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# Performance Improvisation for Longevity Maximization with Ant Colony Optimization in Wireless Sensor Network

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**Abstract:** ***Wireless sensor network (WSN) technologies are increasingly employed in recent years for monitoring purposes in various fields ranging from the engineering industry to our immediate home environments due to their ability to intelligently monitor remote locations at low cost. Maximization of longevity of wireless sensor networks is possible by using effective transmission strategy. An optimal-distance-based transmission strategy based on ant colony optimization is put forward to fulfill such a maximization aim. Clustering mechanism is one of the popular wireless sensor networks routing mechanisms, and it has proven to be an effective approach for organizing the network into a connected hierarchy .In this paper we have proposed a algorithm in order to increase the longevity of wireless sensor network . The simulations result shows that the network longevity have improved.***

**Keywords:** longevity maximization, sensor nodes, wireless sensor network, clustering

## 1. Introduction

A wireless sensor network (WSN) consist of hundreds to thousands of low power multi-functional sensor nodes work in an unattended environment and have sense, computation and communication ability. The basic components of a node are a sensor unit, an ADC (Analog to Digital Converter), a CPU (Central Processing Unit), a power unit and a communication unit. Sensor nodes are micro-electro-mechanical systems (MEMS) that make a computable response to a change in some physical condition related to temperature and pressure. Sensor sense or compute the physical data of the area to be monitor [1].. Sensors nodes are of very small size, use extremely low energy, are operated in high volumetric densities and can be independent and adaptive to the environment. Wireless micro-sensor networks represent a new paradigm for extracting data from the environment. Conventional systems use large, expensive macro-sensors that are often wired directly to an end-user and need to be accurately placed to obtain the data. For example, the oil industry uses large arrays of geophone sensors attached to huge cables to perform seismic exploration for oil. These sensor nodes are very expensive and require large amounts of energy for operation. The most difficult resource constraint to meet is power consumption in wireless sensor networks. The use of wireless sensor networks is increasing day by day and at the same time it faces the problem of energy constraints in terms of limited battery longevity. As each node depends on energy for its activities, this has become a major issue in wireless sensor networks. The failure of one node can interrupt the entire system or application. Every sensing node can be in active, idle and sleep modes. In active mode, nodes consume energy when receiving or transmitting data. In idle mode the nodes consume almost the same amount of energy as in active mode. While in sleep mode, the nodes shutdown the radio to save the energy. Energy constraints end up creating computational and storage limitations that lead to a new set of architectural issues. A wireless sensor network platform must provide support for a suite of application-specific protocols that drastically reduce node size, cost, and power consumption for their target application.

In wireless sensor networks, the only source of life for the nodes is the battery. Communicating with other nodes or sensing activities consumes a lot of energy in processing the data and transmitting the collected data to the sink. In many cases (e.g. surveillance applications), it is undesirable to replace the batteries that are depleted or drained of energy [2]. Many researchers are therefore trying to find energy-aware protocols and algorithms for wireless sensor networks in order to overcome such energy efficiency problems as those stated above. The memory management and the resource management in wireless sensor network is done by operating Systems specially designed for WSNs. Now routing is the major issue in WSNs and this is under network layer issues for sending the data from sensor nodes to sink. Various routing protocols and algorithms for wireless sensor networks are Sensor protocols for Information via Negotiation (SPIN) , Rumor Routing , Direct Diffusion , Low Energy Adaptive Cluster Hierarchy (LEACH), Threshold Sensitive Energy Efficient Sensor network protocol (TEEN),Geographical and energy aware Routing(GEAR), Sequential Assignment Routing(SAR), etc. Amongst them Low-energy adaptive clustering hierarchy protocol is widely used in wireless sensor network, because this protocol dissipates the energy in low level. When the battery power is drained in these devices/nodes then the network cannot be used and all the nodes spend most of the energy while transmitting the data. Therefore ,to increase the longevity of the network, each node has to do only minimal work for transmitting the data. Here all the nodes are grouped into the clusters, and in each cluster one of the nodes is assigned as a Cluster Head (CH). CH collects the data from the surrounding nodes and passes it to the sink. Usually, initial assignment of CH is random and the role of CH is rotated for every fixed duration so that each node will act as a CH at least once in its lifespan. Low-energy adaptive clustering hierarchy algorithm has two phases. They are set up phase and steady state phase. Setup phase is used to choose a CH and steady state phase is used to maintain the CH during the transmission of data.

As a swarm intelligence method, ant colony optimization (ACO) [15] has gained popularity in recent years and has been successfully applied to a large range of combinatorial optimization problems, such as data transmission in wireless sensor networks. An energy-efficient ant-based routing algorithm (EEABR) was presented in [16], in which forward ants and backward ants are defined, and the ant chooses a path according to the actual energy level of nodes and the distance traveled by the forward ant. Based on ant colony optimization, a dynamic and reliable routing protocol (DRRP) was proposed in [17], in which the ant chooses a path according to the energy level of the nodes and the total number of nodes visited by the ant. In [18], an ant colony optimization routing algorithm named ASW was introduced to reduce energy consumption. In this routing algorithm, the distance to the sink and the energy consumption of the path are used to select paths by the ant. Another energy-aware ant colony algorithm (EAACA) was proposed to extend the network longevity [19]. In such a routing algorithm, the next neighbor node of the routing is chosen according to the distance to the sink, the residual energy of the node, and the path of the average energy. An ant colony optimization - based transmission scheme named the unity of MPEE and MPEB (UMM) was presented in [20], in which energy efficiency and energy balancing have been simply considered for longevity maximization of WSNs

This work focuses on analyzing the optimization strategies of routing protocols and algorithms with respect to energy utilization of sensor nodes in Wireless Sensor Network (WSNs). In this paper , we have considered Low-energy adaptive clustering hierarchy protocol as reference and used the ant colony optimization algorithm to increase the longevity of wireless sensor network.

## 2. Literature Review

In the field of data transmission of wireless sensor networks, the concentric corona model has aroused great concern. In the concentric corona model, the optimal transmission ranges of all coronas can effectively improve the network longevity. The concentric corona model consists of a circular multi-hop wireless sensor network. Sensor nodes deployed in the different regions may differ in their maximum transmission range, in concentric corona model. The discussion of such a network model is done by authors in [4] and explained that all the coronas must have the same width and data should by forward by the nodes to the adjacent inner corona. The authors in the [8] advanced a technique that alternating between multi-hop transmission with the fix transmission distance and the single-hop communication directly to the sink, periodically. In [9] the optimum transmission distance for multi-hop communication was obtained by using a single hop transmission and multi-hop communication. The optimal ratio of the number of data cycles operated in a single-hop transmission mode and multi-hop transmission mode over the network longevity was obtained[19] by proposing a hybrid of single hop communication and multi-hop transmission . To achieve the balance energy usage in the network, a hybrid of two transmission scheme was advanced [10], and in [11], a mixed transmission algorithm including flat and hierarchical multi-hop routing was put forward. Further in [12]-[14], mixed transmission scheme including single-hop and multi-hop where presented.

Ant colony optimization [15] which is a swarm intelligence method has been successfully applied to the large range of combinatorial optimization problems and has also gained the popularity in recent years. Ant colony optimization is a method for solving the computational problems. Ant of some species moves randomly in the natural world and as soon as they find the food return to their colony with lying down pheromone trails. Other ants do not keep travelling at random when they find such a path and follow the trail, returning and reinforcing it if they eventually find food. However, with the time, the pheromone trail reducing its attractive strength and start to evaporate. The more the time the pheromones trail will have to evaporate, more time it takes for an ant to travel down the path and back again. A shorter path gets marched more frequently than that of longer one and thus shorter path have higher pheromone density than the longer ones. In [16] backward ants and forward ants are defined and the ant selects a path according to the actual energy level of nodes and the distance travelled by the forward ant , an energy efficient ant based routing algorithm was presented in it . In [17], the ant selects a path according to the total numbers of the nodes visited by the ant and the energy level of the nodes, a dynamic and the reliable routing protocol was proposed in it. In [18] the distance to the sink and the energy consumption of the path are used to choose the path by the ant. To reduce the energy consumption, an ant colony optimization routing algorithm was introduced in [18]. In [19], the next neighbor node of the routing is select according to the residual energy of the node the distance to the sink and the path of the average energy. Energy-aware ant colony algorithm was proposed to extent the network longevity in [19]. In [20] the energy efficiency and the energy balancing have been simply considered for longevity maximization of wireless sensor network, an ant colony optimization based transmission scheme was presented in it.

## 3. Proposed Work

We present performance improvisation for longevity maximization of wireless sensor network to achieve our goal on the basis of the ant colony optimization.

To achieve the energy depletion minimization for the nodes with maximal energy consumption throughout a network, we propose a „global optimal transmission distance acquirement scheme" by designing a network longevity maximization approach. This scheme further helps to extend the network longevity.

### 3.1 The proposed transmission strategy

As shown in the fig.1, we consider a wireless sensor network where nodes are evenly deployed on a disk with a radius R centered at the sink. M disjoint concentric coronas divide this disk. An arbitrary wedge subtended by an angle ϴ is also considered. This is partitioned into M sectors, which are denoted as Ω1 , Ω2 ,……. Ω M by its intersection with M concentric coronas. Suppose each node generate the particular bits of data per second and having the initial uniform energy. This type of sector division can be called as a clustering technique which has some advantages such as more robustness and more scalability [21], [22]. Such a sector division can also be regarded as an effective method of achieving the load balancing with non-uniform clustering manner and this is because of different sizes of sector distribution.

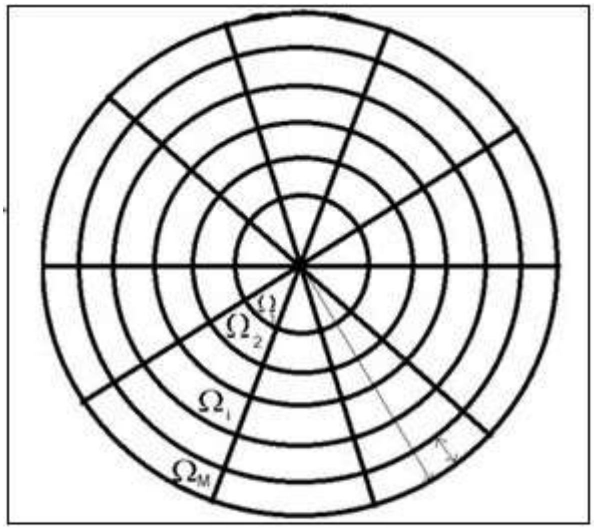


**Figure 1:** Network model

To seek an optimal transmission distance for nodes of each sector is our goal. There is an ant on the every sector initially; here the search is performed by the ant colony optimization. As shown in the fig.2, according to the specific probability, every ant moves from a sector to another towards the sink.

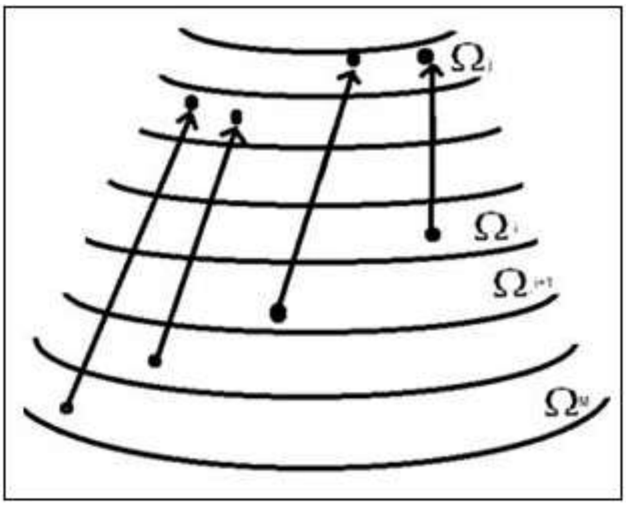


**Figure 2:** The moving mode of ants

In order of the largest to the smallest number of the sector, these ants move one after another. Generally, every ant moves after the ant of the adjacent outer sector has completed its trip, the ant on the most outer sector moves firstly. When any ant moves only one hop, it has finished its full work. A corresponding path is created by an ant when it moves from Ω i to sector Ω j towards the sink and whose distance is, d . “d” is the transmission distance of the nodes in sector Ω i , path is transmission route of this sector. Thus, the routing abstraction is the moving of ant. The solution that is the transmission distance of the nodes for all sectors have been obtained when all the ants completed their task of moving. The best solution is updated and reserved after several iterations.

### 3.2 Flow chart of proposed algorithm

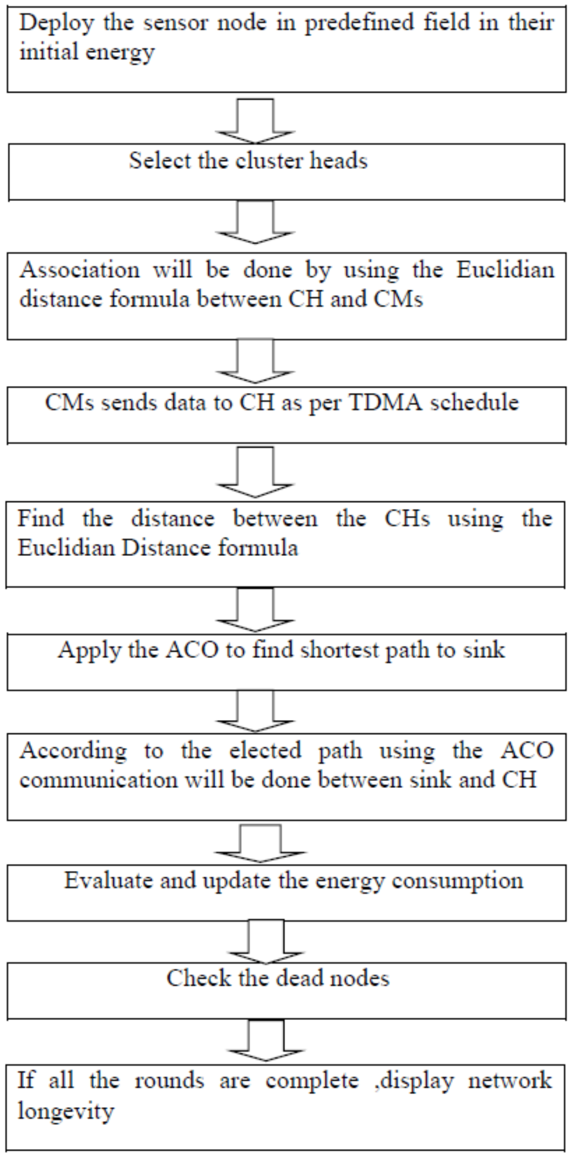



**Figure 3:** Flow chart of proposed algorithm

### 3.3 Optimization Algorithm ACO

The proposed strategy decomposes the sensor network into numerous segments hence called clusters, and cluster heads are chosen in every cluster. Then, ACO based data aggregation come in action and collects sensing information directly from cluster heads by utilizing short distance communications. The cluster-head nodes should be spread throughout the network, as this will minimize the distance the non-cluster-head nodes need to send their data. A sensor node chooses a random number, r, between 0 and 1. Let a threshold value be

**T (n): T (n) = p/ (1-p × ( r mod [1/p] ) ) ..eq(1)**

If this random number is less than a threshold value, T (n), the node becomes a cluster-head for the current round. The threshold value is calculated based on the above given equation where P is the desired percentage to become a cluster-head, r represent the current round, and G represents the set of nodes that have not been selected as a cluster-head in the last (1/P) rounds. After the nodes have elected themselves to be cluster-heads, it broadcasts an advertisement message (ADV). Each non-cluster-head node determines to which cluster it belongs by choosing the cluster-head that requires the minimum communication energy. Member nodes will send data to their CHs as per TDMA schedule. Euclidian distance formula is used to find the distance between the cluster heads. Ant Colony Optimization algorithm is then used to find the shortest path to send data from CHs to the sink. The steps of algorithm to find the shortest path using ant colony optimization are as follow :

***Step1:*** Initialize CHs as ants combined with sink as Destination.

***Step2:*** Going of virtual ant depends on the amount of pheromone on the CHs distances.

***Step3***: The first step in ACO could be the trail collection between neighboring clusters ,some synthetic ants (CHs) are simulated from the CHs to the sink.

***Step4:*** The ahead ants are choosing the following CH randomly for initially taking the data from the length matrix and the ants who are successful in achieving the sink are updating the pheromone deposit at the edges visited by them by an amount (CL), where M is the sum total journey period of the ant and D a constant price that is adjusted in line with the fresh problems to the perfect value.

***Step5***: The following set of the ants can now study on the pheromone deposit feedback left by the formerly visited successful ants and will soon be guided to follow along with the quickest path.

***Step6:*** When someone ant walks from CHi to CHj, the chance in the selection principle for a simple ant is:

$$P_{i,j} = \frac{(\tau_{i,j})^{\alpha} + (\eta_{i,j})^{\beta}}{\Sigma(\tau_{i,j})^{\alpha}(\eta_{i,j})^{\beta}} \quad \text{..eq(2)}$$

where Γi,j represents the amount of pheromone deposit from CHi to CHj ; ηi,j is the trail visibility function that is equivalent to the reciprocal of the energy distance between CHi and CHj; $\alpha$ is the parameter to adjust the amount of pheromone Γi,j ; $\beta$ is a parameter to adjust the heuristic visibility function ηi,j.

***Step7 :*** if the link between two CHs exists , then
Pi,j will be updated
else
Pi,j= 0.
end

***Step8:*** Evaluate the distance between the cluster head i and cluster head j.

***Step9:*** P values will be updated by all the ants which have reached the sink successfully.

***Step10:*** Phermone evaporation ($\rho$) on the edge between CHi and CHj is implemented .

***Step11:*** CHs not chosen by artificial ants , the amount of P decreases exponentially.

***Step12:*** Every moment of time ,t ={ 1,2,3,4,…,n} . all the ants will, after n iteration find the solution and leave the P .

***Step13:*** If ant k has passed some edge between the CHs ,it will leave P which is inversely proportional to with the total length of all the edges ant k has passed from the starting CH to the Sink .

***Step14:*** Now the path with best P value (minimum distance ) is selected to communicate data between CHs and sink.
End

Based upon the elected path the communication will be done between sink and the cluster heads. Then, energy consumption will be evaluated and updated by using following formulas

i. $W(i).E = W(i).E - ((Txenergy + EDA) * (K) + efs * K * (d2)): if d < do$

ii. $W(i).E = W(i).E - ((Txenergy + EDA) * (K) + amp * K * (d4)) : if d > do$

.. eq (3)

where, W(i).E is the energy of ith node, EDA is effective data aggregation, Tx energy is the transmitter energy, k is the packet size, efs represents the free space and amp is the multipath, do is the minimum allowed distance.

## 4. Results and Discussions

Energy efficient WSN deployment is not an easy task due to large number of parameters, i.e., energy parameters and cluster head selection then their data transmission procedure. MATLAB programming platform is used for coding of algorithm using ACO algorithm.

The MATLAB simulation tool is used for simulation purpose. It evaluates the performance of the proposed technique on the following metrics i.e. network lifetime, residual energy (average remaining energy), and throughput by taking 200 sensor nodes. Network longevity of a network is the time when last ever node die in the network. The network longevity , residual energy (average remaining energy), and throughput of the proposed technique is significantly improved. Due to random deployment of the sensor network there exist variation in network longevity whenever simulation is run. But when compared to available protocols and algorithms, it is found that the network longevity of the proposed technique is consistent and maximized than available well-known protocols and algorithms.

### 4.1 Simulation Environment

The proposed algorithm for low energy consumption of nodes in wireless sensor network has been simulated using MATLAB. During simulation an assumption has been made that the system and the channel used are ideal with no attenuation and no channel noise. All the factors that can degrade the system performance are ignored. Various parameters used for the simulation are given in Table 1 . These parameters are standard values used as benchmark for WSNs.

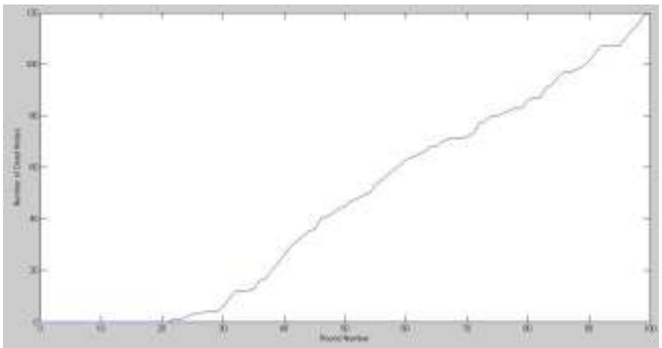
**Table 1:** Experimental Setup

| Parameter | Value |
|---|---|
| Area(x,y) | 100m*100m , 120m*,120m, 150m*,150m |
| Sink(x,y) | 1.5*xm,0.5*ym |
| Nodes(n) | 200 |
| Probability(p) | 0.2 |
| Initial Energy(Eo) | 0.1 |
| Transmitter energy | 50nJ/bit |
| receiver energy | 50nJ/bit |
| Free space(amplifier) | 10nj/bit/$m^2$ |
| Multipath(amplifier) | 0.0013pJ/bit/$m^4$ |
| a (energy factor between normal and advanced nodes) | 1 |
| Maximum number of rounds | 100 |
| Message size | 4000 bits |
| m (fraction of advanced nodes) | 0.0 |
| Effective Data aggregation | 5nJ/bit/signal |

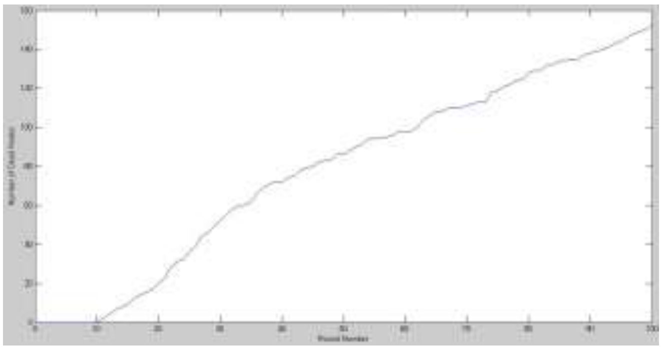
### 4.2 Simulation Results

#### 4.2.1 Dead node

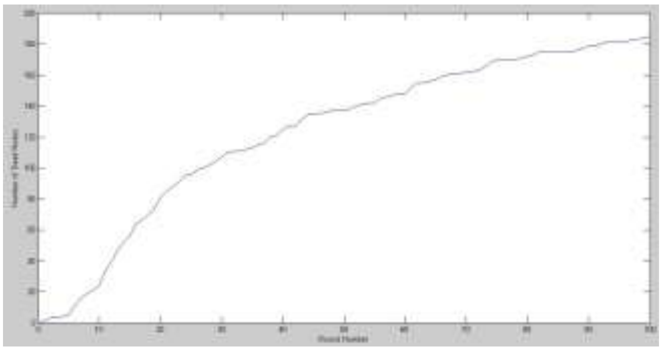
Network longevity is defined as the time difference when network is set up and time when first node died. We have calculated the network longevity through certain parameters like Round No on which first node died. As the nodes are increased, network longevity is increased.



**(a)** Number of Dead nodes vs round number when sensing area is 100m *100m



**(b)**Number of Dead nodes vs round number when sensing area is 120m *120m



**(c)** Number of dead nodes vs round number when sensing area is 150m *150m

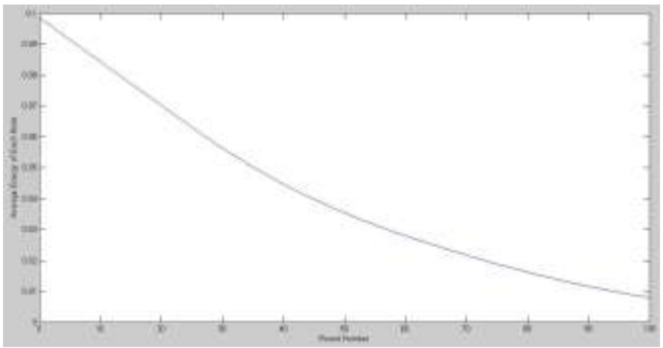
**Figure 4:** Number of dead nodes vs round number with varying sensing area

As shown in Figures 4, the round of the first node dies are decreasing with the increasing of the sensing area which is changing from 100 m *100 m , 120m*120m to 150m*150m . Because of the increasing of sensing area, the density of nodes in the area is decreasing, which results in the distance between two nodes getting farther. One node has to consume more energy to transmit data to the neighbors. As a result, the energy dissipation of a single node and the network become higher. And the time when the first node dies becomes earlier correspondingly, which leads to the decrease of longevity of the network. And thus, the optimum distance obtained by proposed transmission strategy will find out the shortest distance in order to increase the round of the first node dies and thereby increase the network longevity.

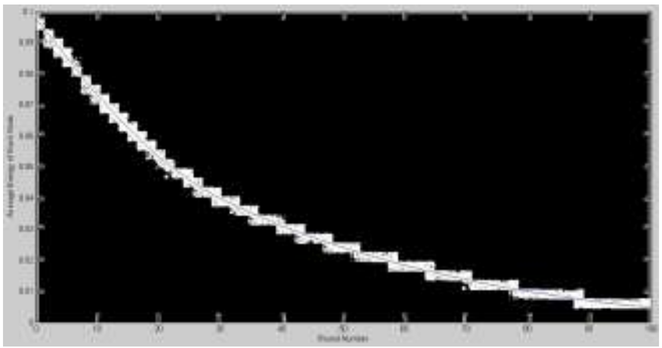
#### 4.2.2 Average energy of each node

The average energy of each node is average remaining energy of each node after completion of data transmission.

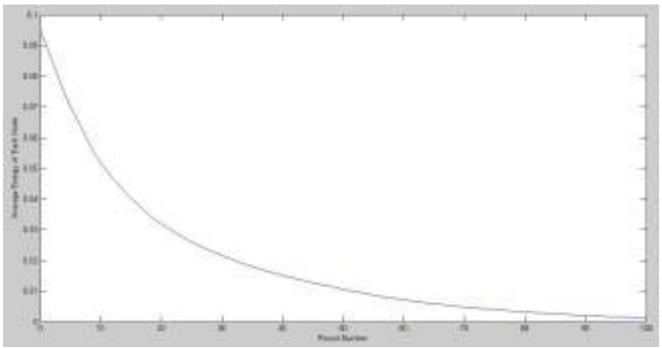
Because of the increasing of sensing area, the density of nodes in the area is decreasing, which results in the distance between two nodes getting farther. One node has to consume more energy to transmit data to the neighbors. As a result, the energy dissipation of a single node and the network become higher.



**(d)** Average energy of each node vs round number when sensing area is 100m*100 m



**(e)** Average energy of each node vs round number when sensing area is 120m*120m



**f)** Average energy of each node vs round number when sensing area is 150m*150m

**Figure 5:** Average energy of each node vs round number with varying sensing area

As the energy consumption evaluation, Figure 5 demonstrates the average residual energy of all sensor nodes for different sensing area. As shown in Figures 5, the average energy of each node decreasing with the increasing of the sensing area which is changing from 100 m *100 m , 120m*120m to 150m*150m According to this figure, average energy of sensor nodes in the figure (d) is greater than figure (e) and (f) of figure 4. Also, the average energy of sensor nodes in the figure (e) is greater than figure (f) of figure 4. And thus, the optimum distance obtained by proposed transmission strategy will find out the shortest distance in order to increase the average energy of each node and thereby increase the network longevity.

## 5. Conclusion and Future Scopes

In this paper, the problem of network longevity maximization in the wireless sensor networks is investigated, and on the basis of the ant colony optimization an optimal-distance based transmission strategy is proposed. A algorithm was proposed to achieve high throughput and increases the network longevity. Throughput was analyzed by calculating the number of dead nodes verses round number for varying sensing area and by calculating average energy of each node verses round number for varying sensor area. The performance analysis using MATLAB shows that longevity of wireless sensor network increases as compared to the already existing algorithms and protocols.

The future scopes of proposed transmission strategy are as follow:

1) In this proposed work single sink node is used, thus for the improvement multiple sink nodes can be used. Multiple sink nodes increases the complexity of routing algorithms.
2) Sink node used is dynamic in nature, thus for further research prospects the static sink node can be assumed.
3) Research can be done by implementing other algorithms on WSN.

This type of simulation is iteration based. However for future work this simulation can also be implemented using another techniques or models.

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