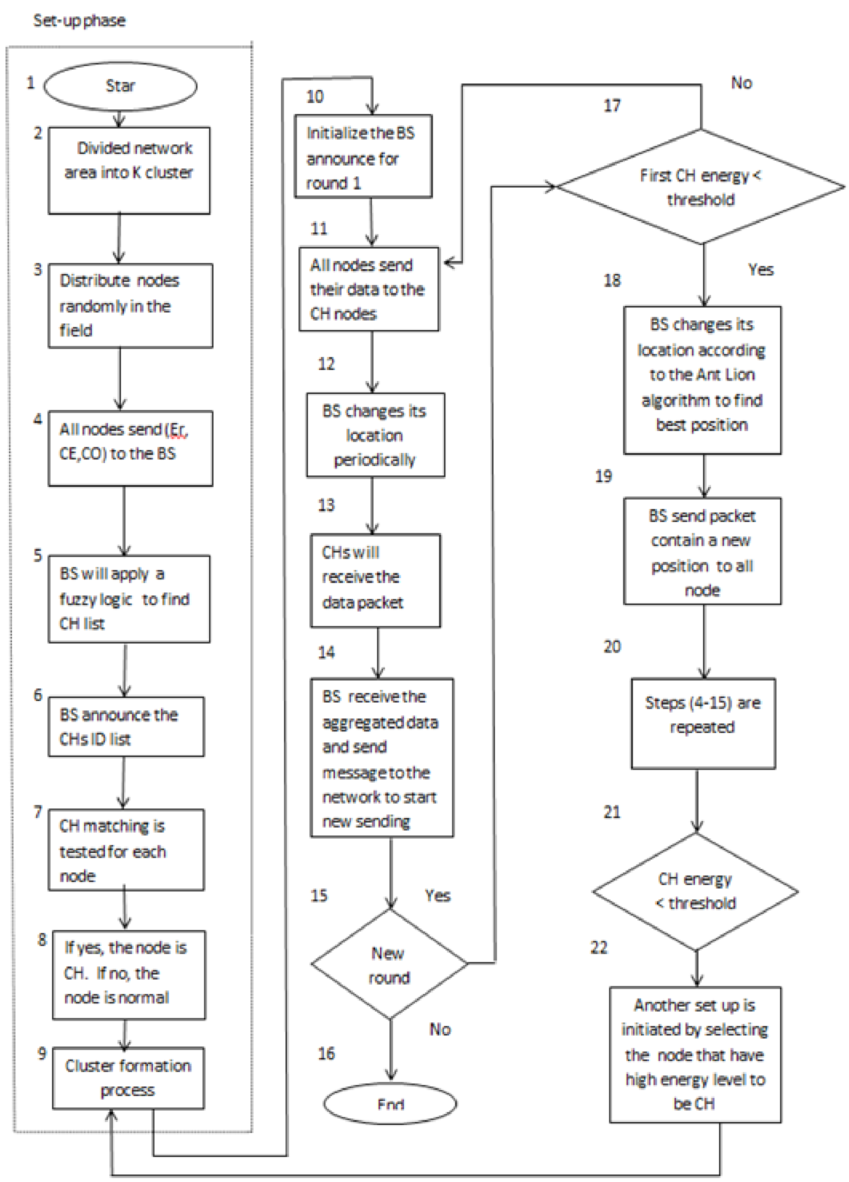

Figure 3: Flowchart summarizing ZRP-FMC-ALO operation

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TABLE I
Parameters for the Proposed Protocols

Parameters	Values
Network Size	(100 * 100) m2
Number of nodes	100
The initial energy of nodes	2 Joules
Packet length	4000 bit
Eelec	$50e-009J/bits$
Efs	$0.0013*10^{-12}J/bit/m$
Emp	$10e-012J/bit$
EBF	$5e-009J/bit$
Routing protocol	ZRP

B. Optimal Number of Clusters in the Network:

The network of the proposed work divided into many clusters, taken to be 4, 9, and 16 with the random deployment of nodes while the sink movement will be Circular with different diagonal sizes. This produces different scenarios.[5]

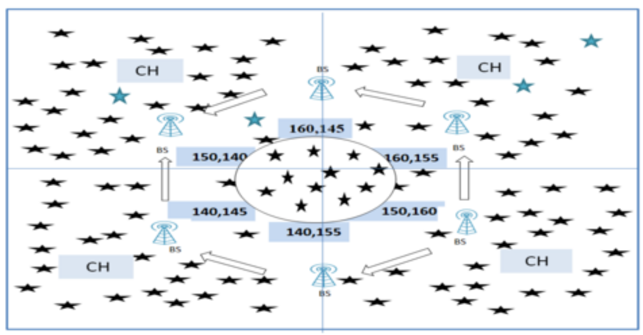

Figure 4: 4-Clusters with small circular sink movement

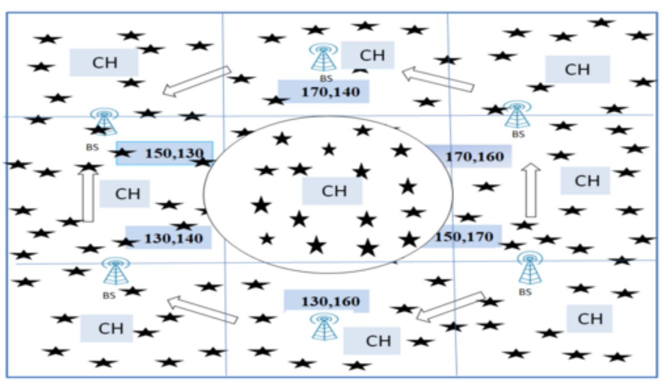

Figure 5: 9-Clusters with medium circular sink movement

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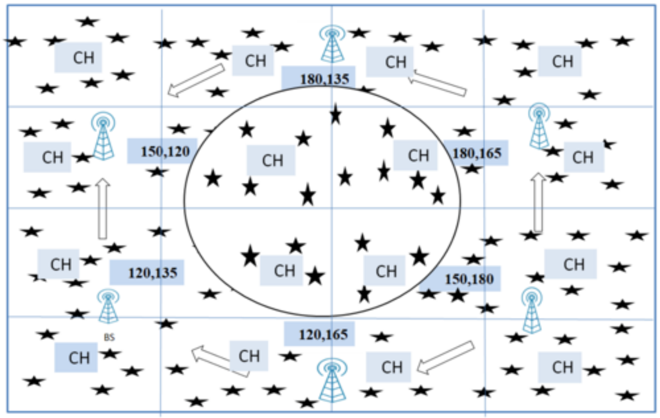

Figure 6: 16-Clusters with large circular sink movement

C. Simulation Results

Network Lifetime

The lifetime of the network has been calculated based on the number of live nodes in terms of ascending percentages range from 1% to 50%. 1% is the first node dies (FND) in the network during a certain transmission round, any WSN having a late death for its first node will be marked by the most balanced network when all nodes are alive and before the death of the first node. Table. II shows the results of the network lifetime based on the rest of the alive nodes left in the network after each communication round.

Table II shows the highest lifetime until the first node dies is obtained in (4) cluster with a Small Circular Sink Movement when ant-lion optimization is applied (SCPBS-ALO). while the maximum lifetime obtained when the last node dies is also in (4) cluster with a Small Circular Sink Movement when ant-lion optimization is applied. Therefore, the network in (4) cluster with an ant-lion algorithm can be more stable and longer lifetime.

TABLE II
Network Life Time for Different Zone number

	BS Movement on	FND at:	HND at:
4-Clusters Scenario	Small circular path	3743	4009
	Medium circular path	3727	3989
	Large circular path	3653	3909
4-Clusters Scenario with ALO	Small circular path	4349	4580
	Medium circular path	4318	4557
	Large circular path	3583	4354
9-Clusters Scenario	Small circular path	2769	3018
	Medium circular path	2687	2933
	Large circular path	2575	2818
9-Clusters Scenario with ALO	Small circular path	3425	3708
	Medium circular path	3115	3427
	Large circular path	3068	3339
16-Clusters Scenario	Small circular path	1281	1450
	Medium circular path	1212	1383
	Large circular path	1125	1304
6-Clusters Scenario with ALO	Small circular path	1590	1900
	Medium circular path	1435	1748
	Large circular path	1322	1515

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Average energy consumption

The average power consumption of the proposed protocol is compared with the number of iterations of the sensor node. The total energy of all sensor nodes is 200 J (i.e. 100 node E/ S = 2J is Average Energy Dissipation). Fig. 7 shows that 4-clusters scenario when the BS move in the small circular range with the ant-lion algorithm(SCPBS-ALO) is the best for the network lifetime compared with other scenarios since a large number of head nodes would be near in the small diagonal size and the base station change its position to select the best path for gathering data when ant-lion algorithm applied notice the energy consumption is reduced.

Figs. 7, 8, 9 : illustrates that the average energy dissipation in its best case within the scenario-small circular diagonal size whether in case ant-lion algorithm (SCPBS-ALO) or without (SCPBS), because the load is equally distributed among CH nodes and at the same time the distance between head nodes become less than it within the medium & large circular diagonal size (MCPBS & LCPBS), also in the medium & large circular diagonal size increasing the multi-hop transmission and reception so the average energy consumption is increased.

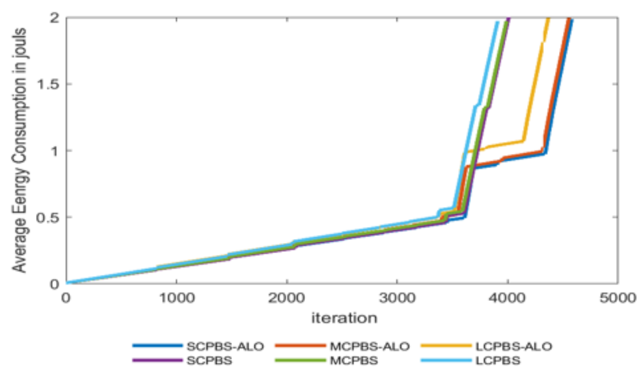

Figure 7: Average energy dissipation 4-clusters

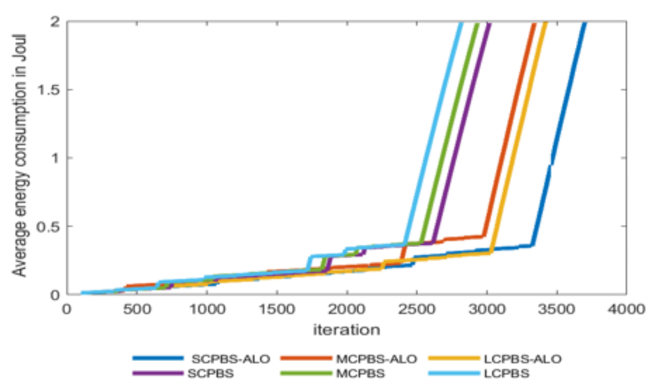

Figure 8: Average energy dissipation 9-clusters

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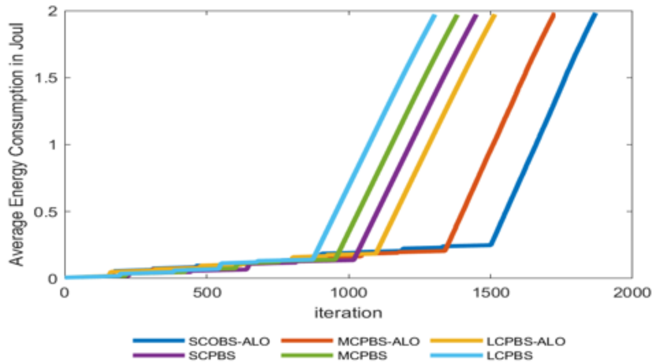

Figure 9: Average energy dissipation 16-clusters

V. TESTING AND COMPARISON FOR ZRP-FMC-ALO

Testing and Evaluations of the proposed protocol show that the best result of energy consumption for all cases is when the network contains 4-clusters and a small circular diagonal sink movement with an ant-lion optimizer (SCPBS-ALO) and compare it with the LEACH protocol. The proposed protocol was compared with other protocols based on the following metrics:

1) **Network lifetime:** The network lifetime depends on the number of live nodes in each iteration. Fig. 10 shows that the proposed protocol (ZRP-FMC-ALO) is more stable than with ZRP-FMC and LEACH protocol because of the delay in the appearance of the first death node and last death node as compared with the other protocols.

TABLE III
Network Lifetime

Protocol	FND	HND
LEACH	1075	1611
ZRP-FMC	3743	4009
ZRP-FMC-ALO	4349	4580

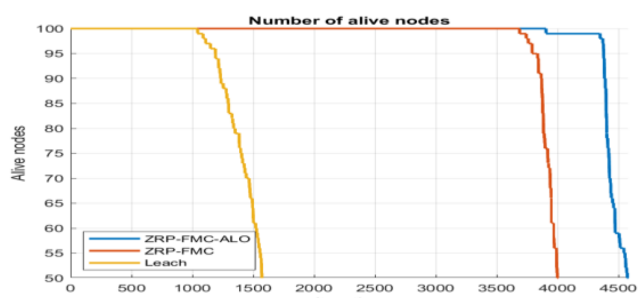

Figure 10: Number of alive nodes per iteration

2) **Average energy consumption:** As showing in Fig. 11. Protocol ZRP-FMC-ALO is consumed lesser amounts of energy along with some iteration compared with the ZRP-FMC protocol that died in round 4009. Then, LEACH has died at

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around 1611. This, in turn, gives an important indicator that the network behavior is balanced and controlled which gives a good outcome for the whole network. Thus, as a result, you can notice the effect of the ant-lion algorithm and the mobile sink node. Therefore, the energy consumption is reduced as much as possible and the network lifespan is maximized.

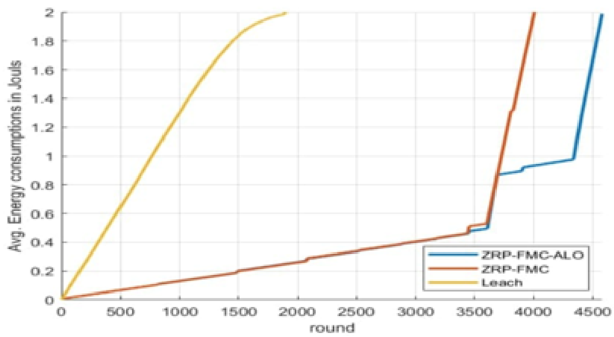

Figure 11: Average energy consumption

TABLE IV
Average Energy Consumption for Several round Comparisons

Iteration / protocol	1000	2000	3000	4000
LEACH	1.3214J	0	0	0
ZRP-FMC	0.1828J	0.3418J	0.4548J	0
ZRP-FMC-ALO	0.1989J	0.3924J	0.5945J	1.1917J

VI. Conclusion

The efficiency of energy consumption and data gathering schemes represents the main challenge that is facing designers in WSN. To overcome this problem, this paper designed a fuzzy clustering protocol based on a zone routing protocol (ZRP) that works with mixed environments contain fixed node and sink mobility for a data-gathering mechanism named (ZRP-FMC). Besides that, it also introduced an ant-lion algorithm to improve the reduction of the average energy consumption by choosing the best position of sink node this protocol named (ZRP-FMC-ALO). As a conclusion, results show that the ZRP-FMC-ALO outperforms ZRP-FMC and LEACH in terms of networks lifetime (FNDs) by 16.19%, 304.5% respectively, (HND) by 14.24%, 184.29% respectively, and in terms of average consumed the ZRP-FMC-ALO outperforms LEACH after 1000 round by 84.9% and outperforms ZRP-FMC after 3000 round by 30.7%) respectively.

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