A Genetic Algorithm Optimized Forward Aware Factor based Energy Balanced Routing in WSN

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Abstract – Wireless Sensor Network is an evolving field of science which has drawn the attention of the researchers all around the world due to its numerous applications. The merits of WSN brings along with them some inherited challenges such as energy management, load balancing, security, stability etc. This paper attempts to solve the problem of energy management by efficient routing mechanism. A forward energy aware technique is proposed which is optimized by Genetic Algorithm. The performance is compared to that of the other algorithms which were existing in the literature. The results are found to be quite better in terms of NLN, PRR and EBF.

Index Terms – Wireless Sensor Network, Routing, Genetic Algorithm, Forward energy aware

1. INTRODUCTION

Wireless Sensor Network has become a foremost field of investigation in communication field. There are various extensions of WSN like MANET, VANET etc. Due to its vast applications, it is inherited with several challenges. The challenges lies in improvement of energy efficiency, reliability, network lifetime etc. Now days, wireless communication technologies are continue to the growth in diverse areas to offer the better opportunities for general business systems. These wireless sensor networks are largely distributed network of light weight, small wireless nodes, placed in huge numbers to monitor an environment of the system. The micro-electro mechanical advances systems made the building like kind of sensors a possibility. These sensor networks are transmitted of tiny or miniaturized electronic devices that are arranged as sensors. Sensors can sense, store, compute, send out and collect information of interests from an environment in that they are located estimated to minute size of sensors, a huge size battery supply that cannot be embedded into them, thus sensors require mechanism for an energy utilization to enhance the life time of sensors in wireless sensor networks, it plays an important role.

There are several challenges faced by WSN in today's era like security, energy management, routing, stability, load balancing etc. Moreover, these wireless Sensor Networks are tiny, battery powered network sensor nodes with limited storage, on-board processing and radio capabilities. These Nodes sense send their reports to a processing center, called "sink." The design of applications and protocols for such networks has to be energy to aware in order to increase the life of the network; because the modification and updation of embedded batteries has a very difficult process once the nodes have been placed.

Energy management forms a key issue in WSN and several researchers have proposed several algorithms for better energy management. The energy of the nodes depletes quite significantly and even if a few of the nodes are dead, that can cause significant packet data loss. To solve this problem, this paper proposes a novel Genetic algorithm optimized forward aware factor based routing in WSN. Genetic algorithm is a well known meta-heuristics technique known to solve optimization problem for years know. There have been several attempts using similar approach by utilizing other algorithms such as Particle Swarm Optimization, Ant Colony Optimization, and Firefly Algorithm etc. The efficacy of Genetic Algorithm is proved to be better and the technique robust in terms of local minima problem also providing better convergence simultaneously.

A forward aware factor is calculated from the nodes locality and remaining energy. The advantage of this approach over LEACH is that in LEACH all nodes have to send data first to cluster heads which can be in reverse direction to the path to base station. Thus this is a serious wastage of energy. This is addressed by using Forward aware factor and is optimized using GA.

The remainder of the paper is as follows. Section 2 describes the various works done in the literature in this field and an extensive survey of a few papers is provided. Section 3 gives a mathematical shape to our problem statement and Section 4 discusses our proposed methodology. The results are shown and discussed in Section 5 and finally Section 6 concludes with a brief discussion on the future works that can be done.

2. LITERATURE REVIEW

There have been several attempts at the problem of clustering in WSN for heterogeneous conditions. Several researchers have proposed various techniques for the same. In [1]

Aderohunmu et. Al. proposed that wireless sensor networks are enhanced equipped to solve more complex functions, in-network processing that need these battery powered sensors to use their constant energy to prolong the effective network life time specifically in a heterogeneous settings. These clustered methods have employed to optimize the energy consumption in energy constrained of wireless sensor networks.An enhanced SEP cluster in three-tier node scenario to prolong an effective network life-time. Simulation results displays the Enhanced-SEP achieves good performance in respect, compared to including clustering algorithms in both homogenous and heterogeneous environments.

In this paper, Katiyar, Vivek [2], proposed that an increased interest in potential use of wireless sensor networks in several fields like battle field surveillance, disaster management, and border security surveillance which is described by Hart, Quaritsch, Dudek and Bokareva. In applications, a huge number of sensor nodes are located that are work unattended and autonomously. Clustering is a key method used to extend the lifetime of sensor network by decreasing energy consumption. It can be increased the network scalability. Researchers in all the fields of wireless sensor network know that these nodes are homogeneous, but nodes can be of individual energy to prolong lifetime of a WSN or its reliability. In this, the impact of heterogeneity survey distinct clustering methods for heterogeneous WSNs, highlighting their features, objectives, complexity, etc.

In this paper, Kumar, N. [3], proposed an effective way to increase the network lifetime of WSN. The clustering algorithms basically utilize two techniques, first one is the selection of cluster head by more residual energy, second one is the rotation of cluster heads on probability basis periodically, for same distribution of energy consumption with sensor nodes in cluster and increase the lifetime of WSN. To forward the data packets to base station, cluster heads make cooperation with cluster heads, on the probability the cluster heads are selected and large residual energy node cannot be opted as cluster head or low residual energy node can be selected as cluster head.

In this paper, I.F. Akyildiz [4] proposed that each sensor node has various components: an internal antenna, a radio transceiver or a microcontroller, connection to an external antenna, an electronic circuit with interfacing to sensors and power source, which has a battery or an embedded, of energy source. The sensor nodes can vary, according to the size, functionality, type, complexity and applications of the different sensor nodes. The cost of multifunctional sensor is mainly larger than the normal one functional sensor node. Cost and Size limitations on sensor nodes conclusion in corresponding limits on the resources such as memory, computational speed, power backup, efficiency, processing speed, durability, accuracy and communications bandwidth.

In this paper, Smaragdakis, Georgios [5] proposed that in terms of the energy of wireless sensor networks which are hierarchically clustered. In networks some nodes have become cluster heads which aggregate the data of cluster members and transfer it to the sink. A percentage of population of sensor nodes is measured with additional energy resources. This is a one source of heterogeneity that display the result from the starting setting or the operation of network evolves. The sensors are uniformly distributed, the coordinates of sink and the dimensions of sensor field are known. It displays the behaviour of sensor networks that becomes unstable once the first one node die, in the presence heterogeneity node.

In this paper, Faisal, S [6] proposed that, wireless Sensor Networks are combinations of thousands of sensor nodes that co-operate to complete a sensing task. Several routing Protocols have been designed for transmission in Wireless Sensor Networks, hybrid routing protocol: Zonal-Stable Election Protocol for heterogeneous WSNs. In this, some nodes can transmit data and information directly to base station during some use clustering method to send the data to base station. It implemented Z-SEP and compare with Low Energy adaptive clustering hierarchy and SEP. The simulation results displayed that Z-SEP increased the stability period or throughput than included protocols like LEACH and SEP.

In this paper, O. Islam [7] proposed a genetic algorithm to generate energy efficient clusters for routing in WSNs. The result displays an intelligent hierarchical clustering scheme which is more efficient than an existing cluster-based routing protocol. The key applications of Wireless Sensor Networks are target tracking, habitat monitoring, security management and surveillance. WSN application consists of all the short sensor nodes which are multi-functional, low-power and low-cost.

In this paper, Azadeh Pourkabirian [8] proposed an energy-aware Quality of Service routing protocol for WSNs. This routing protocol searches an energy-efficient route for the data of delay-constrained in real-time traffic. The defined Quality of Service routing problem is much similar to the PCPO (path constrained path optimization) problems that can be proved in the NP-complete. As a result we display a heuristic solution for aforesaid problem and use a genetic algorithm to generate an energy efficient QoS routing. Moreover, an algorithm creates a sequence of routing paths which increases the system lifetime. The Network lifetime has been defined on that time when first node in the network to be depleted of energies. To prolong the network lifetime, follow all scenarios of the average time.

3. GENETIC ALGORITHM

Genetic algorithms are dominant search technique belongs to evolutionary algorithm class that are used effectively to solve

problems in different aspects of areas. GAs can be implemented straightforward and provide significant gains in performance. Genetic Algorithms are direct, parallel, stochastic method for global search and optimization of problems.

A GA initiated with a set of randomly generated possible solutions for a task called a population. Included individual solution in the population recognized as chromosomes. Every chromosome may possibly be represented as a simple string or an array of genes enclosed with part of solution .A Genetic Algorithm take into account fitness to test on new structures to choose the best population. A fitness function provided the fitness value to each individual.[3] The fortune of an individual chromosome relies on the fitness value.

3.1 Working of GA

Below mentioned are some steps of how the genetic algorithm works

- First, at random population created known as initial population
- The algorithm creates the series of next generations by considering the individual population in current scenario. Following steps are consider
    - Assign scores to each member in the current population
    - Convert these score into more useful range of values
    - Based on the fitness select members as parents
    - Reproduction takes place. Mutation-children produce from single parent by making small changes in it. Crossover-vector pairs of both parents are connected
    - Children of the current scenario used to form next generation
- Procedure stops when any condition of the stopping criteria is met.

4. PROBLEM FORMULATION

The problem at hand is to design an efficient routing mechanism in WSN based on forward aware factor. The factor needs to be optimized for optimal route selection. Thus there is also a need to design an optimization algorithm which is Genetic algorithm in this case.

The problem taken in this paper is to develop a novel protocol to solve the problem of energy efficiency in homogeneous distribution of nodes. The cost of sensor nodes is variable, depending on the functionality, applications and complexity of the individual sensor nodes. The cost of sensor depends on the functionality, complexity of the individual sensor nodes. Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and communications bandwidth.

4.1 LEACH Protocol

LEACH (low-energy adaptive clustering hierarchy) is introduced the "cluster" concept firstly. LEACH implements circularly the reconstruction of clusters continuously during operation, and one reconstruction called a round. Each round is divided into two stages: the cluster establishment phase and stable phase. In cluster establishment phase, selecting cluster head mainly based on number of cluster head of the network, and frequency of being cluster head of every node so far. Specific options: each sensor node generated randomly a value between 0 and 1, if the value is less than the threshold T (n), then it can be the cluster head.

Threshold T (n):

$$T(n) = \begin{cases} \dfrac{p}{1 - p\left(r.\mathrm{mod}.\dfrac{1}{p}\right)} & n \in G \\ 0 & \text{others} \end{cases}$$

In this formula, p is percentage that the cluster head in all nodes, r denote number of round be haven completed, G is a set of nodes be consisted of nodes which did not be cluster head in the last 1 / p round. After selecting the cluster head, the cluster head began broadcasting this information to inform ordinary node in the network. Then the nodes determine to join in which cluster according to signal strength, and response to the cluster head, thus establishment of the cluster is completed. In a stable phase, the ordinary nodes will send data to the cluster head which they belong to; cluster head fuse these data and sends to sink. At the last, the network re-entry into the phase of establishment of cluster, and execute the next round.

LEACH protocol has some deficiencies such as,

1) Some very big clusters and very small clusters may exist in the network at the same time.

2) Unreasonable cluster head selection while the nodes have different energy.

3) Cluster member nodes deplete energy after cluster head was dead.

4) Backward transmission of data in case the cluster head is located in backward direction of nodes when seeing the base station.

The problem is to solve these issues and develop a novel method which would improve the routing by becoming forward energy aware.

5. PROPOSED METHODOLOGY

This paper proposes a novel forward energy aware protocol for routing in WSN using Genetic Algorithm. As described above, there are several advantages of using forward energy aware scheme over normal LEACH, the parameter is optimized using Genetic Algorithm. The overall algorithm can be depicted below as in Figure 1.

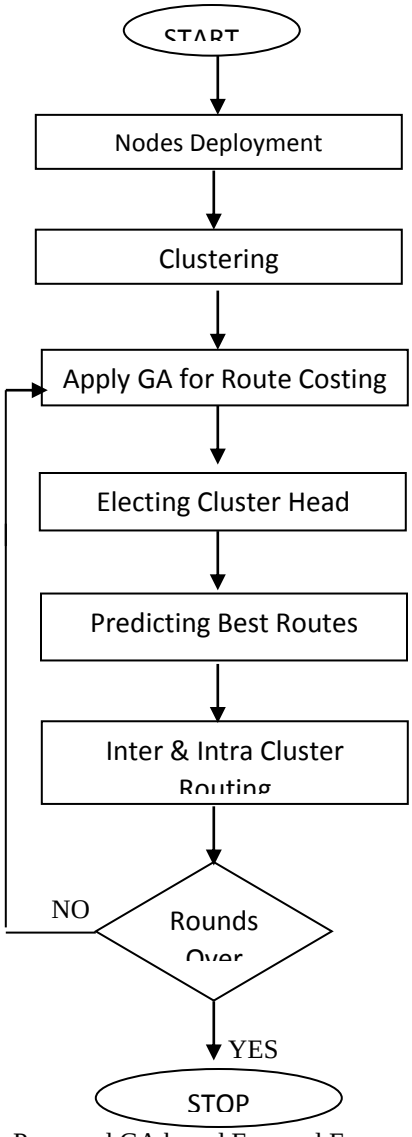

Figure 1: Proposed GA based Forward Energy Aware routing

The fitness is calculated using the following procedures. Presented parameters help in increase the network lifetime and provide a way to less energy consumption.

1. Node distance- The distance between the nodes and their respective CH.
The distance between them

$$d = \sqrt{(xch - xn)^2 + (ych - yn)^2}$$

Where CH *(xch,ych)* and nodes*(xn,yn)* are coordinates of CH and their associated nodes.
Larger the value of d more energy will be consumed as we need to keep the value of d as smaller as possible.
2. Routing Distance to sink- The distance between the CH and sink. Coordinate of sink (xsink,ysink) and CH(xch,ych). The distance between them.

$$dr = \sqrt{(xsink - xch)^2 + (ysink - ych)^2}$$

Similarly as in node distance, larger the distance more energy consumption will be present.
3. Average Ch's distance- As all CHs pass data to one another to transmit data to sink known as multi hop routing. By taking into account radio model shortest will be selected each time.

$$Dch = \sqrt{\frac{(xa - xb)^2 + (ya - yb)^2}{\frac{n(n-1)}{2}}}$$

Where (xa,ya) and (xb,yb) coordinates of two neighbor CH and n(n-1)/2 edges of complete graph.
4. Energy Consumption:

$$E = Et(i, ch) + n * Er + (n - 1) * Eda + Et(ch, sink)$$

where E denotes the energy consumption in network, n denote s total number of nodes in cluster, Et(i,ch) denote energy transmission in nodes while sending data to CH, Er denotes receiving energy in CH, Eda denote energy loss in data aggregation, Et(ch,bs) denote energy transmission in CH while sending data to sink.
5. Number of rounds- Suppose R represents number of rounds need to be performed to complete to computation. R rely on the current status of energy of all the nodes in network. The larger the value of R means the current generation has better fitness value.
6. Number of transmission- Depends upon the current condition of the energy level of the network.
Route cost is given by the following equation:

$$route\ cost = \sum_{i=1}^{a} \frac{\sqrt{(x_a - x) + (y_a - y)}}{a - 1}$$

$$fitness = w1 * route\ cost + w2 * residual\ energy$$

Where w1 and w2 are weights with w1+w2=1.

6. SIMULATION RESULTS AND DICUSSION

The above problem is simulated for a condition of 100 nodes distributed uniformly in a 100x100 unit area. The nodes are given initial set of energies as specified above. Radio model of transmission has been considered. All the simulations are done on a PC of 4 GB RAM, 2.7 GHz processor on MATLAB R2014a. The simulation results are shown below.

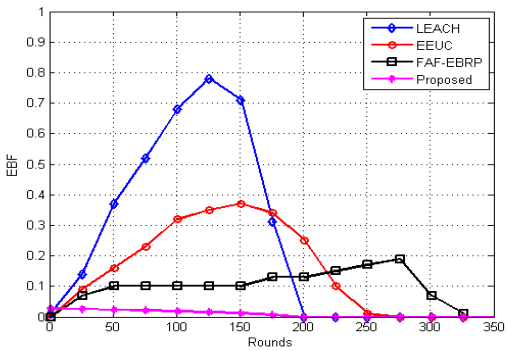

Figure 3: Plot of EBF of our proposed and existing approach

Fig 3 shows the plot of energy balanced factor of our proposed approach and compares it to that of other methodologies. It is observed that the EBF of our proposed approach is easily quite better than that of other approaches like FAF-EBRM, LEACH and EEUC.

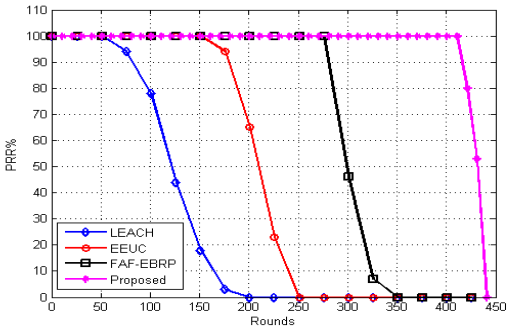

Figure 4: Plot of PRR of proposed vs existing approaches

Fig 4 shows the plot of PRR i.e. the ratio of number of packets received in percentage to that of the number of packets that it is supposed to receive. It is an indicator of packet delivery ratio which is found to be sufficiently high for our approach for most of the time while other approaches has relatively lower PRR value after around 20 iterations. Also the decrease in PRR in our method is sharper ensuring a narrower instability region.

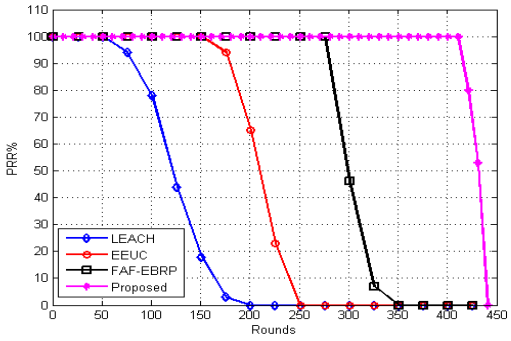

Figure 5: Plot of NLN of proposed vs existing

Figure 5 represents the number of last node alive for each approach. As can be seen the lifetime is greater for our given approach and again sharp decrease in the value during last iterations represents larger stability region.

7. CONCLUSION

A novel GA optimized forward energy aware routing protocol was developed and simulated in MATLAB environment. The routing was optimized using a fitness function depending on residual energy and forward aware factor. It was observed that the proposed algorithm outperforms the existing algorithms in terms of NLN, EBF and PRR. Also the stability is observed to be better in comparison to LEACH, EEUC and FAF-EBRP. In future other, meta-heuristic algorithms can be applied on the problem and tested for efficacy. Also other parameters like trust can be taken into account for security enhancement.

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