International Journal of Mechatronics, Electrical and Computer Technology (IJMEC)
ISSN: 2305-0543 (Online), ISSN: 2411-6173 (Print)
Vol. 10(38), Oct. 2020, PP. 4779-4782

An on-demand scheduling scheme for mobile charger in wireless rechargeable sensor networks

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***Abstract*— Restricted energy of sensor node is a serious concern in wireless sensor networks (WSNs) which causes for loosing data or may be the whole network failure. To overcome this problem the concept of wireless energy transfer (WET) has been introduced which attract huge attention throughout academia and industry to address energy shortages or fulfil the energy requirements. The lifespan of sensor nodes can be extend using WET that restore the battery power of the sensor nodes by recharging the nodes through one or more chargers. However, recharging the nodes in the network is NP-hard problem. In this paper, we present priority scheduling algorithm (PSA) for charging wireless sensor nodes in on-demand wireless rechargeable sensor networks. The lifetime of the sensor nodes is mainly considered as the priority parameters in the proposed PSA algorithm. We simulate the proposed PSA algorithm and compare the results with existing well-known algorithms to show its out performance.**

Keywords*— WSNs, WET, First come first serve, Priority scheduling algorithm, Nearest job next with preemption

I. Introduction

The font Wireless sensor networks can be propagated in specific area and also specific operation to form a multi hop, also considered as subset of Mobile AdhocNETworks (MANET) and also self-organized networks for monitoring. There is various type of sensors such as velocity, light, thermal, IR, vision, position etc. During wireless sensor nodes conversation between each other in the sensor network and transmitting the data or sensing report to the Base Station that time sensor nodes battery power capacity spoiled more fast than other operation time. For that reason, recently wireless sensor networks have suffered enormous problem that is extended lifetime of battery power capacity of wireless sensor nodes. Nowadays wireless energy transfer (WET) has been exploited limited battery power capacity of wireless sensor nodes that's also helping to extend working life capability of wireless sensor networks. Researchers are concerned that the limited battery capacity is limited to the operation of long-range wireless sensor networks in order to conserve energy of sensor nodes to restore the strength of sensor nodes to develop network lifetime. [1], [5], [10], [11], In Wireless rechargeable sensor networks we recharge the sensor node. In the existing studies with node mobile charger (MC) we show that the first through first serve and the adjacent scheduling algorithms will be used with the nearest job. So, it can be delayed to a great extent in the charging process, and the mobile charger (MC) is not being used properly in order to overcome a limitation of the FCFS [4] and NJNP [2] [3] scheduling algorithms is used. However, it may cause delay in the charging process and here mobile charger (MC) is not proper utilized. To overcome this limitation of FCFS, a scheme has been introduced which is based on charging request in charging queue with arrival time. In FCFS, the charging request depends on chronological properties not depend on spatial properties. But in NJNP [2], [7], the sensor nodes are charging onthe basis of spatial and temporal properties which is one of the popular schemes in recharging issue. But there is some limitation in recharging process of sensor nodes. In NJNP, the time slots are useless that causes for minimizing the charging efficiency of the system [9]. In proposed charging technique, the sensor nodes are charged from mobile charger according to the proposed charging scheme. Wirelessly rechargeable of sensor nodes causes for maximizing the life of the networks [14]. Both two existing paper drawbacks are charging tour distance is capable to cover only short distance tour for recharge on needy SNs and every SN charged partially one by one in a set which cause of any needy SN can be died. In this paper introduced Priority Scheduling algorithm (PSA)for recharge the SN through the mobile charger (MC). Here use one mobile charger (MC) which charge the sensor nodes by their priority prefer as lifetime of SN. When any request come in the request queue that time, we charge the sensor node bye the PSA. If in the request queue have more than one request in the request queue, then BS schedule request queue on the basis of priority which is depend on lifetime of SN (minimum lifetime get highest priority). Where lifetime is defined (remaining energy of SN by energy consumption rate) then MC go out for charge the SN. This lowest lifetime of SN Charge first by the MC then second priority then third and so one requesting SNs are charge by this same process. If any situation is come that there is a same priority, then the MC select from those either the basis of their arrival time or FCFS scheduling in the request queue. Although in Priority scheduling algorithm there is more difficulty, but thesis is less probability to die any SNs and it is also suitable scheduling algorithm for the wireless sensor network for charge the SNs.

II. Related Works

From the last few years it is a challenge to charge the sensor nodes through WET in an on-demand charging scheme in the way which way fulfilling the all the required SNs. To solving this problem all the research, academia and

Article History:
Received Date: Apr. 14, 2020, Accepted Date: Jul. 16, 2020, Available Online: Sep. 01, 2020

industry are deeply involved. We study our project related literature we know from that there is a two classes of periodic charging scheme. A mobile charger (MC) charges repeatedly sensor nodes by follow a specific charging schedule periodically. These schemes are referred to as general scheduled schemes because they follow a defined charging schedule [6]. The problem of charging the Sensor nodes in most of the studies a period charging schemes [12], [13] known as a Traveling Salesman Problem (TSP) [8]. The periodic charging schemes are two types one is Single node charging scheme which have one MC to charge only one SN at a time [13] and another one is Multi-node charging scheme which have one MC to charge simultaneously all the SNs present in its charging queue. [12]. Second one is On-demand charging scheme that mean when a sensor node is below the threshold value and it's about to die then this sensor node requesting the base station for charging request. after that base station send an mobile charger(mc) to charge the requesting sensor nodes in WSNs as FCFS [4] and NJNP [2] scheduling algorithms is used. although using above two algorithms it has high amount of charging latency or delay in the charging process and here mobile charger (MC) is not proper utilized. To overcome this limitation of FCFS, a algorithm is presented which charging request come first in charging request queue that serve first which based on arrival time of requesting queue. In FCFS determine the incoming charging request based on temporal properties not followed spatial properties. preemption (NJNP) algorithms is presented [2]. Based on spatial and temporal properties is one type of non-deterministic methods which schedules the charging requesting queue for each SNs in NJNP. NJNP allow the mobile charger to switch location wise closer requesting node if this node sending the charging request to the base station. Although the non-deterministic schemes are more feasible, there are still some leading drawbacks that cannot be ignore [7]. From another existing literature, from the new charging technique, where multiple SNssimultaneously charges by a mobile charger(M) in WRSNs under the energy capacity limit of the mobile charger. Introduced a novel charging utility maximization problem they focus to minimize the sensor node battery power demise where the amount of utility problem increases by charging a SN is balanced to the amount of energy received by the SN [9]. There are still some drawbacks because they assume that their charging path distance minimization the problem of minimizing the travel path which is capable to cover only short distance tour for recharge on needy or requesting SNs. Another existing paper, to wireless charge sensors in a rechargeable sensor networks so that the sum of sensor lifetimes is maximized while the travel distance of the mobile charger is minimized [14]. They are assumed that each SN can be partially charged so that SN can be charged before their depletion. But there is drawback that every SN charged partially one by one in a set before charged depletion, if any needy SN required charged it has to be wait until its serial not come for that SN can be died for charged. So, it is required to develop a new technique for charging schedule which serve the energy supply to the dying SNs for that we can get less probability of dying in SNs which increase lifetime of SNs.

III. Model and Terminologies

In this section, we describe the all models and some important surmise which are necessary to design the proposed scheme

A. *Network model*

In the network model, WRSN is categories in three elements: i) a group of sensor nodes are distributed randomly in a particular area ii) a Mobile Charger (MC) and iii) a base station (BS). The BS which is assumed in the communication range of sensor nodes. BS have sufficient power as compared to sensor nodes. In the WRSN, the BS have all the information about recharging schedule for the MC. The BS also operates as a service station for MC and does provide energy supply to the MC. As a result, MC is supposed to have unlimited energy capacity. MC is an autonomous device with moving capability, can perform computations, and can communicate with the nearby devices. Each MC is responsible to charge sensor nodes falling under its charging radius only. A radio model is used in the proposed scheme which is same as [5].

B. *Charging model*

The charging model used in our paper is same as discussed in [2] which is given in equation 1.

$$P_{re} = \frac{\gamma}{dist((sn_i.M) + \delta)} \tag{1}$$

where,

$$\gamma = \frac{G_s G_r \eta}{L_p} (\frac{\lambda}{4\pi})^2 P_s \tag{2}$$

Where, Ps is source transmission power, dist.(sni, M) is the euclidean distance in between sni and MC(M), Pre is the received power of the SNs, Gs is antenna-gain at source, Gr is the antenna-gain at receiving point Lp signifies the polarization loss, η is the rectifier efficiency, λ denotes signal wavelength and δ is responsible to adjust the Friis free space equation for short distance transmission.

C. *Terminology*

Defination 1: Round (round): when all the sensor nodes send their sensed data to the base station, then it is called a Round.

Defination 2: Request queue (Rqueue): This is a queue that stores the charging request IDs of the Sensor nodes that send the charging request to the Base Station

Defination 3: Charging schedule (Chschedule): This is a row on which the mobile charger MC(M) is applied to charge the requested sensor nodes. (Ch schedule) = M → πi → πi+1 → πnq

Where πi represents the ID of SN that is provided in i^{th} number by the MC and nq.

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EISSN: 2305-0543, PISSN: 2411-6173

IV. PROPOSED WORK

Here we assumed that network operation time are (nt) is fall into a number of iterations. And we have to do following operation in each round. If any SNs falls their remaining energy below a threshold value, then this SN transmit a charging request queue to the BS for recharging. After that BS executes our proposed Priority scheduling algorithm (PSA) to determine a charging schedule for the MC and MC perform operation on the basis of the PSA which described by the BS in every round. And this priority depends on the lifetime of a SN which SN have lowest lifetime that SN get highest priority. On the basis of PSA mobile charger go to the highest priority SN and its all degree nodes (all requesting neighbor node with the range of 100 meter called where degree of that node) are charging one by one after all SNs completed its recharge, SNs acknowledge to the BS that all are completed their recharge. After that BS exclude all the charged node from that charging queue and reschedule the charging queue, send the new schedule to the MC. If in case any new SN request to BS for charge, then BS accept this request and reschedule as the basis of priority but if any node charging that time after completed MC can go to the new schedule for charging. MC have fixed amount of time for each SN that it can recharge.

A. *Implementation of priority scheduling*

Step 1: Lifetime of requesting SNs is calculated by the following equation (lifetime = remaining energy of SN / energy consumption rate of SN).

Step 2: Priority is assigned for each sensor node (SN) based on its lifetime.

Step 3: The SN having lowest lifetime gets highest priority, then the second SN having next lowest lifetime gets second highest priority and so on.

Step 4: Sort the requesting queue according to the priority, if in case two SN priority is same then sort according FCFS.

Step 5: Sorted requesting queue as a schedule for the MC, which schedule perform by the MC for charging the requesting SN.

Step 6: SN and all degree of that SNs are charged by the MC one by one after completing all are acknowledge to the BS for completed recharge.

Step 7: BS exclude all SNs which completed their charged and reschedule the charging request queue for the MC.

Step 8: If new request arrival then reschedules requesting queue for the MC but it can proceed after completing on going charging SN. step 9: Step 5 to step 8 is processing per round.

B. *Illustration*

Let us presume a WRSN scenario with 30 SNs, i.e, S=sn1, sn2, sn3, sn4, sn5, sn6, sn7, sn8, ... sn29, sn30 and an MC(M). We also assume ten (10) charging requests present in the request queue. The number of charging request nq = 10. Let us assume that all node has same energy consumption rate. Which node have less lifetime that node priority first to recharge then this SN acknowledge to the BS after that BS remove this SN from the queue. Let us assume that sn20 is the first priority to recharge, MC go to the sn20 recharge that node and also recharge all the degree of that node(sn25 → sn5) then go to the next priority sn30 recharge that node and also recharge all the degree of that node(sn21 → sn26 → sn16) then go to net priority sn3 recharge that node and also recharge all the degree of that node(sn8 → sn6). So, charging schedule of MC(M) is denoted as M → sn20 → sn25 → sn5 → sn30 → sn21 → sn26 → sn16 → sn3 → sn8 → sn6.

V. SIMULATION RESULTS

For simulations, we have run the proposed algorithm in windows 10 operating system and i5, 8th generation processor along with existing algorithms NJNP and FCFS. We have also considered few simulation parameters which are shown in table I.

TABLE I. Simulation Parameters

Area	200x200
No. of Nodes	200-500
Range	40-70
Speed of MC	5m/s
Charging range	5m
Initial energy of nodes	2J

In Fig. 1, we have shown the charging latency for varying communication range for 300 sensor nodes. It can be observed from the result that the charging latency is minimum for all the cases for the proposed algorithm compared to the existing algorithms. Also, the latency is increasing while the communication range of the sensor nodes increases. The improvement of the proposed technique is due to the instantaneous fitness function in which both the parameters, spatial and temporal factors have been considered to calculate the delay in charging On the other hand, we have shown the charging latency for varying number of sensor nodes by keeping the communication range 50 meters in Fig. 2. It is observed from the figure that the latency is always lowest for the proposed algorithm compared to FCFS and NJNP. Note that, the latency is increased for all the algorithms with increasing sensor nodes. This is because the number of increasing charging request for increasing network size.

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EISSN: 2305-0543, PISSN: 2411-6173

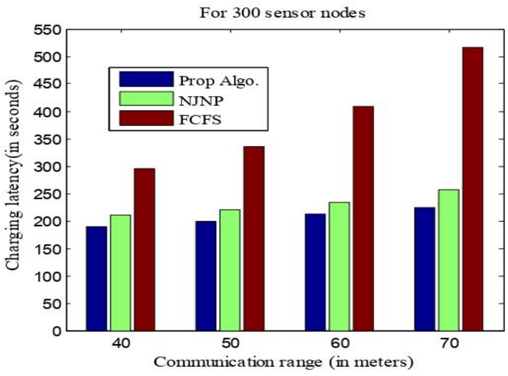

Fig. 1. Comparison in terms of charging latency for varying communication range

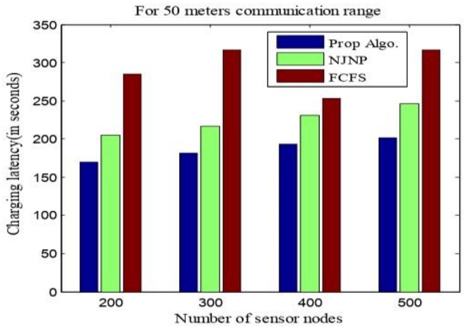

Fig. 2. Comparison in terms of charging latency for varying number of sensor nodes

VI. CONCLUSION

In this paper, we have represented a priority-based scheduling approach which minimizes the death of the sensor nodes in the WSN. In the proposed algorithm, we have considered a priority-based fitness function using spatial and temporal factors. Finally, we have simulated the proposed technique and compared the simulation results with FCFC and NJNP and simulation results shown the outperformance of the proposed algorithm. In our proposed work, we have considered single MC, however in our future attempt; we will consider the use of multiple MC to improve the results.

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EISSN: 2305-0543, PISSN: 2411-6173