Energy Efficient Cluster Based Routing Protocol using Hybrid Metaheuristic in WSNs

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Abstract

The main factor in WSNs that effect the network lifetime is energy dissipation because most of the energy is consumed at the time of cluster formation and transmission or routing of data to BS. Therefore one of the most important challenges in WSN is to design energy efficient routing mechanism which increases the network lifetime with constrained energy resource. Taking this factor into consideration, an optimized technique with GA and GSA is proposed for wireless sensor network that saves power and prolongs network life. The proposed method used GA in order to provide efficient clustering by choosing the best node as CH based on the fitness value. Where GSA is used to route the data of these CHs to the BS by means of efficient routing by choosing best optimal path. The technique is simulated using MATLAB. The experimental results compared with E-OEERP (Enhanced-Optimized energy efficient routing protocol) and results found are promising. From graphical Analysis it has been observed that the proposed work performs better than E-OEERP in terms of throughput, energy consumption, and network lifetime.

Index Terms: Cluster formation, Genetic Algorithm, Gravitational search algorithm Routing.

I INTRODUCTION

Innovations in industries, home and automation in transportation represent smart environments. Data for smart environments are obtained through wireless sensor networks [15]. Technology advancements in the areas of wireless networks have led to the rapid development of wireless micro-sensors for wireless communication. Wireless Sensor Networks (WSNs) are a combination of autonomous devices that are heavily deployed over a large geographical area to perform local computations based on data gathered from the surroundings. These devices are sensor nodes that collaborate to collect the detailed information from sensing area and relay the data to the destination so called sink or base station. The data is the information of the physical conditions of environment such as temperature, humidity; pressure etc. These nodes are equipped with sensing, data processing and radio transmission units. WSNs are playing a vital role in several areas ranging health to battle field. These networks are easy to deploy due to its unique characteristic of self-organizing. WSN can be widely used to perform military tracking and surveillance, natural disaster relief operations, hazardous environment exploration and health monitoring. Constrained energy resource is the most critical issue of WSN as sensor node is equipped with a battery and cannot be recharged easily in most cases. Moreover, sensor nodes consume most of
the energy for data transmission and quickly run out of energy. It is a resource constraint type of network. Cluster formation and routing of data is one of the factors that affect the performance of the network. Therefore one of the most important challenges in WSN is to design energy efficient routing mechanism that improves the performance of the network by providing increased network lifetime with constrained energy resource.

Taking the limited energy resource factor into consideration, an optimized energy efficient clustered based routing technique with GA and GSA is proposed for wireless sensor network that saves power and prolongs network life. The main objective behind this protocol is to keep the sensors operating for as long as possible, thus extending the network lifetime.

The proposed method used GA in order to provide efficient clustering by choosing the best node as CH based on the fitness value. The best fitness function result is considered as best pollution. Therefore depending upon some parameters such as battery life, distance, and best fittest node will be selected as CH. Where GSA is used to route the data of these CHs to the BS by means of efficient routing by choosing best optimal path. Using Gravitational Search Algorithm, the parameters like distance and force between the sensors nodes are taken into consideration for routing the data to BS. Force between the cluster heads is considered while selecting the next best hop.

The rest of the paper is organized in following sections: Related works and the experimental setup of Proposed Protocol are explained in 2 and 3 section respectively. Proposed work is compared with the protocol E-OEERP and discussed in Section 4. Conclusion and future scope is given Section 5.

II RELATED WORKS

N. Purushothaman [1] presented a General Self- Organized Tree-Based Energy Balance routing protocol (GSTEB) to minimize total energy consumption and to balance WSN load. This scheme builds a routing tree using a process where for each round BS assigns a root node and broadcasts this selection to all sensor nodes. Subsequently, each node selects its parent by considering only itself and its neighbors’ information, thereby making GSTEB a dynamic protocol.

N. Zaman[2] introduced energy efficient routing protocol known as Position Responsive Routing Protocol (PRRP) to increase energy efficiency of WSN. Position response routing protocol approach allowed proper distribution of gateway cluster head selection, maximum possible distance minimization among nodes and gateways cluster heads to consume less energy.

L. Ya, W. Pengjun [3] proposed a novel routing protocol for heterogeneous WSN based on beaconing. They introduced EARBB (a Energy-Aware Routing Based on Beaconing) which can provide a reliable and energy-efficient routing scheme for both information collection and dissemination with beaconing packets exchanged between nodes and their neighbours.

C. Gherbi, Z. Aliouat[4] proposed distributed energy efficient adaptive clustering protocol with data gathering for large scale WSN to design sleep control laws that minimize the expected value of a cost function representing both energy consumption costs and holding costs for backlogged packets.

J. Rejina Parvin [5] presented an enhanced-OEERP(E-OEERP) that reduces/eliminates individual node formation and increases the overall network lifetime. It is achieved by applying the concepts of PSO and gravitational search algorithm (GSA) for cluster formation and routing, respectively.

G. Ahmed [6] proposed a method of evolutionary computing for the selection...
of the CHs. The BS periodically runs the proposed algorithm to select new CHs after a certain period of time. Results show that network lifetime is drastically increases.

Sajid Hussain[7] proposed Genetic Algorithm for Hierarchical Wireless Sensor Networks to create energy efficient clusters for data dissemination in wireless sensor networks. The simulation results show that the proposed intelligent hierarchical clustering technique can extend the network lifetime for different network deployment environments.

A. Zahmatkesh [8] proposed a Genetic Algorithm(GA) to optimize sensor nodes’ energy consumption. A multi-objective algorithm is used that generates an optimal number of sensor-clusters with cluster-heads and minimizes the cost of transmission.

Esmat Rashedi [11] introduced a new optimization algorithm Gravitational Search Algorithm (GSA) which is based on the law of Gravity and the notion of mass interactions. In order to evaluate the algorithm, it is examined on a set of various standard benchmark functions.

Norlina Mohd Sabri [13] presented a review of Gravitational Search Algorithm. It intended to dig out the algorithm’s current state of publications, advances, its applications and discover its future possibilities that can be applied in various areas of WSN. This review paper is expected to provide an outlook on GSA especially for those researchers who are keen to explore the algorithm’s capabilities and performances.

III PROPOSED TECHNIQUE

In this paper energy efficient clustered based routing technique with GA and GSA is proposed so as to reduce the power consumption of sensor nodes and extend network lifetime. The concept of Genetic Algorithm (GA) is used for cluster formation. Constructing the optimal routing path to forward the sensed data is another challenging task in WSN. In the proposed system, Gravitational Search Algorithm (GSA) is used to choose the shortest path to BS to transmit the data.

A. Genetic Algorithm

A genetic algorithm is a probabilistic search method that computationally simulates the process of biological evolution. It mimics the process of evolution in nature by repeatedly altering a population of candidate solutions until an optimal solution is found. In GA, nodes initialize the pollution by opting genetic behaviour and by computing the fitness value. The best fitness function result is considered as best pollution. In order to calculate the fitness value three steps (crossover, mutation, selection) are repeated for particular number of generations to find local solution. It is best in case where we have two options for a solution. The chromosome of the GA contains all the building blocks to determine the solution of the problem that is suitable for the genetic operators and the fitness function. Each individual node is represented by a 4 number called ‘gene’. These four Fitness function parameters that influences the implementation of GA:

\[ \text{Node ID } \rightarrow \text{X1 X2 X3 X4} \]

X1: Cluster Distance
X2: Direct Distance to BS
X3: Degree of mobility
X4: Battery power

1. Cluster Distance (CD): The cluster distance is defined as the sum of the distances from the nodes to the CH and the distance from the CH to the BS. For a cluster with k member nodes, the cluster distance CD is computed as follows:

\[ CD = \sum_{i=1}^{k} d_{ih} + d_{hs} \]  \hspace{1cm} (1)
Where $d_{ih}$ is the distance of node i to the CH h and $d_{hs}$ is the distance of the CH h to the BS node s. For a cluster that has large number of widely-spaced nodes, if the cluster distance will be higher, the energy consumption will be higher. Energy consumption would be less if CD should is not large. This metric will control the cluster size.

2. Direct distance to BS (DD): The direct distance to base station is defined as the sum of distances of all the sensor nodes to the BS. This distance is computed as follows:

$$DD = \sum_{i=1}^{m} d_{is}$$ (2)

Where $d_{is}$ is the distance of the node i to the BS nodes. For a larger network, this distance should be minimized; lest the energy of most of the nodes will be wasted. However, for a smaller network that has a few closely located nodes; direct transfer to BS may be a suitable acceptable option.

3. Degree of mobility (M): The mobility of the node has great effect on the network lifetime. The topology of the network gets changed very frequently due to the high mobility of nodes, which leads to reselection of CH rapidly.

4. Battery power (P): Higher the battery power, higher the probability of the node of becoming CH.

Based on these parameters, fitness value can be evaluated as:

$$f(x) = f(x1; x2; x3; x4) = w1*CD$$
$$+w2*DD+w3*M+w4*P.$$ (3)

Here, $w1*CD +w2*DD +w3*M+w4*P=W$

Where W is a combined weight of all the weighting coefficients $w1$, $w2$, $w3$, $w4$ that define the importance of each parameter in the network design

Fig. 1: Possible values for the attributes

In the case of WSN, the fitness function depends upon the four factors discussed above. Nodes with higher energy, low mobility, less cluster distance and less direct distance have high fitness values and can be declared as CHs

B. Gravitational Search Algorithm

Gravitational Search Algorithm (GSA) is an optimization algorithm used in the proposed method for constructing an optimal path for forwarding the sensed data to the base station. It is used for determining the next best hop in the proposed method. GSA is based on the principles of Newtonian Law of Gravity which states that, “Every particle attracts every other particle with a force F which is directly proportional to the product of masses and inversely proportional to the square of distance between them”. This can be defined as

$$F = G \frac{M1M2}{R^2}$$ (4)

Where

$F$ - force of a particle
$G$ - Gravitational constant ($G = 6.8 \times 10^{-11} m^3 kg^{-1} s^{-2}$)
$M1$ and $M2$ - mass of particle 1 & 2 respectively
$R$ - distance between particle 1 and 2

Force between the cluster heads is considered while selecting the next best hop. The force of attraction is large for the nearer node than the farthest node. Higher the force of attraction, better the transmission efficiency and reliability. Furthermore, the node with minimal
distance is considered to choose the next hop. This route request message includes the information like the node’s position, velocity and energy to the neighbour. Neighbour nodes transmit the same request to its available neighbours by replacing the received position, velocity and energy value by its own value. The same process is repeated until it reaches the destination.

Fig.2: Flowchart of Proposed Protocol

IV RESULTS AND DISCUSSIONS

The proposed work has been simulated using MATLAB to study the performance of proposed technique. The objective of the work is to provide the energy efficient clustering and routing scheme in the network and increase nodes lifespan. To implement the work, the network model of hundred sensor nodes is considered and distributed in a large area. Each node is assigned with random energy of 100 joules initially. Maximum number of iterations in the network is set to 10000. In the starting few iterations all the nodes are alive. First node dead is found at round 1500 and as the network reaches 2500 iterations, all the nodes die.

The simulation results compared with E-OEERP (Enhanced-optimized energy efficient routing protocol) is depicted in following different graphs. Following different parameters are taken into consideration to simulate the proposed work:

- Alive nodes
- Total Energy consumption
- Packet Delivery Ratio
- Network lifetime (First node dead, last node dead).

A. Performance Analysis

The following figures are depicting the initial and final stage of the network. The Starting phase showing all the alive nodes
And the last phase is showing the all dead nodes.  

**Fig. 3**: Initial Stage of network

**Fig. 4**: Final Stage of network

The following graph in fig. 5 represents the proposed protocol with number of the alive nodes in the network. Network of total 100 nodes is considered. The graph indicates that all the nodes are alive in the starting iterations. First node dead is found at round 1500 and last node dies at round 2500. Therefore the graph indicates the better stability period and network lifetime.

**Fig. 5**: Number of Rounds Vs Alive Nodes

The graph in fig. 6 shows comparison of energy consumption between the proposed protocol and E-OEERP. The energy consumption of a node is based on sensing, computing and communication. From the results it is observed that the Total Energy Consumption of the proposed protocol is less when compared with other existing E-OEERP. Less energy consumption results indicates the better network lifetime.

**Fig. 6**: Comparison for energy consumption

The graph in fig. 7 shows the throughput comparison of the proposed protocol and
Throughput is defined as the amount of data being transmitted in bits per second (bps or b/s). The graph indicates that throughput of the proposed work is better than E-OEERP. Higher the PDR ratio more is the performance of the system.

**V CONCLUSION AND SCOPE**

One of the most important challenges in WSN is to design energy efficient routing mechanism which increases the network lifetime with constrained energy resource. Taking this factor into consideration, an optimized energy efficient clustered based routing technique with GA and GSA is proposed for wireless sensor network that saves power and prolongs network life. The main objective behind this protocol is to keep the sensors operating for as long as possible, thus extending the network lifetime. The proposed method used GA in order to provide efficient clustering by choosing the best node as CH based on the fitness value. Where GSA is used to route the data of these CHs to the BS by means of efficient routing by choosing best optimal path.

The proposed technique is simulated using MATLAB considering the network of 100 nodes. The experimental results compared with E-OEERP (Enhanced-Optimized energy efficient routing protocol) and results found are promising. Various parameters were taken into consideration while implementation such as alive nodes, total energy consumption, throughput, network lifetime. From graphical analysis it has been observed that the proposed work performs better than E-OEERP.

However, various Heuristic optimization methods have been developed in recent years. But there is still no specific algorithm to achieve the best solution for all optimization problems. Some algorithms provide a better solution for some particular problems than others. Hence, searching for new heuristic optimization techniques is an open problem. This investigation will be extremely useful for energy efficient wireless sensor network. In terms of range of applications, there are still some areas that could be explored by using GSA. It is observed that GSA application has not yet entered in certain areas such as in finance,
economics, military and medical areas. More studies could be done by the scientific community so as to test GSA capabilities in those areas. Hence, in the future, it is expected that many more interesting topics are to be investigated and explored based on GSA in more diverse areas.

REFERENCES