**1. Introduction**

Wireless Sensor Network briefly known as WSN having wide range of application in modern day technology of day to day life. WSN is a tiny device having sensing, communicative, processing and storage units with power back up by non-rechargeable battery. Due to its tiny and compact design it can be deployed in any place whichever suitable either mount or roam. Due to sensing and communicating ability it can be treated as intellectual device in different application area of engineering. The WSN nodes are deployed in the target area to gather various types of important and related information and transfer that information to sink node. Sink node is the controller communicative node used as local server which connects to some other global or local robust network. Sink node act as an administrator node to all controlling sensor nodes. Nowadays this type of network is being used in a modern army, environmental monitoring, battlefield monitoring, body area network, intelligent household etc.

Depending upon the moving nature of WSN, it may be classified to two types and those are static WSN and dynamic WSN. In case of static WSN the whole unit is mounted and fixed to a certain fixed point (co-ordinate with reference to the sink node). In case of dynamic WSN the node is dynamic in nature, though the sink node is generally mounted to a fixed co-ordinate. Now depending upon the need and purpose the node is selected. In our experiment we have used static nodes where the coordinate of sink node as well as typical nodes are fixed and permanent.

In case of typical WSN design, the sensor node is deployed to cover the target area. The sensor node is appointed to sense the related data and transferred to sink node may be directly or via another sensor node. Now in case of our research we have clustered the target area into uniform cell. The cell structure may be trigonal, square or hexagonal in shape but not circular otherwise total area can’t be covered without any area uncovered as depicted in the figure.

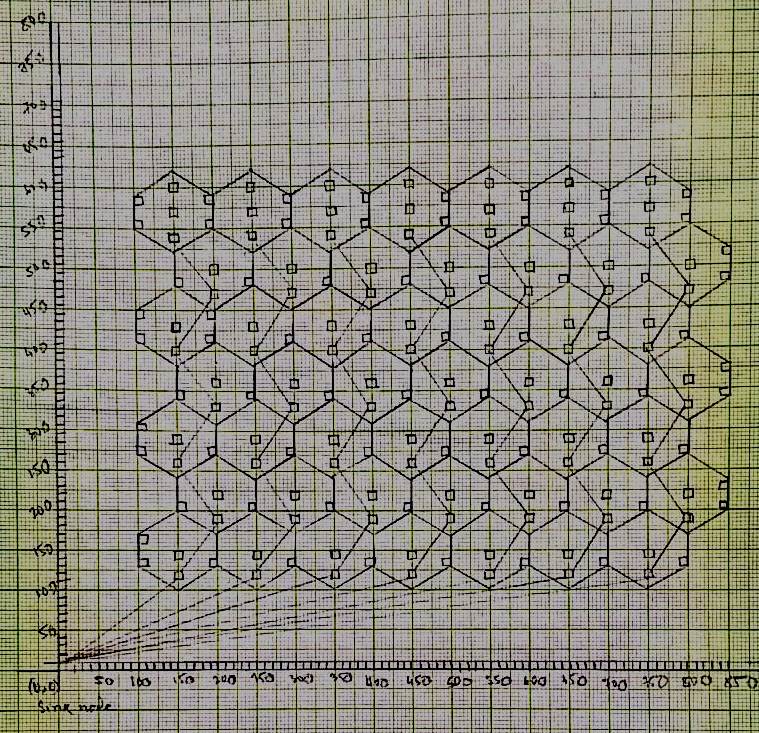
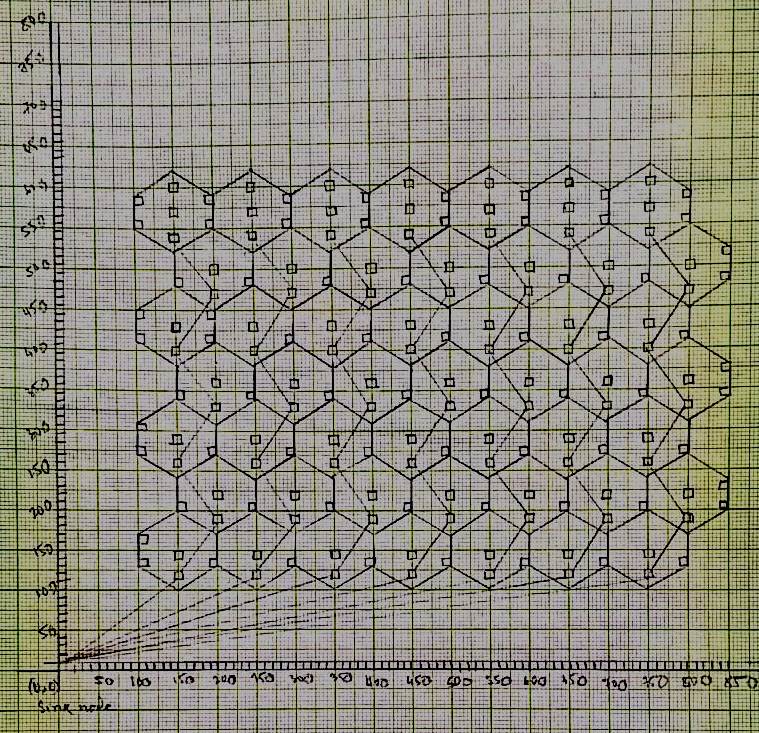


Fig1:

In our research work we have taken imaginary square structure to cover the whole target area to get the cell structure.



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

Our research is based on, Optimization of consumed energy therefore we have used a special ACO algorithm (called …ACO algorithm) by which we can design an efficient network.

In case of WSN building the energy required to become active for certain time is a major concern in our research work.

In this paper we have worked with the following characteristics to make a network reliable should have:

**2. Related Work**

We know that A wireless sensor network (WSN) consists of sensor nodes and they are distributed around a given location. These sensors have limited energy capacity to be active for a long period of time (Pantazis et al. 2013). For the last few years, sensors have improved in their computational capabilities; the batteries are still not highly efficient in comparison. Consequently, to extend the life of a sensor node, research has been pointed towards reducing the demand for energy of the nodes. The reason for doing this, to design the core aspects in a WSN are Energy Efficiency and Reliability (Zenia et al.  2016). By using Energy Efficient (EE) Routing, the life of a sensor node can be extended (ECE 2013). During transmission energy is expended, the most energy efficient route during transmission will consume the least energy.

Basically, routing protocols for WSN are classified into the flat protocol, hierarchical protocol and location-based Protocol (Liao and Zhu 2013). In Flat protocol routing scheme, distribution of the nodes is uniform. In the case of the hierarchical scheme, nodes are given different roles and groups known as clusters (Gajjar 2015). In the case of location-based protocol, each cluster must have a Cluster Head (CH). The cluster head is a node that has higher capabilities than other nodes and is used to relay data to the sink node. Within a distribution of nodes, there may be many possible routes to get to a particular destination. In our approach, we have used this type of protocol to achieve efficient network.

Mathematical models were developed in (Lee and Moon 2014) to determine the most energy efficient route to use in a WSN under resource restriction. The task of determining the most energy efficient route is a hard optimization problem (Wang et al. 2008). Consequently, many meta-heuristic techniques have been developed to find the most optimal energy efficient route.

Liao and Zhu 2013 presented the primary objectives of the wireless sensor network routing protocol design. The main purpose of this protocol is to balance network energy consumption and to improve the efficiency of data transmission. Therefore it will extend the lifetime of the entire network. The paper analyses the usefulness of LEACH protocol in the cluster-head selection, and proposes an enhanced clustering algorithm. This new algorithm takes the node’s remaining energy and location information into account optimizes the selection method of the threshold for electing cluster-head improves optimal cluster-head selection approach that is normal nodes select the optimal cluster-head based on the cost function.

An Adaptive Ant Colony Optimization (ACO) algorithm is proposed in (Ye and Mohamadian 2014) for clustering based dynamic routing in a WSN. This was designed to deal with the impulsive nature of a Wireless Sensor Network. Sensors nodes can be deployed in two different types, sparse or dense nature. The ACO finds the optimal network setting to improve data aggregation so that data redundancy can be reduced. An adaptive routing scheme based on ACO was also developed in (Wang et al. 2008). Route selection is based on the residue energy in the nodes as well as the location of nodes. In this case, clusters were not used in the grouping of nodes. Fuzzy logic was used in addition to ACO in (Gajjar et al. 2015) in a cross-layer WSN protocol stack to optimize routing in a WSN. To improve the Energy Efficiency of the routing protocol, a multilayer approach was adopted. Nodes were grouped into clusters with cluster heads which are closest to the sink. Fuzzy logic was used in the cluster head selection using metrics such as residual energy, number of neighbours and superiority of communication link for the selection. However, ACO was used for reliable and energy efficient inter-cluster routing from cluster heads to sinks. ACO was further used to determine a multi-objective optimization i.e. energy efficiency and security of transmitted data (Luo et al. 2015) in a WSN. The factors used to carry out this include the time delay, bandwidth and energy consumption. Neural Network was used together with ACO  for the purpose of routing in (Li et al. 2015). The neural network is used to select the cluster head while ACO was used to determine the best route. An ACO was used to develop an enhanced routing protocol for WSN (Umadevi and Devapriya 2015) with mobility as the metric.

Artificial Bee Colony meta-heuristics algorithm (Ari et al. 2016) and improved harmony search algorithm (Zeng and Dong 2016) were used to determine the optimal energy efficient route in a WSN. An Improved Genetic Algorithm was developed to eliminate the possibility of choosing an invalid note for routing in a WSN (Yao 2016). Parameters used in the node selection include nodes position in relation to sink, neighbouring nodes, remaining energy and energy requirement. Since this research work was based on using Firefly and Ant Colony optimization algorithms for route optimization, the literature will be based on them.

After a thorough study it can be concluded that there are various challenges of WSN like limited data processing ability due to lower processing speed, lower data transferring speed due to low bandwidth of the communicative unit, lower range of area coverage by the communicative device due to less powerful transmitting and receiving units, It also face limited data storage problem due to its tiny size and last but not the least the WSN suffers from power backup problem again due to its size. Area coverage optimization and power consumption optimization is the main goal of the paper.

**3. Methodology**

In this paper two modified meta-heuristic algorithms (i.e., modified ACO algorithm) have been used, for selecting the cluster head of the efficient WSN and getting the efficient network route.

In Ant Colony Optimization, we select an efficient route by applying the optimization techniques keeping mind the constraints. In this case, we have to cover the target area efficiently subject to fulfilling the condition of constraints (see equation 7A to 7J). After the temporary route is established, each and every route loses some energy due to the transmission and receiving data. When, Energy level comes below the threshold value then the route is broken and we have to detect where the route is broken. The Solution to establish a new Route is found out taking help of nearest adjacent sensor node which was in sleeping condition. Now, the sleeping node will be alive and the previous node will be declared as a dead node. This process will be continued until each and every node is being used and is declared as a dead node. Depending upon the previous condition the lifetime of the entire WSN in fixed. By following this process we have been able to establish a new protocol for WSN to minimize the power consumption and maximize the coverage area.

Box 1. Pseudo-code for ACO

|  |
| --- |
| Step 1: Using randomness property at first generates the *ANTpopulation (population* *variant*) (related to population set generation) and evaluate the *ANTsolution* and fix the *ANTsize (population size* *variant*). Define Attractiveness (τ) and Visibility Function (η). Set the bounds of decision variables.   Step 2: Set the iteration (generation) number *t = 0*.   Step 3: Initialize randomly the *ANTsolution* of the population *ANTpopulation(t) = {pi(t); i=1,…, ANTsize }* .   Step 4: Calculate the next *ANTsolution* using the Attractiveness function (τ) and Visibility Function (η). In this paper, ere Visibility function is matched/correlated with fitness function [*fitness(pi)*] for each variable *pi* of *ANTpopulation(t)* and attractiveness is related to the local Pheromone-updating phenomenon*.*  Step 5: Search the global-best *ANTsolution* (i.e., *ANTpopulation(global)*) having thebest fitness/Visibility rate depending upon global-Pheromoneupdating law and local updating law and choose best solution.  Step 6: Repeat step 1 to 5 until termination criterion is met and increase generation by 1 i.e., *t= t+1*, which is related to time.   Step 7: Check the termination-criterion. If termination criteria are not met, go back to Step 6, otherwise go to Step 8.   Step 8: Print the value of fitness and/or Attractiveness value of *ANTpopulation(global)*.   Step 9: End. |

Update the amount of pheromone using global Update rule and update and compare with ANTsolution obtained by local update rule and choose the best one.

Termination condition?

Yes

No

*PANT(t)*

Find *ANTpopulation(global)*

Print Result

End

Update ANTsolution by local Update rule

rule

*Update ANT solutions*

Initialize *ANTpopulation*

*Initialize ANT solutions*

*Figure The block diagram of the modified ACO algorithm (inspired from [])*

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

* 1. If both (before modification by global update rule and after modification by global update rule) solution is feasible then choose the ANTsolution for which the nearest value of global optimum is achived.
  2. If any one solution is infeasible then discard it and obtain the feasible ANTsolution.
  3. If both (before modification by global update rule and after modification by global update rule) solution is infeasible then discard the ANTsolution and find next ANTsolution.

**4. Solution Methodology:**

In this paper we have some steps through which the entire process of the network formation can be explained.

1. **Indexing for Sensor Nodes**: The sensor nodes to be deployed should be indexed virtually just to denote or keep track the each and every sensor nodes before and after the deployment. This indexing process will also help to form the network in an efficient manner. The indexing has been proposed by the help of row and column number of the cell (as depicted in the figure 2.). It also helps us to get the matrix of row and column number of the target area. The indexing is generally a sequential number.
   1. **Indexing before Deployment**: This is the indexing that is given to the sensor node before deployment which will help us just to keep track the total number of sensor nodes to be deployed and to maintain the serial of sensor nodes.
   2. **Indexing after Deployment:** This type of indexing much more important because this indexing is given to the sensor nodes after deployment and by this indexing the sensor node will be denoted until the sensor node become fully exhausted.

2. **Clustering:** Here clustering meansseparating target area into some uniform chunks. Here our aim is to construct the efficient cluster-cell. The structure of cluster cells has been chosen as square. It can be proved (Katz 2008) that using square cluster-cell the target area can be covered properly and the cost can be energy consumption can be minimized. Here the term efficiently refers to the efficient and uniform coverage of target area with no gap between the neighbouring clusters.



Figure 2. structure of cluster cell and their representation

4. **Deployment of WSN nodes** (different strategies):

A. **Random deployment of sensor nodes**: In case of random deployment the deployment is done randomly means the sensor nodes are deployed to the target area from a certain distance and speed and as it is very difficult to predict the position of sensor nodeso we have used this strategy. Certain numbers of nodes are deployed in the target area in a fixed amount of time and maintain a time interval but, without maintaining any fix strategy. In case of deployment of WSN nodes in some field this type of deployment can be considered.

B. **S pattern deployment**: In this type of deployment deployment-ship follow the S-pattern movement at the time of deployment of sensor nodes. A fixed amount of deployment time and maintaining a time interval and the path of is followed. Here the strating time and ending time of deployment is fixed and the deployment is done in between this (see figure no 5 to 7).

C. **Spiral deployment**: In this type of deployment deployment-ship follow the Spiral-pattern movement at the time of deployment of sensor nodes(see figure no 5 to 7), other criteria is same with previous deployment.

5. **Selection of a sensor node as cluster head**: The selection process has been done by the help of meta-heuristic algorithm i.e., ACO algorithm. Selection of sensor node as a cluster head (CH) is an important job towards development of an efficient network configuration because with the help of cluster head only the internal network is formed.

Here in this paper the selection of 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 by the help of meta-heuristic algorithm i.e., ACO algorithm.

b) After the full exhaustion of one cluster head another sensor node is considered as active cluster head and replaces the previous one.

c) The intermediate network will sustain for some time and thus it will give stability to the whole network to perform for longer period of time and ultimately when all the sensor-nodes of a particular cluster will be exhausted the whole network will be down.

6. **WSN network configuration through modified ACO algorithm:**

Using ACO algorithm choosing the optimized path for the minimization of energy consumption for transmitting the data as well as receiving data: ACO algorithm is used to choose the optimized the path for the minimization of energy consumption for transmitting the data. 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:

(5)

Subject to,

*d do*, for free-space propagation model and *d > do* for two- ray ground propagation model.

Where *do* is the threshold transmission distance.

Where,

(5A)

(5B)

(5C)

For two- ray ground Propagation model

(5D)

(5E)

(5F)

(5H)

Therefore the problem can be defined as objective function as follows

subject to, *d > do* Where *do* is the threshold transmission distance. (6)

where, (6A)

(6B)

(6C)

(6D)

(6E)

(6F)

(6G)

For Free-space propagation model

(6H)

(6I)

(6J)

(6K)

(6L)

(6M)

Therefore the problem can be defined as objective function as follows

subject to, *d <=do* Where *do* is the threshold transmission distance. (7)

where, (7A)

(7B)

(7C)

(7D)

(7E)

(7F)

(7G)

(7H)

(7I)

(7J)

= energy required for the transmitting data packets between two adjacent cluster head for the amplifier to maintain an acceptable signal-to-noise ratio in order to transfer data messages reliably.

= energy required for the transmitting data packets between sink node and cluster head for the amplifier to maintain an acceptable signal-to-noise ratio in order to transfer data messages reliably.

=Electronic energy degenerated during the transmission between two adjacent cluster heads.

=Electronic energy degenerated during the transmission between sink node and adjacent cluster head.

*Etx* = amount of energy used by each node at the time of transmitting data packets.

*Erx* = energy used for receiving data packets.

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

*dxy* (8)

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

Figure 3. Basic block diagram of WSN communicating devices.

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. Now we have applied the coverage optimization for the targeted area and the corresponding coordinate of active cluster head node (Si,Pj: see equation 8-9) has been plotted and surprisingly it has been exactly matched with the coordinates of the first phase cluster head position already detected by the ACO algorithm. After getting an efficient path through the meta-heuristic algorithm i.e., ACO we tried for coverage optimization to cover maximum area and we have used DE-QPSO hybrid algorithm as the optimization technique. Here by maximizing the area coverage we can claim that our designed network is an efficient network with respect to minimization of energy consumption. Here comparison has been made between Coverage Ratio vs. Range [meter] as depicted in Figure 6.

**5. Numerical Result analysis**

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, which further may help us to form a robust routing protocol for minimizing energy consumption.

The following parameter values are used in the experiment for the simulating the system (Lande and Kawale 2016).

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | value | Parameter | value |
| Size of target area | 850 x 650 m2 | Data packet size (k) | 512 bytes |
| Total number of sensor nodes | 49 | Max no. of nodes (in the network) | 217 |
| Initial energy | 1J |  | 50 nJ/bit |
|  | 10pJ • bit−1 •m−2 | Maximum Number of Round | 1000 |

Table 1. Parameters for simulation.

In Table 1, the scale of energy is different for the initial energy, and and those scales are Joule, Nano Joule and Peta-Joule respectively. So for maintaining equivalency all calculations have been done in Peta-Joule in the Table 2 and Table 3.In this section we have plotted the best path of shortest distances (see Figure 5) obtained from the ACO algorithm by solving the equation 7 to 7H on the basis of the data supplied in the Table 1. As the energy consumption is directly proportional with distance between nodes that’s why we have calculated maximum coverage area. We obtained the coordinates of sink node and cluster head as depicted in Table 2 and Table 3.The Table 1 shows the communication between sink node and cluster head, whereas the Table 2 shows the communication between adjustment cluster heads. In the below diagram we are going to show the first phase of path selection until we get the minimum consumed energy for the shortest distance between nodes. Here first phase denotes the consumption of full initial energy (here 1 joule) of a node so that we can declare the node as dead note and in second phase we will not consider that node as participating nodes.

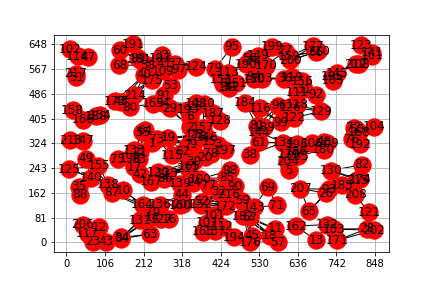


Figure 4. Deployment of WSN nodes for the Expected Coverage Area and

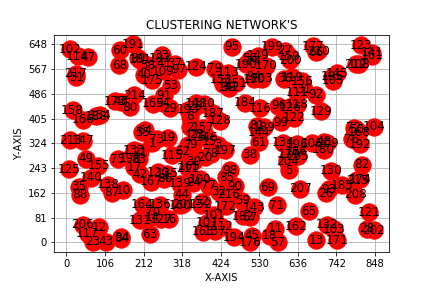


Figure 5. Path Covered in the cluster representation of the network.

**6. Numerical Data representation**

Among two types of propagation models i.e., two ray propagation model and free space propagation models, the second one is related with distance between communicating nodes therefore in our experiment we have chosen only free space propagation model to show the result.

The representation of a node path has been denoted using Path number, source node coordinator and cell index of destination node. Here cell index is denoted as row and column number of the designated cell. The first cell has been considered as the nearest cell to the sink node and it has been denoted as (r1, c1) means row number one and column number one.

As for example, p1\_(0,0)->(r1,c1) denotes the communication of path no one and the source node is the sink node and the destination node belongs cell of the row number one and column number one.

As the path number is associated with a specific communication path therefore we didn’t gave each and individual node number in short when the new node of the cell (r1,c1) will be selected the path number obviously will be changed.

The numerical result related to the supplied data from Table 1 data has been calculated and represented in the below Table 2 and Table 3.

For Free space Propagation model (*dxy d0*)

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Path number\_(sink node)->(row number, Column number) | Calculated threshold distance (d0) in meter | Obtained distance ( dxy) between sink node and cluster head in the feasible range (d0 to dxy) after applying ACO algorithm | Sink node co-ordinate  (x1,y1) for d0 | Cluster node coordinate  (x2,y2) for d0 | Sink node co-ordinate  (x1,y1) for dxy | Cluster node coordinate  (x2,y2) for dxy | Minimized  (in pJ) | Calculated  (in pJ) | Calculated  (in pJ) | total Energy consumption before optimization for specific node (in pJ) | total Energy consumption after optimization for specific node (in pJ) | Difference between total Energy consumption before optimization and total Energy consumption after optimization for one node |
| p1\_(0,0)->(r1,c1) | 192.093727 | 188.1586565 | 0,0 | 150,120 | 0,0 | 147.2,117.2 | 206311424000.00 | 206250134732.80 | 204800000000.00 | 411111424000.00 | 411050134732.80 | 61289267.20 |
| p2\_(0,0)->(r1,c2) | 277.3084925 | 273.9753639 | 0,0 | 250,120 | 0,0 | 247.5,117.5 | 207874560000.00 | 207949824000.00 | 412749824000.00 | 412674560000.00 | 75264000.00 |
| p3\_(0,0)->(r1,c3) | 370 | 367.7152159 | 0,0 | 350,120 | 0,0 | 348.2,118.2 | 210338385100.80 | 210407424000.00 | 415207424000.00 | 415138385100.80 | 69038899.20 |
| p4\_(0,0)->(r1,c4) | 465.7252409 | 462.546776 | 0,0 | 450,120 | 0,0 | 447.4,117.4 | 213563372339.20 | 213684224000.00 | 418484224000.00 | 418363372339.20 | 120851660.80 |
| p5\_(0,0)->(r1,c5) | 562.9387178 | 560.0852792 | 0,0 | 550,120 | 0,0 | 547.6,117.6 | 217648968499.20 | 217780224000.00 | 422580224000.00 | 422448968499.20 | 131255500.80 |
| p6\_(0,0)->(r1,c6) | 660.9841148 | 658.1910969 | 0,0 | 650,120 | 0,0 | 647.6,117.6 | 222544507699.20 | 222695424000.00 | 427495424000.00 | 427344507699.20 | 150916300.80 |
| p7\_(0,0)->(r1,c7) | 759.5393341 | 756.6785976 | 0,0 | 750,120 | 0,0 | 747.5,117.5 | 228252160000.00 | 228429824000.00 | 433229824000.00 | 433052160000.00 | 177664000.00 |
| Energy saving using ACO algorithm after optimizing the consumed energy for the communication between sink node and first cluster head of every path | | | | | | | | | | | | 786279628.8 |

Table 2. Data for the communication between sink node and first cluster head

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Path number\_(sink node)->(row number, Column number) | Calculated threshold distance (d0) in meter | Obtained distance (*dxy*) between sink node and cluster head in the feasible range (d0 to *dxy*) after applying ACO algorithm | Sink node co-ordinate  (x1,y1) for d0 | Cluster node coordinate  (x2,y2) for d0 | Sink node co-ordinate  (x1,y1) for dxy | Cluster node coordinate  (x2,y2) for dxy | Minimized  (in pJ) | Calculated  (in pJ) | Calculated  (in pJ) | total Energy consumption before optimization for specific node (in pJ) | total Energy consumption after optimization for specific node (in pJ) | Difference between total Energy consumption before optimization and total Energy consumption after optimization for one node | |
| p1\_(r1,c1)->(r2,c2) | 86.02325267 | 78.77867732 | 150,120 | 200,190 | 152.6,122.6 | 197.4,187.4 | 205054201036.80 | 205103104000.00 | 204800000000.00 | 409903104000.00 | 409854201036.80 | 48902963.20 | |
| p1\_(r2,c2)->(r3,c1) | 85.17088704 | 200,190 | 150,260 | 202.4,192.4 | 147.6,257.6 | 205097127116.80 | 409903104000.00 | 409897127116.80 | 5976883.20 | |
| p1\_(r3,c1)->(r4,c2) | 79.891927 | 150,260 | 200,330 | 152.2,262.2 | 197.8,327.8 | 205061436211.20 | 409903104000.00 | 409861436211.20 | 41667788.80 | |
| p1\_(r4,c2)->(r5,c1) | 85.27602242 | 200,330 | 150,400 | 202,332 | 148,398 | 205097861120.00 | 409903104000.00 | 409897861120.00 | 5242880.00 | |
| p1\_(r5,c1)->(r6,c2) | 81.00567881 | 150,400 | 200,470 | 151.8,401.8 | 198.2,468.2 | 205068776243.20 | 409903104000.00 | 409868776243.20 | 34327756.80 | |
| p1\_(r6,c2)->(r7,c1) | 85.39601864 | 200,470 | 150,540 | 201.6,471.6 | 148.4,538.4 | 205098699980.80 | 409903104000.00 | 409898699980.80 | 4404019.20 | |
| Energy saving using ACO algorithm after optimizing the consumed energy for the communication path p1 | | | | | | | | | | | | | 140522291.2 |
| p2\_(r1,c3)->(r2,c4) | 86.02325267 | 79.33523807 | 250,120 | 300,190 | 252.2,122.2 | 297.4,187.4 | 205057805516.80 | 205103104000.00 | 204800000000.00 | 409903104000.00 | 409857805516.80 | 45298483.20 | |
| p2\_(r2,c4)->(r3,c3) | 85.26206659 | 300,190 | 250,260 | 302.3,192.3 | 247.6,257.6 | 205097213132.80 | 409903104000.00 | 409897213132.80 | 5890867.20 | |
| p2\_(r3,c3)->(r4,c4) | 80.72719492 | 250,260 | 300,330 | 251.8,261.8 | 297.8,327.8 | 205065093120.00 | 409903104000.00 | 409865093120.00 | 38010880.00 | |
| p2\_(r4,c4)->(r5,c3) | 85.24834309 | 300,330 | 250,400 | 302,332 | 248.2,398.2 | 205098061004.80 | 409903104000.00 | 409898061004.80 | 5042995.20 | |
| p2\_(r5,c3)->(r6,c4) | 80.44874144 | 250,400 | 300,470 | 251.3,401.3 | 298.2,468.2 | 205073417011.20 | 409903104000.00 | 409873417011.20 | 29686988.80 | |
| p2\_(r6,c4)->(r7,c3) | 85.22159351 | 300,470 | 250,540 | 301.8,471.8 | 248.4,538.4 | 205098480435.20 | 409903104000.00 | 409898480435.20 | 4623564.80 | |
| Energy saving using ACO algorithm after optimizing the consumed energy for the communication path p2 | | | | | | | | | | | | | 128553779.2 |
| p3\_(r1,c5)->(r2,c6) | 86.02325267 | 79.33523807 | 350,120 | 400,190 | 352.5,122.5 | 397.7,187.7 | 205057805516.80 | 205103104000.00 | 204800000000.00 | 409903104000.00 | 409857805516.80 | 45298483.20 | |
| p3\_(r2,c6)->(r3,c5) | 85.26206659 | 400,190 | 350,260 | 402.3,192.3 | 348.2,258.2 | 205097763635.20 | 409903104000.00 | 409897763635.20 | 5340364.80 | |
| p3\_(r3,c5)->(r4,c6) | 80.72719492 | 350,260 | 400,330 | 352.2,262.2 | 398.4,328.4 | 205066931404.80 | 409903104000.00 | 409866931404.80 | 36172595.20 | |
| p3\_(r4,c6)->(r5,c5) | 85.24834309 | 400,330 | 350,400 | 402.1,332.1 | 347.9,397.9 | 205097667788.80 | 409903104000.00 | 409897667788.80 | 5436211.20 | |
| p3\_(r5,c5)->(r6,c6) | 80.44874144 | 350,400 | 400,470 | 351.9,401.9 | 397.9,467.9 | 205065093120.00 | 409903104000.00 | 409865093120.00 | 38010880.00 | |
| p3\_(r6,c6)->(r7,c5) | 85.22159351 | 400,470 | 350,540 | 402.6,472.6 | 348.2,538.2 | 205097481011.20 | 409903104000.00 | 409897481011.20 | 5622988.80 | |
|  | Energy saving using ACO algorithm after optimizing the consumed energy for the communication path p3 | | | | | | | | | | | | 135881523.2 |
| p4\_(r1,c7)->(r2,c8) | 86.02325267 | 80.03111895 | 450,120 | 500,190 | 452,122 | 497.7,187.7 | 205062347980.80 | 205103104000.00 | 204800000000.00 | 409903104000.00 | 409862347980.80 | 40756019.20 | |
| p4\_(r2,c8)->(r3,c7) | 85.36462968 | 500,190 | 450,260 | 501.8,191.8 | 448.4,258.4 | 205098480435.20 | 409903104000.00 | 409898480435.20 | 4623564.80 | |
| p4\_(r3,c7)->(r4,c8) | 79.7527429 | 450,260 | 500,330 | 452.2,262.2 | 497.7,327.7 | 205060526080.00 | 409903104000.00 | 409860526080.00 | 42577920.00 | |
| p4\_(r4,c8)->(r5,c7) | 85.23485203 | 500,330 | 450,400 | 502.5,332.5 | 448.2,398.2 | 205097573580.80 | 409903104000.00 | 409897573580.80 | 5530419.20 | |
| p4\_(r5,c7)->(r6,c8) | 80.44874144 | 450,400 | 500,470 | 451.9,401.9 | 497.9,467.9 | 205065093120.00 | 409903104000.00 | 409865093120.00 | 38010880.00 | |
| p4\_(r6,c8)->(r7,c7) | 85.24834309 | 500,470 | 450,540 | 502,472 | 447.8,537.8 | 205097667788.80 | 409903104000.00 | 409897667788.80 | 5436211.20 | |
| Energy saving using ACO algorithm after optimizing the consumed energy for the communication path p4 | | | | | | | | | | | | | 136935014.4 |
| p5\_(r1,c9)->(r2,c10) | 86.02325267 | 79.33523807 | 550,120 | 600,190 | 552.5,122.5 | 597.7,187.7 | 205057805516.80 | 205103104000.00 | 204800000000.00 | 409903104000.00 | 409857805516.80 | 45298483.20 | |
| p5\_(r2,c10)->(r3,c9) | 85.29021046 | 600,190 | 550,260 | 601.8,191.8 | 547.9,257.9 | 205097960243.20 | 409903104000.00 | 409897960243.20 | 5143756.80 | |
| p5\_(r3,c9)->(r4,c10) | 79.47439839 | 550,260 | 600,330 | 552.2,262.2 | 597.5,327.5 | 205058710732.80 | 409903104000.00 | 409858710732.80 | 44393267.20 | |
| p5\_(r4,c10)->(r5,c9) | 85.27602242 | 600,330 | 550,400 | 602.1,332.1 | 548.1,398.1 | 205097861120.00 | 409903104000.00 | 409897861120.00 | 5242880.00 | |
| p5\_(r5,c9)->(r6,c10) | 80.72719492 | 550,400 | 600,470 | 551.6,401.6 | 597.8,467.8 | 205066931404.80 | 409903104000.00 | 409866931404.80 | 36172595.20 | |
| p5\_(r6,c10)->(r7,c9) | 85.23485203 | 600,470 | 550,540 | 602.1,472.1 | 547.8,537.8 | 205097573580.80 | 409903104000.00 | 409897573580.80 | 5530419.20 | |
| Energy saving using ACO algorithm after optimizing the consumed energy for the communication path p5 | | | | | | | | | | | | | 141781401.6 |
| p6\_(r1,c11)->(r2,c12) | 86.02325267 | 79.19608576 | 650,120 | 700,190 | 652.1,122.1 | 697.2,187.2 | 205056901939.20 | 205103104000.00 | 204800000000.00 | 409903104000.00 | 409856901939.20 | 46202060.80 | |
| p6\_(r2,c12)->(r3,c11) | 85.20856764 | 700,190 | 650,260 | 702.2,192.2 | 647.7,257.7 | 205097390080.00 | 409903104000.00 | 409897390080.00 | 5713920.00 | |
| p6\_(r3,c11)->(r4,c12) | 80.30952621 | 650,260 | 700,330 | 651.9,261.9 | 697.8,327.8 | 205064176435.20 | 409903104000.00 | 409864176435.20 | 38927564.80 | |
| p6\_(r4,c12)->(r5,c11) | 85.23485203 | 700,330 | 650,400 | 701.8,331.8 | 647.5,397.5 | 205097573580.80 | 409903104000.00 | 409897573580.80 | 5530419.20 | |
| p6\_(r5,c11)->(r6,c12) | 79.47439839 | 650,400 | 700,470 | 652.4,402.4 | 697.7,467.7 | 205058710732.80 | 409903104000.00 | 409858710732.80 | 44393267.20 | |
| p6\_(r6,c12)->(r7,c11) | 85.36462968 | 700,470 | 650,540 | 701.8,471.8 | 648.4,538.4 | 205098480435.20 | 409903104000.00 | 409898480435.20 | 4623564.80 | |
| Energy saving using ACO algorithm after optimizing the consumed energy for the communication path p6 | | | | | | | | | | | | | 145390796.8 |
| p7\_(r1,c13)->(r2,c14) | 86.02325267 | 80.03111895 | 750,120 | 800,190 | 751.9,121.9 | 797.6,187.6 | 205062347980.80 | 205103104000.00 | 204800000000.00 | 409903104000.00 | 409862347980.80 | 40756019.20 | |
| p7\_(r2,c14)->(r3,c13) | 85.29021046 | 800,190 | 750,260 | 801.8,191.8 | 747.9,257.9 | 205097960243.20 | 409903104000.00 | 409897960243.20 | 5143756.80 | |
| p7\_(r3,c13)->(r4,c14) | 79.61356668 | 750,260 | 800,330 | 752.2,262.2 | 797.6,327.6 | 205059617587.20 | 409903104000.00 | 409859617587.20 | 43486412.80 | |
| p7\_(r4,c14)->(r5,c13) | 85.19577454 | 800,330 | 750,400 | 802.4,332.4 | 747.8,397.8 | 205097300787.20 | 409903104000.00 | 409897300787.20 | 5803212.80 | |
| p7\_(r5,c13)->(r6,c14) | 80.1703187 | 750,400 | 800,470 | 751.7,401.7 | 797.5,467.5 | 205063261388.80 | 409903104000.00 | 409863261388.80 | 39842611.20 | |
| p7\_(r6,c14)->(r7,c13) | 85.20856764 | 800,470 | 750,540 | 802.2,472.2 | 747.7,537.7 | 205097390080.00 | 409903104000.00 | 409897390080.00 | 5713920.00 | |
| Energy saving using ACO algorithm after optimizing the consumed energy for the communication path p7 | | | | | | | | | | | | | 140745932.8 |

Table 3. Data for the communication different cluster head

The proposed ACO algorithm has been run for 50 times to get the best result among those run. The problem (see equation no 5, 6 and 7) has been solved considering a different set of random numbers in the feasible set of constraints (see equation no 5A to 5H, 6A to 6M and 7A to 7J). The proposed algorithm has been solved using the Python programming language in the Anaconda environment of Windows operating system. In this experiment/simulation, a run is considered a successful run if we obtained the solution of the problem, either the same valued result or better than the known best-found solution.

From Table 2 and Table 3 we can calculate total energy saving for the first phase of communication between sink node and different cluster head to cover the whole area and that is 1756090368.00 pj/sec. Therefore we have calculated that 6-7 days of the lifetime of the whole network can be saved with respect to un-optimized Wireless Sensor Network. In the second phase, the path will be changed after consumption of the initial energy store of the corresponding cluster head and so on up to the full energy draining of the selected cluster head.

**7. Conclusion**

The main aim of this paper is to minimize the energy consumption in Wireless Sensor Networks. To minimize the power consumption of a particular Wireless Sensor Network at first, we tried to minimize the traversal path to cover each and every cell of the particular path as well as the traversal path between sink node and cells. The minimizing technique that we have used is Ant Colony Optimizations. In this network configuration we have used only random deployment of WSN nodes and we have studied other two types of deployment processes (S - pattern deployment and spiral deployment) which we could use in future and compare with the existing one.

**References**

Akyildiz, I. F., Su, W., Sankarasubramaniam, Y., & Cayirci, E. (2002). Wireless sensor networks: a survey. Computer networks, 38(4), 393-422.

Ari, A. A. A., Yenke, B. O., Labraoui, N., Damakoa, I., & Gueroui, A. (2016). A power efficient cluster-based routing algorithm for wireless sensor networks: Honeybees swarm intelligence based approach. Journal of Network and Computer Applications, 69, 77-97.

Bin, Z., Jianlin, M., & Haiping, L. (2011, March). A hybrid algorithm for sensing coverage problem in wireless sensor netwoks. In 2011 IEEE International Conference on Cyber Technology in Automation, Control, and Intelligent Systems(pp. 162-165). IEEE.

Cody-Kenny, B., Guerin, D., Ennis, D., Simon Carbajo, R., Huggard, M., & Mc Goldrick, C. (2009, October). Performance evaluation of the 6LoWPAN protocol on MICAz and TelosB motes. In Proceedings of the 4th ACM workshop on Performance monitoring and measurement of heterogeneous wireless and wired networks (pp. 25-30). ACM.

ECE, S. F. (2013). A Survey on Energy Efficient Routing in Wireless Sensor Networks. International Journal, 3(7).

El-Hoiydi, A., & Decotignie, J. D. (2004, July). WiseMAC: An ultra low power MAC protocol for multi-hop wireless sensor networks. In International symposium on algorithms and experiments for sensor systems, wireless networks and distributed robotics (pp. 18-31). Springer, Berlin, Heidelberg.

Gajjar, S., Sarkar, M., & Dasgupta, K. (2015). FAMACRO: Fuzzy and ant colony optimization based MAC/routing cross-layer protocol for wireless sensor networks. Procedia Computer Science, 46, 1014-1021.

Geisberger, R., Sanders, P., Schultes, D., & Delling, D. (2008, May). Contraction hierarchies: Faster and simpler hierarchical routing in road networks. In International Workshop on Experimental and Efficient Algorithms (pp. 319-333). Springer, Berlin, Heidelberg.

Gupta, I., Riordan, D., & Sampalli, S. (2005). Cluster-head election using fuzzy logic for wireless sensor networks (pp. 255-260). IEEE.

Katz, J. E. (2008). Handbook of mobile communication studies. The MIT Press.

Lande, S. B., & Kawale, S. Z. (2016, December). Energy Efficient Routing Protocol for Wireless Sensor Networks. In 2016 8th International Conference on Computational Intelligence and Communication Networks (CICN) (pp. 77-81). IEEE.

Li, T., Ruan, F., Fan, Z., Wang, J., & Kim, J. U. (2015, October). An Improved PEGASIS Protocol for Wireless Sensor Network. In Computer and Computing Science (COMCOMS), 2015 3rd International Conference on (pp. 16-19). IEEE.

Luo, Z., Lu, L., Xie, J., & He, J. (2015, December). An ant colony optimization-based trustful routing algorithm for wireless sensor networks. In Computer Science and Network Technology (ICCSNT), 2015 4th International Conference on(Vol. 1, pp. 1128-1131). IEEE.

Lee, J. H., & Moon, I. (2014). Modeling and optimization of energy efficient routing in wireless sensor networks. Applied Mathematical Modelling, 38(7-8), 2280-2289.

Liao, Q., & Zhu, H. (2013). An energy balanced clustering algorithm based on LEACH protocol. In Applied Mechanics and Materials (Vol. 341, pp. 1138-1143). Trans Tech Publications.

Miao, G., Himayat, N., Li, Y., & Swami, A. (2009). Cross‐layer optimization for energy‐efficient wireless communications: a survey. Wireless Communications and Mobile Computing, 9(4), 529-542.

Pantazis, N. A., Nikolidakis, S. A., & Vergados, D. D. (2013). Energy-efficient routing protocols in wireless sensor networks: A survey. IEEE Communications surveys & tutorials, 15(2), 551-591.

Price, K., Storn, R. M., & Lampinen, J. A. (2006). Differential evolution: a practical approach to global optimization. Springer Science & Business Media.

Sahoo, L., Banerjee, A., Bhunia, A. K., & Chattopadhyay, S. (2014). An efficient GA–PSO approach for solving mixed-integer nonlinear programming problem in reliability optimization. Swarm and Evolutionary Computation, 19, 43-51.

Srivastava, N. (2010). Challenges of next-generation wireless sensor networks and its impact on society. arXiv preprint arXiv:1002.4680.

Sun, J., Xu, W., & Feng, B. (2004, December). A global search strategy of quantum-behaved particle swarm optimization. In IEEE Conference on Cybernetics and Intelligent Systems, 2004. (Vol. 1, pp. 111-116). IEEE.

Tao, D., Ma, H. D., & Liu, L. (2007). Virtual potential field based coverage-enhancing algorithm for directional sensor networks. Ruan Jian Xue Bao(Journal of Software), 18(5), 1152-1163.

Umadevi, M., & Devapriya, M. (2015). An Enhanced Ant Colony Based Approach to Optimize the Usage of Critical Node in Wireless Sensor Networks. Procedia Computer Science, 47, 452-459.

Wang, J., Xu, F., & Sun, F. (2006, October). Benchmarkinng of routing protocols for layered satellite networks. In The Proceedings of the Multiconference on" Computational Engineering in Systems Applications" (Vol. 2, pp. 1087-1094). IEEE.

Wang, X., Li, Q., Xiong, N., & Pan, Y. (2008, October). Ant colony optimization-based location-aware routing for wireless sensor networks. In International Conference on Wireless Algorithms, Systems, and Applications (pp. 109-120). Springer, Berlin, Heidelberg.

Yao, G. S., Dong, Z. X., Wen, W. M., & Ren, Q. (2016). A routing optimization strategy for wireless sensor networks based on improved genetic algorithm. 淡江理工學刊, 19(2), 221-228.

Ye, Z., & Mohamadian, H. (2014). Adaptive clustering based dynamic routing of wireless sensor networks via generalized ant colony optimization. Ieri Procedia, 10, 2-10.

Zeng, B., & Dong, Y. (2016). An improved harmony search based energy-efficient routing algorithm for wireless sensor networks. Applied Soft Computing, 41, 135-147.

Zenia, N. Z., Aseeri, M., Ahmed, M. R., Chowdhury, Z. I., & Kaiser, M. S. (2016). Energy-efficiency and reliability in MAC and routing protocols for underwater wireless sensor network: A survey. Journal of Network and Computer Applications, 71, 72-85.