Title: Construction of efficient Wireless Sensor Networks for Energy Minimization using a modified ACO Algorithm.

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GRAPHICAL ABSTRACT

Step 1: A Deployment Strategy has been chosen from different deployment strategies. (Random, Spiral, S-shaped)

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Step 2: Indexing of each and every node of Wireless Sensor Network (WSN) has been done.

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Step 3: Area-wise clustering has been implemented for target Wireless Sensor Network.

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Step 4: Cluster head for each and every cluster of the Wireless Sensor Network has been selected.

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Step 5: Modified Ant Colony Optimization has been applied to get the optimized energy consumption.

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Step 6: Energy minimization and number of days (saved) has been calculated for the whole WSN.

Abstract: In this paper, we have proposed different deployment strategies and we have applied Area-wise clustering along with modified Ant Colony Optimization to minimize energy consumption.

- **Background**: Previously some deployment strategies were used to enhance the lifetime of WSN but in our research, we have applied some novel deployment strategies (random, spiral, and S-pattern) along with a novel clustering process (i.e., Area-wise clustering) to get better results than the existing literature as shown in Table 4.
- **Objective:** The main objective of the research article is to enhance the lifetime of Wireless Sensor Network with the help of different deployment strategies (random, spiral, and S-pattern), a novel clustering process (i.e., Area-wise clustering), and a Meta-heuristic algorithm (modified ACO).
- **Method:** We have applied different methods for deployment strategies (random, spiral, and S-pattern), clustering process (i.e., Area-wise clustering), and modified versions of ACO to get the desired results.
- **Results:** Random Deployment: 11.15 days to 15.09 days.
  Spiral Deployment: 11.25 days to 15.23 days.
  S-Pattern Deployment: 11.33 days to 15.33 days.
- **Conclusion:** In this paper, efficient Wireless Sensor Networks have been configured considering energy minimization as the prime concern. To minimize the energy consumption a modified ACO algorithm has been proposed. In this research, the minimization of energy consumption leads to an increment of the lifetime of WSN to a significant margin theoretically. The obtained result has been compared with the existing literature and it has been found that the proposed algorithm produced a better result than the existing literature.

Keywords: Wireless Sensor Network (WSN), Deployment Strategy; Clustering Process; Ant Colony Optimization (ACO); Meta-heuristic Methods; Cluster Head (CH).

1. INTRODUCTION

A wireless sensor network is employed in various fields like medicine, agriculture, meteorology, etc. WSN eases many tasks in real life especially in the area of surveillance. It can be a solution to some inspiring problems like “War Field Monitoring”, “Temperature Sensing”, “Pressure Sensing”, etc. Apart from sensing the major job of WSN is to transmit and receive data in the network. Wireless Sensor Network has a good range of applications in modern technology. WSN is a tiny device having sensing, communicative, processing, and storage units with power back-up usually by a non-rechargeable battery. The WSN nodes are deployed within the target area to collect various sorts of important information and transfer that information to the sink node. Nowadays this sort of network is getting used to facilitate the modern army for “environmental monitoring” [1], “Battlefield Monitoring” [2], “Body Area Network” (BAN), “Intelligent Household”, “Smart Home System” etc. The Sink node [3] is the controller communicative node acting as an administrator node in the WSN.

Depending upon the nature of WSN, it is classified into two types and those are static WSN [4] and dynamic WSN [5]. In the case of static WSN, the whole unit is mounted and fixed to a certain fixed point (co-ordinate system is maintained referencing “sink node” as origin). In the case of dynamic WSN, the node is dynamic, though the sink node is generally mounted to a fixed coordinate (generally considered as origin). Now depending upon the need and purpose the node is selected to develop the communication network. In our experiment, static nodes were used where the coordinate of the sink node [6] as well as typical nodes are fixed and permanent (considered as origin).

In the case of a typical WSN design, the sensor nodes are deployed to cover the target area. [7]. The sensor nodes are deployed to sense the required data like weather information or enemy related information in case of the battlefield of modern war system and transfer it to the sink node may be directly or via another sensor node. Now in the case of our research, the target area has been clustered. A cell structure is defined as the arrangement of cells in a particular network. The cell structure may be triangular or square in structure but not circular. A circular cell structure leaves out a lot of areas. Out of the remaining square was chosen as the triangular structure cannot cover more area as compared to the square cell structure. In this paper, our objective is to minimize the energy consumption of a WSN. The traversal path is being minimized to cover every cell of the particular path as well as the traversal path between the sink node and cells. The movement of the ants motivated us in using a modified Ant Colony Optimization technique though which provides us the shortest path.

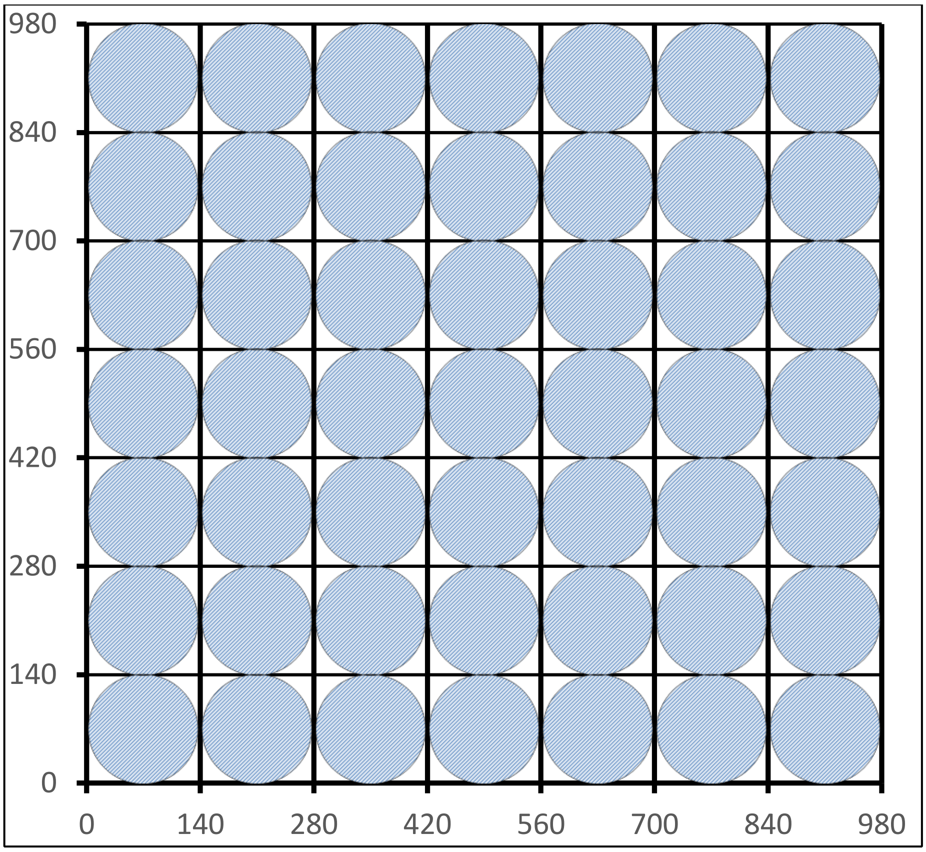

Figure 1: Clusterization of the whole area using a circular cluster cell structure.

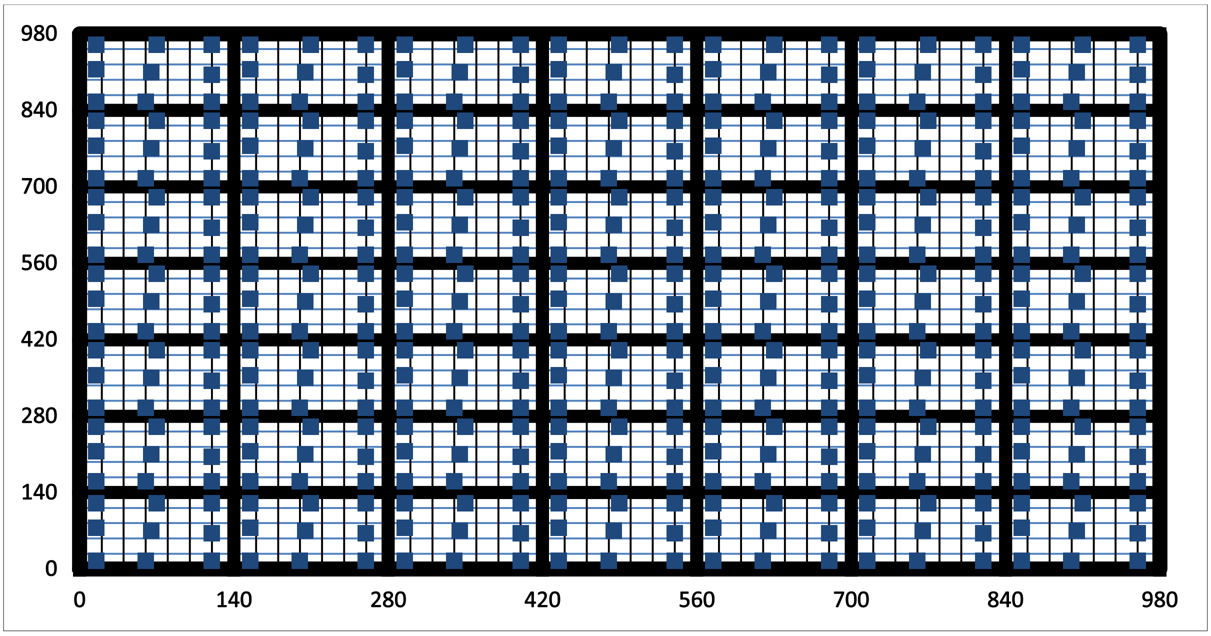

Figure **2**: Clusterization of the whole area using a square cluster cell structure.

The shaded circle indicates the clusterization of the whole area using a circular cluster cell structure (Figure 1). We can see that there are gaps between the circular clusters [8] which lead to wastage of space. Due to this reason, circular clustering has not been adopted.

The whole area has been divided into multiple square structures (Figure 2). The dots in the figure denote the position of WSN nodes. The nodes have been arranged in such a manner that the maximum area is covered by each node while maintaining the uniformity. This deployment will vary in the case of real-life WSN deployment.

Each cell consists of more than one sensor node (denoted as N). The sink node (denoted as SN) acts as a control point like the local server node [9]. The main aim of the network is to transfer information from one node of a particular cell to another node of an adjacent cell using minimum total power consumption. Each cell is considered as one cluster and each cluster having an active sensor node. The active node of each cluster is called Cluster-Head (CH) [10] The Cluster-Head is connected with another Cluster-Head of a different cell or cluster and thus a network is established. The established network will persist until all Cluster-Head becomes fully exhausted due to a shortage of power backup and after that, the exhausted Cluster-Head will be replaced by another Cluster-Head and so on until all cluster heads of the cluster become exhausted. Here two types of communication will take place i.e., inter-cluster communication (CH-CH communication) [3] or Sink-Cluster communication (SN-CH communication).

The WSN lifetime is dependent on the battery life of the WSN. The lifetime of WSN depends upon so many design factors like the “Deployment Strategy” of WSN nodes and the “Clustering Process”. The deployment strategy has a great effect on the power consumption and network coverage of sensor networks. In the clustering process, the area is divided into many clusters for creating the congestion-free transmission. After clustering, some specific nodes are selected to design the network and some of them are designated as “Cluster Head” or “Leader node” for those clusters. After that, a modified version of the ACO algorithm has been implemented for getting the shortest path to design an effective and succinct network for the minimization of energy consumption. The obtained result by applying different deployment strategies has been compared with an identical network of various works of literature. A significant amount of energy saving has been observed and recorded for the proposed algorithm. The obtained result has been compared with some existing literature and it claimed better results than other implemented results of existing literature.

In section 2 we have done the “Literature Survey” which indicates the related work about WSN by different researchers. After that, the “Solution Methodology” is described in section 3 where we have discussed how a modified ACO helps to find the shortest path. Then after sections 5 and 6, we have introduced “Numerical Data Analysis” and Data Representation” where we displayed the data in terms of tables and pictures. In section 6 we have explained the “Result Analysis” which has been represented in terms of the “number of days” the network can sustain. At last, we have completed a “Cnclusion” in section 7 which discussed the scope for future work.

2. LITERATURE SURVEY

Kurt et al. [11] has suggested a new power optimization technique to increase network lifetime. Pughat et al. [12] have proposed the technique of DPM (Dynamic Power Management) which helps to control the duty cycle efficiently which helps in minimize power consumption. Yildiz et al. [13] explained how minimized handshaking helps in reducing the optimized power level which in turn increases the lifetime of the WSN. Akbas et al. [14] discussed how to maintain a balance between data packets size and transmission energy. Small data packet size increases the transmission energy while large data packet size will be difficult to transmit hence can result in loss of data. Hua et al. [15] suggested the concept of a UAV (unmanned aerial vehicle) that helps in establishing a flexible movement path that helps in reliable communication. Lei et al. [16] Expressed the concept of IWSMACO which is a modified version of ACO (Ant colony optimization) based on the information weight factor. Paniri et al. [17] Suggested MLACO (method based on ant colony optimization) which uses supervised and unsupervised learning algorithms. Arjunan et al. [18] Introduce a hybrid algorithm based on fuzzy logic unequal clustering and ACO. Here fuzzy logic is used to select cluster heads. Gajjar et al. [19] Explained how the LEACH cluster algorithm can be used to select cluster heads which reduces the consumption of energy. Boubrima et al. [20] suggested that deployment is an important concept of WSN. Aznoli et al. [21] Proposed deployment can be classified as deterministic and non-deterministic. Tsai et al. [22]

Introduced a new meta-heuristic algorithm called SE (Search Economics) to solve the deployment problem of WSN. Benatia et al. [23] Proposed MODS (Multi-Objective deployment strategy) for solving the placement problem to optimize it. Arya et al. [24] Suggested optimizing the physical distance and signal strength between two nodes. Mohajerani et al. [25] Advise us to use a routing algorithm that uses special parameters to reduce energy consumption by each node. Gajjar et al. [26] explained to use a combination of ACO based MAC and unequal clustering cross-layer protocol for cluster head selection. Nayyar et al. [27] suggested using swarm intelligence based computational techniques to improve the overall WSN. Wang et al. [28] suggested that information could be exploited fully and used in the later optimization process; the quality of the succeeding solutions would be improved significantly. Guo et al. [29] said his paper introduces the chaos theory into the KH optimization process intending to accelerate its global convergence speed. Gao et al. [30] explained the advantage of the DE algorithm is that it uses a special evolutionary strategy of difference vector sets to carry out mutation operation. Wang et al. [31] suggested that by simplifying and idealizing the migration of monarch butterflies, a new kind of nature-inspired met heuristic algorithm, called monarch butterfly optimization (MBO) can be constructed. Gu et al. [32] mentioned the problem of NSGA-III. Yi et al. [33] discussed the drawbacks of MOEAs. Zhang et al. [34] introduced the information feedback models to improve the ability of NSGA-III to solve large-scale optimization problems. Gu et al. [35] proposed the standard MOEA/D algorithm, the update process of individuals is a forward search process without using the information of previous individuals.

3. SOLUTION METHODOLOGY

In our paper, a modified version of the ACO algorithm is implemented for the minimization of consumed energy in WSN. This technique has acquired attention due to its precision towards the optimal results. In Ant Colony Optimization, several artificial ants build solutions are considered towards the optimization problem. These exchange data about the quality of these results via a communication media, "pheromone trail, which is reminiscent of the one adopted by real ants" [36].

The original ACO algorithm acknowledged as the Ant System was presented in [36]. A brief discussion on ACO is followed next.

In this algorithm, we have used the ants as the solution variance which solves the optimization problem by applying the state transition rule. The solution can be enhanced by "the Local Search Algorithm". Then the ant adapts "...the amount of pheromone on the visited edges by applying a local pheromone updating rule" [36]. Once all ants have finished their operations, "the amount of pheromone is modified by applying a global updating rule" [36]. ACO activity may be realized with the following two equations Equation 1 and Equation 2.

$$\tau_{ij} = \begin{cases} (1-\rho).\tau_{ij} + \rho.\Delta\tau_{ij}, & \text{if(i, j)} \in \text{best solution} \\ \tau_{ij} & \text{otherwise} \end{cases} \tag{1}$$

The local pheromone updating rule is shown in Equation 2.

$$\tau_{ij} = \{\tau_{ij}.(1-\varphi) + \varphi.\tau_0 \tag{2}$$

Contribution: Modification in ACO algorithm: At first the ANT solution is updated using the local update rule. Then the updated ANT solution is modified using the global update rule and ultimately the ANT solution is compared with a previous feasible solution and has taken the following strategies:

a) If both (before modification by global update rule and after modification by global update rule) solution is feasible then choose the ANT solution for which the nearest value of global optimum is achieved.
b) If anyone solution is in-feasible then discard it and obtain the feasible ANT solution.
c) If both (before modification by global update rule and after modification by global update rule) solution is in-feasible then discard the ANT solution and find the next ANT solution.
d) In this paper, a modified meta-heuristic algorithm is used (i.e., modified ACO algorithm) that has been used, for selecting the cluster head of the efficient WSN to get the efficient network route.
e) In the modified ACO there are 2 types of updates (i.e. global update as well as a local update) the global update guarantees to obtain the nearest value to the global optimum.in other cases, the local update rule guarantees local optimum to the nearest value in our modified ACO algorithm we have used at first the local update rule and then the global update rule. If the solution is found in the local optimum then the solution will be selected and if the solution is found in global optimum the global optimum selected. In this strategy, we can do the local search as well as global search therefore there is

every chance to miss out on any feasible solution from the solution space. In the case of DE-QPSO there is some chance to miss out the local or global solution because de is generally used for global searching and PSO used for local searching.in our proposed modified ACO as we are searching the local solution(using local update rule) firstly and then the global solution, therefore, there is very less chance to miss out any solution. Therefore we can tell our proposed algorithm as a local search among global search, which is the specialty of our proposed modifies algorithm.

Pseudo-code for modified ACO

Step 1: Initialize the parameters of the ACO algorithm, including the number of ants to be deployed, the maximum number of iterations, the tune-able parameters, and the initial level of pheromone.
Step 2: Randomly select a node within any cluster and select the other node from another cluster until all the clusters are covered and follow the ACO rule (ACO update rule).
Step 3: If all paths have been traversed by each ant, then continue; otherwise go to step 2.
Step 4: Evaluate the path using the update rule to achieve accuracy depending upon verification.
Step 5: After evaporation of the pheromone, find the ant with the best path. Only permit those ants to deposit pheromone on its traversed paths. If the maximum number of iteration max has not reached go back to step 2; otherwise, go to the next step.
Step 6: Search for the globally best path which produces the highest accuracy among all local best solutions.
Step 7: End

In this paper, the entire process of network formation has been done through the following steps:
3.1. Indexing for Sensor Nodes: The sensor nodes to be deployed must be indexed virtually to denote or keep track of each sensor nodes before and after the deployment. This indexing process will also help to construct the network. The indexing has been proposed with the help of row and column number of the cell (as depicted in figure 2.). It also helps us to know the row and column number of the matrix of the target area. The indexing is a sequential number.

The Overall Proposed Algorithm

Step 1: A Deployment Strategy has been chosen from different deployment strategies. (Random, Spiral, S-shaped)
Step 2: Indexing of every node of Wireless Sensor Network (WSN) has been done.
Step 3: Area-wise clustering has been implemented for the target Wireless Sensor Network.
Step 4: Cluster head for every cluster of the Wireless Sensor Network has been selected.
Step 5: Modified Ant Colony Optimization has been applied to get the optimized energy consumption.
 Step 5A: Initialize the parameters of the ACO algorithm, including the number of ants to be deployed, the maximum number of iterations, the tune-able parameters, and the initial level of pheromone.
 Step 5B: Randomly select a node within any cluster and select the other node from another cluster until all the clusters are covered and follow the ACO rule (ACO update rule).
 Step 5C: If all paths have been traversed by each ant, then continue; otherwise go to step 2.
 Step 5D: Evaluate the path using the update rule to achieve accuracy depending upon verification.
 Step 5E: After evaporation of the pheromone, find the ant with the best path. Only permit those ants to deposit pheromone on its traversed paths. If the maximum number of iteration max has not reached go back to step 2; otherwise, go to the next step.
 Step 5F: Search for the globally best path which produces the highest accuracy among all local best solutions.
 Step 5G: End of modified ACO.
Step 6: Energy minimization and the number of days (saved) has been calculated for the whole WSN.
Step 7:End of the proposed algorithm.

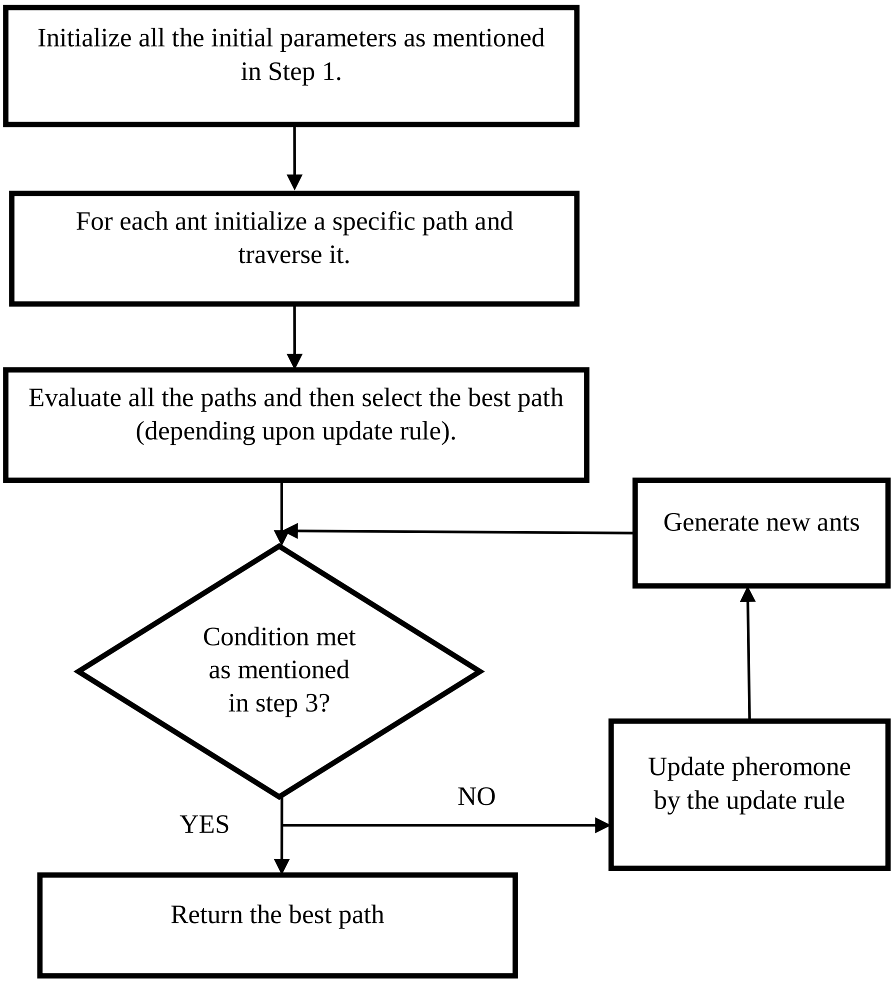

Figure **3**: Flowchart of the modified ACO algorithm

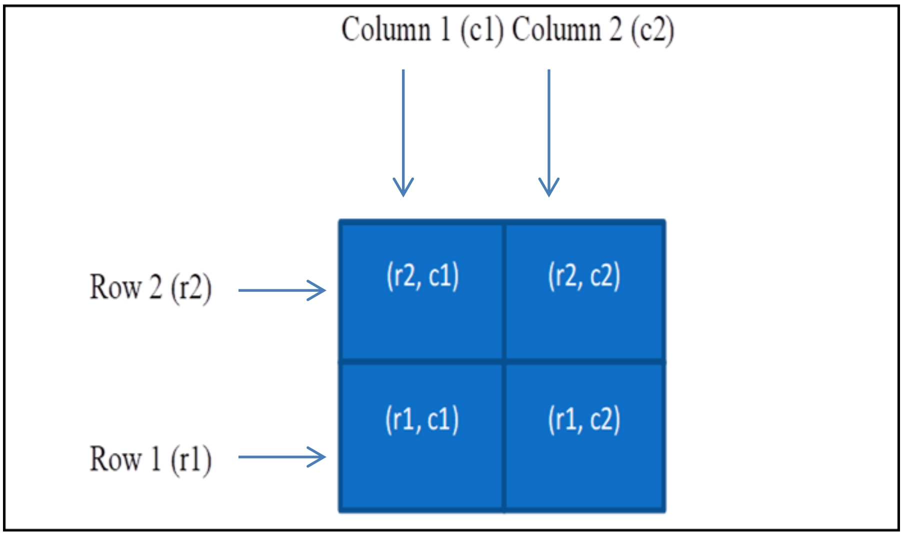

Figure 4: Structure of cluster cell and their representation

3.1.1. Indexing before Deployment: This is the indexing that is given to the sensor node before deployment. It will help us to keep track of the total number of sensor nodes to be deployed and to maintain the sequence of sensor nodes. (Figures 6, 7, 8, 10, 11, 12, 14, 15, 16).

3.1.2. Indexing after Deployment: This type of indexing much more important because this indexing is assigned to the sensor nodes after deployment. By this indexing, the sensor node will be denoted until the sensor node becomes fully exhausted. (Figures 9, 13, 17)

3.2. Clustering: Here clustering means dividing the target area into some uniform or equal-size sectors. The aim is to construct an efficient network. The structure of cluster cells has been chosen as a square. It can be proved [37] that using square cluster-cell the target area can be covered properly. Here the term "efficient network" refers to the efficient and uniform coverage of the target area with no communication gap between the neighboring clusters. The importance of the clustering process to minimize energy is to segregate the target area into uniform sectors which will help to construct an efficient network as well as to cover the target area uniformly.

3.3 Different strategies for the deployment of WSN nodes:

The importance of deployment strategies to minimize the energy of WSN is to predict the position of nodes in the WSN especially in case of S-pattern deployment as well as spiral deployment.

In the case of random deployment, it is not so easy to predict the position of WSN nodes but this deployment is realistic deployment strategies which are very practical in a real-life situation, therefore, this strategy has been considered in our work.

3.3.1. Random deployment of sensor nodes: Here we consider the deployment to be done from a certain distance. In the case of random deployment, it is very difficult to predict the position of sensor nodes. A fixed amount of nodes are deployed for a fixed amount of time. For example, suppose we have to deploy x amount of sensor nodes in y amount of time. Therefore we don't have any fixed strategy to cover the target area.

3.3.2. S-pattern deployment: In this type of deployment deployment-strategy follow the S-pattern deployment of sensor nodes. The deployment time is considered a fixed period. The time interval between two deployments is assumed as fixed time and the path is followed as a fixed path.

Here the starting time and ending time of deployment are fixed and the deployment is done in between this period (see figures no 5 to 7).

3.3.3. Spiral deployment: In this type of deployment we follow the Spiral-pattern at the time of deployment of sensor nodes, other criteria are the same as previous deployment.

3.4. Selection of a sensor node as cluster head: The selection process has been done with the help of a meta-heuristic algorithm i.e., ACO algorithm. The selection of a sensor node as a cluster head (CH) is an important job towards the development of an efficient network configuration because with the help of the cluster head only the internal network is formed.
Here in this paper, the selection of the cluster head has been done by calculating the uniform distance between different nodes in a cluster maintaining the following conditions:

a) One cluster head has been selected from each cluster and the process has been done with the help of a meta-heuristic algorithm i.e., modified ACO algorithm.
b) After the full exhaustion of energy of one cluster head, another sensor node is considered as an active cluster head and the previous cluster head becomes inactive.
c) The intermediate network will sustain for some time and when the cluster head of any cluster cell will be exhausted it will form another network thus it will give stability to the whole network to perform for a longer period and ultimately when all the sensor-nodes of a particular cluster will be exhausted the whole network will go down.

3.5. WSN network configuration through modified ACO algorithm:

In the ACO Algorithm, we choose the minimized path for transmitting and receiving information among the nodes.
The linear problem as described below:
The energy consumption during successful data transmission between cluster head (CH) to cluster head (CH) and cluster head (CH) to sink node (SN) has been calculated and minimized using the below-maintained equations:
The energy consumption during successful data transmission between cluster head (CH) to cluster

head (CH) and cluster head (CH) to sink node (SN) has been calculated and minimized using the below-maintained equations [39]:

$$\text{Minimize}\left(E_{\text{communication}}^{\text{Total}}(R,d)\right) \quad (3)$$

Subject to,

$d \leq d_o$, for free-space propagation model and $d > d_o$ for two- ray ground propagation model.

Where d_o is the threshold transmission distance.

Here R is the size of the data packet to be communicated.

Where,

$$E_{\text{communication}}^{\text{Total}}(R,d) = E_{\text{receiving}}^{\text{Total}}(R) + E_{\text{transmission}}^{\text{Total}}(R,d) \quad (4)$$

$$E_{\text{receiving}}^{\text{Total}}(R) = E_{\text{receiving}}^{\text{SN-CH}}(R) + E_{\text{receiving}}^{\text{CH-CH}}(R) \quad (5)$$

$$E_{\text{transmission}}^{\text{Total}}(R,d) = E_{\text{transmission}}^{\text{SN-CH}}(R,d) + E_{\text{transmission}}^{\text{CH-CH}} \quad (6)$$

$$E_{\text{transmission}}^{\text{SN-CH}}(R,d) = E_{\text{charge}}^{\text{SN-CH}}(R) + E_{\text{resonator}}^{\text{SN-CH}}(R,d) . \quad (7)$$

$$E_{\text{transmission}}^{\text{CH-CH}}(R,d) = E_{\text{charge}}^{\text{CH-CH}}(R) + E_{\text{resonator}}^{\text{CH-CH}}(R,d) \quad (8)$$

$$E_{\text{receiving}}^{\text{SN-CH}}(R) = E_{\text{charge}}^{\text{SN-CH}}(R) * (R) \quad (9)$$

$$E_{\text{receiving}}^{\text{CH-CH}}(k) = E_{\text{charge}}^{\text{CH-CH}}(R) * (R) \quad (10)$$

$$E_{\text{resonator}}^{\text{SN-CH}}(R,d) = E_{ts}^{\text{SN-CH}} * d^2 \quad (11)$$

$$E_{\text{resonator}}^{\text{CH-CH}}(R,d) = E_{ts}^{\text{CH-CH}} * d^2 \quad (12)$$

$E_{\text{resonator}}^{\text{CH-CH}}$ = energy required for the transmitting data packets between two adjacent cluster head for the amplifier to maintain an acceptable signal-to-noise ratio to transfer data messages reliably.

$E_{\text{resonator}}^{\text{SN-CH}}$ = energy required for the transmitting data packets between sink node and cluster head for the amplifier to maintain an acceptable signal-to-noise ratio to transfer data messages reliably.

$E_{\text{charge}}^{\text{CH-CH}}$ =Electronic energy degenerated during the transmission between two adjacent cluster heads.

$E_{\text{charge}}^{\text{SN-CH}}$ =Electronic energy degenerated during the transmission between the sink node and adjacent cluster head.

$E_{\text{transmission}}$ = amount of energy used by each node at the time of transmitting data packets.

$E_{\text{receiving}}$ = energy used for receiving data packets.

Measurement of distance between two cluster heads is done using the following formula

$$d_{xy} = \sqrt{(x1 - x2)^2 + (y1 - y2)^2}$$

E_{ts}= Amount of energy consumption by a single node for free-space propagation

Where (x1, y1) and (x2, y2) are coordinates of reference nodes and d_{xy} is the distance measured between two adjacent cluster heads and the notation d_{xy} and d are the same.

Now in terms of minimizing the total energy transmission and using the proposed ACO algorithm, the optimized path has been established as shown in Figure 5. The data used from Table 1. After getting an efficient path through the meta-heuristic algorithm i.e., ACO total energy saved was determined in hours. In this paper, the tolerance percentage has been fixed to ±15% which is the most acceptable tolerance in the case of Wireless Sensor Network. The designed network is an efficient network concerning the minimization of energy consumption.

In this section, the energy minimization problem was solved using ACO. The proposed method was tested using the data of Table 1 using the ACO algorithm and obtained the optimized path for the network for minimizing energy consumption.

The following parameter values are used in the experiment for simulating the system. [40].

4. NUMERICAL DATA ANALYSIS

Table **1**: Parameters for simulation.

Parameters	Values	Parameters	Values
Deployment Area	980 x 980 m^2	Data packet size (R)	4096 bits
Total number of Clusters	49	Max no. of nodes (in the network)	490
The initial energy of each node	1J	E_{charge}	50nJ/bit
E_{ts}	10pJ • bit−1 •m−2	Maximum Number of Rounds	6000

In Table 1, different units (Joule, Nano Joule, and Pico-Joule) were used Therefore to maintain uniformity, all calculations have been done in Pico-Joule in Table 2, Table 3, and Table 4.In this paper the best path is plotted for shortest distances (see

Figures 9, 13, 17) obtained from the ACO algorithm for different deployments by solving the equations 1 to 10 based on the data supplied in Table 1. As the energy consumption is directly proportional to the distance between nodes that's why we have calculated the maximum coverage area. Table 1 shows the communication between the sink node and the cluster head, whereas Table 2, 3, and 4 shows the communication between adjustment cluster heads. In the below diagram we are going to show the 4 phases of forming a network and finding the shortest path. The first process is the deployment were three strategies namely random, spiral, and S-pattern have been used (see Figures 6, 10, and 14 respectively). The next step is the division of the nodes into clusters or clustering (See Figures 7, 11, 15). The third process consists of electing the Cluster Heads. (See Figures 8, 12, 16) and the fourth process includes connecting all the cluster heads among themselves using the ACO algorithm (See Figures 8, 12, 16).

5. NUMERICAL DATA REPRESENTATION

Now the numerical data is being represented with the help of tabular format depicted below. With the help of table 2, Energy Saving (E_s) calculations applying random deployment and Area-wise clustering processes have been done. With the help of table 3, Energy Saving (E_s) calculations have been done applying spiral deployment and Area-wise clustering process. With the help of table 4, Energy Saving (E_s) calculations applying S-pattern deployment and Area-wise clustering process have been done.

We have used certain notations to calculate the energies. A brief description of them is given below. (This notation can be found in Tables 2,3 and 4)

1) E_tx0: This indicates the actual energy required to transform the data packets from one node to another (equation 5 and 6)
2) E_tx(min): This is E_tx0 but after applying minimum possible tolerance.
3) E_tx(max): This is also E_tx0 but after applying maximum possible tolerance.
4) total0: This the total energy required during the whole communication (transmitting and receiving) among the nodes.
5) totalxy(min): This is the total energy required but after applying minimum possible tolerance.
6) totalxy(max): This is the total energy required but after applying maximum possible tolerance.
7) maxEng: This is the difference between totalxy(max) and totalxy(min).
8) minEng: This is the difference between total0 and totalxy(min).
9) avgEng: This is the difference between totalxy(max) and total0.

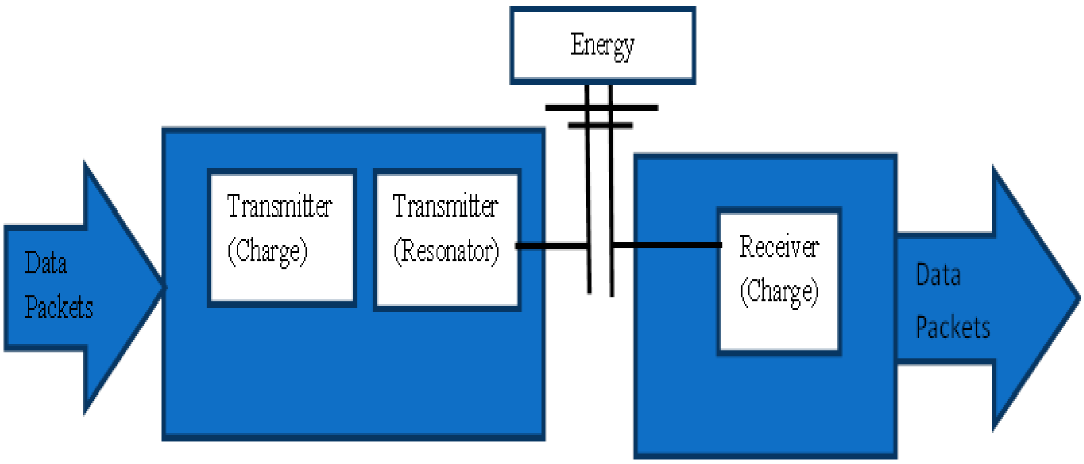

Figure 5: Block Diagram of WSN nodes with transmitter and receiver

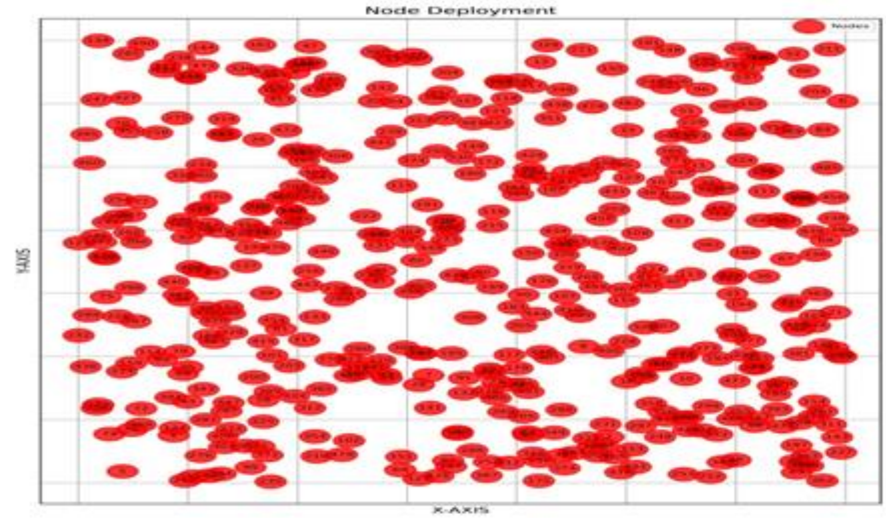

Figure 6: Random deployment: The above figure shows the random deployment of the nodes in the area.

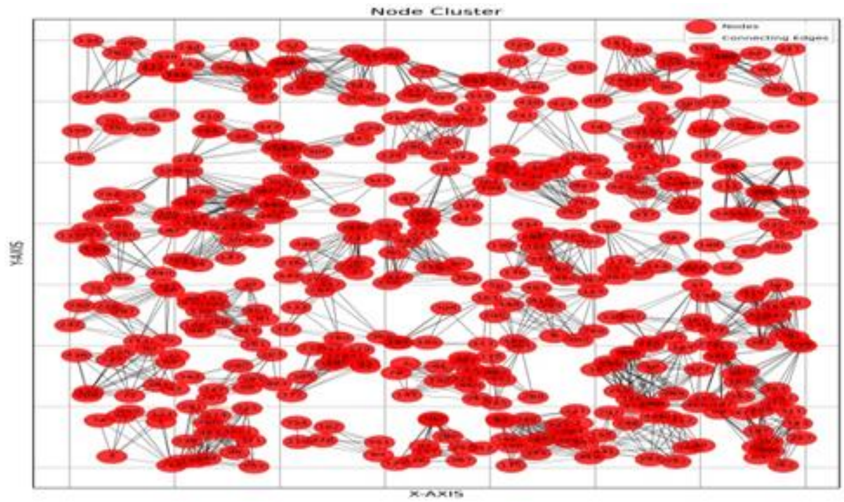

Figure 7: Random clustering-This figure shows how the nodes are grouped into clusters.

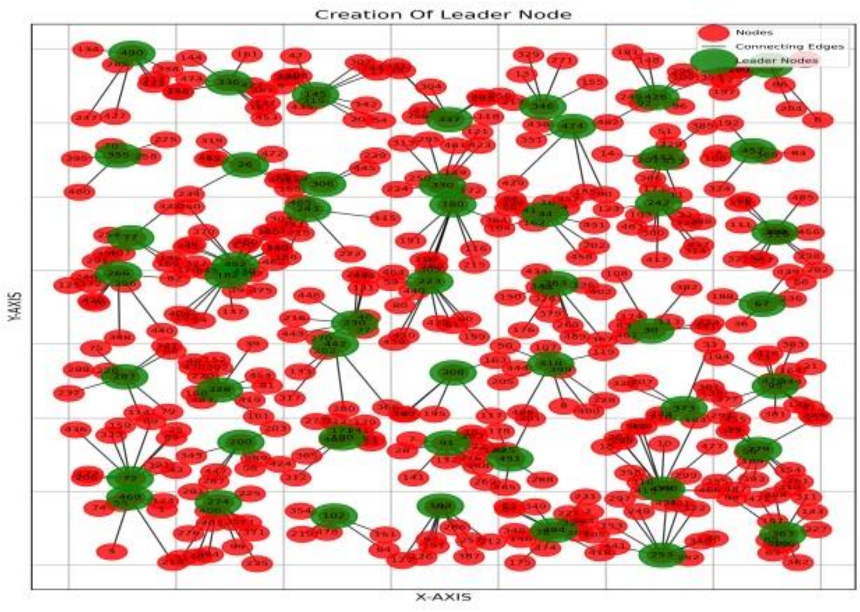

Figure 8: Leader Nodes of the clusters-The above figure shows the leader nodes of their respective clusters denoted by the green color.

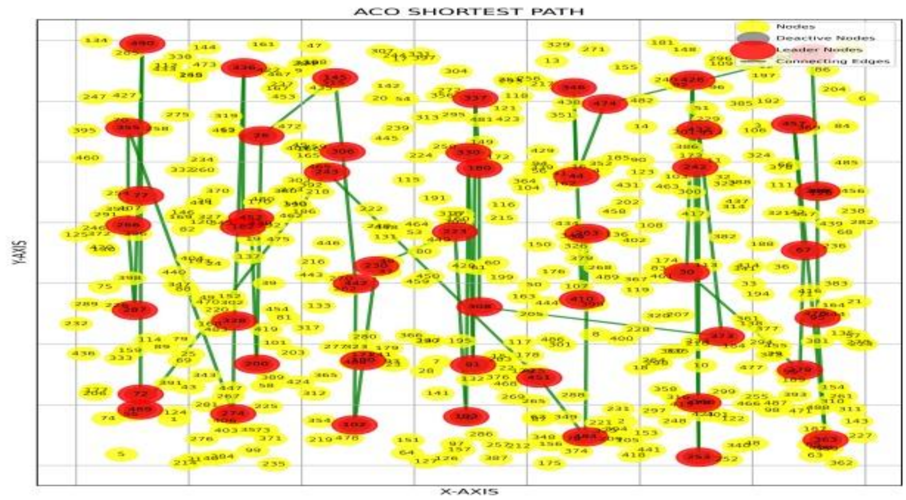

Figure 9: Shortest path after applying ACO Algorithm denoted by green lines.

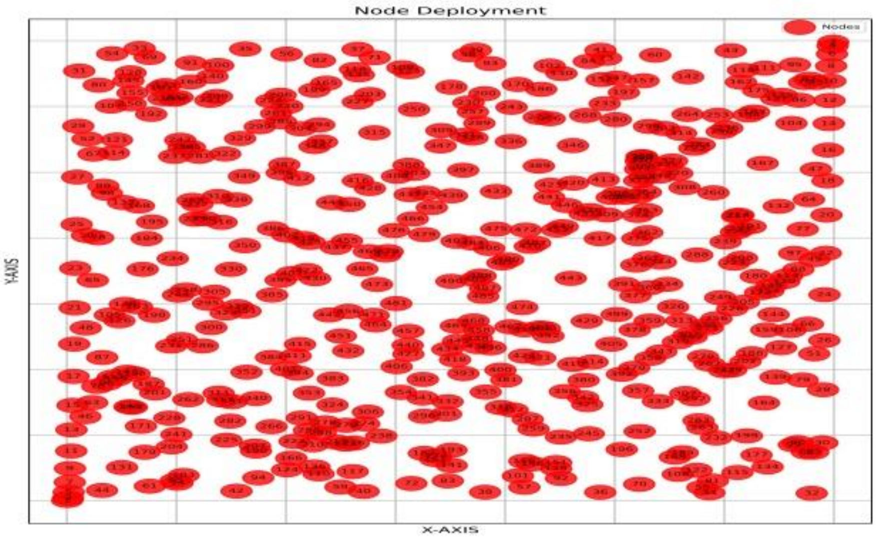

Figure 10: Spiral deployment-The above figure shows the deployment of nodes spirally starting from the upper left side and ending at the center.

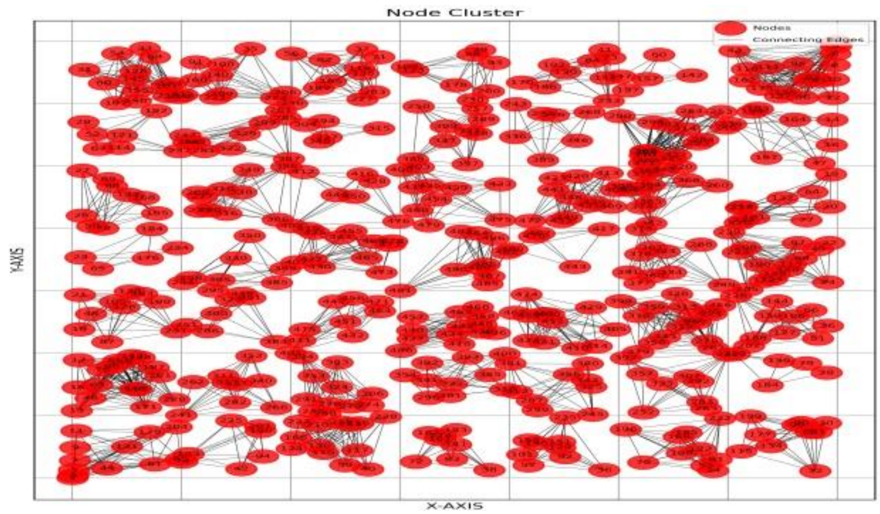

Figure 11: Spiral Clustering-This figure shows the clusters formed within the nodes and is connected through black lines.

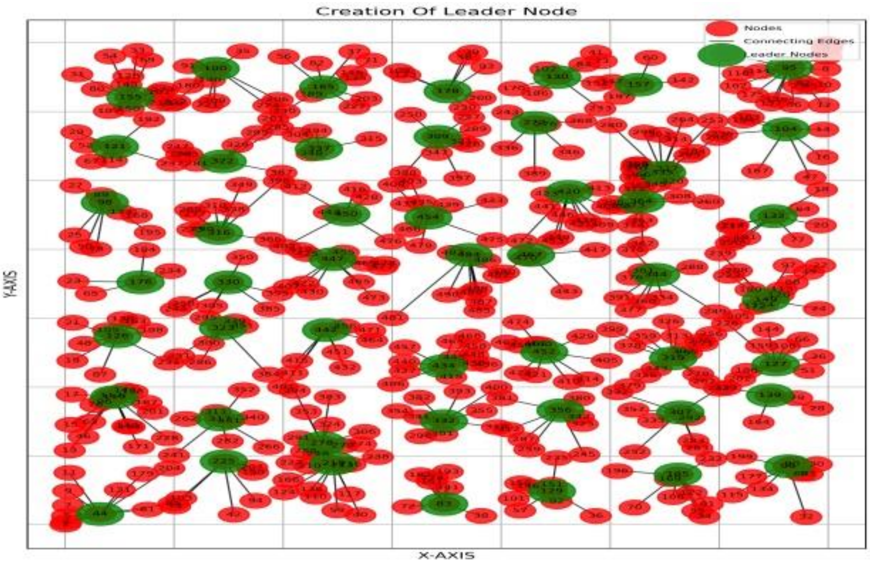

Figure 12: Leader nodes or head nodes of the clusters. The green nodes indicate the leader nodes of the respective clusters.

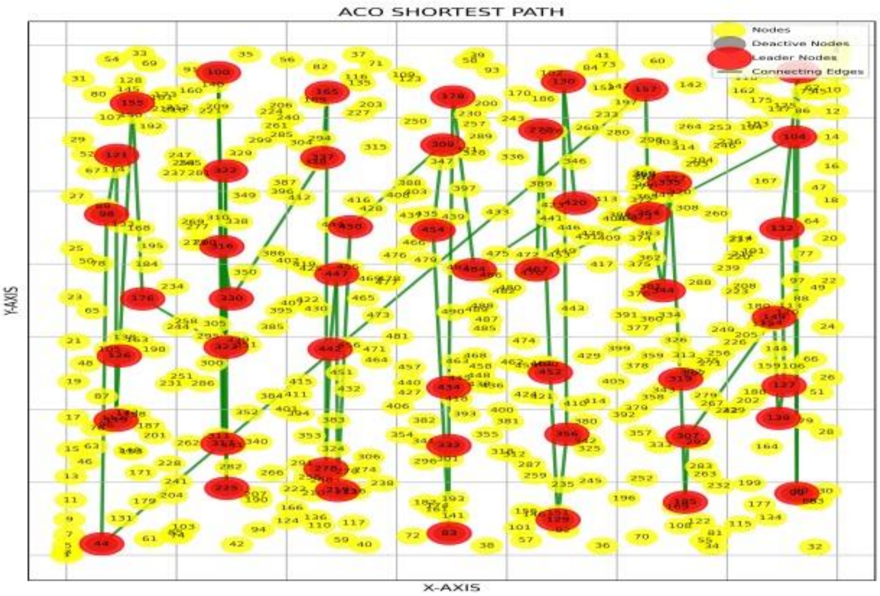

Figure 13: Shortest path obtained after applying ACO denoted by green lines.

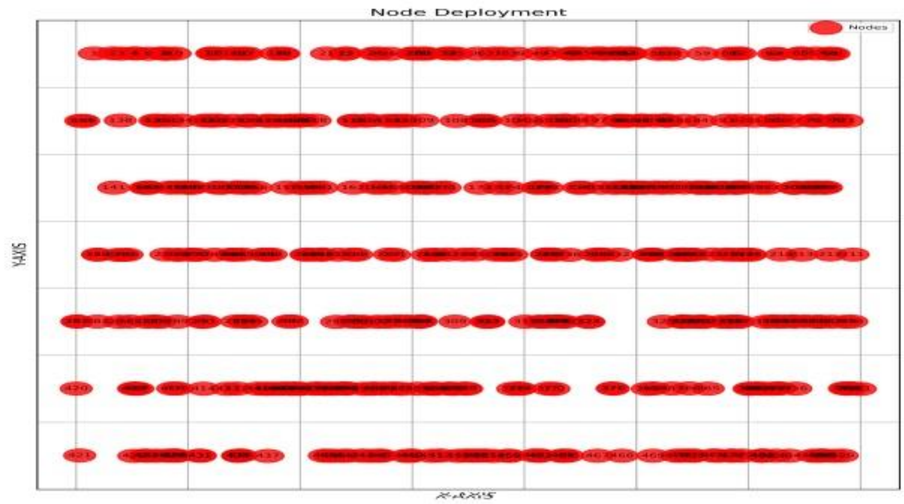

Figure 14: S-pattern Deployment-This above figure shows the deployment of the nodes in an s-pattern fashion.

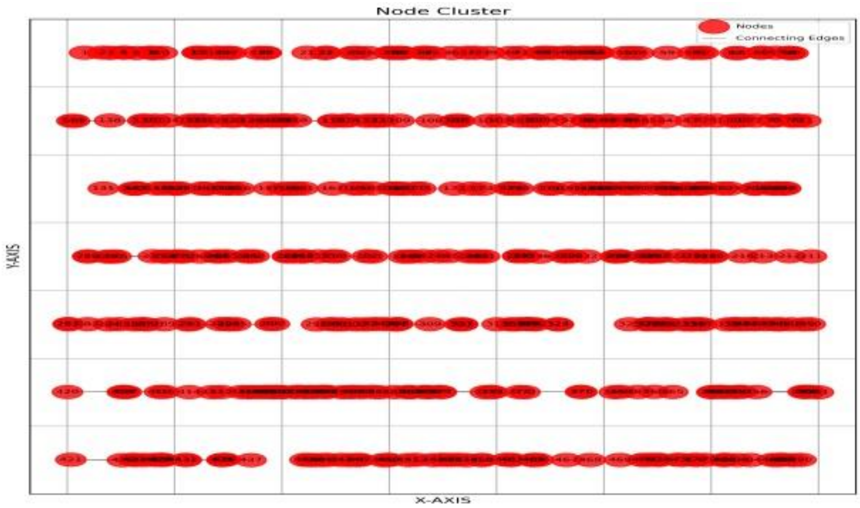

Figure 15: S-pattern Clustering-This figure shows the clustering of the nodes in an s-pattern manner.

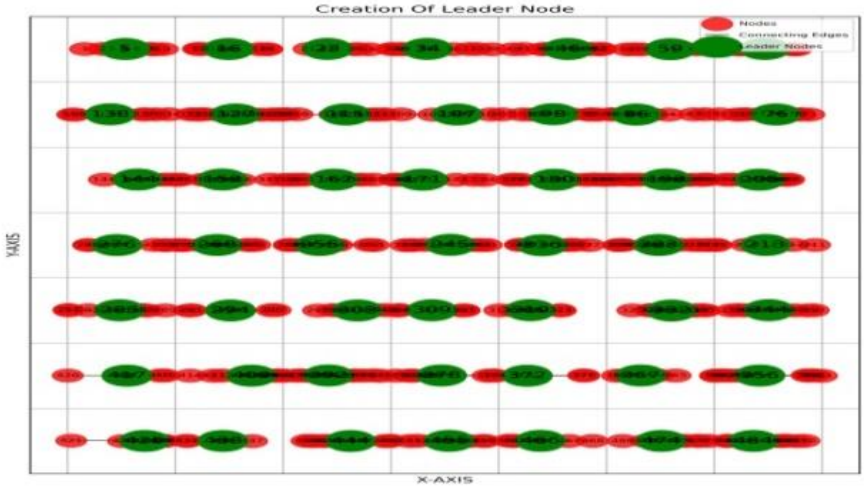

Figure 16: Leader nodes or head nodes of the clusters- The green nodes indicate the leader nodes of the respective cluster

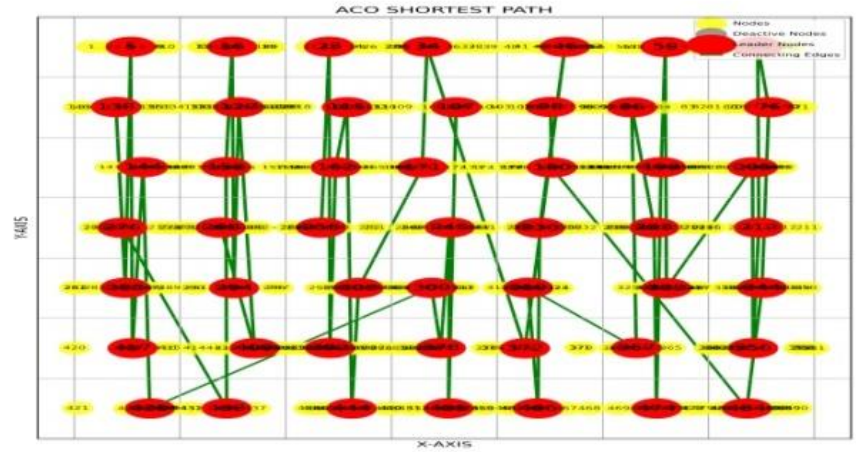

Figure 17: Shortest path after applying the ACO algorithm denoted by the green line.

Table **2**: Energy saving (E_S) calculations applying S-pattern deployment strategy and Area-wise clustering process

	dmin(d=42mm or 4.2cm)				**dmax(d=42mm or 4.2cm)**															
INO-CL NO.	(x1-d/2)	(y1-d/2)	(x2-d/2)	(y2-d/2)	(x1+d/2)	(y1+d/2)	(x2+d/2)	(y2+d/2)	dis(zero)	dxy(min)	dxy(max)	E_tx0	E_tx(min)	E_tx(max)	max Eng	min Eng	AvgEng	total0	totalxy(min)	totalxy(max)
1-1	-2.1	-2.1	65.28	68.03	2.1	2.1	69.48	72.23	97.2537	91.31526	103.1923	50418.28	49298.48	51608.65	2310.168	1119.804	1190.364	50418.28	49298.48	51608.65
1-2	65.28	68.03	68.28	208.3	69.48	72.23	72.48	212.5	140.3021	136.0753	144.6493	60644.67	59476.48	61883.42	2406.936	1168.188	1238.748	60644.67	59476.48	61883.42
1-3	68.28	208.3	73.42	348.04	72.48	212.5	77.62	352.24	139.8345	135.5433	144.2427	60513.69	59331.98	61765.96	2433.984	1181.712	1252.272	60513.69	59331.98	61765.96
1-4	73.42	348.04	96.92	488.73	77.62	352.24	101.12	492.93	142.6391	137.8478	147.5141	61305.93	59962.01	62720.4	2758.392	1343.916	1414.476	61305.93	59962.01	62720.4
1-5	96.92	488.73	89.81	628.26	101.12	492.93	94.01	632.46	139.711	135.8018	143.7595	60479.17	59402.13	61626.78	2224.656	1077.048	1147.608	60479.17	59402.13	61626.78
1-6	89.81	628.26	83.93	768.45	94.01	632.46	88.13	772.65	140.3133	136.3631	144.3998	60647.81	59554.89	61811.29	2256.408	1092.924	1163.484	60647.81	59554.89	61811.29
1-7	83.93	768.45	34.85	908.48	88.13	772.65	39.05	912.68	148.3821	145.906	151.0513	62977.25	62248.55	63776.51	1527.96	728.7	799.26	62977.25	62248.55	63776.51
1-8	34.85	908.48	215.44	68.65	39.05	912.68	219.64	72.85	859.0269	862.2645	855.8182	778887.2	784460.1	773384.8	11075.23	5572.896	5502.336	778887.2	784460.1	773384.8
1-9	215.44	68.65	188.95	208.48	219.64	72.85	193.15	212.68	142.3171	139.0589	145.7446	61214.15	60297.37	62201.49	1904.112	916.776	987.336	61214.15	60297.37	62201.49
1-10	188.95	208.48	190.93	348.65	193.15	212.68	195.13	352.85	140.184	135.9881	144.5022	60611.55	59452.77	61840.89	2388.12	1158.78	1229.34	60611.55	59452.77	61840.89
1-11	190.93	348.65	210.24	487.91	195.13	352.85	214.44	492.11	140.5924	135.9026	145.3736	60726.22	59429.52	62093.49	2663.976	1296.708	1367.268	60726.22	59429.52	62093.49
1-12	210.24	487.91	212.45	628.13	214.44	492.11	216.65	632.33	140.2374	136.0346	144.5622	60626.53	59465.4	61858.22	2392.824	1161.132	1231.692	60626.53	59465.4	61858.22
1-13	212.45	628.13	189.03	768.52	216.65	632.33	193.23	772.72	142.3301	138.9625	145.8618	61217.85	60270.58	62235.68	1965.096	947.268	1017.828	61217.85	60270.58	62235.68
1-14	189.03	768.52	175.03	908.36	193.23	772.72	179.23	912.56	140.5391	136.8556	144.373	60711.23	59689.45	61803.56	2114.112	1021.776	1092.336	60711.23	59689.45	61803.56
1-15	175.03	908.36	342.97	68.55	179.23	912.56	347.17	72.75	856.4372	859.7463	853.1566	774444.7	780123.7	768836.3	11287.42	5678.988	5608.428	774444.7	780123.7	768836.3
1-16	342.97	68.55	322.61	208.3	347.17	72.75	326.81	212.5	141.2253	137.757	144.8542	60904.59	59937	61942.75	2005.752	967.596	1038.156	60904.59	59937	61942.75
1-17	322.61	208.3	366.29	348.78	326.81	212.5	370.49	352.98	147.1141	141.8834	152.3968	62602.57	61090.91	64184.8	3093.888	1511.664	1582.224	62602.57	61090.91	64184.8
1-18	366.29	348.78	350.87	488.58	370.49	352.98	355.07	492.78	140.6478	137.0121	144.4365	60741.82	59732.3	61821.89	2089.584	1009.512	1080.072	60741.82	59732.3	61821.89
1-19	350.87	488.58	326.85	628.51	355.07	492.78	331.05	632.71	141.9766	138.6326	145.4864	61117.37	60179	62126.29	1947.288	938.364	1008.924	61117.37	60179	62126.29
1-20	326.85	628.51	324.74	768.58	331.05	632.71	328.94	772.78	140.0859	136.0164	144.2851	60584.06	59460.47	61778.2	2317.728	1123.584	1194.144	60584.06	59460.47	61778.2
1-21	324.74	768.58	297.27	907.99	328.94	772.78	301.47	912.19	142.0906	138.8695	145.4831	61149.75	60244.73	62125.33	1880.592	905.016	975.576	61149.75	60244.73	62125.33
1-22	297.27	907.99	499.05	68.71	301.47	912.19	503.25	72.91	863.1953	866.3119	860.1083	786066.1	791456.4	780746.4	10710	5390.28	5319.72	786066.1	791456.4	780746.4
1-23	499.05	68.71	486.83	208.24	503.25	72.91	491.03	212.44	140.0641	136.3225	143.9536	60577.95	59543.83	61682.63	2138.808	1034.124	1104.684	60577.95	59543.83	61682.63
1-24	486.83	208.24	483.81	348.56	491.03	212.44	488.01	352.76	140.3525	136.3113	144.5248	60658.82	59540.78	61847.42	2306.64	1118.04	1188.6	60658.82	59540.78	61847.42
1-25	483.81	348.56	511.25	488.31	488.01	352.76	515.45	492.51	142.4185	137.5278	147.3862	61243.02	59873.9	62682.69	2808.792	1369.116	1439.676	61243.02	59873.9	62682.69
1-26	511.25	488.31	460.9	628.36	515.45	492.51	465.1	632.56	148.8258	146.393	151.4526	63109.13	62390.93	63897.89	1506.96	718.2	788.76	63109.13	62390.93	63897.89
1-27	460.9	628.36	490.01	768.47	465.1	632.56	494.21	772.67	143.1021	138.1739	148.1045	61438.2	60052.04	62894.93	2842.896	1386.168	1456.728	61438.2	60052.04	62894.93
1-28	490.01	768.47	483.42	908.79	494.21	772.67	487.62	912.99	140.4747	136.547	144.5398	60693.13	59605.08	61851.74	2246.664	1088.052	1158.612	60693.13	59605.08	61851.74
1-29	483.42	908.79	636.31	67.96	487.62	912.99	640.51	72.16	854.6171	858.0119	851.2503	771330.4	777144.4	765587	11557.39	5813.976	5743.416	771330.4	777144.4	765587
1-30	636.31	67.96	648.55	208.78	640.51	72.16	652.75	212.98	141.3509	136.8564	145.9489	60940.09	59689.67	62261.07	2571.408	1250.424	1320.984	60940.09	59689.67	62261.07
1-31	648.55	208.78	639.6	348.39	652.75	212.98	643.8	352.59	139.8966	136.047	143.8884	60531.05	59468.79	61663.88	2195.088	1062.264	1132.824	60531.05	59468.79	61663.88
1-32	639.6	348.39	622.27	488.64	643.8	352.59	626.47	492.84	141.3166	137.743	145.0455	60930.39	59933.14	61998.2	2065.056	997.248	1067.808	60930.39	59933.14	61998.2
1-33	622.27	488.64	643.26	627.95	626.47	492.84	647.46	632.15	140.8824	136.1492	145.704	60807.86	59496.62	62189.66	2693.04	1311.24	1381.8	60807.86	59496.62	62189.66
1-34	643.26	627.95	668.26	768.21	647.46	632.15	672.46	772.41	142.4706	137.6407	147.3816	61257.87	59904.96	62681.33	2776.368	1352.904	1423.464	61257.87	59904.96	62681.33
1-35	668.26	768.21	627.62	907.92	672.46	772.41	631.82	912.12	145.5008	142.7361	148.4519	62130.49	61333.59	62997.96	1664.376	796.908	867.468	62130.49	61333.59	62997.96
1-36	627.62	907.92	786.64	68.37	631.82	912.12	790.84	72.57	854.4774	857.8364	851.1465	771091.6	776843.3	765410.4	11432.9	5751.732	5681.172	771091.6	776843.3	765410.4
1-37	786.64	68.37	754.28	208.44	790.84	72.57	758.48	212.64	143.7594	140.7028	146.9926	61626.77	60757.29	62566.82	1809.528	869.484	940.044	61626.77	60757.29	62566.82
1-38	754.28	208.44	762.36	348.65	758.48	212.64	766.56	352.85	140.4426	136.0653	144.9312	60684.13	59473.77	61965.05	2491.272	1210.356	1280.916	60684.13	59473.77	61965.05
1-39	762.36	348.65	744.58	488.02	766.56	352.85	748.78	492.22	140.4996	136.9454	144.2108	60700.13	59714.05	61756.76	2042.712	986.076	1056.636	60700.13	59714.05	61756.76
1-40	744.58	488.02	787.09	628.69	748.78	492.22	791.29	632.89	146.9529	141.7453	152.2141	62555.15	61051.72	64129.14	3077.424	1503.432	1573.992	62555.15	61051.72	64129.14
1-41	787.09	628.69	751.75	768.68	791.29	632.89	755.95	772.88	144.3818	141.4296	147.5143	61806.12	60962.34	62720.46	1758.12	843.78	914.34	61806.12	60962.34	62720.46
1-42	751.75	768.68	767.48	908.68	755.95	772.88	771.68	912.88	140.8809	136.2886	145.5708	60807.43	59534.58	62150.84	2616.264	1272.852	1343.412	60807.43	59534.58	62150.84
1-43	767.48	908.68	882.95	68.65	771.68	912.88	887.15	72.85	847.9291	851.5312	844.3534	759943.7	766065.3	753892.7	12172.61	6121.584	6051.024	759943.7	766065.3	753892.7
1-44	882.95	68.65	901.02	208.78	887.15	72.85	905.22	212.98	141.2903	136.6358	146.038	60922.94	59629.34	62287.1	2657.76	1293.6	1364.16	60922.94	59629.34	62287.1
1-45	901.02	208.78	886.16	348.71	905.22	212.98	890.36	352.91	140.7168	137.0617	144.5237	60761.22	59745.92	61847.09	2101.176	1015.308	1085.868	60761.22	59745.92	61847.09
1-46	886.16	348.71	899.04	488.08	890.36	352.91	903.24	492.28	139.9639	135.4484	144.5824	60549.89	59306.27	61864.07	2557.8	1243.62	1314.18	60549.89	59306.27	61864.07
1-47	899.04	488.08	897.17	628.34	903.24	492.28	901.37	632.54	140.2725	136.1953	144.4788	60636.36	59509.17	61834.12	2324.952	1127.196	1197.756	60636.36	59509.17	61834.12
1-48	897.17	628.34	895.15	768.77	901.37	632.54	899.35	772.97	140.4445	136.3719	144.6464	60684.67	59557.3	61882.59	2325.288	1127.364	1197.924	60684.67	59557.3	61882.59
1-49	895.15	768.77	900.24	908.06	899.35	772.97	904.44	912.26	139.383	135.0929	143.7904	60387.61	59210.1	61635.68	2425.584	1177.512	1248.072	60387.61	59210.1	61635.68
2-1	-2.1	-2.1	69.34	68.02	2.1	2.1	73.54	72.22	100.1024	94.16297	106.0418	50980.49	49826.66	52204.87	2378.208	1153.824	1224.384	50980.49	49826.66	52204.87
2-2	69.34	68.02	55.94	208.11	73.54	72.22	60.14	212.31	140.7294	137.025	144.583	60764.77	59735.85	61864.24	2128.392	1028.916	1099.476	60764.77	59735.85	61864.24
2-3	55.94	208.11	98.38	348.42	60.14	212.31	102.58	352.62	146.588	141.3797	151.85	62448.05	60948.23	64018.43	3070.2	1499.82	1570.38	62448.05	60948.23	64018.43
2-4	98.38	348.42	51.46	487.97	102.58	352.62	55.66	492.17	147.2267	144.682	149.9635	62635.69	61892.88	63449.06	1556.184	742.812	813.372	62635.69	61892.88	63449.06
2-5	51.46	487.97	86.01	628.02	55.66	492.17	90.21	632.22	144.2488	139.1989	149.3641	61767.71	60336.35	63269.63	2933.28	1431.36	1501.92	61767.71	60336.35	63269.63
2-6	86.01	628.02	84.71	768.89	90.21	632.22	88.91	773.09	140.876	136.7806	145.099	60806.05	59668.94	62013.71	2344.776	1137.108	1207.668	60806.05	59668.94	62013.71
2-7	84.71	768.89	31.14	908.27	88.91	773.09	35.34	912.47	149.3202	147.0068	151.8309	63256.53	62571.01	64012.61	1441.608	685.524	756.084	63256.53	62571.01	64012.61
2-8	31.14	908.27	213.69	68.5	35.34	912.47	217.89	72.7	859.3824	862.6089	856.185	779498.2	785054.1	774012.8	11041.3	5555.928	5485.368	779498.2	785054.1	774012.8
2-9	213.69	68.5	174.01	208.74	217.89	72.7	178.21	212.94	145.7455	142.9417	148.7338	62201.76	61392.34	63081.74	1689.408	809.424	879.984	62201.76	61392.34	63081.74
2-10	174.01	208.74	198.99	348.18	178.21	212.94	203.19	352.38	141.6599	136.8271	146.5739	61027.51	59681.67	62443.92	2762.256	1345.848	1416.408	61027.51	59681.67	62443.92
2-11	198.99	348.18	243.29	488.66	203.19	352.38	247.49	492.86	147.2994	142.0572	152.5928	62657.12	61140.25	64244.55	3104.304	1516.872	1587.432	62657.12	61140.25	64244.55
2-12	243.29	488.66	182.53	628.67	247.49	492.86	186.73	632.87	152.6256	150.5462	154.905	64254.58	63624.16	64955.56	1331.4	630.42	700.98	64254.58	63624.16	64955.56
2-13	182.53	628.67	171.48	768.12	186.73	632.87	175.68	772.32	139.8871	136.107	143.8132	60528.41	59485.13	61642.25	2157.12	1043.28	1113.84	60528.41	59485.13	61642.25
2-14	171.48	768.12	174.42	908.54	175.68	772.32	178.62	912.74	140.4508	136.2258	144.7961	60686.42	59517.48	61925.92	2408.448	1168.944	1239.504	60686.42	59517.48	61925.92

2-15	174.42	908.54	317.74	68.09	178.62	912.74	321.94	72.29	852.5824	856.0304	849.1621	767856.8	773748	762036.2	11711.78	5891.172	5820.612	767856.8	773748	762036.2
2-16	317.74	68.09	319.57	208.02	321.94	72.29	323.77	212.22	139.942	135.7507	144.2561	60543.75	59388.25	61769.82	2381.568	1155.504	1226.064	60543.75	59388.25	61769.82
2-17	319.57	208.02	371.63	348	323.77	212.22	375.83	352.2	149.3474	143.968	154.7678	63264.64	61686.79	64913.06	3226.272	1577.856	1648.416	63264.64	61686.79	64913.06
2-18	371.63	348	347.91	488.66	375.83	352.2	352.11	492.86	142.646	139.287	146.1693	61307.87	60360.86	62325.45	1964.592	947.016	1017.576	61307.87	60360.86	62325.45
2-19	347.91	488.66	353.28	628.47	352.11	492.86	357.48	632.67	139.9131	135.615	144.3276	60535.67	59351.44	61790.47	2439.024	1184.232	1254.792	60535.67	59351.44	61790.47
2-20	353.28	628.47	324.68	768.55	357.48	632.67	328.88	772.75	142.9698	139.7827	146.3287	61400.37	60499.21	62372.08	1872.864	901.152	971.712	61400.37	60499.21	62372.08
2-21	324.68	768.55	292.36	908.62	328.88	772.75	296.56	912.82	143.7504	140.6925	146.9849	61624.19	60754.37	62564.57	1810.2	869.82	940.38	61624.19	60754.37	62564.57
2-22	292.36	908.62	505.33	68.41	296.56	912.82	509.53	72.61	866.7809	869.8351	863.7566	792269.1	797573.2	787035.5	10537.63	5304.096	5233.536	792269.1	797573.2	787035.5
2-23	505.33	68.41	496.47	208.2	509.53	72.61	500.67	212.4	140.0705	136.2175	144.0654	60579.74	59515.21	61714.84	2199.624	1064.532	1135.092	60579.74	59515.21	61714.84
2-24	496.47	208.2	494.96	348.56	500.67	212.4	499.16	352.76	140.3681	136.2797	144.585	60663.21	59532.15	61864.83	2332.68	1131.06	1201.62	60663.21	59532.15	61864.83
2-25	494.96	348.56	477.66	488.56	499.16	352.76	481.86	492.76	141.0648	137.4914	144.7938	60859.29	59863.89	61925.25	2061.36	995.4	1065.96	60859.29	59863.89	61925.25
2-26	477.66	488.56	498.41	628.86	481.86	492.76	502.61	633.06	141.8261	137.1026	146.6382	61074.65	59757.11	62462.75	2705.64	1317.54	1388.1	61074.65	59757.11	62462.75
2-27	498.41	628.86	477.24	768.04	502.61	633.06	481.44	772.24	140.7808	137.3435	144.3808	60779.24	59823.24	61805.81	1982.568	956.004	1026.564	60779.24	59823.24	61805.81
2-28	477.24	768.04	496.46	908.08	481.44	772.24	500.66	912.28	141.3528	136.6679	146.129	60940.61	59638.11	62313.67	2675.568	1302.504	1373.064	60940.61	59638.11	62313.67
2-29	496.46	908.08	647.58	68.89	500.66	912.28	651.78	73.09	852.6882	856.0912	849.313	768037.1	773852.2	762292.6	11559.58	5815.068	5744.508	768037.1	773852.2	762292.6
2-30	647.58	68.89	677.69	208.46	651.78	73.09	681.89	212.66	142.7809	137.8273	147.8073	61346.4	59956.37	62806.99	2850.624	1390.032	1460.592	61346.4	59956.37	62806.99
2-31	677.69	208.46	644.94	348.17	681.89	212.66	649.14	352.37	143.4972	140.4573	146.7147	61551.45	60688.26	62485.19	1796.928	863.184	933.744	61551.45	60688.26	62485.19
2-32	644.94	348.17	646.18	488.81	649.14	352.37	650.38	493.01	140.6455	136.4721	144.9421	60741.15	59584.64	61968.22	2383.584	1156.512	1227.072	60741.15	59584.64	61968.22
2-33	646.18	488.81	685.68	628.77	650.38	493.01	689.88	632.97	145.4271	140.2743	150.638	62109.05	60636.87	63651.8	3014.928	1472.184	1542.744	62109.05	60636.87	63651.8
2-34	685.68	628.77	673.84	768.22	689.88	632.97	678.04	772.42	139.9517	136.1978	143.853	60546.49	59509.84	61653.69	2143.848	1036.644	1107.204	60546.49	59509.84	61653.69
2-35	673.84	768.22	628.52	908.01	678.04	772.42	632.72	912.21	146.9529	144.3498	149.7464	62555.15	61796.88	63383.97	1587.096	758.268	828.828	62555.15	61796.88	63383.97
2-36	628.52	908.01	790.49	68.78	632.72	912.21	794.69	72.98	854.7171	858.0592	851.4033	771501.3	777225.5	765847.6	11377.97	5724.264	5653.704	771501.3	777225.5	765847.6
2-37	790.49	68.78	782.43	208.61	794.69	72.98	786.63	212.81	140.0621	136.183	144.0817	60577.39	59505.8	61719.54	2213.736	1071.588	1142.148	60577.39	59505.8	61719.54
2-38	782.43	208.61	744.1	348.8	786.63	212.81	748.3	353	145.3356	142.4854	148.3689	62082.43	61262.08	62973.33	1711.248	820.344	890.904	62082.43	61262.08	62973.33
2-39	744.1	348.8	804.78	488.12	748.3	353	808.98	492.32	151.9609	146.4493	157.5037	64052.12	62407.4	65767.4	3360	1644.72	1715.28	64052.12	62407.4	65767.4
2-40	804.78	488.12	780.18	628.22	808.98	492.32	784.38	632.42	142.2433	138.9181	145.7349	61193.17	60258.25	62198.65	1940.4	934.92	1005.48	61193.17	60258.25	62198.65
2-41	780.18	628.22	751.2	768.67	784.38	632.42	755.4	772.87	143.4087	140.2319	146.7572	61526.04	60624.97	62497.67	1872.696	901.068	971.628	61526.04	60624.97	62497.67
2-42	751.2	768.67	799.8	908.09	755.4	772.87	804	912.29	147.6479	142.3229	153.0181	62759.9	61215.81	64374.54	3158.736	1544.088	1614.648	62759.9	61215.81	64374.54
2-43	799.8	908.09	881.7	68.39	804	912.29	885.9	72.59	843.6846	847.4695	839.9247	752763.7	759164.5	746433.5	12731.04	6400.8	6330.24	752763.7	759164.5	746433.5
2-44	881.7	68.39	908.58	208.45	885.9	72.59	912.78	212.65	142.6161	137.7401	147.57	61299.34	59932.32	62736.91	2804.592	1367.016	1437.576	61299.34	59932.32	62736.91
2-45	908.58	208.45	938.78	348.35	912.78	212.65	942.98	352.55	143.1225	138.1683	148.1491	61444.05	60050.49	62908.17	2857.68	1393.56	1464.12	61444.05	60050.49	62908.17
2-46	938.78	348.35	891.03	488.12	942.98	352.55	895.23	492.32	147.7014	145.1827	150.4126	62775.72	62038.03	63583.96	1545.936	737.688	808.248	62775.72	62038.03	63583.96
2-47	891.03	488.12	894.28	628.51	895.23	492.32	898.48	632.71	140.4276	136.1933	144.7818	60679.91	59508.62	61921.77	2413.152	1171.296	1241.856	60679.91	59508.62	61921.77
2-48	894.28	628.51	892.76	767.92	898.48	632.71	896.96	772.12	139.4183	135.3309	143.635	60397.46	59274.46	61591.01	2316.552	1122.996	1193.556	60397.46	59274.46	61591.01
2-49	892.76	767.92	909.63	908.12	896.96	772.12	913.83	912.32	141.2113	136.5889	145.9291	60900.64	59616.53	62255.3	2638.776	1284.108	1354.668	60900.64	59616.53	62255.3
3-1	-2.1	-2.1	73.84	68.23	2.1	2.1	78.04	72.43	103.5046	97.56949	109.4401	51673.19	50479.8	52937.14	2457.336	1193.388	1263.948	51673.19	50479.8	52937.14
3-2	73.84	68.23	54.66	208.35	78.04	72.43	58.86	212.55	141.4266	137.9162	145.0954	60961.49	59980.87	62012.66	2031.792	980.616	1051.176	60961.49	59980.87	62012.66
3-3	54.66	208.35	102.51	348.87	58.86	212.55	106.71	353.07	148.4436	143.1379	153.7956	62995.49	61448.46	64613.08	3164.616	1547.028	1617.588	62995.49	61448.46	64613.08
3-4	102.51	348.87	50.45	488.05	106.71	353.07	54.65	492.25	148.5978	146.2354	151.1569	63041.32	62344.79	63808.4	1463.616	696.528	767.088	63041.32	62344.79	63808.4
3-5	50.45	488.05	105.56	628.72	54.65	492.25	109.76	632.92	151.08	145.6568	156.5407	63785.16	62175.89	65464.99	3289.104	1609.272	1679.832	63785.16	62175.89	65464.99
3-6	105.56	628.72	93.09	768.08	109.76	632.92	97.29	772.28	139.9168	136.1841	143.798	60536.71	59506.11	61637.87	2131.752	1030.596	1101.156	60536.71	59506.11	61637.87
3-7	93.09	768.08	30.07	908.38	97.29	772.28	34.27	912.58	153.8038	151.7951	156.013	64615.61	64001.74	65300.04	1298.304	613.872	684.432	64615.61	64001.74	65300.04
3-8	30.07	908.38	242.13	68.18	34.27	912.58	246.33	72.38	866.548	869.6075	863.5186	791865.5	797177.1	786624.4	10552.75	5311.656	5241.096	791865.5	797177.1	786624.4
3-9	242.13	68.18	196.58	208.78	246.33	72.38	200.78	212.98	147.7943	145.1896	150.5884	62803.16	62040.02	63636.86	1596.84	763.14	833.7	62803.16	62040.02	63636.86
3-10	196.58	208.78	202.9	348.73	200.78	212.98	207.1	352.93	140.0926	135.7666	144.5334	60585.94	59392.56	61849.89	2457.336	1193.388	1263.948	60585.94	59392.56	61849.89
3-11	202.9	348.73	246.56	488.18	207.1	352.93	250.76	492.38	146.1249	140.8888	151.413	62312.5	60809.65	63885.9	3076.248	1502.844	1573.404	62312.5	60809.65	63885.9
3-12	246.56	488.18	247.76	628.07	250.76	492.38	251.96	632.27	139.8951	135.7232	144.1912	60530.65	59380.78	61751.09	2370.312	1149.876	1220.436	60530.65	59380.78	61751.09
3-13	247.76	628.07	200.58	768.43	251.96	632.27	204.78	772.63	148.0773	145.5316	150.814	62886.88	62139.45	63704.87	1565.424	747.432	817.992	62886.88	62139.45	63704.87
3-14	200.58	768.43	173.32	908.74	204.78	772.63	177.52	912.94	142.9336	139.6985	146.3383	61390	60475.66	62374.9	1899.24	914.34	984.9	61390	60475.66	62374.9
3-15	173.32	908.74	383.45	68.04	177.52	912.94	387.65	72.24	866.5628	869.6339	863.5216	791891.1	797223.2	786629.6	10593.58	5332.068	5261.508	791891.1	797223.2	786629.6
3-16	383.45	68.04	307.45	207.93	387.65	72.24	311.65	212.13	159.2018	157.6192	160.9881	66305.21	65803.82	66877.17	1073.352	501.396	571.956	66305.21	65803.82	66877.17
3-17	307.45	207.93	342.51	348.57	311.65	212.13	346.71	352.77	144.9442	139.8864	150.0666	61968.81	60528.21	63479.97	2951.76	1440.6	1511.16	61968.81	60528.21	63479.97
3-18	342.51	348.57	357.25	488.11	346.71	352.77	361.45	492.31	140.3164	135.7498	144.9825	60648.68	59388.01	61979.91	2591.904	1260.672	1331.232	60648.68	59388.01	61979.91
3-19	357.25	488.11	325.23	627.94	361.45	492.31	329.43	632.14	143.4493	140.383	146.6922	61537.71	60667.39	62478.59	1811.208	870.324	940.884	61537.71	60667.39	62478.59
3-20	325.23	627.94	320.72	768.72	329.43	632.14	324.92	772.92	140.8522	136.8574	144.9803	60799.35	59689.96	61979.3	2289.336	1109.388	1179.948	60799.35	59689.96	61979.3
3-21	320.72	768.72	323.34	908.79	324.92	772.92	327.54	912.99	140.0945	135.8792	144.4311	60586.47	59423.15	61820.35	2397.192	1163.316	1233.876	60586.47	59423.15	61820.35
3-22	323.34	908.79	487.01	68.39	327.54	912.99	491.21	72.59	856.1892	859.523	852.8838	774020	779739.8	768370.8	11369.06	5719.812	5649.252	774020	779739.8	768370.8
3-23	487.01	68.39	472.57	208.41	491.21	72.59	476.77	212.61	140.7626	137.0931	144.5831	60774.11	59754.52	61864.27	2109.744	1019.592	1090.152	60774.11	59754.52	61864.27
3-24	472.57	208.41	519.71	348.62	476.77	212.61	523.91	352.82	147.9224	142.6274	153.2646	62841.02	61302.56	64450.04	3147.48	1538.46	1609.02	62841.02	61302.56	64450.04
3-25	519.71	348.62	516.49	488.29	523.91	352.82	520.69	492.49	139.7071	135.6731	143.8733	60478.08	59367.18	61659.54	2292.36	1110.9	1181.46	60478.08	59367.18	61659.54
3-26	516.49	488.29	433.55	628.74	520.69	492.49	437.75	632.94	163.1111	161.7326	164.6925	67565.25	67117.44	68083.61	966.168	447.804	518.364	67565.25	67117.44	68083.61
3-27	433.55	628.74	473.75	768.29	437.75	632.94	477.95	772.49	145.2248	140.0558	150.4507	62050.24	60575.62	63595.42	3019.8	1474.62	1545.18	62050.24	60575.62	63595.42
3-28	473.75	768.29	497.77	908.84	477.95	772.49	501.97	913.04	142.5877	137.783	147.4752	61291.26	59944.15	62708.93	2764.776	1347.108	1417.668	61291.26	59944.15	62708.93
3-29	497.77	908.84	653.74	68.72	501.97	913.04	657.94	72.92	854.4754	857.8522	851.1267	771088.3	776870.4	765376.7	11493.72	5782.14	5711.58	771088.3	776870.4	765376.7
3-30	653.74	68.72	608.33	208.42	657.94	72.92	612.53	212.62	146.8951	144.2962	149.6846	62538.16	61781.4	63365.47	1584.072	756.756	827.316	62538.16	61781.4	63365.47
3-31	608.33	208.42	646.94	348.34	612.53	212.62	651.14	352.54	145.1494	140.0142	150.3438	62028.34	60563.97	63563.27	2999.304	1464.372	1534.932	62028.34	60563.97	63563.27
3-32	646.94	348.34	648.62	488.04	651.14	352.54	652.82	492.24	139.7101	135.5234	144.0201	60478.91	59326.6	61701.78	2375.184	1152.312	1222.872	60478.91	59326.6	61701.78
3-33	648.62	488.04	634.36	628.02	652.82	492.24	638.56	632.22	140.7045	137.0291	144.5305	60757.75	59736.98	61849.08	2112.096	1020.768	1091.328	60757.75	59736.98	61849.08
3-34	634.36	628.02	683.18	767.95	638.56	632.22	687.38	772.15	148.2019	142.8761	153.5727	62923.8	61373.58	64544.58	3171	1550.22	1620.78	62923.8	61373.58	64544.58
3-35	683.18	767.95	629.93	908.42	687.38	772.15	634.13	912.62	150.2244	147.8851	152.759	63527.38	62830.02	64295.31	1465.296	697.368	767.928	63527.38	62830.02	64295.31
3-36	629.93	908.42	773.18	68.79	634.13	912.62	777.38	72.99	851.7623	855.2099	848.3424	766459.1	772344	760644.8	11699.18	5884.872	5814.312	766459.1	772344	760644.8
3-37	773.18	68.79	738.23	208.12	777.38	72.99	742.43	212.32	143.6466	140.687	146.787	61594.35	60752.84	62506.42	1753.584	841.512	912.072	61594.35	60752.84	62506.42

3-38	738.23	208.12	727.71	348.52	742.43	212.32	731.91	352.72	140.7936	136.9931	144.738	60782.83	59727.12	61909.1	2181.984	1055.712	1126.272	60782.83	59727.12	61909.1
3-39	727.71	348.52	739.83	488.03	731.91	352.72	744.03	492.23	140.0355	135.5416	144.6337	60569.93	59331.52	61878.91	2547.384	1238.412	1308.972	60569.93	59331.52	61878.91
3-40	739.83	488.03	801.77	628.65	744.03	492.23	805.97	632.85	153.6572	148.1362	159.2085	64570.55	62904.32	66307.33	3403.008	1666.224	1736.784	64570.55	62904.32	66307.33
3-41	801.77	628.65	743.48	768.17	805.97	632.85	747.68	772.37	151.207	149.052	153.5616	63823.55	63176.5	64541.17	1364.664	647.052	717.612	63823.55	63176.5	64541.17
3-42	743.48	768.17	752.08	908.86	747.68	772.37	756.28	913.06	140.9526	136.5609	145.4543	60827.64	59608.88	62116.95	2508.072	1218.756	1289.316	60827.64	59608.88	62116.95
3-43	752.08	908.86	864.04	68.63	756.28	913.06	868.24	72.83	847.6565	851.278	844.0612	759481.5	765634.2	753399.3	12234.94	6152.748	6082.188	759481.5	765634.2	753399.3
3-44	864.04	68.63	896.96	208.44	868.24	72.83	901.16	212.64	143.6334	138.6179	148.7171	61590.56	60174.91	63076.77	2901.864	1415.652	1486.212	61590.56	60174.91	63076.77
3-45	896.96	208.44	950.79	348.81	901.16	212.64	954.99	353.01	150.3376	144.9324	155.7818	63561.41	61965.41	65227.97	3262.56	1596	1666.56	63561.41	61965.41	65227.97
3-46	950.79	348.81	916.88	488.21	954.99	353.01	921.08	492.41	143.4651	140.4685	146.6412	61542.25	60691.41	62463.64	1772.232	850.836	921.396	61542.25	60691.41	62463.64
3-47	916.88	488.21	892.85	628.44	921.08	492.41	897.05	632.64	142.274	138.9284	145.785	61201.89	60261.09	62213.25	1952.16	940.8	1011.36	61201.89	60261.09	62213.25
3-48	892.85	628.44	901.89	768.68	897.05	632.64	906.09	772.88	140.5311	136.1261	145.0455	60708.98	59490.31	61998.21	2507.904	1218.672	1289.232	60708.98	59490.31	61998.21
3-49	901.89	768.68	917.32	907.97	906.09	772.88	921.52	912.17	140.142	135.556	144.8265	60599.79	59335.42	61934.72	2599.296	1264.368	1334.928	60599.79	59335.42	61934.72
4-1	-2.1	-2.1	95.37	68.02	2.1	2.1	99.57	72.22	120.0717	114.2136	125.9375	55377.22	54004.74	56820.25	2815.512	1372.476	1443.036	55377.22	54004.74	56820.25
4-2	95.37	68.02	84.3	208.18	99.57	72.22	88.5	212.38	140.5965	136.8148	144.5234	60727.37	59678.29	61847.01	2168.712	1049.076	1119.636	60727.37	59678.29	61847.01
4-3	84.3	208.18	63.99	348.69	88.5	212.38	68.19	352.89	141.9703	138.4961	145.604	61115.56	60141.16	62160.52	2019.36	974.4	1044.96	61115.56	60141.16	62160.52
4-4	63.99	348.69	101.22	488.57	68.19	352.89	105.42	492.77	144.7497	139.6426	149.9183	61912.49	60460.04	63435.49	2975.448	1452.444	1523.004	61912.49	60460.04	63435.49
4-5	101.22	488.57	110.64	628.59	105.42	492.77	114.84	632.79	140.3365	135.9203	144.8617	60654.34	59434.32	61944.91	2510.592	1220.016	1290.576	60654.34	59434.32	61944.91
4-6	110.64	628.59	63.11	768.25	114.84	632.79	67.31	772.45	147.5263	145.0014	150.2438	62724.02	61985.4	63533.19	1547.784	738.612	809.172	62724.02	61985.4	63533.19
4-7	63.11	768.25	66.85	908.2	67.31	772.45	71.05	912.4	140	135.7508	144.3685	60559.99	59388.27	61802.27	2413.992	1171.716	1242.276	60559.99	59388.27	61802.27
4-8	66.85	908.2	194.35	68.04	71.05	912.4	198.55	72.24	849.7794	853.3151	846.2706	763085.1	769106.7	757134	11972.69	6021.624	5951.064	763085.1	769106.7	757134
4-9	194.35	68.04	203.29	208.21	198.55	72.24	207.49	212.41	140.4548	136.0526	144.9667	60687.55	59470.31	61975.36	2505.048	1217.244	1287.804	60687.55	59470.31	61975.36
4-10	203.29	208.21	165.27	348.31	207.49	212.41	169.47	352.51	145.1672	142.3072	148.2103	62033.53	61211.34	62926.28	1714.944	822.192	892.752	62033.53	61211.34	62926.28
4-11	165.27	348.31	177.93	488.81	169.47	352.51	182.13	493.01	141.0692	136.5623	145.6789	60860.53	59609.26	62182.35	2573.088	1251.264	1321.824	60860.53	59609.26	62182.35
4-12	177.93	488.81	168.91	628.48	182.13	493.01	173.11	632.68	139.961	136.1135	143.9507	60549.07	59486.89	61681.81	2194.92	1062.18	1132.74	60549.07	59486.89	61681.81
4-13	168.91	628.48	163.09	767.98	173.11	632.68	167.29	772.18	139.6214	135.6705	143.7091	60454.12	59366.49	61612.31	2245.824	1087.632	1158.192	60454.12	59366.49	61612.31
4-14	163.09	767.98	164	908.62	167.29	772.18	168.2	912.82	140.6429	136.4797	144.9301	60740.44	59586.7	61964.74	2378.04	1153.74	1224.3	60740.44	59586.7	61964.74
4-15	164	908.62	315.59	68	168.2	912.82	319.79	72.2	854.1789	857.5807	850.8049	770581.5	776404.6	764828.9	11575.7	5823.132	5752.572	770581.5	776404.6	764828.9
4-16	315.59	68	368.45	208.32	319.79	72.2	372.65	212.52	149.9463	144.556	155.3766	63443.88	61856.45	65101.87	3245.424	1587.432	1657.992	63443.88	61856.45	65101.87
4-17	368.45	208.32	373.25	348.53	372.65	212.52	377.45	352.73	140.2921	136.0113	144.6902	60641.88	59459.08	61895.25	2436.168	1182.804	1253.364	60641.88	59459.08	61895.25
4-18	373.25	348.53	359.79	488.47	377.45	352.73	363.99	492.67	140.5858	136.884	144.4371	60724.38	59697.22	61822.09	2124.864	1027.152	1097.712	60724.38	59697.22	61822.09
4-19	359.79	488.47	365.7	628.56	363.99	492.67	369.9	632.76	140.2146	135.9008	144.6438	60620.14	59429.02	61881.82	2452.8	1191.12	1261.68	60620.14	59429.02	61881.82
4-20	365.7	628.56	318.11	768.28	369.9	632.76	322.31	772.48	147.6025	145.0789	150.3185	62746.49	62007.87	63555.66	1547.784	738.612	809.172	62746.49	62007.87	63555.66
4-21	318.11	768.28	278.32	907.99	322.31	772.48	282.52	912.19	145.2657	142.4713	148.2455	62062.13	61258.08	62936.74	1678.656	804.048	874.608	62062.13	61258.08	62936.74
4-22	278.32	907.99	512.59	68.49	282.52	912.19	516.79	72.69	871.5748	874.5067	868.6737	800602.7	805721.9	795554	10167.86	5119.212	5048.652	800602.7	805721.9	795554
4-23	512.59	68.49	508.3	208.29	516.79	72.69	512.5	212.49	139.8658	135.8655	144	60522.44	59419.44	61696.01	2276.568	1103.004	1173.564	60522.44	59419.44	61696.01
4-24	508.3	208.29	457.91	348.89	512.5	212.49	462.11	353.09	149.357	146.9184	151.9887	63267.51	62545.03	64060.56	1515.528	722.484	793.044	63267.51	62545.03	64060.56
4-25	457.91	348.89	471.27	488.79	462.11	353.09	475.47	492.99	140.5365	136.0088	145.166	60710.5	59458.4	62033.16	2574.768	1252.104	1322.664	60710.5	59458.4	62033.16
4-26	471.27	488.79	513.59	628.25	475.47	492.99	517.79	632.45	145.7397	140.529	151.0043	62200.07	60708.4	63762.31	3053.904	1491.672	1562.232	62200.07	60708.4	63762.31
4-27	513.59	628.25	516.8	768.1	517.79	632.45	521	772.3	139.8868	135.6536	144.2405	60528.33	59361.9	61765.31	2403.408	1166.424	1236.984	60528.33	59361.9	61765.31
4-28	516.8	768.1	431.95	907.93	521	772.3	436.15	912.13	163.5602	162.251	165.0729	67711.95	67285.4	68209.06	923.664	426.552	497.112	67711.95	67285.4	68209.06
4-29	431.95	907.93	618.8	68.69	436.15	912.13	623	72.89	859.7888	862.9902	856.6165	780196.7	785712.1	774751.9	10960.15	5515.356	5444.796	780196.7	785712.1	774751.9
4-30	618.8	68.69	682.38	208.58	623	72.89	686.58	212.78	153.6608	148.114	159.2359	64571.63	62897.76	66316.06	3418.296	1673.868	1744.428	64571.63	62897.76	66316.06
4-31	682.38	208.58	652.76	348.06	686.58	212.78	656.96	352.26	142.5904	139.4434	145.9113	61292.01	60404.47	62250.12	1845.648	887.544	958.104	61292.01	60404.47	62250.12
4-32	652.76	348.06	655.22	487.94	656.96	352.26	659.42	492.14	139.9016	135.6912	144.2338	60532.47	59372.09	61763.4	2391.312	1160.376	1230.936	60532.47	59372.09	61763.4
4-33	655.22	487.94	633.38	628.86	659.42	492.14	637.58	633.06	142.6024	139.1777	146.1882	61295.43	60330.44	62330.98	2000.544	964.992	1035.552	61295.43	60330.44	62330.98
4-34	633.38	628.86	686.66	768	637.58	633.06	690.86	772.2	148.9923	143.5885	154.4354	63158.7	61577.65	64810.31	3232.656	1581.048	1651.608	63158.7	61577.65	64810.31
4-35	686.66	768	609.82	908.85	690.86	772.2	614.02	913.05	160.4466	158.8732	162.2223	66703.11	66200.7	67276.07	1075.368	502.404	572.964	66703.11	66200.7	67276.07
4-36	609.82	908.85	792.12	68.57	614.02	913.05	796.32	72.77	859.8278	863.0562	856.6283	780263.8	785826.1	774772	11054.06	5562.312	5491.752	780263.8	785826.1	774772
4-37	792.12	68.57	785.54	208.09	796.32	72.77	789.74	212.29	139.6751	135.7487	143.7397	60469.13	59387.71	61621.1	2233.392	1081.416	1151.976	60469.13	59387.71	61621.1
4-38	785.54	208.09	719.38	348.78	789.74	212.29	723.58	352.98	155.4697	153.558	157.5822	65130.82	64540.05	65792.15	1252.104	590.772	661.332	65130.82	64540.05	65792.15
4-39	719.38	348.78	818.14	488.9	723.58	352.98	822.34	493.1	171.4268	165.5773	177.2823	70347.15	68375.84	72389.02	4013.184	1971.312	2041.872	70347.15	68375.84	72389.02
4-40	818.14	488.9	808.13	628.82	822.34	493.1	812.33	633.02	140.2776	136.4619	144.2371	60637.81	59581.84	61764.33	2182.488	1055.964	1126.524	60637.81	59581.84	61764.33
4-41	808.13	628.82	737.9	768.84	812.33	633.02	742.1	773.04	156.6456	154.877	158.6171	65497.85	64946.9	66119.37	1172.472	550.956	621.516	65497.85	64946.9	66119.37
4-42	737.9	768.84	804.59	908.86	742.1	773.04	808.79	913.06	155.0908	149.5061	160.701	65013.16	63312.07	66784.8	3472.728	1701.084	1771.644	65013.16	63312.07	66784.8
4-43	804.59	908.86	857.21	68.61	808.79	913.06	861.41	72.81	841.896	845.837	837.9786	749748.9	756400.3	743168.1	13232.18	6651.372	6580.812	749748.9	756400.3	743168.1
4-44	857.21	68.61	886.53	208.26	861.41	72.81	890.73	212.46	142.6947	137.7596	147.7038	61321.78	59937.72	62776.41	2838.696	1384.068	1454.628	61321.78	59937.72	62776.41
4-45	886.53	208.26	864.61	348.78	890.73	212.46	868.81	352.98	142.2194	138.7998	145.8008	61186.36	60225.4	62217.88	1992.48	960.96	1031.52	61186.36	60225.4	62217.88
4-46	864.61	348.78	875.9	487.97	868.81	352.98	880.1	492.17	139.6471	135.1761	144.2242	60461.32	59232.57	61760.63	2528.064	1228.752	1299.312	60461.32	59232.57	61760.63
4-47	875.9	487.97	889.77	628.58	880.1	492.17	893.97	632.78	141.2924	136.7523	145.9331	60923.55	59661.2	62256.46	2595.264	1262.352	1332.912	60923.55	59661.2	62256.46
4-48	889.77	628.58	883.32	768.79	893.97	632.78	887.52	772.99	140.3583	136.4263	144.4275	60660.45	59572.14	61819.31	2247.168	1088.304	1158.864	60660.45	59572.14	61819.31
4-49	883.32	768.79	878.58	908.65	887.52	772.99	882.78	912.85	139.9403	135.9543	144.061	60543.29	59443.56	61713.58	2270.016	1099.728	1170.288	60543.29	59443.56	61713.58
5-1	-2.1	-2.1	20.86	67.97	2.1	2.1	25.06	72.17	73.73579	68.48938	79.08033	46396.97	45650.79	47213.7	1562.904	746.172	816.732	46396.97	45650.79	47213.7
5-2	20.86	67.97	27.45	208.45	25.06	72.17	31.65	212.65	140.6345	136.301	145.0818	60738.06	59537.95	62008.73	2470.776	1200.108	1270.668	60738.06	59537.95	62008.73
5-3	27.45	208.45	111.77	348.7	31.65	212.65	115.97	352.9	163.6457	157.8886	169.4154	67739.92	65888.82	69661.59	3772.776	1851.108	1921.668	67739.92	65888.82	69661.59
5-4	111.77	348.7	102.62	488.63	115.97	352.9	106.82	492.83	140.2288	136.385	144.215	60624.13	59560.86	61757.96	2197.104	1063.272	1133.832	60624.13	59560.86	61757.96
5-5	102.62	488.63	75.49	628.8	106.82	492.83	79.69	633	142.7714	139.5328	146.1796	61343.67	60429.41	62328.48	1899.072	914.256	984.816	61343.67	60429.41	62328.48
5-6	75.49	628.8	97.22	768.43	79.69	633	101.42	772.63	141.3108	136.5598	146.1487	60928.73	59608.59	62319.43	2710.848	1320.144	1390.704	60928.73	59608.59	62319.43
5-7	97.22	768.43	25.39	908.81	101.42	772.63	29.59	913.01	157.6899	155.9665	159.6158	65826.09	65285.55	66437.19	1151.64	540.54	611.1	65826.09	65285.55	66437.19
5-8	25.39	908.81	165.05	67.98	29.59	913.01	169.25	72.18	852.3497	855.8184	848.9084	767460	773385.1	761605.5	11779.66	5925.108	5854.548	767460	773385.1	761605.5
5-9	165.05	67.98	155.74	208.24	169.25	72.18	159.94	212.44	140.5686	136.7291	144.5504	60719.54	59654.84	61854.8	2199.96	1064.7	1135.26	60719.54	59654.84	61854.8
5-10	155.74	208.24	210.57	348.83	159.94	212.44	214.77	353.03	150.9035	145.4841	156.3608	63731.88	62125.63	65408.69	3283.056	1606.248	1676.808	63731.88	62125.63	65408.69
5-11	210.57	348.83	255.97	488.38	214.77	353.03	260.17	492.58	146.7493	141.4817	152.0665	62495.36	60977.06	64084.22	3107.16	1518.3	1588.86	62495.36	60977.06	64084.22

5-12	255.97	488.38	156.86	627.97	260.17	492.58	161.06	632.17	171.1963	170.3039	172.2889	70268.16	69963.41	70643.47	680.064	304.752	375.312	70268.16	69963.41	70643.47
5-13	156.86	627.97	225.32	768.51	161.06	632.17	229.52	772.71	156.3274	150.7247	161.9541	65398.26	63677.94	67189.14	3511.2	1720.32	1790.88	65398.26	63677.94	67189.14
5-14	225.32	768.51	161.29	908.71	229.52	772.71	165.49	912.91	154.1294	152.1556	156.3042	64715.88	64111.33	65390.99	1279.656	604.548	675.108	64715.88	64111.33	65390.99
5-15	161.29	908.71	315.17	68.44	165.49	912.91	319.37	72.64	854.244	857.6326	850.8833	770692.7	776493.7	764962.3	11531.35	5800.956	5730.396	770692.7	776493.7	764962.3
5-16	315.17	68.44	305.13	208.14	319.37	72.64	309.33	212.34	140.0603	136.2462	144.0185	60576.89	59523.03	61701.32	2178.288	1053.864	1124.424	60576.89	59523.03	61701.32
5-17	305.13	208.14	376.28	348.69	309.33	212.34	380.48	352.89	157.5329	151.9	163.1876	65776.63	64033.63	67590.19	3556.56	1743	1813.56	65776.63	64033.63	67590.19
5-18	376.28	348.69	333.47	487.97	380.48	352.89	337.67	492.17	145.7107	143.0264	148.5841	62191.61	61416.55	63037.24	1620.696	775.068	845.628	62191.61	61416.55	63037.24
5-19	333.47	487.97	308.2	628.01	337.67	492.17	312.4	632.21	142.3017	139	145.7708	61209.77	60280.99	62209.12	1928.136	928.788	999.348	61209.77	60280.99	62209.12
5-20	308.2	628.01	360.32	768.86	312.4	632.21	364.52	773.06	150.1839	144.8087	155.6003	63515.22	61929.55	65171.44	3241.896	1585.668	1656.228	63515.22	61929.55	65171.44
5-21	360.32	768.86	327.49	908.61	364.52	773.06	331.69	912.81	143.5544	140.517	146.7695	61567.87	60705.02	62501.28	1796.256	862.848	933.408	61567.87	60705.02	62501.28
5-22	327.49	908.61	516.14	68.89	331.69	912.81	520.34	73.09	860.65	863.8419	857.4875	781678.5	787182.8	776244.8	10937.98	5504.268	5433.708	781678.5	787182.8	776244.8
5-23	516.14	68.89	457.4	208.74	520.34	73.09	461.6	212.94	151.6852	149.5405	154.0293	63968.41	63322.37	64685.01	1362.648	646.044	716.604	63968.41	63322.37	64685.01
5-24	457.4	208.74	456.76	348.24	461.6	212.94	460.96	352.44	139.5015	135.3865	143.7441	60420.66	59289.52	61622.36	2332.848	1131.144	1201.704	60420.66	59289.52	61622.36
5-25	456.76	348.24	467.65	488.54	460.96	352.44	471.85	492.74	140.722	136.2643	145.2858	60762.68	59527.97	62067.96	2539.992	1234.716	1305.276	60762.68	59527.97	62067.96
5-26	467.65	488.54	423.05	628.15	471.85	492.74	427.25	632.35	146.561	143.9351	149.377	62440.11	61677.31	63273.48	1596.168	762.804	833.364	62440.11	61677.31	63273.48
5-27	423.05	628.15	468.36	767.99	427.25	632.35	472.56	772.19	146.9974	141.733	152.3114	62568.22	61048.24	64158.76	3110.52	1519.98	1590.54	62568.22	61048.24	64158.76
5-28	468.36	767.99	542.07	908.72	472.56	772.19	546.27	912.92	158.865	153.206	164.5438	66198.1	64432.08	68034.67	3602.592	1766.016	1836.576	66198.1	64432.08	68034.67
5-29	542.07	908.72	666.44	68.37	546.27	912.92	670.64	72.57	849.5034	853.0566	845.977	762616	768665.5	756637.1	12028.46	6049.512	5978.952	762616	768665.5	756637.1
5-30	666.44	68.37	581.73	208.87	670.64	72.57	585.93	213.07	164.0611	162.735	165.5897	67876.03	67442.68	68379.95	937.272	433.356	503.916	67876.03	67442.68	68379.95
5-31	581.73	208.87	652.76	348.52	585.93	213.07	656.96	352.72	156.676	151.0396	162.3341	65507.38	63772.95	67312.38	3539.424	1734.432	1804.992	65507.38	63772.95	67312.38
5-32	652.76	348.52	583.94	488.84	656.96	352.72	588.14	493.04	156.2879	154.4687	158.3091	65385.89	64820.57	66021.77	1201.2	565.32	635.88	65385.89	64820.57	66021.77
5-33	583.94	488.84	692.05	628.06	588.14	493.04	696.25	632.26	176.2668	170.3751	182.1616	72029.98	69987.69	74142.83	4155.144	2042.292	2112.852	72029.98	69987.69	74142.83
5-34	692.05	628.06	578.51	768.52	696.25	632.26	582.71	772.72	180.611	180.0819	181.3333	73580.34	73389.5	73841.75	452.256	190.848	261.408	73580.34	73389.5	73841.75
5-35	578.51	768.52	604.39	908.05	582.71	772.72	608.59	912.25	141.9098	137.0556	146.8439	61098.4	59744.23	62523.12	2778.888	1354.164	1424.724	61098.4	59744.23	62523.12
5-36	604.39	908.05	767.42	68.29	608.59	912.25	771.62	72.49	855.4389	858.7756	852.1305	772735.6	778455.5	767086.4	11369.06	5719.812	5649.252	772735.6	778455.5	767086.4
5-37	767.42	68.29	734.4	208.09	771.62	72.49	738.6	212.29	143.6467	140.6154	146.8557	61594.36	60732.69	62526.59	1793.904	861.672	932.232	61594.36	60732.69	62526.59
5-38	734.4	208.09	827.9	348.56	738.6	212.29	832.1	352.76	168.7426	162.9233	174.57	69434.07	67504	71434.7	3930.696	1930.068	2000.628	69434.07	67504	71434.7
5-39	827.9	348.56	825.93	488.56	832.1	352.76	830.13	492.76	140.0139	135.9401	144.2172	60563.88	59439.71	61758.61	2318.904	1124.172	1194.732	60563.88	59439.71	61758.61
5-40	825.93	488.56	750.27	628.84	830.13	492.76	754.47	633.04	159.3829	157.7827	161.1862	66362.91	65855.39	66941	1085.616	507.528	578.088	66362.91	65855.39	66941
5-41	750.27	628.84	733.51	768.46	754.47	633.04	737.71	772.66	140.6223	137.0325	144.3674	60734.64	59737.9	61801.95	2064.048	996.744	1067.304	60734.64	59737.9	61801.95
5-42	733.51	768.46	744.5	908	737.71	772.66	748.7	912.2	139.9721	135.5102	144.5404	60552.19	59323.02	61851.92	2528.904	1229.172	1299.732	60552.19	59323.02	61851.92
5-43	744.5	908	925.89	68.02	748.7	912.2	930.09	72.22	859.342	862.5753	856.1378	779428.7	784996.2	773931.9	11064.31	5567.436	5496.876	779428.7	784996.2	773931.9
5-44	925.89	68.02	933.58	208.63	930.09	72.22	937.78	212.83	140.8201	136.4546	145.2973	60790.31	59579.87	62071.31	2491.44	1210.44	1281	60790.31	59579.87	62071.31
5-45	933.58	208.63	861.26	347.99	937.78	212.83	865.46	352.19	157.0076	155.3175	158.9019	65611.39	65083.54	66209.81	1126.272	527.856	598.416	65611.39	65083.54	66209.81
5-46	861.26	347.99	922.7	488.72	865.46	352.19	926.9	492.92	153.5572	148.0434	159.1016	64539.81	62876.86	66273.31	3396.456	1662.948	1733.508	64539.81	62876.86	66273.31
5-47	922.7	488.72	903.86	628.42	926.9	492.92	908.06	632.62	140.9647	137.4449	144.6428	60831.04	59851.09	61881.54	2030.448	979.944	1050.504	60831.04	59851.09	61881.54
5-48	903.86	628.42	883.29	768.76	908.06	632.62	887.49	772.96	141.8395	138.375	145.464	61078.44	60107.65	62119.79	2012.136	970.788	1041.348	61078.44	60107.65	62119.79
5-49	883.29	768.76	937.41	908.83	887.49	772.96	941.61	913.03	150.1618	144.7503	155.6119	63508.58	61912.66	65175.06	3262.392	1595.916	1666.476	63508.58	61912.66	65175.06
															838600.7	**412773.6**	**425827.2**			

The value of R, E_charge, E_ts, and E_{rx} has been considered 4096 bits, 50000 Pico-Joules, 10 Pico-Joules, and 204800000 Pico-Joules respectively. Similarly, we have calculated the average energy, minimum energy, and maximum energy for random as well as square deployment. The below table shows the comparison of results.

Table **3:** Comparison of results of 3 deployments strategies.

Deployments	Maximum Energy (pJ)	Minimum Energy (pJ)	Average Energy (pJ)
S-shaped	838600.7	412773.6	425827.2
Random	864823.7	426308.4	438525.9
Spiral	848969	418425.9	430717.5

6. RESULT ANALYSIS

We have used the data from Table 3 for experimental purposes. As it is visible in Table 3 that the S-shaped in performing better than the other 2 deployment strategies. So we have compared the data of S-shaped deployment with the data taken from existing literature [39]. Applying our strategies (deployment strategies and clustering process) we have obtained a large set of results as depicted in Tables 2, 3, and 4.

Applying Random Deployment Strategy and Area-wise Clustering Process

The calculations of the energy saved are shown in table 2. There are five iterations and the energy saved has been calculated for every node which sums up to 864823.7 Pico-Joules in case of maximum energy saving. Considering the initial energy of nodes as 1 Joule and not taking duty cycle into account we have calculated the number of days by using the formula

$$days = \frac{1\times10^{12}\ \text{Joules}}{86400\times E_S} \quad (13)$$

Where E_s=Energy saved and 1day=86400 seconds.
Putting the value of E_S as 864823.7 we get 13 days and 3 hours or 315 hours.
So this network can save up to 267.75 hours to 362.25 hours or 11.15 days to 15.09 days.

Applying Spiral Deployment Strategy and Area-wise Clustering Process

The calculations of the energy saved are shown in table 3. There are five iterations and energy saved that have been calculated for every node which sums up to 848969.0 Pico-Joules in case of maximum energy saving. Considering the initial energy of nodes as 1 Joule and not taking duty cycle into account we have calculated the number of days by using the formula

$$days = \frac{1\times10^{12}\ \text{Joules}}{86400\times E_S} \quad (14)$$

Where E_s=Energy saved and 1day=86400 seconds.
Putting the value of E_S as 864823.7 we get 13 days and 6 hours or 318 hours.
So this network can save up to 270.3 hours to 365.7 hours or 11.25 days to 15.23 days.

Applying S-pattern Deployment Strategy and Area-wise Clustering Process

The calculations of the energy saved are shown in table 2. There are five iterations and energy saved that have been calculated for every node which sums up to 838600.7 Pico-Joules in case of maximum energy saving. Considering the initial energy of nodes as 1 Joule and not taking duty cycle into account we have calculated the number of days by using the formula

$$days = \frac{1\times10^{12}\ \text{Joules}}{86400\times E_S} \quad (15)$$

Where E_s=Energy saved and 1day=86400 seconds.

Putting the value of E_S as 864823.7 we get 13 days and 8 hours or 320 hours. So it can be concluded that the concept can save up to 272 hours to 368 hours or 11.33 days to 15.33 days of a lifetime of WSN. Therefore, from the above calculations, we can say that the s-pattern deployment is performing better than the other two deployments as the network will remain active for a longer time in the case of s-pattern deployment. In this research work, the obtained result (the lifetime of WSN) has been compared with the paper of [38] by scaling up the external environmental parameters like covered area size, several nodes deployed, several rounds have also been compared and it has been seen that the lifetime saving can be done 10 to 11 days by applying their method which can be increased 1 to 5 days in case of random deployment strategies using modified ACO. Lifetime saving can be increased.

We have compared our work with other literature [39] to prove that our experiments have yielded better results than other papers.

Table **4**. Comparison of results obtained by our proposed algorithm and existing literature [39].

Parameters / Algorithms	Totalxy (max)	Totalxy (min)	Energy Saved	Days
ACO and Random Deployment	100389425972.31	100389269395.97	864823.68	13.38
ACO and Spiral Deployment	100388152202.95	100387999246.18	848969.016	13.63
ACO and S-pattern Deployment	36589595.82	36436618.21	838600.728	13.8
DE-QPSO	17214960557260.80	17215930368000.00	969810739.2	7
DE	21862999907721.216	21864231567360	1,231,659,638.784	5.5
QPSO	19280755824132.096	19281842012160	1086188027.904	6.2

In this table, we have compared our work to another literature [38] and found out that our experiment has performed better than the existing literature [39]. We have obtained a value of about 13 days which is 6 days more than the value obtained by applying the DE-QPSO algorithm. In our experiment, we have covered a large area (1 km^2) than the existing literature [39]. Other than that, we have also deployed more nodes and have more clusters as well. Some parameters such as equivalent distribution, number of iterations, maximum energy have been set to a permissible range to get a better result set. In practical life, the level may not match with the theoretical result due to physical dependencies like external environmental factors.

7. CONCLUSION

In this paper, efficient Wireless Sensor Networks have been configured taking energy minimization as the prime concern. To minimize the energy consumption a modified ACO algorithm has been proposed. In this research minimization of energy consumption leads to an increment of the lifetime of WSN to a significant margin theoretically. The obtained result has been compared with the existing literature and it has been found that the proposed algorithm produced better results than the existing literature. There are some challenges present in the research work and one of the prime challenges is the selection of the type of deployment techniques to get the minimum energy consumption. One can use fuzzy logic and fuzzy inference rule in the future to decide which type of deployment should be applied to get the minimum energy consumption and increasing the lifetime of the overall network. There is some difference between the theoretical result and the practical because of physical dependencies like some external environmental factors in practical life, which is not considered in the theoretical experimental environment. One can incorporate those parameters in their experiment and think about future work related to WSN. In this research work, some physical dependencies like different environmental hazards as well as physical hazards have been considered. To implement those hazards in the experimental environment an allowable level of tolerance percentage should be incorporated, which is also another challenge in this research work. In the future, one can work on these challenges. One can incorporate uncertainty and random function in the obtained experimental result to make the situation more realistic because the reality is full of uncertainty and randomness. Fuzzy system configuration can be a good choice to figure out the situation.

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