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Low Power Wireless Sensor Network Energy Transfer using Robot

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Abstract:
Wireless sensor Networks have many applications in industrial monitoring, hardware and software platforms, Earth sensing and data logging. These sensors are to be charged frequently increasing its maintenance costs. Our approach is to exploit the routing protocol to find the optimum cluster head by comparing the energy level of the nodes and their corresponding distances from the base station. The robot thus travels to the positions of these cluster heads to charge the nodes. Path selection involves a routing metric which is computed using the parameters like bandwidth, network delay, hop count, path cost, load, MTU (Maximum Transmission Unit), reliability, network lifetime and energy level. This improves the network lifetime and energy efficiency.

Keywords: Wireless Sensor Network (WSN), Cluster Head, Initial Node, Routing Algorithm.

I.INTRODUCTION

A Wireless Sensor Network (WSN) is a wireless network of various devices which are spatially distributed to monitor the physical or environmental conditions using sensors. WSN has various applications in areas like health care, environmental, commercial, military, utilities and remote monitoring. For electricity grid, water municipals and streetlights, wireless sensors provide a cost efficient method to reduce energy usage and better resource management for collecting system health data. Energy management is a key constraint in WSNs. But with the recent advancement in the wireless transfer of energy these constraints can be reduced. In [1] they presented a robot assisted maintenance framework using WSN, the main challenge was to position the robot for maximum energy harvesting. And by using LEACH-C protocol the robots has a particular position and moves to the sensor nodes for charging and stays in its position for a particular period. In [2] the authors have given the various methods of wireless charging, with the existing networks they have created new opportunities for resource allocation.. In [3] they have observed that the Internet of Thing will play a major role for future communication. Internet is mostly used for sending and receiving information and therefore it’s an important part of communication and networking. The use of security and privacy in internet has been surveyed in [4]. In [5], the framework works on visualization, computation, storage and networking. A new model for energy harvesting based on MAC in WSN has been shown in [6]. In [7]-[9] various methods for energy harvesting has been surveyed. In [10]-[12] energy harvesting using robot is introduced and these robots will visit the site and will charge the sensor nodes.

II. PROPOSED MODEL

A. Cluster Head Formation:

In the method of selecting a cluster head, initially the node with the highest residual energy will be selected as the cluster head to increase the network lifetime. We will consider an initiator node which will collect information of the network. We will assume that the sink node has information about all the sensor nodes and their position in the network. The cluster head (CH) is selected based on the residual energy of the nodes which is identified by the initiator nodes (I). In a network, CH consumes more energy than other nodes. But the network performance decreases when the energy of the cluster head goes down. This problem is reduced by balancing the energy consumption of the network by changing the CH in a cluster based upon its residual energy. The cluster head selection process takes place by the following steps.

1. A message for energy is sent by the initiator node I (EREQ) which consists of its own residual energy level (RLini) information to its neighboring nodes.
2. The sensor node Si (RLi) and the initiator node compares its energy level.
3. If RLi is greater than RLini, then, Si sends back a message for energy (EREP). Or else Si waits for cluster head advertisement messages (CHADV).
4. For the first cycle the initiator node (I) selects the cluster head which has the maximum residual energy and the for the next cycle the initiator node will be the one which is having the second maximum residual energy.
5. The initiator node changes for every round whenever the energy level of the node decreases. When the initiator nodes selects the CH, clusters are formed in the network.
6. The nodes in every cluster sends a CHADV to the CH and CH sends it to the sink node along with the cluster ID. A join request message JREQ is transmitted by the member node along with CHADV.

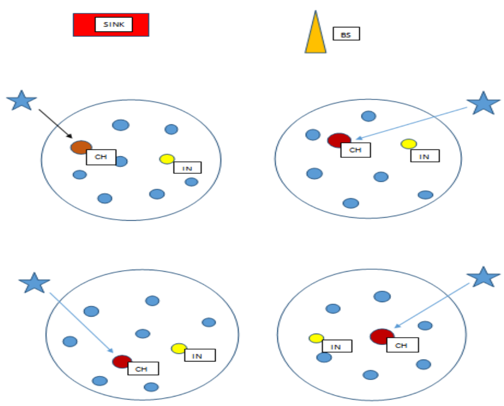

Figure.1.Wireless Sensor Network with cluster head formation

B. Energy Transfer

We use a robot for charging the dead nodes through the selected cluster heads. Consider that each robot has some initial energy and its movement is used to increase the network lifetime. Initially the robot is situated in a position and gets the energy using any existing energy harvesting techniques. After the cluster head formation, the information regarding the number of dead nodes and their location is sent to the robot of that particular cluster. The Robot then moves in a fixed trajectory towards the cluster heads to transfer the energy and moves back to the initial position. Therefore in each round the dead nodes are reduced to zero, increasing the network lifetime. In our proposed method we are using first order radio model to calculate the energy consumption in data transmission by sensors. According to this model, we assume that Eelec= 50nJ/bit is used by the network to run the transmitter or receiver circuitary and Eamp= 100pJ/bit/metre square is required for transmitter.

E_{tx} (k,d) = E_{tx} -elec(k) + E_{tx} -amp(k,d)

E_{rx} (k) = E_{rx} -elec(k)

E_{da} (k) = E_{da} -elec(k)

Where transmitted energy is given as Etx, Erx is the received energy, Eda is the data aggregation rate, k represents number of bits and d represents distance.

Energy consumed by the transmitter to calculate the data received by the robots is 15nJ/bit. The neighbouring nodes will be sent a token from each node in the cluster after sending its data. Thus, all the nodes transmit their information to the cluster heads in the cluster and the robot gets that information from the cluster heads.

III. SIMULATION

Initially the number of nodes is taken in the range 0 to 100. Here we have set it to 40. These 40 nodes were formed into 4 different clusters and each cluster has a cluster head elected, which are denoted as CH. The red coloured sphere represents the base station, which is assumed to have the information regarding the distances and energy levels of the nodes. Different colours were used do represent different clusters.

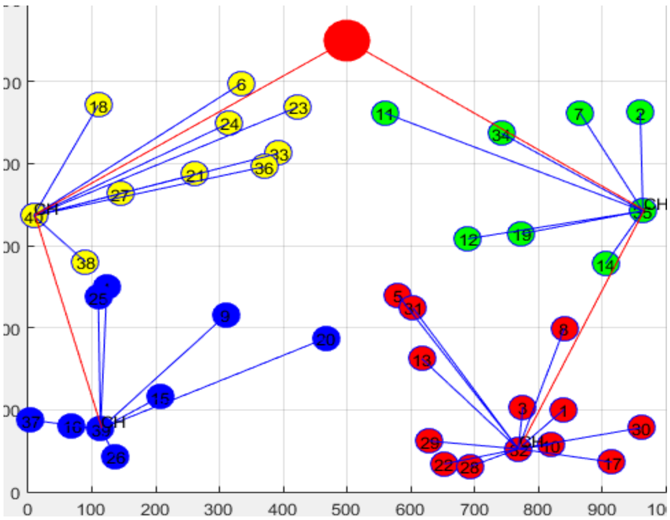

Figure.2. Cluster Head Formation

In the proposed algorithm the energy utilized to transfer data is reduced by reducing the path for transferring the energy. Thus, the number of dead nodes is decreased compared to existing method (LEACH-C) and also the energy level of the nodes is increased.

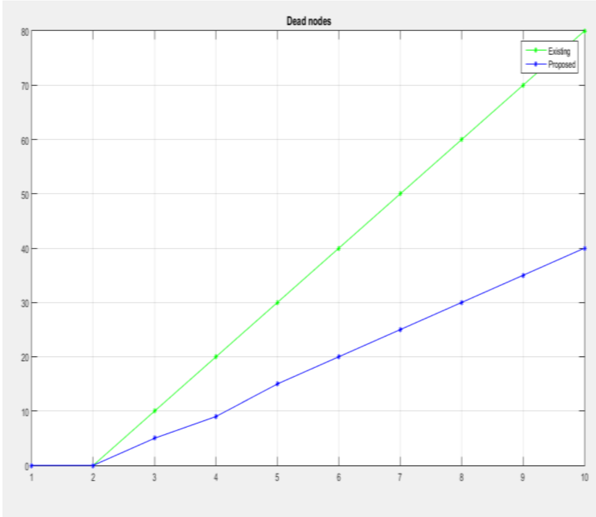

Figure.3.Comparison of number of dead nodes in a particular round in the LEACH-C and Proposed method

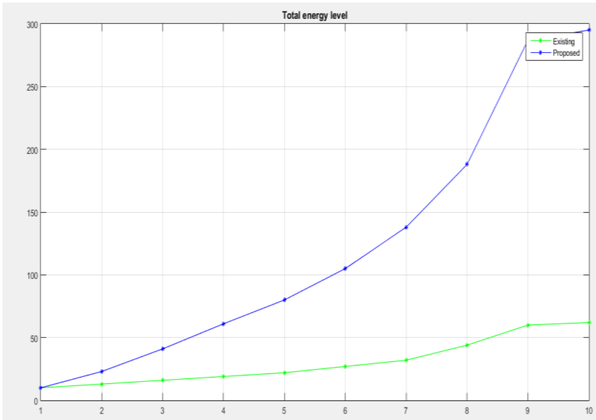

Figure.4. Comparison of energy level of nodes in a particular round in the LEACH-C and Proposed method

Table .1. Parameters used in simulation

Parameter	**Value**
Simulation duration	450 seconds
No. of nodes	100
Area of Simulation	200*200 m^2
No. of charging robots	3
No. of cluster heads	Variable(4, 6)
Round time	33 hours
Robot Visit Time	Varying (100-850seconds)
Data packet size	100 bytes
Data traffic model	1 packet per TDMA slots
Initial energy of nodes	0.5J
Initial energy of robots	50J

Here we have considered the initial positions of robots are (250,250), (350,350) and (450,450). The network size is taken as 200*200 m. The initial energy of the nodes is taken as 0.5J and that of the robots is 50J.After the cluster heads are formed, the robots will move towards the cluster heads for charging. These cluster heads are responsible for charging the remaining nodes in that particular cluster. Then the robots move back to their initial position to get the energy for the next round. The round time is expressed as the total number of active periods for different cycles. For instance, consider that the sensor must report the oil level reading by using a smart grid application of a power generator once per every minute. Moreover, the slot is assumed to be 1 ms; which means the active period of the node is 1 ms and for the remaining of the minute it sleeps. Assume that the cluster has 10 nodes, then that cluster will be active for 10 ms, which is equal to one round time. Then, the time of simulation with a round time of 20 seconds will be equal to an actual real time operation of (20/10 ms)* 1 min = 2000 minutes (≈ 33 hours). And therefore for every round the robot will visit the site for few seconds which is equivalent to the RVT, and then for obtaining a new cluster the nodes will communicate with the BS. This cyclic behaviour can be observed in every 20 seconds. Therefore, if the period of charging (i.e., the RVT) is x seconds and this is sufficient enough to allow the cluster to perform for 33 hours, hence we can say that our model is very effective.

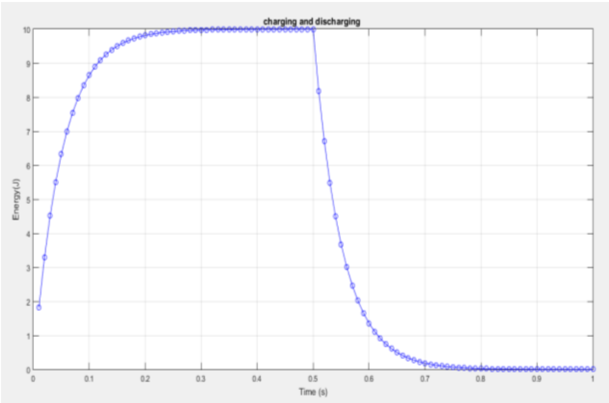

Figure.5.Charging and discharging graph of nodes using robots

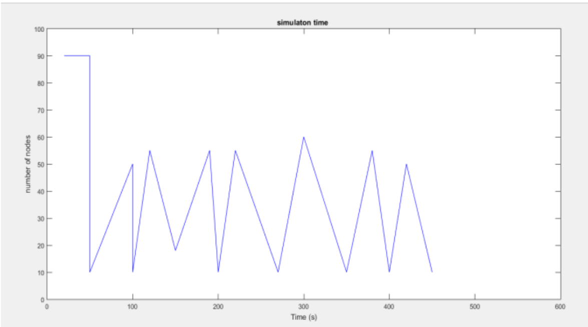

Figure.6. Number of nodes alive at different time intervals

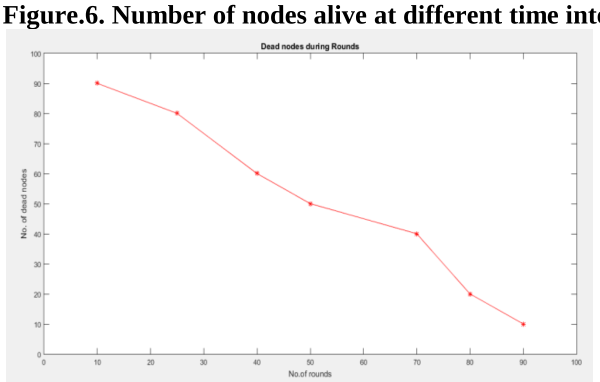

Figure.7. Number dead nodes after every round

Based on the optimal positions of the mobile chargers the wireless sensor network is designed to maximize the total energy harvested.

$$\max_{\forall j} p_r = \max_{\forall j} \sum\nolimits_{\forall i} p_t \, d_i^{-2}$$

Where the non-cluster-head node's total received power is given as pr and the emitter side power transmitted is given as pt (i.e., charger). Therefore by assuming that the transmitted power is equal to unity, the above equation can be written as;

$$\max_{\forall j} p_r = \max_{\forall j} \sum\nolimits_{\forall i} d_i^{-2}$$

As the energy harvested is increased and the utilised energy is minimised, the network lifetime decreases. Figure 8 shows that the network lifetime is just 4.5 seconds if the LEACH-C method is used, which is increased to 5 seconds in the proposed method.

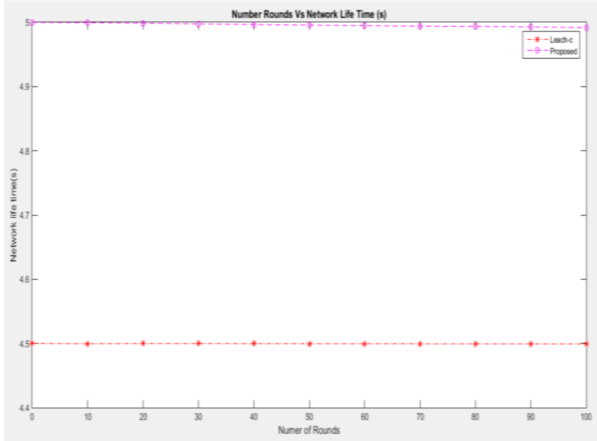

Figure.8. Comparison of Network Lifetime for each round in the LEACH-C and proposed method

The robots which are used to charge the nodes are located at the centre; each robot visits the nearest CH. The shortest Hamiltonian cycle is used to calculate the travel path of each charger that can be given as follows,

$$L \approx (pqk)^{\frac{1}{2}} f\left(\frac{k}{pq}\right) + (p+q) g\left(\frac{k}{pq}\right)$$

A path which is undirected or directed graph that visits each vertex only once is called a Hamiltonian path (or traceable path) in the mathematical field of graph theory. A Hamiltonian cycle (Hamiltonian circuit or Hamiltonian path) is a cyclic path. The main problem of Hamiltonian path, which is NP-complete, determines that such paths and cycles exist in graphs.

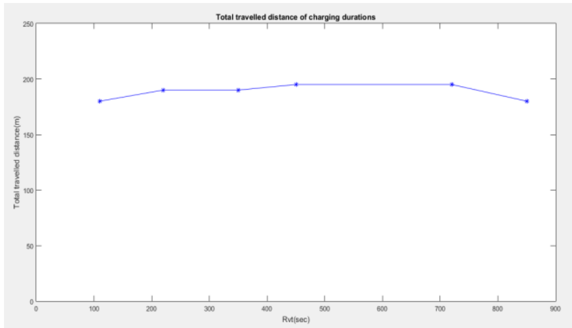

Figure.9. Total distance travelled in each round

IV.CONCLUSION

Although Wireless Sensor Networks (WSNs) have many applications in area monitoring, water quality monitoring, natural disaster prevention and data logging, their energy management is a constraint. Advancement in energy-harvesting techniques provides a wide solution for recharging the sensors to increase the network lifetime and maintaining the operation of network. In the proposed work, we have implemented a low power wireless sensor network energy transfer using robot. Our approach is to exploit the routing algorithm to find the appropriate cluster heads and then calculate the energy of the nodes for selecting the cluster heads. If the particular cluster head loses energy, the node with full energy level can be elected as a cluster head. This approach optimised the use of the number of robots as well the routing method that uses minimum energy and maintain high fairness and coverage. Several issues must be further investigated in future like the impact of heterogeneous sensor network, path optimization, frequency to be charged given for the consumption of energy for each cluster.

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