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Review On Energy Protection Approaches Of Sensor Nodes With Batteries In Rechargeable Wireless Sensor Networks

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Abstract

In Wireless Sensor Networks, since the dimensions and capacity of sensor nodes battery is very less which ascend energy control issues. To resolve such issues in sensor networks, several investigations had done using energy conservation methods. This survey intended about several energy conservation approaches utilized for maintaining sensor nodes battery capacity during the year 2016 to 2021. Moreover, this review paper discusses challenges, solving research gaps in rechargeable wireless sensor networks, scheduling algorithms for sensing nodes life span, several metrics to enhance the nodes efficiency along with its scalability in sensor networks which are recharged.

Keywords- Wireless Rechargeable Sensor Networks (WRSN), sensor nodes, battery, Wireless Energy Transmitter.

1. Introduction

Nowadays, Wireless Rechargeable Sensor Networks utilized extensively in several industries, technology field too with the support of batteries. Since the smallest amount dimensions and capacity of battery sensor nodes which spoil network lifespan with energy control problems. Many investigators recommended energy consumption methods to maintain battery in sensor nodes that makes network life time long lasting. To resolve such issues in WRSN, latest improvement named as Wireless Energy Transmitters being functional to revive the nodes with sensors non-wiredly. Such mechanism attained with portable chargers together with WET. Figure 1 depicts the architecture of WRSN comprises service station, mobile chargers, sensor nodes, base station. [1]

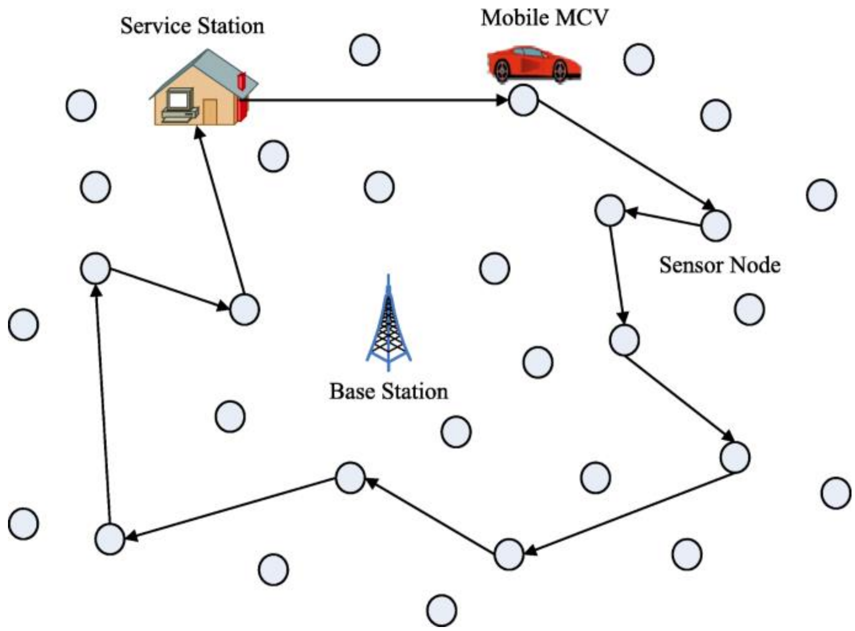

Figure 1. Architecture of WRSN

2. Background

To discuss the network lifespan and performance, several recharging schemes of sensor nodes need to be analyzed in WRSN. Here the authors scrutinized recharging methods (i) Recharging based on radiation, (ii) Recharging based on resonant (iii) Recharging based on Adaptive Algorithm.

i. Recharging based on radiation

Nowadays recharging based on radiation have developed quickly from early period to adult stage. Some profitable products afford power to network sensor nodes within specific distance. Also, several nodes were deployed to get the charging series to increase the lifespan of every sensing nodes via chargers named as powercast Wang et al. [5]. The correlation among sequence charging and network life span are demonstrated by Tian et al. [2].

The charging of sensor nodes ranges from fast charging to slow charging was investigated by Zhao et al. [11] in addition the procedure while charging evaluated using formula (1).

$$charging\ process = \int_0^t \rho(z)dz \qquad (1)$$

Here t signifies time period while charging sensor nodes formulated as equation (2)

$$\rho(z) = \frac{1}{p} CV e^{(-z/p)} \qquad (2)$$

Whereas CV corresponds greatest capability of every sensor node battery, p is non-changeable time.

From above equations, author of [11] finalized the battery explicit energy formulated as (3)

$$\int_0^t \rho(z)dz = CV\left[1 - e^{-\frac{t}{p}}\right] \qquad (3)$$

If all the available sensor nodes overall completely charged leads to low effectiveness because of high quantity of time is needed.

ii. Recharging based on resonant

When compare to recharging based on radiation, this recharging scheme in sensing nodes carried large quantity of energy with more effectiveness. In some investigation, sensor node batteries are not able to charge fully hence several recharging methods to traverse the sensing nodes in network environment. Similarly, vehicles recharging capability as well as movable rate transformed into formulation method then intentionally optimize charge scheduling especially certain sources.

iii. Recharging based on Adaptive algorithm

For acquiring energy based information, BS demands the sensor nodes using energy consumption schemes and then BS adaptively isolates into several partitions in accordance with initiating request origin. For network isolation, Wang et al. [5] used k-means approach. The principle behind k-means making similar values grouped as cluster 1, and dissimilar values grouped as cluster 2. Hence, these approach suitable for isolating the nodes which are charged and recharged. The inter node distance can be estimated using equation (4)

$$S = \sum_{j=1}^{m} \sum_{i=1}^{n_r} \left\| n_i^{(j)} - \mu^{(j)} \right\|^2 \qquad (4)$$

The term $\left\| n_i^{(j)} - \mu^{(j)} \right\|^2$ defined the distance among node which is to be recharge and centroid portion with respect to available nodes in the network.

iv. Recharging based on online

The authors of Yang et al. [13] utilized radial basis function for recharging sensor nodes battery to evade power undernourishment. The overall wireless rechargeable sensor network architecture is illustrated in figure 2.

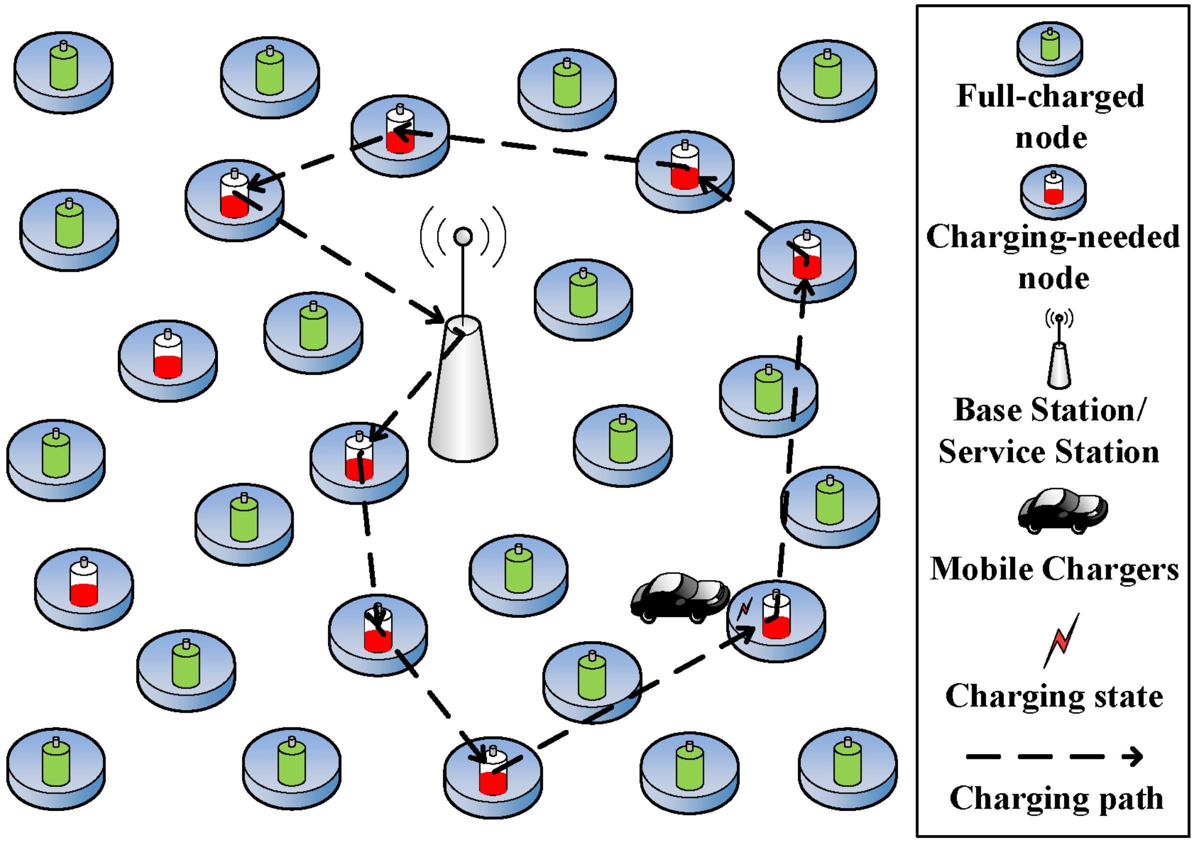

Figure 2. Overall structural design for WRSN by [13]

There are four phases of charging sensor nodes to recognize online charging namely idle, move, recharging battery of sensor nodes and regression methods.

3. Charging scheduling methods

The sensor nodes lifetime depends on the undertaking charging method in Wireless Rechargeable Sensor Network [9]. Two factors namely consistent and substantial factors should be scheduled during the time of charging sensor nodes. The factors based on consistent like speed of nodes travelling, number of nodes, and charging power. The factors based on substantial such as finding initial period of charging, choosing the sensor nodes need to be charged, optimizing charging pathway, finding separate charging period of every node in the network. Based on these scheduled while charging nodes, the charging scheduling methods are categorized. The illustration of charging pathway for every sensor node in network depicts in figure 3.

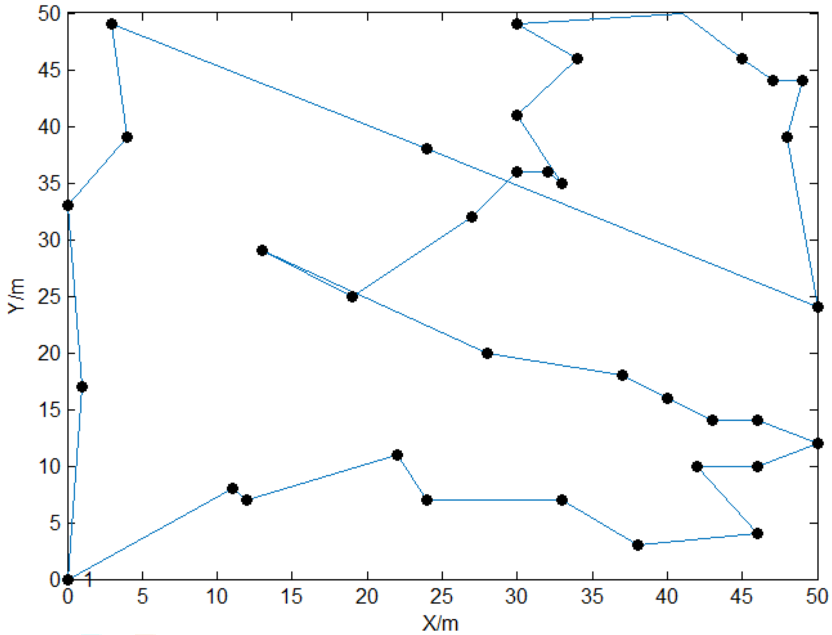

Figure 3 Method of charging pathway for every sensor node

The statistical intention task for charging pathway defined as equation (5)

$$\min L = dist\left(x_0, x_1 + \sum_{i=1}^{m-1} dist(x_i, x_{i+1}) + dist(x_m, x_0)\right) \quad (5)$$

L signifies the distance travelled among nodes, x_0 and x_m represents the initial and final nodes for data transmission.

Zhang et. al [8] determined novel algorithm named as Multi Nodes Rechargeable Algorithm suitable for recharging many sensor nodes within specific period of time. Also, this approach intent to minimize the docking sites quantity as well as converge the path travelled by sensor nodes. Consequently, energy utilization has great reduction while moving wireless charging vehicle with scalability enhancement. Mo et al. [6] determined the structural design of many mobile chargers in network that optimize charge arrangement, duration of movable nodes as well as recharging duration. Moreover, power utilization scheme appropriate in series of charging based on lifespan for sensor nodes and then isolating into several nodes hence the charging competence gets increased. Figure illustrates the framework of optimal multiple mobile chargers designed by [6]

The rechargeable rate for every sensor node available in WRSN can be evaluated using equation (6)

$$\text{Rechargeable rate} \sum_{i=1}^{n} x_{0,\,i}^{k} = \sum_{j=1}^{n} x_{j,0}^{k} \leq 1 \qquad \nabla k \in K \qquad (6)$$

i. Power usage

During transmitting and receiving data by charging sensor nodes, the power consumption can be estimated using equation (7) by [8]

$$P_i(t) = \rho \sum_{k\epsilon N}^{k\neq i} f_{ki} + \sum_{j\epsilon N}^{j\neq i} C_{ij} f_{ij} + C_{iB} f_{iB} \qquad i \in N \qquad (7)$$

Every sensor node lifespan can be formulated as equation (8)

$$\eta_i = \frac{l_{live}^i}{l_{live}^i + l_{dead}^i} \qquad (8)$$

Zho et al. [11] used spatial-temporal charging scheduling for recharging sensor nodes in WRSN environment.

4. Approaches used for sensor nodes charging

Prasanna Babu et al. [7] proposed Recha algorithm which has two criterias such as lifetime of the network as well as number of nodes energetic in a specific amount of time and Nearest Job Next with Preemption to maximize the network lifetime by efficiently scheduling a mobile charger. Xu 2016 proposed an efficient algorithm which appropriate for sensor lifetime maximization issues. Hence the utilize of mobile charger to wirelessly charge sensors in WRSN hence the lifetime of sensor is enhanced when the travelling distance of mobile charger is diminished. Liu et al. [3] discovered MC scheduling method for reduction in network data failure as a result of assumption with both sensor node connectivity as well as power. Moreover, the weight of entire sensor nodes available in WRSN are increased to build the charging schemes depends on MC wandering distance within certain limit. Based on overall roaming distance of MC for every visit and charging duration of every sensor nodes Ye et al. [4] increase the sensors charging service. Wei et al. [1] used solitary MC to promise that every network sensor nodes are executing precisely. This makes to refill the power for all sensing nodes available in WRSN. Zhao et al. [11] provides a charging scheduling and timer to enhance conventional power effectiveness while reducing the number of energy-depleted nodes. In WSN the method for allocating hybrid services support the quality of service. Several investigations on charging scheduling algorithms are summarized in table 1.

Table 1. Comparison of scheduling algorithms

Investigators	Year	Algorithms used	Intention of work
Zhang Fan et al. [8]	2018	Multi node Rechargeable algorithm	Better performance in docking sites quantity, node path travelling time-span.
Ma et al. [9]	2020	Modified Ant colony algorithm	Diminish network charging period, Enhancement in network energy.
Wang et al. [5]	2019	Numerical approach, Travelling salesman problem	Correctness and effectiveness of energy consumption models, minimize latency
Tian et al. [2]	2021	Charging method	Diminish overflow of data
Mo et al. [6]	2019	Multiple Mobile charging scheme	Increase in network scalability, and efficiency with respect to quality as well as computation time. Reduction in energy usage as well.
Zho et al. [11]	2020	Online-offline algorithm were deployed	Increase in charging effectiveness

5. Parameters summarization

This section discusses about used sensor nodes, consumption rate based on energy, speed of sensor node moving, time duration are described as table 2

Table 2. Summarization of parameters

Prior work	Sensor nodes	Energy consumption rate	Moving speed of sensor node	Time taken to charge
Zhang Fan et al. [8]	100, 500, 1000	50 J per bits	-	Mathematical formulation
Ma et al. [9]	10, 20, 30, 40 and 50	50 Joule per minute	2 minute / sec	5 minute
Wang et al. [5]	500	5.59 Joule per minute	NA	NA
Tian et al. [2]	600	5.4-10.8 Joule per minute	Portable vehicle-5min/sec UAV-15 minutes/ second	Charging threshold-5 hours
Mo et al. [6]	50	1 Joule per minute	1 min/second	5 minute
Zho et al. [11]	200	NA	NA	NA

Moreover, energy depletion and power savings were determined by wang et al. [] is described in table to show exhausting power of sensor nodes battery as well as quantity of energy storage in battery.

	Energy depletion	Power savings
Wang et al. [5]	30 to 50 %	10 to 20 %

6. Comparison on network performance metrics

Metrics such as node utilization, cost while charging and finding efficiency of mobile vehicle are summarized in table 3 to enhance the network performance.

Table 3. Comparisons on network performance metrics

Existing survey	**Usage of nodes**	**Charging cost**	**Charging efficiency of MV**
Fan et al. [8]	✓	✓	NA
Wang et al. [5]	✓	✓	✓
Mo et al. [6]	✓	✓	✓
Tian et al. [2]	✓	NA	✓
Zho et al. [11]	✓	✓	✓
Yang et al. [13]	✓	✓	✓
Liu et al. [3]	✓	✓	✓

7. Conclusion

Traditional wireless sensor networks are primarily motorized by battery, on the other hand the competence of the batteries confines the sensor network's duration. This survey discusses about charging scheduling approaches helpful in finding recharging capacity of sensor nodes in WRSN. Moreover, algorithm used, intention of priori research work are analyzed. Several parameters such as number of used sensor nodes, energy consumption rate, moving speed of sensor nodes, and time duration for charging are summarized in this research work. This review helps in findings the research gap on energy protection approaches of sensor nodes battery in WRSN.

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