Scalable Energy Renewal Approach for Wireless Sensor Network through Wireless Charging

Rosline Mary.A, Sudhakar.K.N, Dr.Jitendranath Mungara

Abstract— Paramount threat to wireless sensor network is self-contained in the life of its batteries. Consumption of energy increases due to the usage rate increase and less priority given for conservation. Objective of providing uninterrupted network operation cannot be sacrificed and hence charging sensor nodes prudently from external source such as a mobile charger vehicle (mcv) will address this issue. Using a single mobile charger vehicle depletes time and not suitable for more number of nodes. Charging with mobile of charging vehicle and finding out its number in a cluster environment based on increase in number of nodes is proposed. Path of charging vehicle is optimized. To evaluate the performance of this algorithm, we conduct simulation in large scale networks.Simulation results demonstrates that this approach significantly increases the life of batteries and enhances uninterrupted service with energy renewed.

Index Terms— clustering, lifetime, optimization, wireless power transfer, wireless sensor network (WSN).

1 Introduction

IN a Wireless Sensor Network (WSN), sensor nodes are powered by batteries that can operate for only a short period of time, which results in shorter network lifetime. Extending the sensor network lifetime for long-term operation is a long-lasting and fundamental problem.Hence, many energy conservation schemes [1] were proposed to battle the constraint with these schemes, the rate of energy consumption is slowed down, but consumed energy cannot be compensated.Therefore, the effectiveness of these schemes is inherently restrained by the amount energy preloaded to sensor nodes.

To address this issue, harvesting the ambient energy from various environmental sources such as solar, wind, vibration ([2], [3],[4]) has recently been proposed. However, a limitation of the energy harvesting based approach is that it is subject to the availability of the ambient energy, which is uncontrollable.

A new strategy called node reclamation and replacement ,a robot or human labor called mobile repairmen periodically reclaims sensor nodes of low or no energy supply, replaces them with fully charged sensor nodes, and brings the reclaimed sensor nodes are recharged, temporarily stored ,and can be used to replace other sensor nodes in later time. This approach is applicable to WSN that are deployed in environments accessible to robots or human labors, such as roadside,plants,factories,parks,forests,gardens and so on[5].

- *Rosline Mary.A is currently pursuing masters degree program in computer science and engineering in CMR Institute Of Technology,Bangalore,India, E-mail: rosy.prabu@gmail.com*
- *Sudhakar.K.N is an Associate Professor in computer science and engineering in in CMR Institute Of Technology,Bangalore,India, E-mail: sudhakar.kn@cmrit.ac.in*
- *Dr.Jitendranath Mungara is a Dean and Professor in computer science and engineering in CMR Institute Of Technology,Bangalore,India, E-mail: jmungara@yahoo.com*

1.1. Wireless charging Technology

The emerging wireless charging Technology creates perpetual power source to provide power-over-distance, one-to-many charging and controllable wireless power. Particularly, employing the two strongly coupled magnetic resonant objects, Kurs et al [6] exploit the resonant technique to transfer energy from one storage device into another without any wires and plugs. In addition to wireless power transfer, they experimentally showed that the source energy storage device does not need to be contact with the energy receiving device for efficient energy transfer. A highlight of their experiment was to fully power a 60w light bulb from a distance of 2m away, with about 40% power transfer efficiency.

[7]Wireless power charging Technology, power can be transferred from the transmitting antenna of a power charger to the receiving antennas of a power charger to the receiving antenna s of sensor nodes via radio. The power is then transferred to DC voltage which can either be utilized by the sensors directly or stored in the rechargeable batteries.

Recently, wireless power transfer based on radio frequency (RF) between 850-950 MHZ (with a center frequency of 915MHZ) has been explored. Under such radiative energy transfer technology, an RF transmitter broadcast radio waves in the 915MHZ ISM band, and an RF Receiver tunes the same frequency band to harvest radio power.However,it was found in [8],[9]and [10] that a receiver operating under such radiative energy transfer technology can only obtain about 45mW power when it is 10cm away from the RF Transmitter ,with about 1% power transfer efficiency, The technology is also sensitive to obstructions between sources and devices ,requires Complicated tracking mechanisms if relative positions change and poses more stringent safety concerns. Due to these issues the potential of RF based power transfer technology is limited.

1.2. Motivation

Wireless sensor networks (WSN) today are mainly powered by batteries. Due to limited energy storage capacity in a battery at each node, a WSN can only remain operational for a limited amount of time.

To prolong its lifetime, there have been a flourish of research efforts in the last decade. Despite these intensive efforts, the lifetime of a WSN remains a performance bottleneck and is perhaps one of the key factors that hinder its wide-scale deployment.

The rest of the paper is organized as Follows. The following Section 2 outlines Literature Survey. Section 3 presents the proposed scheme to maximize the lifetime of the wireless sensor network. We evaluate our method in Section 4 using simulation. Finally, Section 5 concludes the paper.

2 Literature Survey

The application wireless charging Technology to sensor networks is still in its infancy stage.Peng et al[10] recently study the feasibility of using the wireless charging technology to prolong sensor network lifetime. The key idea is to dispatch a mobile robot to move around the network and charge energy to a selected set of lifetime bottleneck sensor nodes. Here two types of routing are used. If energy-minimum routing is used nodes on the intersection of multiple energy minimum routes may be overused even though the charger keeps charging them. When the energy consumption rates of these nodes exceed the charging capability, they deplete their energy quickly and the extension in the network lifetime is limited

Alternatively, if energy balanced routing is used; the overall energy consumption in the network is increased as routes with longer path are used to bypass low energy routes which are on shorter and more energy efficient routes. Hence energy replenished into the network may not be utilized efficiently.

In another recent report [9], to maximize network lifetime under the constraint of limited charging capability, dynamic and imperfect communication environment and heterogeneous node attributes. Here they employ energy balanced routing and energy minimum routing in a balanced way to exploit their strengths while avoiding or mitigating the problems caused by using only one of them. This approach requires periodical information exchanges between sensor nodes and charger. Based on exchanges, the charger keeps track of the global energy status of the network, schedules it's charging activities accordingly, and disseminates the charging schedule to the network. In between sensor nodes use a carefully designed charging aware routing metric to estimate their routing costs and make routing decisions; this way sensor nodes are guided to balance between energy balanced routing and energy minimum routing while the protocols run by them remain simple and localized.

The recent breakthrough in energy transfer technology for a WSN [11] a mobile vehicle carrying a power charging station to periodically visit each sensor node and charge it wirelessly. The problem here is not suitable for dense sensor network. Because here they are using a single charger vehicle and also takes lot of time when the number of nodes increases in the sensor network.

3 Proposed System

The Following Proposed System Consists of Problem Definition, Software Architecture and finally the proposed Solution

3.1 Problem Definition

Wireless Sensor Network is operated by small batteries. We envision employing a mobile vehicle carrying a power-charging station to periodically visit each sensor node and charge it wirelessly. This mobile wireless charging vehicle (WCV) can either be manned by a human or be entirely autonomous. In this Paper, we investigate the fundamental question of whether such a new technology can be applied to remove the lifetime performance bottleneck of a WSN. That is, through periodic wireless recharge, we show that each sensor node will always have an energy level above a minimum threshold so that the WSN remains operational forever.

3.2. Software Architecture

The software architecture of the proposed system is shown below:

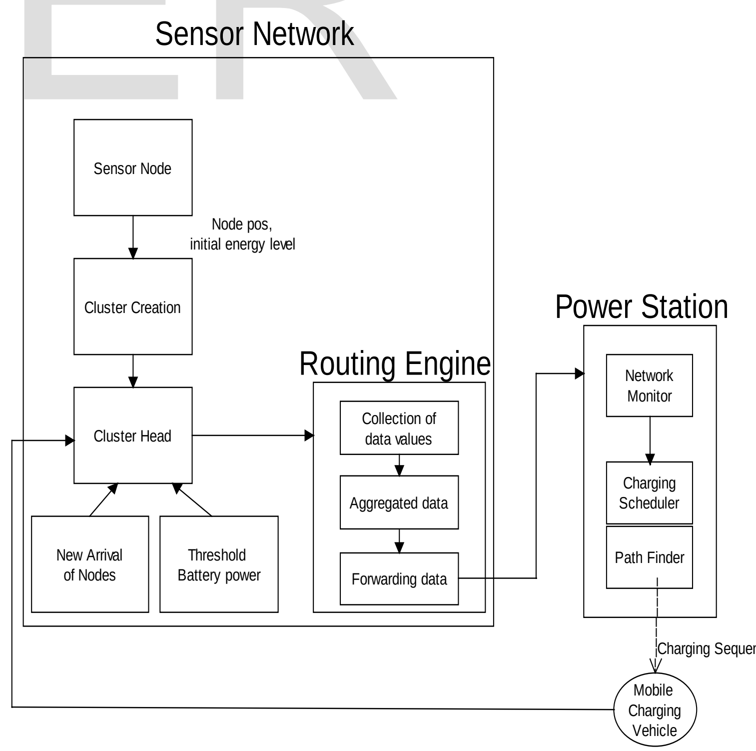

Figure 1.System Architecture of the Proposed System

The working of WSN proposed architecture model illustrated in Figure 1 works by selecting group of nodes and divided into clusters. These clusters will satisfy the intended parameter requirements and conditions. The parameters like nodes positions, initial energy level, and battery consumption were used to determine the number of nodes that would be considered in a cluster. Now a cluster head (CH) is selected among nodes lies inside each and every cluster. CH will be responsible for administration of all other nodes inside respective cluster and collecting the data from nodes inside the cluster and transferring the data to the Power station. All data are collected and aggregated by a routing engine and forwarding to the power station. Because power station is monitored by each clusters in the network. Depends on the number of clusters, the mobile charging vehicles found. Each vehicle having own movement scheduler and path finder to finds the optimal path based on the energy level of each CH and invokes Mobile charging vehicle to move. The Mobile Charging Vehicle has the charging sequence to charge the sensor nodes battery.

The following are the elements of software architecture:

Sensor node: Sensor node is the primary working component that performs various activities like cluster creation, data collection, transfer data among switching centers and so on

Sensors Parameters: The parameters like bandwidth, memory, time-to-live, radio signal strength Indicator (RSSI) are identification factors for WSN architecture.

Newly Arriving Node: Current numbers of nodes present in the cluster and newly arriving nodes are managed by functional parameters used in cluster creation parameters.

Cluster Creation: Collection of nodes that satisfy the parameter requirements ultimately form a cluster.

Cluster Head Assignment: An individual cluster head is selected by evaluating the minimum cost of that node who will serve as the head. Each cluster is an area to be served by a charging vehicle. Order in which the charging vehicle visits the node in the cluster is decided by charging vehicle path finder module

Threshold battery power: Threshold battery power is checked or evaluated against the present status of battery of the cluster head.

Routing Engine: Data is collected from various nodes partitivating in the communication and forwarded to the power station for further access.

Power station: It monitors the sensor network and find out the charging sequence for the clusters in the network. The Movement Scheduler finds the optimal path based on the energy level of sensor and invokes Mobile charging Vehicle to move.

Mobile Charging Vehicle: It moves in optimal path from cluster head's sensor node to other to charge the sensor battery.

3.3 Proposed Solution

It has two parts

3.3.1 How to find the minimum number of charging vehicle

3.3.2 The path for each Charging vehicle.

3.3.1 Finding the minimum number of charging vehicle

Given a sensor network with nodes distribution, the goal now to find the minimum number of charging vehicles needed. We need to make some assumption to calculate the minimum number of charging vehicles.

All the sensor nodes are of same type.

Let the rate of charge discharge at node is RD. Let the initial energy of Node is IE.

We keep the lower most value for the energy to be in sensor as 25 % of IE.

The node will discharge to minimum value in

$$T_{hold} = IE * .75 / RD.$$

So every sensor node should get the Charging vehicle visited in T_{hold} time period.

Let the time to charge a sensor node be Tch.

So the maximum number of nodes a charging vehicle can charge is

$N_{max} = Thold/T_{ch} - T_{travel}$

Where T_{travel} is the travel time of the mobile charging vehicle.

Ttravel can be reduced if the sensors are very nearby and not far off.

If the maximum distance between the sensors is taken as D, then the T_{travel} can be estimated as

$T_{travel} = N_{max} * D$

To reduce the Ttravel, we need to partition the network into many clusters.

The condition for clustering is maximum distance cannot cross D.

We collect the value for D as input and begin to cluster nodes in such way that if the distance between nodes is less than D and the maximum number of nodes cannot cross N_{max}.

Once the number of clusters is found, that is the number of minimum number of charging vehicles needed to be present in the network.

3.3.2 Finding the path for each vehicle

Once the clusters are found, the next task is to determine the path for the movement of the charging vehicle.

To find the path of movement, we construct a graph with sensor nodes as vertexes and distance between nodes as edge weights. Now we have the travelling sales man problem visiting all the nodes in shortest path.

We find the solution for it using the standard travelling sales man solution and the charging vehicle has to travel in this path in the cluster.

4 Simulation Result

Extensive simulations have been conducted to evaluate the performance of the proposed system in a large scale networks. For the experiments, we used a WSN simulator which we implemented in Java and executed the simulator on a PC with Pentium Dual Core Processor, minimum of 20GB of hard disk drive, 16GB of RAM, Windows XP and Java.In the simulations, 100 nodes are randomly deployed in a 650 m x 650 m field. Initially each node is set with the energy of 200J.Topology used is flat addressing. The Simulation was carried out different number of nodes using Prowler Simulator.

A wireless sensor network simulation environment which comprises of Net bean Development Tool and for Coding Java was installed.We define the lower most energy level of each node 25%.If it below the value the node fails.The mobile charging vehicle is a mobile robot,the rest are set as a static nodes.Data transmission occurs from the source to the sink node.Energy for each node is obtained before and after the transmission.As a Mobile Charging Vehicle periodically moves around the network,each node is recharged,thus the Network can remain operational forever.

We show Simulation results obtained through computer simulations in Fig.2 for number of failed nodes and Fig.3 for Ratio of failed nodes.

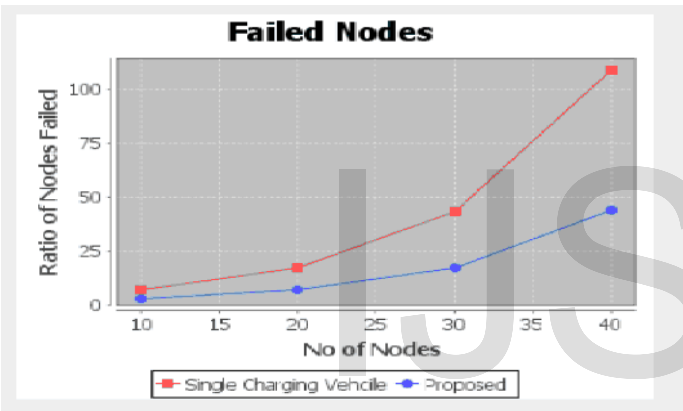

Figure 2.Number of Failed Nodes

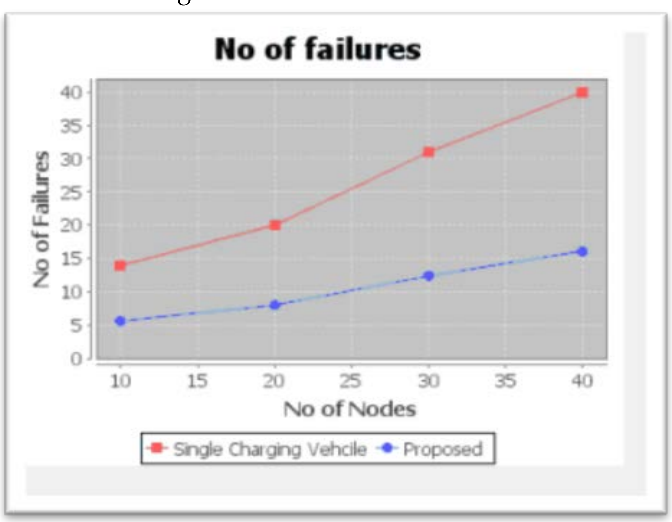

Figure 3.Number of Failures

Both Fig. 2 and Fig.3 shows that the number of failures by proposed method was less than single mobile vehicle charger. The reason of reduction is that more charging vehicles are used depends on the number of number of clusters and also distribute the energy very quickly to nodes in the sensor networks .However, we confirmed that our proposed method takes reasonably shorter time and gives complete 100% energy. The above results support that our proposed method achieves a less number of failed nodes with reasonably small fraction of WSN Lifetime reduction.

5 Conclusion and Future work

In this paper, we propose a scalable energy renewal approach using clustering to prolong sensor network lifetime. We present the design and implementation of the energy renewal approach and evaluate its effectiveness using simulations in large-scale networks. The result shows that comparsion to the single mobile vehicle charger, the proposed method has less number of failed nodes in the network. We examined the Scenario where a mobile charging vehicle periodically visits each node and charge them wirelessly without the use of any plugs and wires. We examined that wireless power transfer can be performed from one energy source to multiple energy receiving vehicles at its travelling path and has the potential to work in densely deployed sensor networks.

Some more issues are left open for future research such as global energy status calculation, mobile charging vehicle failure & identification. It is a very interesting and complicated problem, which is to be studied in the future.

References

[1] I.Akyildiz,W.Su,Y.Sankarasubramanian,E.Cayirei ,"Wireless Sensor Networks:A Survey",Computer Networks,Vol.38,no:4,2002.

[2] A.Kansal, D.Potter, and M.B.Srivastava,"Performance aware tasking for environmentally powered sensor networks,"SIGMETRICS Perform.Eval.Rev. vol.32, no.1, pp 223-234.

[3] C.Park and P.Chou,"Ambimax: Autonomous energy harvesting platform for multi-supply wireless sensor nodes."in SECON,2006

[4]]S.M.Jose,J.O.Mur-mir,R.Amirtharajah,A.P.Ch and J.H.Lang,"Vibration-to-electric energy conversion,"IEEE Transaction on Very Large Scale Integration(VLSI)Systems,vol.9,no.1,pp 64-76,2001.

[5] B.Tong, G.Wang, W.Zhang and C.Wang."Node reclamation and replacement for long lived Sensor Networks,"in Proc.of IEEE SECON 2009, Rome, Italy, 2009.

[6] A.Kurs, A.Karalis, M.Robert, J.D.Joannopoulos, P.Fisher, and M.Soljacic,"Wireless power transfer via strongly coupled magnetic resonances,"Science, vol.317, pp.83-86, 2007.

[7] Powercast,http://www.powercastco.com

[8] Z.Li,Y.Peng,W.Zhang,and D.Qino,"J-RoC:A joint routing and Charging scheme to prolong sensor network lifetime,"in Proc.IEEEICNP,Vancouver,BC,Canada, Oct17-20,2011,pp 373-382

[9] Y.Peng,Z.Li,W.Zhang,and D.Qiao,"Prolonging sensor network lifetime through wireless charging,"in Proc,IEEE RTSS,San Diego,CA,2010,pp 129.

[10] B.Tong,Z.Li,G.Wang,and W.Zhang, "How wireless power charging technology affects sensor network deployment and routing,"in *Proc. IEEE ICDCS,Genoa,Italy,Jun 2010,pp.438-447.*

[11]]Y.Shi,L.Xie,Y.T.Hou,and H.D.Sherali,"Making Sensor Networks Immortal:An Energy Renewal Approach with Wireless Power Transfer,"IEEE/ACM Transactions on Networking,2012