Survey on Recharging Methods of Sensor Nodes in Wireless Rechargeable Sensor Networks

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Abstract: ***A wireless rechargeable sensor network (WRSN) has a collection of sensor nodes that are deployed randomly. The energy efficient wireless sensor network design is one of the most crucial challenges today. Because not easy to recharge sensor nodes in different types of WRSN. Normally challenging coherent recharging methods are only achieves energy efficiency of sensor nodes. In WRSNs, the mobile chargers are used to recharge the sensors. The optimal solution is to reach the node and to recharge within dedication time duration and range of conditions. The mobile charger takes the shortest path which gives best result to route all nodes and recharge them after choosing proper anchor point. Many energy efficient recharging methods are available, it concentrates both on sensor nodes recharging and data collection. In this paper some feasible schemes are explored to visit all the nodes in shortest path and perform the action and also the performances of the different scheme are compared.***

Keywords: WRSN, mobile salver, WCV, GCHA, TSP

1. Introduction

A wireless sensor network (WSN) is a collection of distributed self-governing sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. And also cooperatively pass their collected data through the network to a main location or base station. The environmental condition changes monitoring process is very hard because the changes in Environment will mitigate the undesirable effects. This became bad effect both living and non living things like contamination and destruction of domain and lose of lives. So the proper monitoring and measurement system have been needed to monitor every occurrence in surrounding domain.

Normally WSN applications are categorized in forest area, industrial area and threat area. In forest area, it capable in area monitoring**,** health care monitoring, environmental/ earth sensing, air pollution monitoring, forest fire detection, landslide detection, water quality monitoring, natural disaster prevention. In industrial monitoring, it involvement in machine health monitoring where impossible to reach a wire to machinery place or rotated machine[1] have changed their place of dimension**,** data logging like monitoring the collection of data like monitoring water overflow in nuclear power plants, water/waste water monitoring, structural health monitoring where monitor the condition of civil infrastructure and related geo-physical processes close to real time, and over long periods through data logging, using appropriately interfaced sensors and in wine production. In threat detection, sensor used for detecting a ground-based nuclear device such as a nuclear "briefcase bomb."

The forest area biological wealth needs to be permanently diminished by some factor. The factors may be a single factor or combination factor. We want to frequently measure the condition of tree, plants and animals. By continues observation we can reduce the degradation, deforestation, land degradation and forest fire detection. Normally WSNs have been widely used in many fields, including smart homes, environment monitoring, traffic management, and industrial manufacturing [1]-[6]. Sensor nodes are battery-powered [7] by other node where energy curtailments are a critical issue in restricting the development of WSNs. Where the battery charging are usually done by a mobile vehicles that are equipped with a charger and they are rotated in shortest path until recharge all the sensor nodes in their network area within a communication range R_c. But some nodes belongs in out of communication rang, the cannot be charged by mobile chargers [3][4]. If they are uncharged during long time periods [4], they possible to go to dead conditions. Sometimes the MCs need to wait on site until the sensor is properly charged. It is possible that some sensors withdraw their energy while the charging vehicle is assisting the other. If a sensor exhausts its energy, it's sensing the quality and whole network connectivity disgraceful. So before design an energy efficient rechargeable WSN, first interpret all possible recharging [6] ways and data collection methods[2]. In this paper contain the following main contributions.

- To deliver the importance of energy efficiency in WRSN.
- To Analyses some mobile recharging methods which give efficient result in recharge the sensor node.
- And also discussed the contribution of each method and it performance relation explained through graph.

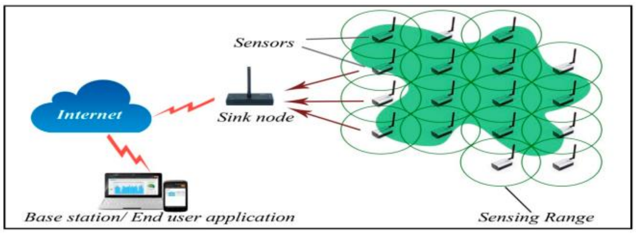

Figure 1: Architecture of Wireless Sensor Network

2. Importance of Energy Efficiency in WRSN

Energy maintenance is important factors in network field**.** Moreover energy constraints with routing have challenging process in fast few years. But we can predict the energy consumption in network that give long lifetime of network and increase the performance of the network through Quality of service. However recharging process has more challenges in sensor node environment and the node battery level maintenance only gives network lifetime. Also give growth in QOS. Because due to limited battery power the node also have limited involvement. Both energy replenishment[3] and data collection also important constraints in improve the quality of service in network environment.

3. Recharging Methods

The charging technologies enlargements in wireless sensor network have increase the study to give feasible solution on charging algorithms for WRSNs. These algorithms fall into two categories: static wireless charging algorithms[3] and dynamic wireless charging algorithms based on mobile charger. Here the content has discussion of previously used techniques[5] on recharging methods for energy replenishment in the network.

3.1 Near-optimal velocity control method for mobile charging (NOVC)

A single mobile charger was traveling along with trajectory movement in randomly deployed sensor nodes in wireless rechargeable sensor network(WRSN) that the path followed by an charger movement in extending the action of given force or guidance. Here, the author point out velocity control problem to improve the network lifetime [8]. If there is a node far from charger trajectory movement, the charger spends more time to recharge that node and also reduce the overall charged energy of all nodes. This problem solved by the spatial temporal discretization method. Where a least charged node which are in bottleneck was found then it can be first charged. Repeat the process until get the overall performance of the network with the least "capability of being charged". The simulation result describe the network life time could achieved 2.5 time greater in by proposed velocity control method compare to baseline method. And also extend the charging model in non-ominidirectional and also joint optimization of moving trajectory and velocity. The author proposed algorithm has multi-node wireless energy charging algorithm in a WRSN [26].

3.2 Multi-Node Wireless Energy Charging (MNWEC)

A single sensor node has been charged at a time, which produce scalability problem in WRSN. This problem can be solved by multi node charging. So the optimal solution was taken by wirelessly charging vehicle (WCV) [13]. And also the author proposed cellular structure that partionate 2 dimensional plane in to hexagonal cell. Then the WCV travel along the cell and recharging multiple nodes. This travelling method's optimization key factors are jointly optimized traveling path, flow routing, and charging time. And also optimal technique employed with discretization and Reformulation and linearization technique (RLT). When WCV charging range exceed the reception rate reduced in each cell.

a) A Mobile Data Gathering Framework Vehicle Movement Costs and Capacity Constraints (MDGR)

To solve recharge scheduling problem and to balance energy consumption and latency the dedicated data gathering vehicle and multiple charging vehicles are employed. The proposed WRSN has the charging vehicle's 1. Energy consumption, 2. Capacity limits, 3. Energy efficiency and 4. Data latency. After the cluster formation, the profitable traveling salesman problem was formulated [14] for minimize the replenished energy loss and the prove NP-hardness This can be performed by two algorithms. 1. Greedy algorithm-to maximize growth of profit at each steps, 2. Adaptive algorithm – to partition the network and get a capacitated minimum spanning tree. This partition used to reduce transient energy depletion. And also the author proposed low latency mobile data gathering schemes, with minimum number of vehicles to recharge the nodes and formulate recharging optimization problem into profitable by TSP. But it has the challenges to how to dispatch and coordinate multiple data gathering vehicles and to minimize traveling distance.

b) Minimizing the Number of Mobile Chargers to Keep Large-Scale WRSNs

The author exploit the Minimum Mobile Chargers problem (MMCP) in WRSN and that can be solved by divide the problem in to two sub problems, Tour construction problem(TCP) and tour assignment problem(TAP)[19]. These problems are NP-hard Problems. This was worked out by introducing Greedily Construct, Heuristically Assign (GCHS) scheme. Here, jointly charging and routing algorithm was used. Based on tour schedulable condition, it was greedily splits the cycle in to schedulable subtours and it assigned a minimum number of mobile chargers (MC). MC has GCS-Greedy Charging Scheme to charge with reasonable computational complexity. In future, computational complexity can be reduced when using TSP. The analysis shows GCHA scheme had half of MC compare to NMV scheme and the optimal solution have complexity in load balance between MCs.

c) Joint Power Charging and Routing Method (JPCR)

The author was presented a joint optimization model that have charging efficiency and routing, rather than the typical charging optimization problem considering only the predefined data gathering route. Also author proposed a Genetic Algorithm [20] based optimization frame work to find the optimal routing tree, in which the specific many to one routing tree is coded as an individual for evaluation. This work achieves quick convergence by an efficient individual encoding schemes and effective constraints handling mechanism. And Heuristic algorithm used to find the optimal resident location with the given routing tree. From the calculation of minimum moving distance and total charging time, the fitness of each individual was evaluated. The simulation result was showed our proposed algorithm achieves a substantial improvement compare with the predefined route.

d) Collaborative Mobile Charging Policy for Perpetual Operation in Large-scale WRSN (CMCP)

In this paper, the low energy level nodes are charged by the MCs which are in movement. The MCs are charging itself and also recharge all other the nodes in network [21]. Initially the network was formed as centroidal circles to communicate and recharge the nodes. Using this sourrending circle partition, the performance was easily carried. The existing system has number of problem accomplished with both wireless charging and the combination of energy replenishment and data collection. But this proposed Hop-based Mobile Charging Policy (HMCP) used to minimize the number of mobile charger usage and concentrate both the sensors unbalanced energy consumption rate and MC's limited energy capacity. It also has little connection between energy replenishment and data collection. From the HMCP, HMCP+ also proposed, that have single MC to charge all the sensor nodes in each region. This proposed work have proper plan to consume less amount of energy compare to existing.

e) HEED: A Hybrid, Energy-Efficient, distributed Clustering Approach

Load balancing on sensor node constraints are important in WRSN. As an efficient network need the energy efficient sensor and network must balance both salability and lifetime of network. Here, topology control approach is an effectively achieved by clustering method. The proposed algorithm is Hybrid Energy Efficient Distributed clustering (HEED), that select the cluster head periodically and recharge which less residual energy due to hybrid of node. It also exploits the opportunity of multiple transmission power at sensor nodes. HEED brings out an allied multihop intercluster network which an itemized solidity model and also specified relation between cluster range and transmission range hold.

4. Result and Discussion

When we compare the computational complexity of NOVC, MNWEC, MDGR, JPCR, HEED have different cost due to energy efficiency of sensor node. Where, NOVC have highest computational cost compare to other, that have $O(n^4)$. But the nearest neighbor heuristic algorithm have the computational cost $O(n^3)$. Where, the TSP have $O(n^2)$, nodes life time region is O(n log n), route implementation cost is $O(n^2)$ and adaptive algorithm has O(n3). But compare to above two minimizing number of mobile charger algorithm[16] have less cost $O(n^{2.2})$. HEED has a worst case processing time complexity of O(n) per node. The restriction is essential for terminating the algorithm in O(1). HEED has a worst case message exchange complexity of O(n) per node.

The following graph explains the performance of above schemes in terms of energy efficiency and life time in computational cost. Figure 1 represents the computation cost of life time constraint and Figure 2 represents the computation cost of energy consumption factor with different kind of recharging method. From this figure, we can observed NOVC have high life time when its energy consumption low value compare to MNWEC, MDGR, JPCR, HEED. But HEED have worst case computation cost O(1) to terminate the node compare to other.

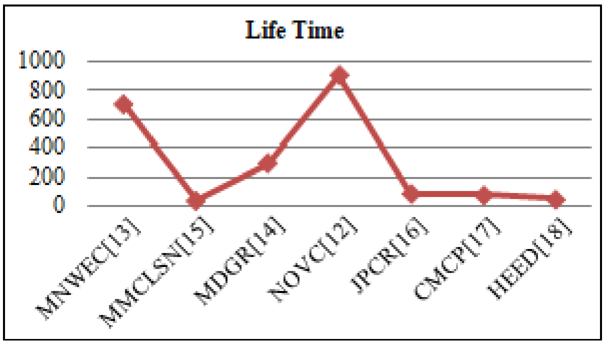

Figure 2: Computation Cost of Life Time

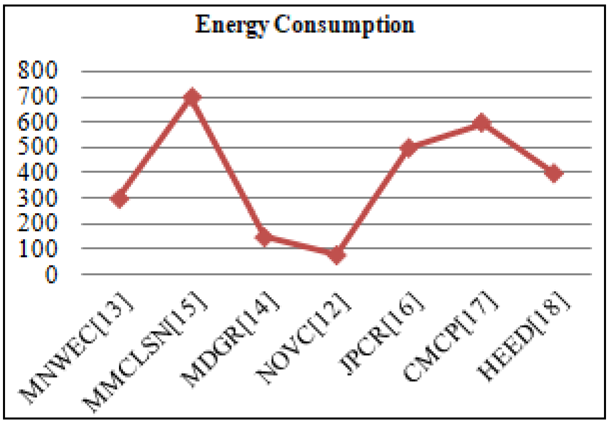

Figure 3: Computation Cost of Energy Consumption

5. Conclusion

The ultimate aim of efficient wireless recharging method is to design the enlarged lifetime of the network by guardianship the sensors viable for a top time. In view of energy consumption on transmission, it is very high correlated to that of sensing, the efficient mobile charging algorithm should be lay out to reduce energy consumption while transmitting data.

In this paper, different recharging methods based on data-centric routing, grouping or clustering of sensors, location information, network heterogeneity and QoS are discussed. These surveys are helps in understanding the working of these protocols and the advantages of these algorithms combined together may be a good research direction for future applications.

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