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Research paper

Reinforce Coverage Area of Sensor Mote in Wireless Ad-Hoc Networks Using Genetic Algorithm

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Abstract

Wireless sensor based communication is everlasting growing sector within the industry of communication. In WSN improving the life expectancy of the network depends on the energy dissipation of senor devices. Diminishing the energy dissipation of sensor device will enhance the lifetime and device failure which helps in better availability and coverage area of sensor network. One of the dynamic research fields in wireless sensor network is that of coverage. Coverage can be defined as how well each point of interest is monitored by sensor network. In this paper, we investigate the cluster head selection issue, particularly focusing on applications where the upkeep of full network coverage is the fundamental prerequisite. Coverage maintenance for extended period is a pivotal issue in wireless sensor network because of the constrained inbuilt battery in sensors. Coverage maintenance may be prolonged by utilizing the network energy efficiently, by keeping an adequate number of sensors in sensor covers. The clustering algorithm is a solution to reduce energy consumption which can be helpful to the scalability and network lifetime. Assuming serious energy rebalancing with additional clustering algorithm, a Genetic algorithm (GA) based clustering algorithm which evaluates the fitness function by considering the two major parameters distance and energy has been proposed in this paper. Simulation result shows that the proposed solution finds the optimal cluster heads and has prolonged network lifetime and maximum coverage.

***Keywords**: Coverage area, cluster head, genetic algorithm, packet loss rate, residual energy, throughput.*

1. Introduction

A wireless sensor network comprises spatially dispersed self-governing sensor nodes to agreeably supervise physical or natural conditions, for example, temperature, sound, vibration, weight, movement or contaminations. Recent years have seen significant activates in wireless communication and implanted micro-sensing small scale Electro-Mechanical systems (MEMS) advances which have prompted the rise of Remote Sensor Systems (WSNs) as a standout amongst the most encouraging innovations. Remote sensor systems are growing rapidly and have been broadly utilized as a part of both military and nonmilitary personnel applications, for example, target following, observation, and security administration.

Sensor hubs are normally powered by little batteries where exchanging or reviving these batteries is regularly not possible. In this manner, most of the time, the lifetime of a sensor network is over as before long because the battery power in the crucial node(s) is drained. In this manner, numerous protocols were proposed to scale back the energy utilization all through the entire network and, therefore, broaden the network lifetime as well as cover maximum area of WSN. Information gathered in WSNs are transmitted among all hubs through routing and converged into the sink hub. Therefore, the routing algorithm decides if the data can be transmitted totally or not, and significantly influences the performance of the network. Energy required for transmission is straightforwardly relative to the distance transferred from the sensor's packet to the sink.

Consequently, clustering techniques in routing protocols were proposed to decrease energy utilization comes about because of information transmission from sensor node to a cluster head (CH) or to sink which increment the network lifetime. The efficient strategies for cluster head selection and rotation are also proposed as a part of clustering approach. The sensor element nodes are assembled into groups topographically and are fit for working into two roles as a sensor node and as the cluster head node. As a sensor node, it detects the task and sends the sensed information to its cluster head.

As a cluster head node, a hub accumulates information from its cluster members, performs information fusion, and transmits the information to the base station. To adjust the accessibility of individual nodes and the entire network, choosing applicable CHs turns into a key advance.

LEACH is the first ever distributed cluster based routing protocol that provides refined solution but suffer from the downside as a result of cluster head selection. It considers the probabilistic model to elect cluster head and tries to balance the load at every sensor node in a rotation basis. In set-up phase, leach forms cluster head choice, cluster formation and TDMA scheduling of nodes are formed. In steady state phase, nodes send the data to cluster head (CH) and it aggregate the data and send to base station. Re-clustering is finished over regular time period to rotate cluster head among all nodes that create network load balance. However the drawback is, it does not consider the residual energy of nodes for cluster head selection. There have been numerous techniques proposed to address this need is discussed in the review of literature below.

Shijun He et al proposed a novel method that combines genetic algorithm and fuzzy C-means clustering algorithm (FCM) to improve the sensitivity of the initial value of FCM [1] which uses the membership to describe the possibility of cluster. In this paper [2], an energy efficient sensor network is obtained by using effective topology control in case of any node failure in hazardous environment. Based on residual energy, bandwidth and memory capacity, cluster head is selected using genetic algorithm

Shiyuan Jin et al [3] present an optimization algorithm called genetic algorithm to minimize the total communication distance using clustering process in a sensor network. Clustering can reduce communication cost, because all the nodes in a cluster need to send data only to cluster heads rather than directly to base station or sink node. Mohammed Omari et al [4] address a Global and local sensor clustering protocol (GLCP) first divide the network in to domains based on fuzzy logic and combined with genetic algorithm to select cluster head of each domain. A round robin method is implemented for re-clustering to select new cluster head based on token ring topology.

In this paper [5] Mohammad Karimi et al proposed two algorithms GP-Leach and HS-leach for optimization of energy consumption. MATLAB Simulation results shows that compared to Leach, GP and HS algorithm have optimal number of cluster heads with less power consumption and increasing network lifetime. Keyur Rana et al [6] proposed an integrated method of cluster head selection on lower tier based on genetic algorithm and scheduled routing on higher tier in two tier wireless sensor network using A-star algorithm to extend the life of WSN. Based on fitness value cluster head is selected and it depends on maximum dissipated energy of any node of a routing schedule.

In this paper [7] Heena Dhawan et al made a comparative study on various descendants of LEACH, a hierarchical routing protocol to achieve maximum network lifetime, scalability and reliability. Nodes in the network can be selected as cluster head circularly and randomly to optimize energy consumption in the network. Abbas Karimi et al proposed a fuzzy logic and chaotic based genetic algorithm [8] in order to increase the network lifetime. Fuzzy logic is implemented based on three important variables – energy, density and centrality to select the best cluster head and base station nodes. A fuzzy interference technique called Mamdani method to input the parameters of fuzzy logic controller are node density, node centrality and node energy.

Wei-gang Ma et al address a novel method EECCA [9] for the objective of optimization in selecting better nodes and depends on the overall distribution of nodes with guaranteed stability of the number of cluster heads. Genetic algorithm filter these problems by setting the threshold value and concentration of nodes in the local area can be avoided and reduce the energy consumption. Abdulaziz Shehab et al [10] address a new genetic algorithm to develop a cluster based WSN in which cluster heads change from round to round based on residual energy, vulnerability index and distance from Base station.

Padmalaya Nayak et al presents a cluster based routing protocol [11]in which cluster head is selected based on two major parameters distance between nodes and Cluster head, distance between cluster head and base station and residual energy of the nodes and evaluated by fitness function in to the new generation of population using Darwin’s principle of the survival of the fittest. Dynamic clustering algorithm using fuzzy logic and genetic algorithm is proposed in this paper [12] to select the best cluster head in the senor network. Reduction of MSE directly reduces energy consumption and increase life time of sensor network.

Aya Taha et al [13] proposed a genetic algorithm for finding optimal number of cluster heads and position of the cluster head based on fitness function the cluster head will be selected with minimal energy consumption to transfer data from node to CH and cluster head to sink node which automatically maximize the lifetime of sensor nodes. Vipin Pal et al proposed a solution that considers tradeoff between intra cluster communication distance, cluster head to base station distance and residual energy of nodes for cluster head selection [14]. Re-clustering is done over regular time periods to rotate the role of cluster head among all nodes that makes network load balance.

Riham S.Elhabyan et al present a Non-deterministic polynomial NP-hard problem for finding the optimal set of cluster heads. The problem of cluster head selection [15] is formulated as a single-objective optimization problem aiming to obtain clusters that maximize the network energy efficiency and link

GA is a transformative strategy that is equipped for taking care of any real time issues even with lacking information in hands. This feature makes GA more successful in different applications. In the field of WSN a large variety of research work exploiting GA have been done. Different clustering techniques considering the parameters like vulnerability, number of transmissions, field coverage, network spatial arrangement etc were discussed in the literature.

In this paper cluster head should be chosen in such a way that the coverage of the sensor network is maximize by considering residual energy and distance of nodes in wireless sensor network. With the maximum connectivity, the coverage of the network is automatically maximized. The intelligent selection of the cluster head is done and energy consumption is compared with other algorithms like ACO, LOA and proposed genetic algorithm.

2. Network and Radio Model

In this section, the network models as well as the radio model are explained. We consider a network model similar to that used in [16]. Radio energy dissipation model is used for analysis of energy dissipation in the wireless sensor network.

Network Model

For persistent monitoring of WSN, we consider a homogeneous sensor network with random deployment of nodes. All sensor nodes are assumed to be stationary and everyone is aware of its position in the field via GPS modules. In most of the applications, it’s tough to access the sensors in remote and therefore their batteries are not rechargeable.

Each node has limited transmission power level and thus limited radio coverage. The sensor network will work in progressive mode, in which nodes are grouped in to clusters with cluster head in each group for energy efficiency. The sensor nodes gather information from the encompassing condition and send data to the CHs.

Since the intra-cluster perceived information is highly correlate, data aggregation techniques can be enforced at the cluster heads to combine signals in to a fixed length of packet which in turn transmit to a sink node. CH rotation is important so as to realize balance energy dissipation among the sensor nodes.

Radio Model

The radio model clarifies how energy is consumed by detector nodes. Such model characterizes the energy required for transmission and gathering by sensor nodes to transmit q-bits message for a separation d, and the energy dissipation may be obtained as [17],

$$E_{Tx}(q,d) = E_{Tx\text{-}elec}(q) + E_{Tx\text{-}amp}(q,d) \qquad (1)$$

Where,

$$E_{Tx\text{-}elec}(q) = q\,E_{elec} \qquad (2)$$

$$E_{Tx\text{-}amp} = \begin{cases} E_{fs} q d^2, & d < d_0 \\ E_{amp} q d^4, & d \geq d_0 \end{cases} \qquad (3)$$

Equation (1) implies that energy required for transmission is equivalent to that required by the transmitter electronics $E_{Tx\text{-}elec}$, additionally required transmitter amplifier $E_{Tx\text{-}amp}$ to compensate for propagation loss. Where $E_{Tx\text{-}elec}$ indicates the hardware and relies upon digital coding, modulation, filtering and spreading of the signal.

E_{fs} and E_{amp} measures the amplifier energy that depends on gap between sender and receiver with acceptable bit-error rate. The electronic equipment energy is outlined by (2) for short distance less than d_0 and for those larger than d_0. In order to receive q-bit data packet, sensor node dissipate energy equals to,

$$E_{Rx}(q) = E_{Rx\text{-}elec}(q) = q\, E_{elec} \quad (4)$$

Every CH dissipates energy as a result of receiving signals from its member nodes, aggregating the received signal and transmitting to the sink.

3. Genetic Algorithm (GA) Based Cluster Head Selection

GA is a search based optimization technique based on the principles of natural and genetic selection. It is used for solving difficult problems with near-optimal solutions. It starts with a set of possible solutions called initial population which is randomly generated to solve the problem. Every individual solution is called chromosome and its length must be same. GA is based on the survival of fittest theory. A fitness function is calculated for each chromosome which depends on objective function.

The chromosome with high fitness value will have high chance to mate. Two parent chromosomes are selected for crossover to produce new offspring. A better solution is obtained by applying mutation GA operator to randomly selected chromosome. Crossover and Mutation create a new set of population with best fitness value. Elitism is a method of copying a new set of best fitness value chromosome in to a newly generated population to guarantee that the new generation is at least fit as the previous one. In this way, the better solutions keep arising over generations until the algorithm reaches stopping criteria.

Population Initialization

The population is defined as a set of chromosomes and each chromosome is a set of genes. It consists of randomly generated individual solutions to the problem. For higher accuracy of algorithm, requires large size of population. We use binary representation for representing a normal nodes and cluster head nodes position as 0 and 1. For example,

s0 s1 s2 s3 s4 s5 s6 s7 s8
0 1 0 0 1 0 0 1 0

Individual nodes s1, s4, s7 are cluster head nodes and remaining are regular nodes. Genetic algorithm is used to determine the cluster head in order to increase the coverage area of sensors and reduce energy consumption, which leads to increase network lifetime.

Fitness Function

The Fitness function also known as evaluation function determines the optimum solution to the given problem. We consider two important parameters, residual energy and distance from base station to sensor nodes is calculated in this paper. Thus each individual is evaluated by the following combined fitness function components:

$$\text{Fitness} = D_c + E_c \quad (5)$$

Where D_c is the cost of the distance and E_c is the cost of the energy. The value of the D_c and E_c can be calculated as given in the given equation

$$D_c = \frac{d_{sn-ch}}{d_{sn-ch} + d_{ch-bs}} \quad (6)$$

$$E_c = \frac{E_i}{E_T} \quad (7)$$

Where $d_{sn\text{-}ch}$ is the distance of sensor node to cluster head and $d_{ch\text{-}bs}$ is the distance of cluster head to base station. E_i is the energy of individual sensor node and E_T is the total residual energy of all sensor nodes within the cluster.

Selection

It is the process of selecting the fittest individual for mating in order to reproduce offspring for the next generation. Individuals with high fitness value have more chance to be selected for reproduction. A tournament selection is used to select k-random chromosomes from the population based on the high fitness value are more likely to be selected as the parents. It also even work with negative fitness values.

Elitism is a method which copies the best chromosomes to new population. It can very rapidly increase the performance of genetic algorithm, because it prevents the loss of best found solution.

Crossover

Crossover is a genetic operator used to vary the chromosomes from one generation to the next generation. In this paper we use one-point crossover, a random crossover point is selected and the tail of its two parents are interchanged to get new off-springs. The two individuals exchange their portions that are separated by the crossover point.

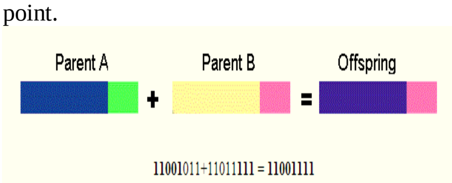

Fig. 1: One-point crossover

By this method if any regular node"0" becomes cluster head "1" after crossover, then remaining regular nodes should verify that they are nearer to new cluster head. If so the new cluster head detached from the previous cluster head. If cluster head becomes normal sensor node after crossover, then all of its previous member must search for cluster heads.

Mutation

Mutation alerts one or more gene values in a chromosome from its initial state. In mutation, the solution may change entirely from the previous solution. The mutation operator is applied to each bit of an individual with a probability of mutation rate. A bit whose value is 0 is mutated into 1 and vice versa.

Parent: 1 1 1 0 0 1 1 0

⇩

Parent: 1 1 0 0 0 1 1 0

Termination

Finally termination condition of GA is important to determines based on number of generations are reached or no improvement in the number of iterations in the population or when optimum fitness value reached a predefined value. Chromosomes with least fitness value die thereby giving space to new offspring.

4. Results and Discussion

In this section, the experimental results obtained from the simulation tool NS2 are discussed to measure the performance of the proposed genetic algorithm.NS2 is a discrete event simulator which is mainly used to maintain the protocols in the network. The sensor nodes are randomly distributed in the network. The simulation area contains 50 nodes deployed in the simulation area 800 ×400m.

Throughput

Throughput is the rate of successful message delivery over a communication channel. It is then calculated by dividing the file size by the time to get the throughput in kilobits per second.

$$\text{Throughput} = \frac{No.of\ Bytes\ recieved\ sucessfully}{Time\ taken}$$

If packet delivery ratio increases, automatically throughput increases.

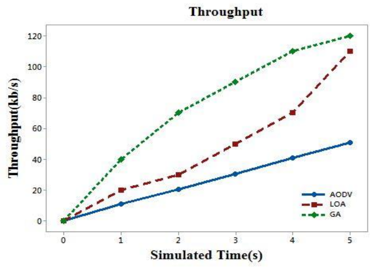

Fig. 2: Throughput of genetic algorithm

From the graph it is inferred that, throughput is increased for genetic algorithm compared to AODV and Lion optimization Algorithm (LOA). Nearly 18% of throughput increases compared to other algorithms.

Packet Delivery Ratio

It is the ratio of packets that are successfully delivered to a destination compared to the number of packets that have been sent by the sender. In order to calculate packet delivery ratio we need total number of packets sent and received packets.

$$\text{PDR} = \frac{Sum\ of\ datapackets\ recieved\ by\ each\ destination}{sum\ of data\ packets\ generated\ by\ each\ source} \times 100$$

Packet delivery ratio describes inclusiveness, accuracy and consistency of routing protocol. From the simulation graph it is observed that GA delivers packet more accurately than AODV and LOA.

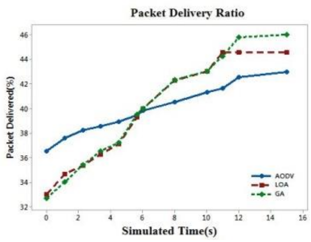

Fig. 3: Packet delivery ratio

Residual Energy

It is the energy left after completion of the entire routing process of the networks. A node looses a particular amount of energy for every packet transmitted and every packet received. As a result the value of initial energy in a node gets decreased. The current value of energy in a node after receiving or transmitting routing packets is the residual energy.

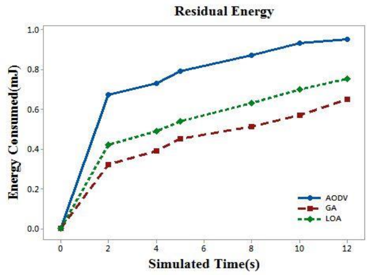

Fig. 4: Residual energy

Residual energy of the node is evaluated by accessing inbuilt variable energy at different times. [18] The average energy consumption increases with increase in number of node increases.

End to End Delay

It refers to the time taken for a packet to be transmitted across a network from source to destination. It comprises of transmission delay, propagation delay, processing delay and queuing delay.

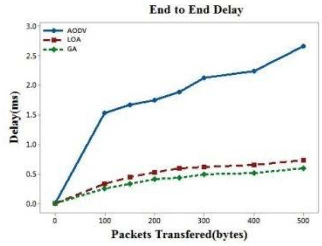

Fig. 5: End to end delay

End to end delay is the time interval between arrivals of data packet at the destination minus the period of the data packet sent by the source node. From the simulation graph it is inferred that average end to end delay is greater in AODV compared to LOA, but increases with node density.

From the simulation graph6, it is inferred that packet loss in sensor network increases with number of hops to attain a destination. Compared to AODV and LOA, coverage area increases with minimum number of sensors in the field region using genetic algorithm.

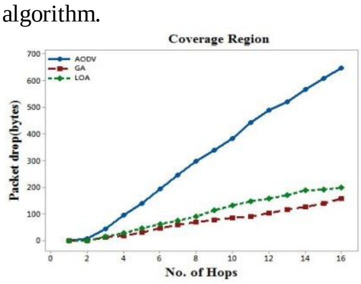

Fig. 6: Coverage increases compared with LOA and AODV

5. Conclusion

In this paper, we propose a GA-based method to reduce communication distance in the sensor network and residual energy through clustering. Based on fitness function value that select cluster head according to residual energy and considering trade-off of inter and intra cluster communication distance optimize the number of cluster heads thereby increasing network lifetime and enhance coverage area of WSN. Each cluster head send data to the neighboring cluster head in a chain like system and send data to the base station covering maximum area of coverage with less number of cluster heads based on genetic algorithm.

We compare our algorithm with other routing protocols like AODV and LOA (Lion Optimization algorithm) in terms of throughput, residual energy, packer delivery ratio, packet loss rate and to end delay. Simulation results show that our approach is an efficient and effective method of finding solution to this type of problems.

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