International Journal of Ad hoc, Sensor & Ubiquitous Computing (IJASUC) Vol.3, No.3, June 2012

IMPROVING WIRELESS SENSOR NETWORKS PERFORMANCE BY USING CLUSTERED VIRTUAL RINGS

Hosny M. Ibrahim Nagwa M. Omar Ali H. Ahmed

hibrahim@uencom.com nagwa_omar@hotmail.com alihussin.it@gmail.com

Information Technology Department,
Faculty of Computers and Information,
Assiut University,
Assiut, Egypt

ABSTRACT

Wireless sensor networks (WSN) are the subject of the era due to its importance and wide applications. The last decade of research focused on how to improve its performance in terms of enlarging lifetime and better handling network dynamics. Many WSN applications such as monitoring and reporting are time critical so, the performance of WSN can not include lifetime only, but also other performance measures such as delay must be taken into consideration as well. This paper focuses on the WSN network layer which includes routing techniques as a main key in high performance applications. A routing technique based on virtual rings and genetic algorithm is proposed to shorten the round delay time. This technique uses virtual ring features in addition to clustering methods to divide the sensors in the network into groups contain nearby sensors. The main advantage of this proposed technique is that it maximizes the interval of the first node failure besides obtaining a reasonable delay in forwarding data to sink through the usage of the virtual rings.

KEYWORDS

Wireless Sensor Networks; Virtual Ring; Genetic Algorithm; Clustering Algorithms.

1. INTRODUCTION

Wireless sensor networks (WSN) originally motivated by military applications in 1978 in the Defense Advanced Research Projects Agency (DARPA) [1, 2, 3]. DARPA focused on wireless sensor network research challenges such as networking technologies, signal processing techniques and distributed algorithms to develop military applications such as battlefield surveillance and sniper detection. Nowadays WSN is used in many industrial and civilian application areas, including industrial process monitoring and control, machine health monitoring, environment, habitat monitoring, healthcare applications, home automation, and traffic control [4, 5, 6]. In 1996 University of California, Los Angeles proposed the concept of Wireless Integrated Network Sensors or WINS [7]. In 1999, the Smart Dust project [8] began at the University of California at Berkeley focusing on the design of extremely small sensor nodes called motes. The goal of this project was to demonstrate that a complete sensor system can be integrated into tiny devices, possibly the size of a grain of sand or even a dust particle. By 2000, The PicoRadio project [1] by Berkeley Wireless Research Center (BWRC) focused on the development of low-power sensor devices, whose power consumption is so small that they can power themselves from energy sources of the operating environment such as solar energy.

DOI : 10.5121/ijasuc.2012.3304

Sensor networks share many similarities with other distributed systems, but they are subject to a variety of challenges and constraints. These constraints impact the design of a WSN application, leading to protocols and algorithms that differ from their counterparts in other distributed systems. The main constraints encountered in WSN are energy, decentralized management and security.

The quality of real-time applications requires a delay sensitive routing protocol. Due to sensors' limited energy, they have to perform simple and efficient operations without losing the delay requirements for delivering the collected data. A routing protocol that is aware to time constraints differs from the majority of conventional routing protocols. For the applications which requires small delay and good routes from destination to source, route is not chosen according to minimum hops only but also some network factors such as collisions and retransmissions which mainly affects the communication performance are taken into consideration. Sometimes a route has the smallest number of hops but the delay in that route may exceed the maximum acceptable delay for the application [9].

The objective of this paper is to develop a multi-hop routing technique which handles many of the wireless sensor networks challenges such as enlarging lifetime and shortening the delay and constitutes a full solution for them. The proposed technique attempts to cluster the sensors in the wireless network according to their locations with the base station to construct multiple power-efficient rings chosen by the genetic algorithm which is used to get the least power consuming virtual ring. Then, routing information is broadcasted from the base station to all the sensors to be stored and used in delivering data to the base station. Every sensor can reach the base station through a path which is part of the constructed ring. Clustering and inter-ring multi-hop routing cause the total network delay and negotiation for obtaining routing information are minimized and network lifetime is maximized. The genetic algorithm and the clustering algorithm both operate on the base station instead of sensors to minimize the load on sensors' resources. Minimizing nodal reception and transmission power prolongs its lifetime which indeed maximizes the total network lifetime. The maximization of lifetime and the reasonable delay which is produced in the proposed technique are urgent for real-time monitoring and reporting applications.

The remainder of this paper is organized as follows: section 2 illustrates the proposed technique, section 3 shows the simulation results compared to related work. Conclusion is given in section 4.

2. THE PROPOSED ROUTING TECHNIQUE

The proposed technique is an energy aware proactive multi-hop routing technique based on genetic algorithm which makes use of the ring topologies. Genetic algorithm is used in the ring selection process because of its high performance in the rapid global search. The proposed protocol divides the sensor network into groups of nearby sensors, all the sensors in a group constructs a ring. The limitation in sensors memory, processing and energy is also considered in our work as sensor stores small routing table contains only four entries. The evolutionary process of clustering and ring selection is carried out in the base station; this minimizes sensor processing and power consumption. The proposed technique characteristics result in enlarging the interval of the first sensor failure. A valuable feature of the proposed technique is that it enables network to continue its operation even if a number of failed nodes exists. We assumed that every node knows its position and sends it to the base station during the initialization phase via a direct communication. The position is determined by small-sized, low power, low cost GPS receivers and position estimation techniques based on signal strength measurement, this makes our assumption trivial. Different studies have discussed position-based routing protocols and have proposed low cost solutions for determining the nodes positions [10, 11]. The simulation results show that the proposed protocol shortens the average delay compared with other techniques. The proposed technique is described in details in the following subsections.

2.1 Clustering

Cluster analysis or clustering is the task of assigning a set of objects into groups (called clusters) so that the objects in the same cluster are more similar (in some sense or another) to each other than to those in other clusters [12]. Clustering is a main task of explorative data mining, and a common technique for statistical data analysis used in many fields [13,14]. Clustering techniques [15] are applied when there is no class to be predicted but the instances are to be divided into natural groups. These clusters presumably reflect some mechanism that is at work in the domain, from which instances are drawn, a mechanism that causes some instances to bear a stronger resemblance to each other than they do to the remaining instances. There are variety of clustering algorithms can be found in [12,13,14,15].

In this paper, simple K-means clustering algorithm is used for grouping nearby sensors. K-means is an evolutionary algorithm where K is the number of clusters and means stands for a cluster mean. The main goal of the algorithm is to partition 2D placed points (sensors) into a set of clusters K. The optimal number of clusters gives minimum power dissipation per round and hence prolongs lifetime is referred by Kopt. Clustering chooses “centers” c1, c2,…, ck for the clusters C1, C2,…, Ck that minimizes the objective function [15]:

$$\varphi = \sum_{j=1}^{k} \sum_{i=1}^{n} \left\| X_i^{(j)} - c_j \right\|^2 \tag{1}$$

Where $\left\| X_i^{(j)} - c_j \right\|^2$ is a chosen distance measure between a node point $X_i^{(j)}$ and the cluster centre, c_j. During this paper the optimum number of cluster K which gives maximum lifetime and smaller delay, is referred by Kopt and is obtained experimentally.

The following pseudocode illustrates K-Means Algorithm Steps:

1. Start with K arbitrary centers (In practice: randomly chosen from data points).
2. Assign each object to the group that has the closest centroid.
3. When all objects have been assigned, recalculate the positions of the *K* centroids.
4. Repeat Steps 2 and 3 until the centroids no longer move. This produces a separation of the objects into groups from which the metric to be minimized can be calculated.

In the proposed technique, multi-hop transmission is used within a cluster to save the average sensor power, and the single hop approach in data transmission between the base station and the ring cluster head The cluster heads are the closest nodes in every ring to the base station , this to minimize delay. The simulation results that are proposed in [16- 21] show that if a multi-hop transmission is adopted between clusters then the closer the node to the base station, the more the traffic it has to relay. Unless some action is taken to correct this imbalance, different nodes will drain their batteries at different times, resulting in early loss of coverage and potential partitioning of the sensor network. Accordingly, in this paper the multi-hop approach is not utilized for transmitting data to the base station and the cluster heads directly communicate with the Base station.

Using the clustering algorithm to group nearby sensors reduce the time of round as well as average energy dissipation which can be described as follows:

Clustering reduces time of a round: If all of the sensors involved in a single virtual ring then the average number of hops to base station is *N/4* where N is the number of sensors. Dividing (Clustering) the sensor network into *M* distinct clusters will decrease the average number of hops to *N/4M* and indeed the time needed by a packet to reach base station will reduced, section 2.5 illustrates this in detail.

Clustering reduces average energy dissipation: Clustering decreases the number of hops consequently the total required transmission and reception power consumed in every hop decreases. In the proposed technique the sensor network will be divided into a set of clusters all of them share the base station. The base station is connected to every cluster via two sensors as shown in figure 2.

For every cluster the ring topology is chosen to constitute all the sensors in a cluster, the minimum power ring is selected by the genetic algorithm. The following subsections focus on the construction of the ring within every cluster.

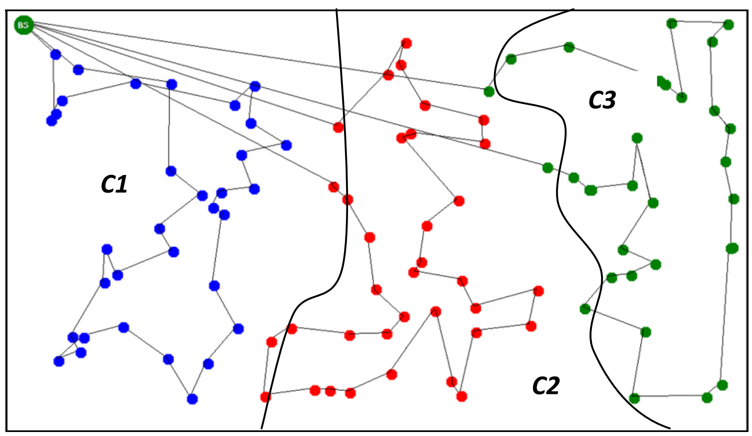


Fig.2. A sensor network of 100 random distributed sensor divided into 3 clusters ,and each cluster constitutes a virtual ring containing the base station.

2.2 Cluster Topology

In multi-hop transmission, route can be fully connected, mesh, bus or ring like, but the first three are either inapplicable or introduces loops and live lock may occur [22, 23]. Live lock causes sensors power to drain quickly due to the continuous transmission of the same data. Even if a search algorithm is used to find and eliminate those loops, efficiency (in terms of processing delay, power consumption during control packet transmission and retransmission during sensor negotiation) will drop heavily depending on the used search algorithm. Problems in fully connected, mesh star and bus topologies [22, 23] guided us to use the ring topology in the proposed work. During this paper we will refer to ring as virtual ring. The term virtual means that the constructed rings may have intersections in the actual topology. There are two main advantages of the ring topologies:

1. Each sensor communicates only with two sensors.
2. Every cluster sensor is connected via only a single ring without introducing loops.

For the first advantage; a sensor communicates only with two sensors; previous and next hop sensor .Next hop sensor is located on the *shortest-hop* path to the base station while previous hop is located on the reverse *longer-hops* path to the base station. Accordingly the routing table of any sensor contains only two entries, this saves the memory required to store it. Figure 3 and Table 1, shows a simple network of 30 sensors and the base station deployed randomly and the routing table of some sensors. The number above circles is the sensor's ID. One should notice that the ring which passes through all sensors is not always simple and obvious as in figure 3.

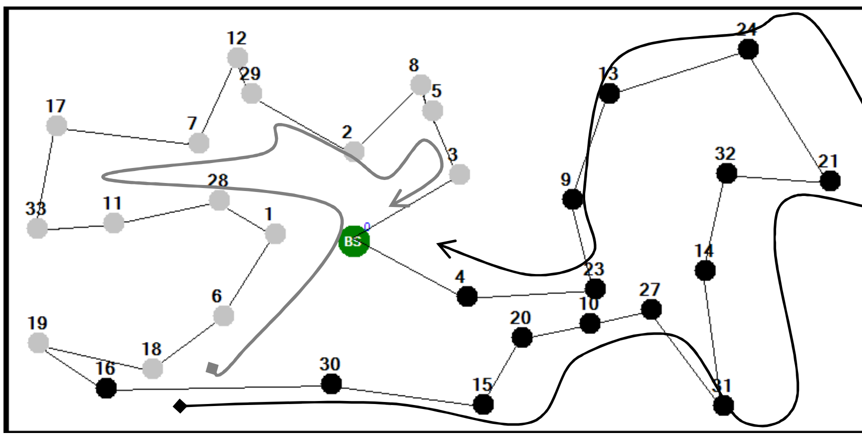


Fig.3. WSN Virtual Ring and Routing within a cluster

Figure 3 shows a cluster sensors which have two color sets, this to indicate where are the direction of the defaults next hops in every set (as indicated by arrows), i.e. sensor 19's next hop is 18 ,in contrast sensor 18 ;which has sensor 30 as its next hop. Table(1) lists the routing table of some sensors shown in the previous cluster .

Table 1. Routing Table of some Sensors of the Network shown in Fig.3.

Sensor ID	Next Hop	Previous Hop
3	Base Station	5
23	4	9
9	23	13
8	5	2
4	Base Station	23

Additional tuning is added to this advantage is that; two next hops and two previous hops are used as primary and alternate hops. This modification will double routing table size but the benefit beyond this is: if the primary next hop fails, source sensor increases transmission power by a prespecified amount (later in this paper we will quantify this power amount) and use the alternate next hop instead of routing data via previous hop. Hence WSN lifetime is extended and can operate during the failure of the first node. The cluster in figures.3,4 show the usage of alternate paths in a virtual ring that consists of 30 sensors in addition to the base station. Figure 4 shows the original path from sensor 16 to base station via sensor 23 as primary next hop. If sensor 23 fails then sensor 16 increases transmission power and use the alternate next hop instead of routing data via sensor 22 which will consume more time and power. This is illustrated in figure 5 and table (2).

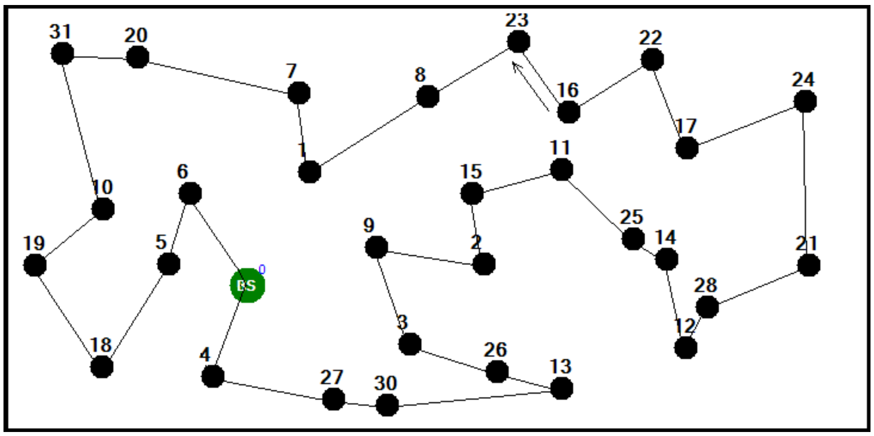


Fig.4. Original route taken by sensor 16

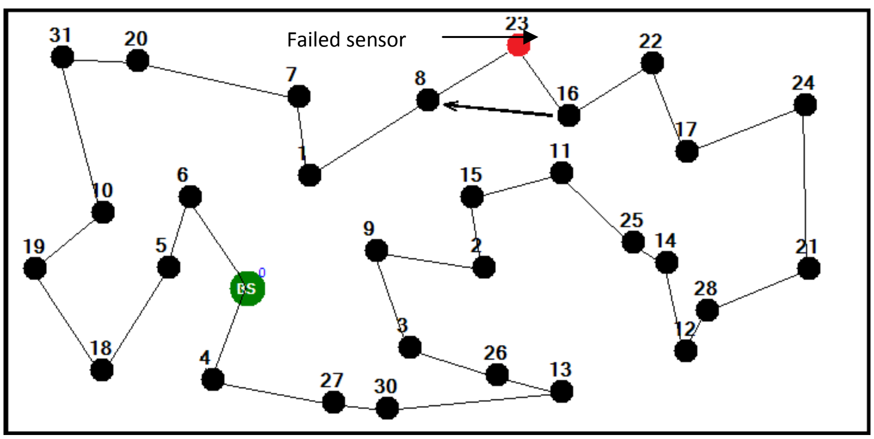


Fig.5. Using alternative next hop due to sensor 23 failure.

Table 2. Sensor No.16 Routing Table.

Next Hop	Previous Hop	Alternate Next Hop	Alternate Previous Hop
23	8	22	17

The second advantage for the ring topology is that all sensors in a cluster are connected via only one ring without introducing any loops. Genetic algorithm [24] is used to connect all the sensors belonging to the same cluster together in a single ring.

Ring topologies are characterized by a self healing feature in which backup paths exists [22]. The proposed technique in this paper uses this feature in an efficient manner to extend network lifetime and enables network to survive if the node's next and alternate next hops fails. If the two next hops failed, source sensor prepares packet that includes both the sensed data and the addresses of the failed next hops and route packet to base station via original previous hop. In case of the original previous hop failure, source sensor uses alternate previous hop - this is the last alternative- hence network lifetime extended to the third sensor failure. The longer reverse paths will not be used for a long time which negatively affects sensors resources but as soon as base station receives a packet indicates that a an alternate previous hop used, base station recalculates a new virtual ring for the involved clusters excluding the reported failed sensors, then beacon messages contains the route updates are transmitted to all the sensors. Those beacon messages are sent after a fixed time interval or when any sensor's previous hop failure is reported. Figure 6 shows the path taken to base station by sensor 16 after the failure of both sensors 23 and 8; black circles represent the nodes along the path.

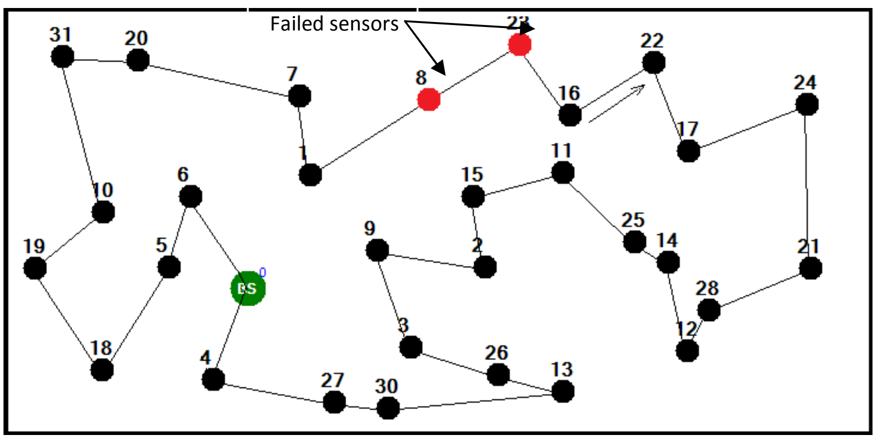
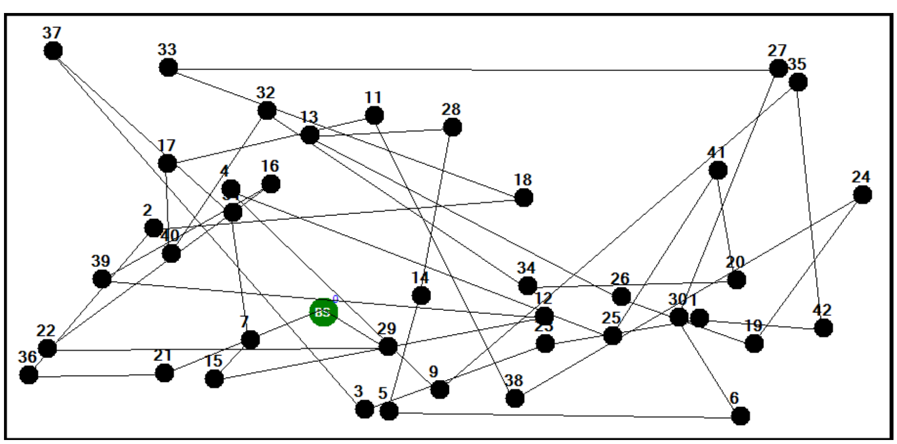
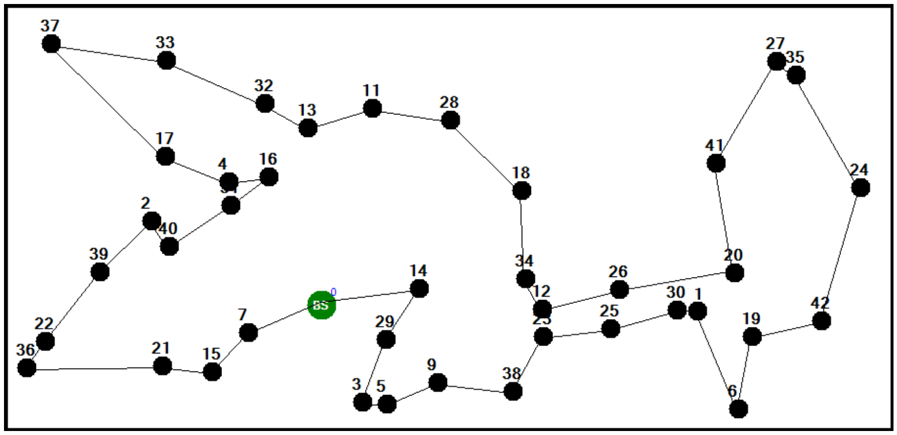


Fig.6. Ring Topology Healing Feature

Virtual rings must constructed carefully to minimize total consumed power. Power mainly depends on the distance between transmitter and receiver, if the virtual ring connects long spaced sensors, then the resulted ring is power consuming. Figure 7 shows an example of power efficient and power consuming virtual ring topologies. Genetic algorithm is used in the proposed work to construct power saving virtual rings.



(a) Power Consuming Ring



(b) Power Efficient Ring

Fig.7. Virtual Ring Power Aware Conducting

2.3 Wireless Energy Transmission Model

The proposed work in this paper minimizes load, processing and memory usage which minimizes the consumed power and maximizes the network lifetime. Constructing efficient route mainly depends on the number of hops to base station, network portioning and total transmission power per packet [25]. All of those constraints can be substituted by sensor transmission and receiving power which depends on distance between sensors. Actually if the total transmission and reception power is minimized, network lifetime will increase rapidly. The power constraint can be replaced by only the distance [26, 27]. Power saving virtual ring is the ring which minimizes distances between sensor and its next hop. As genetic algorithm as well as other evolutionary techniques [24, 29,30] are known to find the optimum solution for problems. Genetic algorithm is used in the proposed work for the following advantages:

1- Solves problems with multiple solutions.

2- Solves every optimization problem which can be described with the chromosome encoding.

3- Genetic algorithm is a method which is very easy to understand and it practically does not demand the knowledge of mathematics.

4- Genetic algorithms are easily transferred to available simulations and models.

The mentioned advantages motivate us to use Genetic algorithm in constructing a virtual ring containing all cluster sensors with minimum link distances between sensors. In [31] it is found that longer multi-hop routes consumes less power than single-hop routes so in the proposed technique multi-hop routing within a cluster is used as shown in figure 8. Typically increasing one hop between source and destination causes total transmission power to drop to the half. Power is directly proportional to the square of distance for constant received power. In this work the average number of hops from source to base station is actually more than the hops involved in the shortest path techniques but from other perspective we have saved sensors memory and processing required in the negotiation for shortest path.

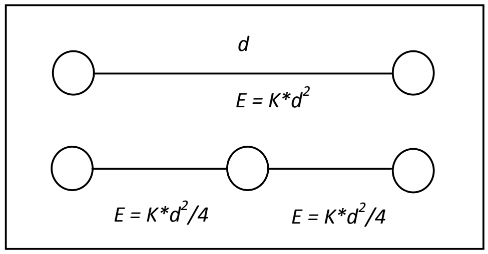


Fig.8. Power Saving in Multi-hop Routing

In order to construct power saving virtual rings, one parameter is needed to be adjusted for optimality which is the total distance between sensors. Eqs.(2) and (3) illustrate the model for the radio hardware energy dissipation [32, 33]where the transmitter dissipates energy to run the radio electronics and the power amplifier, and the receiver dissipates energy to run the radio electronics, as shown in figure 9. For the experiments described in the proposed work, both the free space power loss (d^2) and the multipath fading, [34, 35] power loss (d^4) channel models were used, depending on the distance from the transmitter to the receiver. Power control can be used to invert this loss by appropriately setting the power amplifier if the distance is less than a threshold d_0 , the free space model is used; otherwise, the multipath model is used.

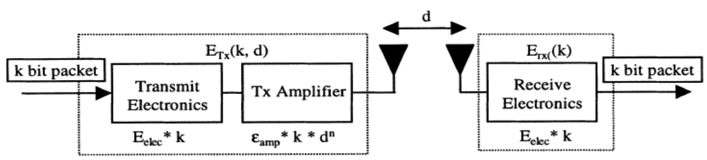


Fig.9. Radio energy dissipation model.

$$E_{TX}(k,d) = \begin{Bmatrix} KE_{elec} + K\varepsilon_{fs}d^2 & d \le d_0 \\ KE_{elec} + K\varepsilon_{mp}d^4 & d > d_0 \end{Bmatrix}$$

(1)

$$E_{RX}(k,d) = KE_{elec} \tag{2}$$

Where E_{TX} and E_{RX} are the transmission and receiving power respectively and *K* is the packet length in bits, *d* is the Euclidian distance from source to destination in meters,

$$\varepsilon_{mp} = 0.0013 pJ/bit/m^4 \; , \; \varepsilon_{fs} = 10 pJ/bit/m^2,$$
$$E_{elec} = 50 nJ/bit \quad and \quad d_0 = \sqrt{\varepsilon_{fs}/\varepsilon_{mp}} \tag{3}$$

Eq.2 is very useful in calculating the power required while communicating with a destination sensor far away from the source by distance ***d*.** later in this paper we will show that the base station sends routing information and the transmission power required to reach nearby sensors if needed.

2.4 Genetic Algorithm

Genetic algorithms belong to the larger class of evolutionary algorithms (EA), which generate solutions to optimization problems using techniques inspired by natural evolution, such as, mutation, selection, and crossover on chromosomes. The proposed routing techniques uses genetic algorithm for its simplicity and hardware consistency. Chromosome coding is a formulation to the problem which an optimum solution is required. In order to start the algorithm, the following operations must be fulfilled: (1) Gene selection and chromosome coding (2) Cost function formulation. These operations are illustrated in detail in the following subsections.

2.4.1 Chromosome Coding

Equation (4) describes the chromosome which represents a virtual ring. Every sensor in the network has a unique identification number (ID). The virtual ring is represented by the sequence of sensor ids in any permutation without repeating. If there is a sensor network of N sensors then a virtual ring that contains all sensors is represented by the following design variable (DV):

$$DV = [\, S_0 , S_1, S_2 , S_3 , \ldots , S_{N-1}] \tag{4}$$

This represents a ring that connects sensor S_i by sensor S_{i+1}, S_{N-1} by sensor S_0 and so on.

2.4.2 Cost Function Formulation

According to eq.1, Distance is considered the cost metric. As mentioned earlier power saving virtual rings is the rings with small distances between sensors. Distance between a sensor, i, and any other sensor, j, is calculated as:

$$d_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \tag{5}$$

Where x_i , y_i are sensor i coordinate and x_j , y_j are the coordinates for any other sensor , j, in the network. A vector $\boldsymbol{LD_i}$ for each sensor, i ,in the network is obtained with the following format:

$$LD_i = [X_{i0}, X_{i1}, X_{i2}, \ldots\ldots X_{ij}, \ldots\ldots X_{iN-1}] \qquad where\ \ i \neq j \ \ and\ \ i, j \in [0, N-1] \tag{6}$$

Where the segment X_{ij} is either d_{ij}^2 or d_{ij}^4 as shown in eq.7 according to the distance between the sensor i and sensor j and value of d_0 that is mentioned in eq.2.

$$X_{ij} = \begin{cases} 0 & if\ the\ segment\ is\ not\ chosen \\ d_{ij}^2\ \ or\ d_{ij}^4 & if\ the\ segment\ is\ chosen \end{cases} \tag{7}$$

Genetic algorithm chooses only one segment from every LD_i and sets the other segments to zero so that the energy cost is the sum of all the contents of every LD_i. Equation (6) shows the change in LD_i values. A ring will contain N non zero segments chosen from the N^2 segments from every LD_i which belongs to each sensor. The energy cost (EC_K) for the K^{th} constructed virtual ring is:

$$EC_K = \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} X_{ij} \qquad , X_{ij} \in LD_i \tag{8}$$

Eq.8 attempts to add *N x N* segments but only *N* of them segments have a non zero values according to eq.7.

2.5 Delay Analysis of the Proposed Routing Technique

In this section a formula for average packet delay from the source to the base station is obtained. During the delay analysis, the processing and propagation delays are assumed to be negligible when compared to transmission delay; sensors are assumed to be deployed randomly; and clusters are assumed to have equal size. Let ***N*** be the total number of sensors divided into K_{opt} clusters. Sensors in a cluster are divided into two equal sets i.e. the set has *N/2* sensors. The best case for routing within a set is the situation where the source sensor has the base station as its next-hop, and the worst case is met when the source sensor is located at the end of the set. The average number of hops is considered one half the sensors in the set *N/4*. Packet delay mainly depends on the number of hops *H* from the source to the base station. On average *H* can be obtained as follows::

$$H = \frac{N}{4K_{opt}} \tag{9}$$

If the packet length is *L* bits and *R* bits/sec is the rate of transmission then the average delay time ,*D,* in seconds is expressed as:

$$D = \frac{HL}{R} \tag{10}$$

Then the total round time is:

$$D_{total} = \frac{NHL}{R} \tag{11}$$

Note that if a total network failure occurs, an extra delay is incurred, which is the time consumed by genetic algorithm in reconstructing virtual rings. In section(3) virtual ring reconstruction delay is quantified.

2.6 The Proposed Technique in Action

This section collects the previously discussed steps together to build the proposed routing technique. The following pseudocode show how the proposed routing technique works on the base station and on any sensor. In the proposed work, genetic algorithm operates on the base station only to overcome the resulted delay. Also it operates only in case of any previous hop failure.

2.6.1 The Proposed Routing Technique Operation on the Base Station

The algorithm operation on base station is divided into three main operations:

1. Clustering sensors according to their location.
2. Computing the minimum length virtual ring for every cluster.
3. Distributing routing and power information to every sensor
4. Processing sensor's received data

The first operation is clustering sensor network into K_{opt} clusters , K_{opt} is obtained experimentally such that minimum power dissipation per round and maximum lifetime it achieved.

The second operation is computing the minimum length virtual ring for every cluster. It requires base station to know the position of every sensor in the topology which was discussed earlier in this paper. In this operation, genetic algorithm is the main key, the following pseudocode illustrates the steps held by genetic algorithm to obtain the minimum ***EC*** virtual ring:

1. Set MAX_GENERATION
2. Create a random initial population of 100 virtual rings through random creation of a set of DV.
3. Calculate the EC of every created DV according to eq.1 through 7
4. Perform crossover and mutation on the DV of the fittest virtual rings i.e. Minimum EC.
5. Add the new child virtual rings to the population
6. If the population size is greater than or equal MAX_GENERATION
    i. Find the minimum EC virtual ring
7. Else repeat steps 4,5,6
8. End

Note that the sample could be saturated before reaching a population size of 100000000, so it is better to set *MAX_GENERATION* to a value function of sensors number.

The third operation is the distribution of routing information to all the sensors in the topology, this is achieved via a high power message (beacon message) from base station so that every sensor can receive his routing table and the power needed to reach every hop in the routing table.

The fourth operation is handling the data received from sensors. A packet received by the base station holds information about specific event or any other monitored phenomena and contains information about the path taken from the source. A received packet can either come from original next hops (this is the ordinary case) or another hop (either alternate next or previous hops) in case of the primary sensor's failure. The second case required the base station to mark the failed sensors that are indicated in the received packet so that they will not be involved in the new virtual ring. The following pseudocode illustrates the steps held by the base station to fullfill this operation:

1. Read active sensor list location information
2. Divide Network into K_{opt} Clusters
3. Calculate the minimum power virtual ring for every cluster
4. Distribute routing information and the power amount required to reach any hop in the routing table to every sensor the network.
5. Set up a timer for resending new route updates
6. If the timer interval elapsed
    i. Go to step 1

7. If a packet arrived
    i. Examine packet header and extract path information
        If a packets comes from an alternate previous hop
            a. Mark the indicated failed sensors
            b. Process data
            c. Go to step 1
    ii. Mark the indicated failed sensors (if any) and update active sensor list
    iii. Process packets data
    iv. Go to step 4.
8. End.

The timer is used to prevent the oscillation that occurs if a total network failure occurs, this case is illustrated in figure 10.

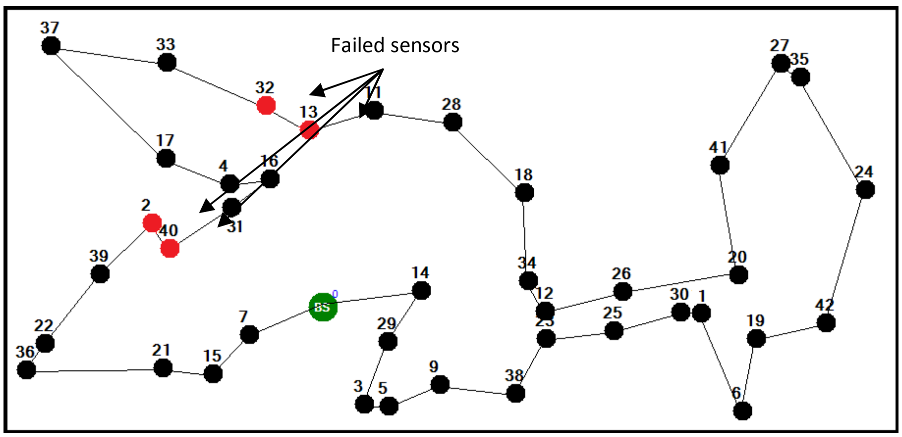


Fig.10. The situation that indicates when a total network failure is met.

For the network in figure 10, it is obvious that sensors 33**,** 37**,** 17**,**4**,**16 and 31 can't route any information to the base station due to sensors 2, 40, 32 and 13 failure so, any packet transmitted will continue to oscillate back and forth, this is the main reason of using a timer**.**

2.6.2 The Proposed Routing Technique Operation on a Sensor

Every sensor in the network has to:

1. Negotiate with the base station to establish the location information.
2. Listen for the route updates and power information sent by the base station.
3. Use its routing table and power information in forwarding data to the base station.

Operation 1 and 2 are trivial, the following pseudocode illustrates operation 3 in details:

Assuming a data is required needed to be transmitted to the base station:

1. Prepare a packet contains the sensed data and send it via the next hop –but keep copy of it in the memory
2. If acknowledgment not received from the receiving hop
    i. Encapsulate next hop ID in the stored packet header and sent it via alternate next hop with

the specified transmission power

ii. If acknowledgment is not received from the receiving hop

a. Add alternate next hop ID in the stored packet header and sent it via previous hop

b. If acknowledgment is not received from the receiving hop

-Add previous hop ID in the stored packet header and sent it via alternate previous hop

-If acknowledgment not received from the receiving hop

Wait for the new route and power information.

3.End

3. SIMULATION RESULTS

In order to test the proposed routing technique simulations are used. Genetic algorithm performance is tested via a special simulator built using C# .Net. Routing and power information obtained from the previous simulator is supplied as input into readymade simulator. The network has following characteristics:

1. Fixed; i.e., sensors and the base station are not moving after deployment.
2. All nodes initially have equal energy and the base station has infinite power supply, powerful computation, and processing abilities.
3. A round is defined as the process of gathering all the data from nodes to the sink, regardless of how much time it takes.

Most of the simulations results are obtained using the following parameters (unless otherwise mentioned):

1. Sensor deployment is random on a given area of 100x100m.
2. The sink node is located and fixed at a (100,100) position.
3. Initial sensor energy is chosen to be 1J.
4. In a single round every sensor transmits ten 500-byte packets.
5. Number of sensors is 100.
6. Number of runs for every experiment is 10.
7. Transmission rate is 2Mbps.

3.1 Obtaining the Optimal Number of Clusters K_{opt}

The following experiments are held to determine practically the optimal number of clusters. The first experiment shown in figure 11 is held to highlight the relationship between number of clusters and average number of rounds before the first failure occurrence.

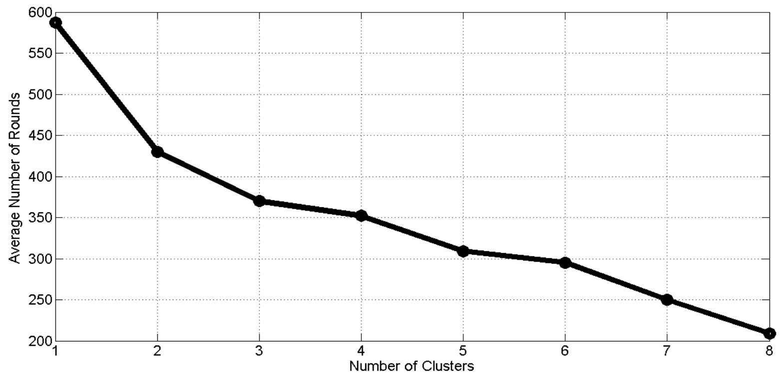


Fig.11. Number of clusters versus average number of rounds.

As shown in the figure, increasing number of clusters negatively affects the number of rounds and sensor network lifetime is indeed decreased. Increasing the number of clusters reduces the number of hops from the source sensor to the base station. Over increasing the number of cluster causes the path to the base station to be close to the minimum hops path. A minimum hop path contains long separated hops, which requires more power from the sensors.

Figure 12 shows the relationship between number of clusters and the time required to gather information from all the sensors i.e. time of a single round.

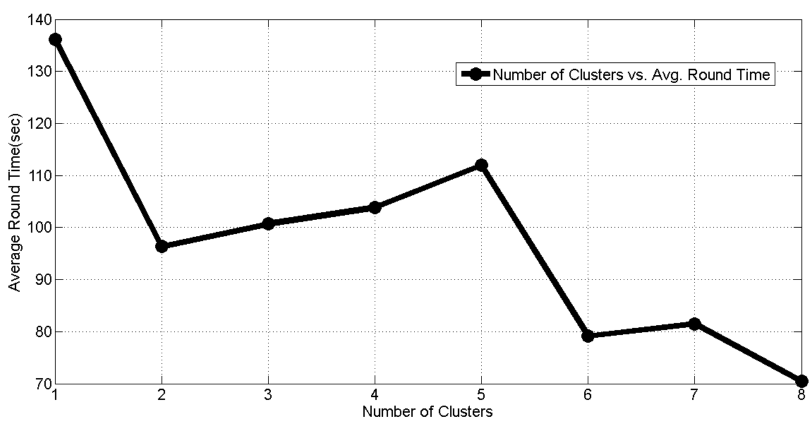


Fig.12. Number of cluster vs. average round time.

As shown from the figure, increasing the number of clusters reduces the average round time , as mentioned later increasing clusters gives shorter-hop paths which indeed decreases round time.

By combining the two previous experiments, the optimal number of clusters K_{opt} can be obtained. K_{opt} is chosen such that; gives maximum lifetime and minimum delay in the same time. The tradeoffs between the two previous experiments gives that it can be 6 , 7 or 8. For the next experiments K_{opt} is chosen to be 7.

3.2 Genetic Algorithm Delay Analysis.

The following experiment is held to obtain the delay incurred during clustering and the construction of a virtual ring. Virtual ring construction depends on the number of sensors. Figure 13, shows the time consumed in ring construction versus the number of sensors in a ring.

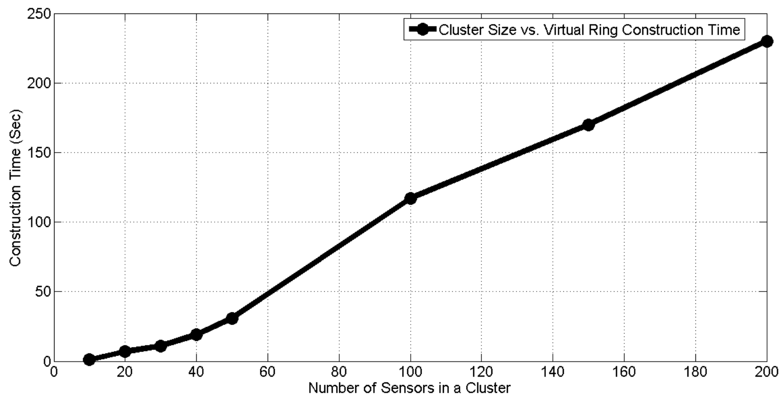


Fig.13. Cluster size vs. average construction time.

One should note that this delay is suffered if and only if a total network failure occurs. Also such delay depends on the processing power of the base station.

3.3 The Proposed Routing Technique Lifetime Analysis

This experiment is held to show the lifetime of the proposed technique compared with LEACH(E)[36] and Direct which is illustrated in[37]. Figure 14 shows the lifetime of each routing technique.

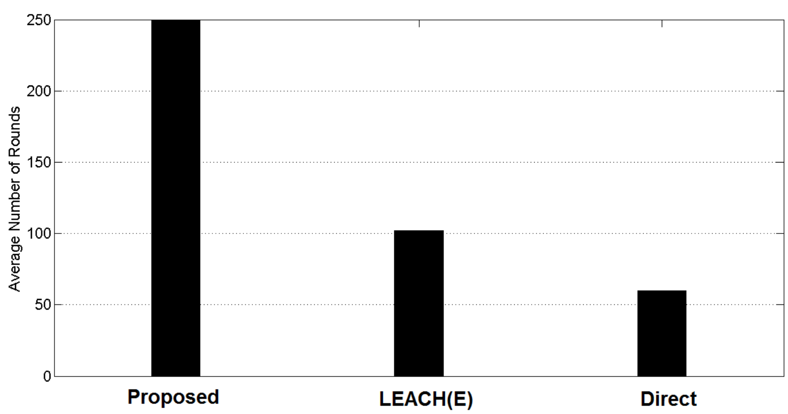


Fig.14.Lifetime of Proposed/LEACH(E)/Direct techniques

As shown in the figure the proposed technique gives maximum lifetime compared with LEACH(E) and Direct techniques.

3.4 The Proposed Routing Technique Delay Analysis

To compute the average delay from any sensor to the base station, parameters in Equation (11) are substituted as follows: K_{opt} = 7, N = 100 and channel bit rate of 2Mbps which gives the average delay time = 71 ms. Figure 15 compares the proposed technique against LEACH [36] and Direct [37].

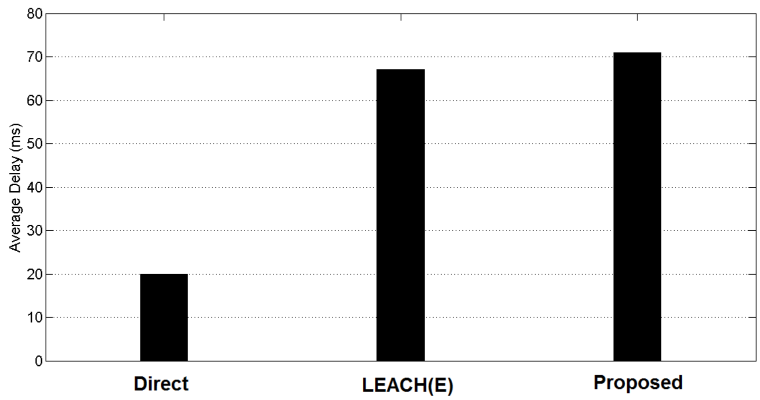


Fig.15. Average Delay time

It is shown from the figure that the proposed technique average delay approaches the LEACH(E), but one should note the light weight resource consumption and the lifetime of the network.

4. CONCLUSION

In this paper, we propose a new centralized routing algorithm for WSN using genetic algorithm. Simulation results show that the proposed protocol can give reasonable average round delay compared with other techniques. In the same time the proposed technique prolongs the network lifetime hence more data is delivered to base station. Using the clustered - ring topologies made the proposed technique fault tolerant, simple and applicable in wireless sensor network.

5. REFRENCES

[1] W. Dargie, and C. Poellabauer, "Fundamentals of Wireless Sensor Networks Theory and Practice", Wiley, 2010.

[2] N. Xu "A survey of sensor network applications," IEEE Communications Magazine,Vol.40, No.8, pp. 102-114, 2002.

[3] S. P. Kumar "Sensor networks: Evolution, opportunities, and challenges", Proceedings of the IEEE, Vol.91, No.8, pp 1247-1256, 2003.

[4] K. Akkaya, and M. Younis," A survey on routing protocols for wireless sensor networks", Ad Hoc Networks, Vol.3,No.3, pp.325-349, 2005.

[5] K. Khedo, R. Perseedoss, and A. Mungur." A Wireless Sensor Netwok Monitoring System," International Journal of Wireless &Mobile Networks (IJWMN),Vol.2,No.2, pp. 31-45, 2010.

[6] M. Zorzi "Wireless sensor networks", IEEE Wireless Communications, Vol.11, No.6, pp. 2-2, 2004.

[7] G. J. Kaiser, and W. J. Pottie ,"Integrated Network", Communications of the ACM, Vol.43 , No. 5, pp. 51-58, 2000.

[8] S. Srivathsan, and S. S. Iyengar, "Minimizing latency in wireless sensor networks: a survey", Proceedings of the third conference on IASTED, Anaheim, CA, USA, ACTA Press, pp. 159–164, 2007.

[9] D. S. J. D. Couto, D. Aguayo, B. A. Chambers, and R. Morris, "Performance of multihop wireless networks: shortest path is not enough", SIGCOMM Comput. Commun. Rev., Vol. 33, no. 1, pp. 83–88, 2003.

[10] N. Patwari, and A. O. Hero III, "Signal strength localization bounds in ad hoc & sensor networks when transmit powers are random", Fourth IEEE Workshop on Sensor Array and Multichannel Processing, 2006.

[11] W. Zhuang, G. Song, J. Tan, and A. Song, "Localization for hybrid sensor networks in unknown environments using received signal strength indicator", Proc. of the IEEE International Conf. on Information and Automation, 2008.

[12] Y.Yang, , X.Guan and J.You, "CLOPE: A fast and effective clustering algorithm for transactional data", Proceedings of the Eighth ACM SIGKDD International Conference on Knowledge Discovery and Data Mining, pp. 682–687,2002.

[13] M.Ester,H.Kriegel, P.Sander, and X. Xu ,"A density-based algorithm for discovering clusters in large spatial databases with noise", Proceedings of the Second International Conference on Knowledge Discovery and Data Mining , pp. 226–231, 1996.

[14] M.Ankerst, M.Breunig, H.Kriegel, and P. Sander," OPTICS: Ordering points to identify the clustering structure", Proceedings of the ACM SIGMOD International Conference on Management of Data, pp. 49–60, 1999.

[15] N.Slonim, N.Friedman and N.Tishby," Unsupervised document classification using sequential information maximization", Proceedings of the 25th International ACM SIGIR Conference on Research and Development in Information Retrieval , pp. 120–136, 2002.

[16] T. Shu, M. Krunz and S. Vrudhula, "Power Balanced Coverage-Time Optimization for Clustered Wireless Sensor Networks", Proc. of the 6th ACM international Symposium on Mobile Ad Hoc Networking and Computing, pp.111-120, 2005.

[17] W. B. Heinzelman, A. Chandrakasan, H. Balakrishnan "Energy-Efficient Communication Protocol for Wireless Microsensor Networks", Proc. of the 33rd IEEE International Conference on System Sciences, pp. 1–10, 2000.

[18] A. Manjeshwar, and D. P. Agarwal, "TEEN: A Routing Protocol for Enhanced Efficiency in Wireless Sensor Networks", 1st International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile Computing, 2001.

[19] A. Manjeshwar and D. P. Agarwal, "APTEEN: A Hybrid Protocol for Efficient Routing and Comprehensive Information Retrieval in Wireless Sensor Networks", Proc. of International Parallel and Distributed Processing Symposium, pp.195-202,2002.

[20] A. Khadivi, M. Shiva, and N. Yazdani, "EPMPAC: an efficient power management protocol with adaptive clustering for wireless sensor networks", Proc. Of International Conference on Wireless Communications, Networking and Mobile Computing, Vol.2, pp. 1154-1157, 2005.

[21] A. Khadivi and M. Shiva, "FTPASC: A Fault Tolerant Power Aware Protocol with Static Clustering for Wireless Sensor Networks", Proc. of IEEE International Conference on Wireless and Mobile Computing, pp. 397- 401, 2006.

[22] F. LEWIS "Wireless Sensor Network, Technologies, Protocols, and Applications", Computer Networks, Vol.38, No.4, pp. 393-422, 2002.

[23] A. Nanda, and A. Kumar, "Node Sensing & Dynamic Discovering Routes for Wireless Sensor Networks", International Journal of Computer Science and Information Security, Vol. 7, No. 3, pp. 122-131, 2010.

[24] W. Daniels "An Introduction to Numerical Methods and Optimization Techniques" , Elsevier North-Holland, 1978.

[25] L. Gavrilovska, and S. Krco " Application and Multidisciplinary Aspects of Wireless Sensor Networks", Springer, 1982

[26] S. N. Sivanandam ,and S. N. Deepa ," Introduction to Genetic Algorithms", Springer, 2008.

[27] H. Callaway " Wireless Sensor Networks: Architectures and Protocols", CRC Press, 2004.

[28] R. Nallusamy and K. Duraiswamy " Energy efficient dynamic shortest path routing in wireless Ad hoc sensor networks using genetic algorithm", International Conference on Wireless Communication and Sensor Computing (ICWCSC) , pp. 1-5 , 2010.

[29] L. Chi, and D. Fan " Genetic Algorithm", Biotechnology and applied biochemistry, Vol.58, No.3 ,pp. 175-84, 2011.

[30] Y. K. S. N. D. Goldberg, B. Karp, and S. Seshan "Genetic algorithms in search, optimization and machine learning", Addision-Wesley, 1989.

[31] S. Fedor and M. Collier "On the problem of energy efficiency of multi-hop vs one-hop routing in Wireless Sensor Networks", 21st International Conference on Advanced Information Networking and Applications Workshops (AINAW'07), Vol.2, pp. 380-385 , 2007.

[32] B. Heinzelman, P. Chandrakasan, and H. Balakrishnan "An application-specific protocol architecture for wireless Microsensor networks", IEEE transaction on wireless communication ,Vol.1, No.4, pp.660-670, 2002.

[33] K. Dasgupta, K. Kalpakis, and P. Namjoshi "An efficient clustering-based heuristic for data gathering and aggregation in sensor networks", IEEE Wireless Communications and Networking , pp.1948-1953,2003.

[34] W. Heinzelman, P. Chandrakasan, and H. Balakrishnan "An application-specific protocol architecture for wireless microsensor networks", IEEE Transactions on Wireless Communications, Vol.1,No.4,pp. 660-670, 2002.

[35] T. Rappaport and others "Wireless communications: principles and practice", Prentice Hall PTR New Jersey, pp. 737-740, 1996.

[36] W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "Energy efficient communication protocol for wireless sensor networks", Proc. of the Hawaii International Conf. on System Sciences, pp. 737-740, 2000.

[37] G. Wenliang, S. Huichang, Y. Jun ,and Z. Yifei "Application of Genetic Algorithm in Energy-Efficient Routing ", China-Japan Joint Microwave Conference , pp. 737-740, 2008.