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Energy Balancing Technique Using Genetic Algorithm Based Clustering For a Wireless Sensor Network

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Abstract— Even though wireless sensor network is widely used in industrial and home applications, still reduce the energy consumption and network lifetime enhancement remains a major challenge. Clustering is method of grouping nodes based on their geographical location, nodes recheability etc. and is a suitable solution for reduced energy consumption. In this paper, a new technique using genetic algorithm is proposed for clustering of sensor nodes. The clustering is based on the amount of nodes available energy and the received signal strength value of the nodes in a particular region. Using the proposed technique, balanced energy consumption is maintained between all the nodes in the network. The proposed technique consumes less energy compared to the network without clustering.

Index terms — Wireless Sensor network, Clustering, Lifetime enhancement, Energy consumption, Available energy, Received signal strength.

1 INTRODUCTION

A network constructed "for a special purpose" is a Wireless Adhoc Network. In Adhoc networks the devices are close to a human user and interact with humans. Instead of focusing interaction on humans, a network which focuses on interacting with environment is desired. This paved way for a Wireless Sensor Network (WSN), which is a network embedded in environment [1]. It is a self-configuring network of small sensor nodes communicating among themselves using radio signals. WSNs can be deployed in almost any environment, especially those in which conventional wired sensor systems are not possible like dangerous battlefields, outer space, deep oceans and many more applications [2][3]. Each sensor node is equipped with a processor that works in various modes (Sleep, Idle, Active), power source with low power battery, multiple types of memory with limited capacity, Radio Frequency transceiver with an antenna for transmitting and receiving the acquired data to some storage site, and sensors for temperature, humidity, light, etc. [1], [2], [3], [4], [5].

Since WSN continue to be resource constrained network, various algorithms and techniques have been developed to reduce the energy consumption and thereby enhance the network lifetime [6], [7], [8], [9], [10]. Clustering is one such technique that effectively minimizes energy consumption by reducing the energy consumedby individual nodes. The mainmotivation of clustering is to construct a reduced topology that will save energy and preserve important network characteristics, such as connectivity and coverage. Figure 1 shows the communication process involved in clustering. Initially all the nodes exchanges 'Hello' packets and 'Ack' packets. Based on the individual nodes performance some nodes get elected as cluster heads and remaining declared as cluster slave. The Cluster Slaves (CS) gathers data from the environment and passes it to the Cluster Head (CH). The CH in turn forwards the data to the nearby CH and the procedure gets repeated till data reaches the sink node. The network comprises with the CHs is said to be the communication subnet.

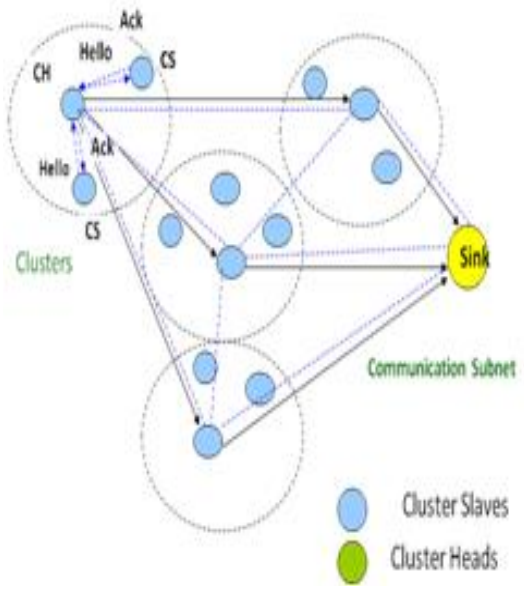

Fig. 1. Communication process through Clustering

In this paper, a novel technique for clustering of WSN using Genetic Algorithm (GA) is proposed. The nodes key features like the

remaining energy and Received Signal Strength Indicator (RSSI) were considered for the selection of best CH nodes.

This paper is organized as follows: Section 2 gives the review on various existing clustering techniques. Overview of GA is given in section 3. Section 4 is dealt with the proposed methodology. Results and discussions are dealt in section 5. Conclusion and future work is given in section 6.

2 Literature Review

Around ten to thousand sensors would be incorporated based on the various applications of WSN. Data collection and data dissemination are the main issues carried out by all the individual sensors used. The data dissemination is the time and energy consuming work. The data collected using these sensors must be transmitted to the sink using direct long distance communication or short multi hop communication. By short multi hot communication, the overall energy consumption is reduced. Clustering is one such approach that performs the above said function. Soft computing tools based clustering can bring good results compared to the conventional type of clustering.

LEACH (Low-Energy Adaptive Clustering Hierarchy), a clustering based protocol that has been introduced initially, utilizes randomized rotation of cluster heads to evenly distribute the energy load among the sensors (Heinzelman et al 2000). But this protocol fails to consider the residual energy, geographical location and other information which may lead to the earlier death of cluster heads. After that many protocols has been developed to extend LEACH and to overcome its limitations [11]

Ge Ran et al (2010) proposed a new methodology LEACH-FL that improves LEACH protocol using Fuzzy Logic and chooses battery level, distance and node density as the attributes for the CHs selection. LEACH depends on a probability model in which there is a possibility that the selected CHs may be very close to each other or it may be located in the edge of the WSN. Whereas in LEACH-FL, the probability of a node to be selected as a CH is increased with the increase of the battery level and node density. The probability of a node to be selected as a CH is decreased with the increase of the distance between the node and the BS. The energy consumption of the proposed system is much lower than that of LEACH [12].

Hussain et al (2007) investigated intelligent techniques for cluster formation and management. Direct Distance to Base Station (DD), Cluster Distance (C), Standard Deviation (SD), Transfer Energy (E), and Number of Transmissions (T) are used in the fitness function. The GA is used in the Base Station (BS) whose outcome identifies suitable clusters for the network. All the sensor nodes receive the packets broadcasted by the BS (complete network details) and clusters are created accordingly. The proposed technique extended the network lifetime for different network deployment environments [13].

Hussain and Islam (2007) proposed a methodology using Genetic Algorithm to generate balanced and energy efficient data aggregation spanning trees for WSN. In a data gathering round, the energy resources of heavily loaded nodes get depleted earlier than others. This necessitates a collection of trees to balance load among nodes and consume less energy. The fitness is determined by residual energy, transmission load, receive load and the distribution of load. Data aggregation tree is created at the base station using GA and schedule packet is broadcasted to all the nodes. Each sensor node extracts its own information from the schedule packet and use the schedule for a given number of rounds, as specified in the schedule. At the last round of the current schedule, each node appends its residual energy level to the data packet. The results showed that GA is better than other data aggregation tree-based approaches in terms of extending network lifetime [14].

In the process of clustering, a communication subnet with reduced number of nodes is selected and given more responsibilities. Since the selected subset of nodes performs more work that the unselected nodes, energy drain will be more in the selected nodes. Therefore an effective approach that will rotate the role of the nodes with the final goal of spending their energy evenly and extending the network lifetime becomes necessary.

3 Overview of Genetic Algorithm

Based on the concepts of natural selection and genetic inheritance given by Darwin an evolutionary algorithm called GA was developed. Any kind of real time problems that are not possible to solve using other techniques can be solved using a GA. GA maintains a set of solutions as the initial population for the problem identified and apply iterativelya set of stochastic operators. The stochastic operators include Selection, Crossover and Mutation. GA encodes solutions as fixed length “bit strings” like 11100111, 10001110 etc. Each encoded bit represents some aspect of the proposed solution to the problem. A best set of bit strings is selected for performing crossover and mutation operations. Crossover and mutation preserves “good bits” from different parents. The bit strings representing the solution need to be tested and scored indicating how well that solution is for the problem defined. The score is given as a function and is often called as fitness function. Each iteration of the process of testing and scoring is called a generation. Generally a GA is iterated for more number of generations till a best set of fitness function is obtained. The entire set of generations is called a run. The main components of a GA are the encoding technique, initial population generation, selection of parents, stochastic operators, evaluation function and termination condition [15], [16].

4 Proposed Methodology

After the initial deployment each node exchanges ‘Hello’ packet. On receiving the ‘Hello’ packet, the neighboring node estimates the

RSSI using equation 1 and the Available Energy (AE) using equations 2-5. The estimated RSSI and AE is exchanged via 'Ack' packet. The node with maximum RSSI and AE is declared to be the CH node and the other nodes are declared as CS.

$$RSSI = -10\, n \log 10\, d + A \text{ (dBm)} \quad (1)$$

Where n is signal propagation constant, d is the Distance from sender and A is the Received signal strength at 1 meter distance

The following considerations were done for calculation of RSSI. The minimum criteria required for a node to be a neighbor is its distance should be less than 200m. Case 1 to case 3 gives the parameters for the calculation of RSSI based on the range of the distance.

Case 1: Distance < 80 Then n = 4, A=0.5
Case 2: Distance > 80 &< 100 Then n = 3,
A=0.75
Case 3: Distance > 100 Then n = 2, A=1

To transmit a k-size packet over a distance of d, the amount of energy consumed for transmission E_{Tx}, is given by equation 2. Amount of energy E_{Rx} spent to receive a k-bit size message is given by equation 3. Total amount of energy spent by each nodes is computed by equation 4 and the nodes Available Energy (AE) is computed by equation 5.

$$E_{Tx} = (E_{elec} * k) + (E_a * k * d^2) \quad (2)$$

$$E_{Rx} = (E_{elec} * k) \quad (3)$$

$$E_{Tot} = E_{Tx} + E_{Rx} \quad (4)$$

$$AE = \text{Initial Energy} - E_{Tot} \quad (5)$$

where, Eelec is the energy spent by the transmitter or receiver circuitry and considered to be 50 nJ / bit and Ea is the energy spent for the transmitter amplifier and considered to be 100 pJ / bit / m^2.

RSSI and AE considered for CH selection were represented by the variables x1 and x2. The fitness function for the CH selection is formulated and given by equation 6.

$$f(x) = 0.5\, x1 + 0.5\, x2 \quad (6)$$

Since the available energy and RSSI plays a major role in the network performance, equal weight assignment is made for both the parameters. A threshold is set for the fitness function and when the number of CHs elected were around 10 percent of the total nodes then the process ends. For a connected network 10 percent CHs are mandatory.

5 RESULTS AND DISCUSSIONS

The simulation parameters for the proposed GA based clustering technique is given in Table 1.

The proposed technique is simulated using Network Simulator and the node configuration and the simulation parameters for the proposed clustering technique is given in Table 2.

TABLE 1
PARAMETERS FOR THE PROPOSED GA

PARAMETER	VALUE
Population size	25,50
Selection type	Roulette wheel
Crossover rate	0.7
Crossover type	one point
Mutation rate	0.005
Generation size	100

TABLE 2
SIMULATION PARAMETERS

Parameters	Value
Deployment Region	1000 m x 1000 m
Number of Nodes	50
Initial Energy	100 Joules
Transmission Power	0.8 mW
Receiving Power	0.2 mW
Idle Power	0.003 mW
Transmission Rate	250 Kbps
Software Tools	NS 2.34

The network deployment of 50 nodes using the proposed technique is shown in figure 2.

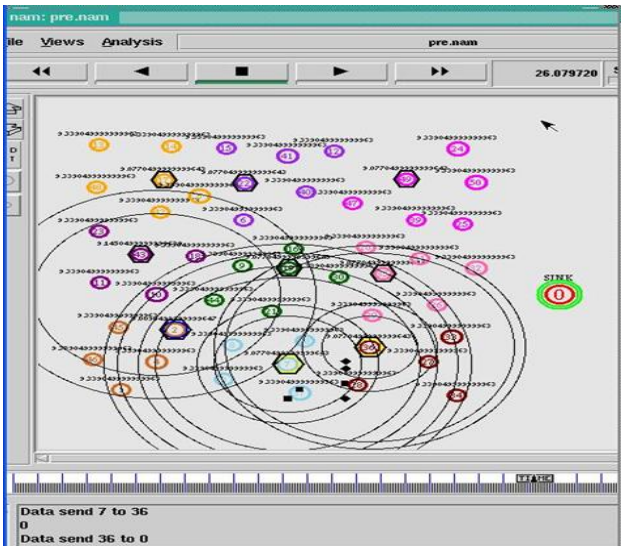

Fig. 2.Network deployment screenshot in NS2

Throughput and Delay calculation is made for the proposed technique. A comparison of the proposed technique is made with that of the network without clustering technique. It is proved from the graph, that the throughput is high using the proposed technique whereas delay gets decreased using the proposed technique compared to the network without clustering. Throughput comparison is shown in Figure 3 and Delay comparison is shown in Figure 4.

Fig. 3.Comparative Analysis on Throughput

The individual nodes energy consumption is computed using the proposed technique for the considered network deployment. Also for the same deployment, individual nodes energy consumption without clustering technique is computed. The energy comparison between the proposed clustering technique and the network without clustering is shown in Figure 5. From the Figure 5, it has been proved that the proposed technique consumes less energy compared to the network without clustering.

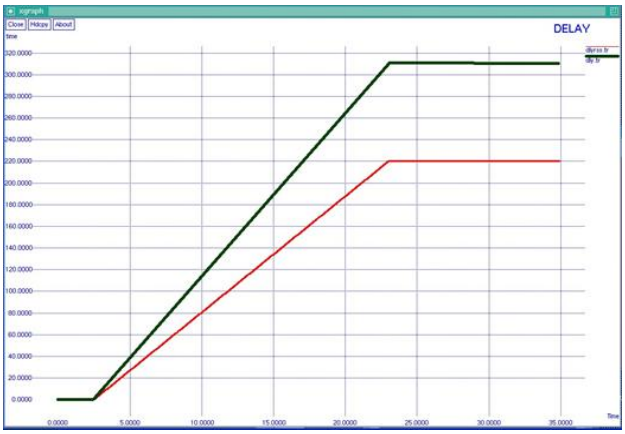

Fig. 4. Comparative Analysis on Delay

Fig. 5.Comparative Analysis on Energy Consumption

6 CONCLUSION

WSN can be deployed in any environment where human intervention is not feasible. An effective energy balancing technique can increase the network lifetime to a maximum number. With this motive, a GA based clustering technique that considers nodes available energy and RSSI is proposed. It has also been proved that the proposed technique increases throughput by decreasing the delay and energy consumption.

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