International Journal of Research in Engineering, Science and Management
Volume-1, Issue-10, October-2018
www.ijresm.com | ISSN (Online): 2581-5792

Deploying Mobile Charger Ion WSN Field: A Survey

Priyanka[1], Preeti Prajapati[2]
[1]*M. Tech. Scholar, Department of ECE, N.C. College of Engineering, Panipat, India*
[2]*Assistant Professor, Department of ECE, N.C. College of Engineering, Panipat, India*

***Abstract*—Wireless energy transfer is a promising technology to prolong the lifetime of wireless sensor networks (WSNs), by employing charging vehicles to replenish energy to lifetime-critical sensors. Existing studies on sensor charging assumed that one or multiple charging vehicles being deployed. Such an assumption may have its limitation for a real sensor network. On one hand, it usually is insufficient to employ just one vehicle to charge many sensors in a large-scale sensor network due to the limited charging capacity of the vehicle or energy expirations of some sensors prior to the arrival of the charging vehicle. On the other hand, although the employment of multiple vehicles can significantly improve the charging capability, it is too costly in terms of the initial investment and maintenance costs on these vehicles. In this paper we investigated the latest work done by researchers in this filed considering the several bounds.**

***Index Terms*—Medical monitoring, Energy efficiency, QOS Network**

I. Introduction

A. Wireless Sensor Networks

Efficient design and implementation of wireless sensor networks has become a hot area of research in recent years, due to the vast potential of sensor networks to enable applications that connect the physical world to the virtual world. By networking large numbers of tiny sensor nodes, it is possible to obtain data about physical phenomena that was difficult or impossible to obtain in more conventional ways. In the coming years, as advances in micro-fabrication technology allow the cost of manufacturing sensor nodes to continue to drop, increasing deployments of wireless sensor networks are expected, with the networks eventually growing to large numbers of nodes. Potential applications for such large-scale wireless sensor networks exist in a variety of fields, including medical monitoring, environmental monitoring, surveillance, home security, military operations, and industrial machine monitoring. To understand the variety of applications that can be supported by wireless sensor networks, consider the following two examples.

Surveillance. Suppose multiple networked sensors (e.g., acoustic, seismic, video) are distributed throughout an area such as a battlefield. A surveillance application can be designed on top of this sensor network to provide information to an end-user about the environment. In such a sensor network, traffic patterns are many-to-one, where the traffic can range from raw sensor data to a high level description of what is occurring in the environment, if data processing is done locally.

The application will have some quality of service (QoS) requirements from the sensor network, such as requiring a minimum percentage sensor coverage in an area where a phenomenon is expected to occur, or requiring a maximum probability of missed detection of an event. At the same time, the network is expected to provide this quality of service for a long time (months or even years) using the limited resources of the network (e.g., sensor energy and channel bandwidth) while requiring little to no outside intervention. Meeting these goals requires careful design of both the sensor hardware and the network protocols.

Medical Monitoring. A different application domain that can make use of wireless sensor network technology can be found in the area of medical monitoring. This field ranges from monitoring patients in the hospital using wireless sensors to remove the constraints of tethering patients to big, bulky, wired monitoring devices, to monitoring patients in mass casualty situations, to monitoring people in their everyday lives to provide early detection and intervention for various types of disease. In these scenarios, the sensors vary from miniature, body-worn sensors to external sensors such as video cameras or positioning devices. This is a challenging environment in which dependable, flexible, applications must be designed using sensor data as input. Consider a personal health monitor application running on a PDA that receives and analyzes data from a number of sensors (e.g., ECG, EMG, blood pressure, blood flow). The monitor reacts to potential health risks and records health information in a local database. Considering that most sensors used by the personal health monitor will be battery-operated and use wireless communication, it is clear that this application requires networking protocols that are efficient, reliable, scalable and secure. To better understand why traditional network protocols are not suitable for these types of sensor network applications, in the remainder of this section we will categorize the unique features of sensor networks and the performance metrics with which protocols for sensor networks should be evaluated. It should be noted that sensor networks do share some commonalities with general ad hoc networks. Thus, protocol design for sensor networks must account for the properties of ad hoc networks, including the following.

- Lifetime constraints imposed by the limited energy supplies of the nodes in the network.
- Unreliable communication due to the wireless medium.
- Need for self-configuration, requiring little or no human intervention.

However, several unique features exist in wireless sensor networks that do not exist in general ad hoc networks. These features present new challenges and require modification of designs for traditional ad hoc networks. • While traditional ad hoc networks consist of network sizes on the order of 10s, sensor networks are expected to scale to sizes of 1000s. Incorporating these unique features of sensor networks into protocol design is important in order to efficiently utilize the limited resources of the network. At the same time, to keep the protocols as light-weight as possible, many designs focus on particular subsets of these criteria for different types of applications. This has led to quite a number of different protocols from the data-link layer up to the transport layer, each with the goal of allowing the network to operate autonomously for as long as possible while maintaining data channels and network processing to provide the application's required quality of service. Because sensor networks possess these unique properties, some existing performance metrics for wireless network protocols are not suitable for evaluating sensor network protocols. For example, since sensor networks are cooperative in nature, fairness becomes much less important. Depending on the application, delay may be either much more or much less important in sensor networks. Much more important to sensor network operation is energy-efficiency, which dictates network lifetime, and the high level QoS, or fidelity, that is met over the course of the network lifetime. This QoS is application-specific and can be measured a number of different ways. For example, in a typical surveillance application, it may be required that one sensor remains active within every sub region of the network, so that any intruder may be detected with high probability. In this case, QoS may be defined by the percentage of the environment that is actually covered by active sensors. In a typical tracking application, this QoS may be the expected accuracy of the target location estimation provided by the network.

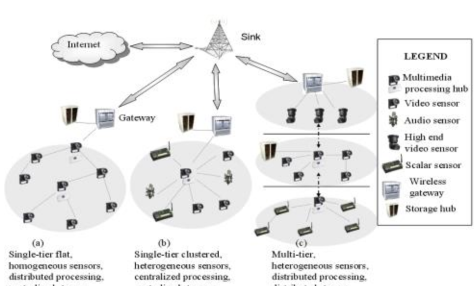

Fig. 1. Wireless sensor networking

II. Literature Survey

T. Zou et.al [1] proposed a novel charging model that a charging vehicle can carry multiple low-cost removable chargers and each charger is powered by a portable high-volume battery. When there are energy-critical sensors to be charged, the vehicle can carry the chargers to charge multiple sensors simultaneously, by placing one portable charger in the vicinity of one sensor. Under this novel charging model, we study the scheduling problem of the charging vehicle so that both the dead duration of sensors and the total travel distance of the mobile vehicle per tour are minimized. Since this problem is NP-hard, we instead propose a (3 +ε)-approximation algorithm if the residual lifetime of each sensor can be ignored; otherwise, we devise a novel heuristic algorithm, where is a given constant with $0 < \varepsilon \leq 1$. Finally, the performance is evaluated through experimental simulations. Experimental results show that the performance of the proposed algorithms are very promising.

Chi Lin et.al [2] developed a hybrid clustering charging algorithm (HCCA), which firstly constructs a network backbone based on a minimum connected dominating set built from the given network. Next, a hierarchical clustering algorithm which takes advantage of location relationship, is proposed to group nodes into clusters. Afterward, a K-means clustering algorithm is implemented to calculate the energy core set for realizing energy awareness. To further optimize the performance of HCCA, HCCA-TS is proposed to transform the energy charging process into a task splitting model. Tasks generated from HCCA are split into small tasks, which aim at reducing the charging time to enhance the charging efficiency. At last, simulations are carried out to demonstrate the merit of the schemes. Simulation results indicate that HCCA can enhance the performance in terms of reducing charging times, journey time and average charging time simultaneously. Moreover, HCCA-TS can further improve the performance of HCCA.

L. Khelladi et.al [3] proposed solution, called On-demand Multi-node Charging (OMC), features an original threshold-based tour launching (TTL) strategy, using request grouping, and a path planning algorithm based on minimizing the number of stopping points in the charging tour. Contrary to existing solutions, which focus on shortening the charging delays, OMC groups incoming charging requests and optimizes the charging tour and the mobile charger energy consumption. Although slightly increasing the waiting time before nodes are charged, this allows taking advantage of multiple simultaneous charges and also reduces node failures. At the tour planning level, a new modeling approach is used. It leverages simultaneous energy transfer to multiple nodes by maximizing the number of sensors that are charged at each stop. Given its NP-hardness, tour planning is approximated through a clique partitioning problem, which is solved using a lightweight heuristic approach.

P. Victer Paul et.al [4] explained about the various swarm based optimization algorithms such as CBA, Optimization Algorithm Based on Bacteria Behavior, GWO, ESA and KH algorithm. These existing bio inspired algorithms can be applied to solve many problems. But, algorithms based on intelligent animals like Human, Chimpanzee and Dolphin can solve the problems in an efficient and optimized way. Dolphin is one of the most intelligent animal which can solve complex problems in an efficient manner. It also provides multiple operators. Thus the bio inspired algorithm based on intelligent animals can be used to overcome the disadvantages of the previous algorithms. Yinyan Zhang et.al [5] extended a bio-inspired algorithm called the porcelain scaber algorithm (PSA) to solve constrained optimization problems, including a constrained mixed discrete-continuous nonlinear optimization problem. Our extensive experiment results based on benchmark optimization problems show that the PSA has a better performance than many existing methods or algorithms. The results indicate that the PSA is a promising algorithm for constrained optimization. Yinyan Zhang et.al [6] based on the observation of two major survival rules of a species of woodlice, i.e., porcellio scaber, we design and propose an algorithm called the porcellio scaber algorithm (PSA) for solving optimization problems, including differentiable and non-differential ones as well as the case with local optimums. Numerical results based on benchmark problems are presented to validate the efficacy of PSA.

G. Han et.al [7] proposed a grid-based joint routing and charging algorithm for IWRSNs to solve the charging problem in a proactive way. On the one hand, a new routing protocol is designed according to charging characteristics of the charger to achieve local energy balance. On the other hand, different charging times are allocated at different charging points on the basis of energy consumption caused by the routing process to achieve global energy balance. Simulation results verify superiority of our proposed algorithm in solving the balancing energy problem and improving survival rates of nodes.

A. Madhja et.al [8] enhanced the collaborative feature by forming a hierarchical charging structure. We distinguish the Chargers in two groups, the hierarchically lower Mobile Chargers which charge sensor nodes and the hierarchically higher Special Chargers which charge Mobile Chargers. We define the Coordination Decision Problem and prove that it is NP-complete. Also, we propose a new protocol for 1-D networks which we compare with a state of the art protocol. Motivated by the improvement in 1-D networks, we propose and implement four new collaborative charging protocols for 2-D networks, in order to achieve efficient charging and improve important network properties. Our protocols are either centralized or distributed, and assume different levels of network knowledge.

C.Lin et.al [9] developed a hybrid clustering charging algorithm (HCCA), which firstly constructs a network backbone based on a minimum connected dominating set built from the given network. Next, a hierarchical clustering algorithm which takes advantage of location relationship, is proposed to group nodes into clusters. Afterward, a K-means clustering algorithm is implemented to calculate the energy core set for realizing energy awareness. To further optimize the performance of HCCA, HCCA-TS is proposed to transform the energy charging process into a task splitting model. Tasks generated from HCCA are split into small tasks, which aim at reducing the charging time to enhance the charging efficiency. At last, simulations are carried out to demonstrate the merit of the schemes. Simulation results indicate that HCCA can enhance the performance in terms of reducing charging times, journey time and average charging time simultaneously. Moreover, HCCA-TS can further improve the performance of HCCA.

C.Li et.al [10] proposed a TemporAl & Distantial Priority charging scheduling algorithm (TADP), which takes both the distance between nodes and the mobile charger and the arrival time of charging requests into consideration, and quantizes these two factors step by step. TADP forms a mixed priority queue which directs mobile charger to replenish the energy for nodes. At last extensive simulations are conducted to demonstrate the advantages of TADP. Simulation results reveal that TADP can achieve better scheduling performance in guaranteeing the scheduling success of the high-priority tasks and improving stability of the system.

L.Xie et.al [11] study the interesting problem of co-locating a wireless charger (for WET) and a mobile base station on the same mobile platform – the wireless charging vehicle (WCV). The WCV travels along a preplanned path inside the sensor network. Our goal is to minimize energy consumption of the entire system while ensuring that (i) each sensor node is charged in time so that it will never run out of energy, and (ii) all data collected from the sensor nodes are relayed to the mobile base station. We develop a mathematical model for this problem (OPT-t), which is time dependent. Instead of solving OPT-t directly, we show that it is sufficient to study a special subproblem (OPT-s) which only involves space-dependent variables. Subsequently, we develop a provably near-optimal solution to OPT-s. Our results offer a solution on how to use a single mobile platform to address both WET and data collection in sensor networks.

W. Tu et.al [12] studied wireless charging strategy based on the analysis of a combination of two factors, including the residual energy of sensor nodes and the travelled distance of the charging car. Firstly, we theoretically analyze the limited size of the sensor network to match the capability of a charging car. Then, the networked factors are selected as the weights of traveling salesman problem (TSP) to design the moving path of the charging car. Thirdly, the charging time of each sensor node is computed based on the linear programming problem for the charging car. Finally, a charging period for the network is studied. The experimental results show that the proposed approach can significantly maximize the lifetime of the wireless sensor network.

Z. Chen et.al [13] presented a mobile charging policy for perpetual operation of large-scale wireless rechargeable sensor networks (WRSNs). In these networks, dedicated mobile chargers (MCs) move throughout the network and supply energy for power-limited sensors. The MCs not only charge the sensors but also charge each other. We develop a hop-based mobile charging policy (HMCP) minimizing the number of required MCs. The HMCP considers both the sensors' unbalanced energy consumption rate and the MCs' limited energy capacity. The minimum number of MCs is is formulated as an integer programming problem. We first verify the existence of an optimal solution, and later design an algorithm to obtain the optimal solution. Based on HMCP, we propose HMCP+ for the case that only one MC can recharge sensors in each region. HMCP+ plans MCs' paths to decrease mobile energy consumption by MCs. Finally, performance of the proposed polices is validated through the simulation results.

F. Chen et.al [14] formulated the problem of delay minimization as a Traveling Salesman Problem with Speed Variations (TSP-SV) which jointly considers both charging and moving delay. We further solve the problem using linear programming to generate (1) the moving path of the charger, (2) the moving speed variations on the path and (3) the stay time at each charging spot. We also discuss possible ways to reduce the calculation complexity. Extensive simulation experiments are conducted to study the delay performance under various scenarios. The results demonstrate that our proposed method achieves much less completion time compared to the state-of-the-art work.

H. Dai et.al [15] investigated the minimum MCs problem (MinMCP) for two-dimensional (2D) wireless rechargeable sensor networks (WRSNs), i.e., how to find the minimum number of energy-constrained MCs and design their recharging routes in a 2D WRSN such that each sensor node in the network maintains continuous work, assuming that the energy consumption rate for all sensor nodes are identical. By reduction from the Distance Constrained Vehicle Routing Problem (DVRP), we prove that MinMCP is NP-hard. Then we propose approximation algorithms for this problem. Finally, we conduct extensive simulations to validate the effectiveness of our algorithms.

S. Nikoletseas et.al [16] studied how to efficiently transfer energy wirelessly in populations of battery-limited devices, towards prolonging their lifetime. In contrast to the state-of-the-art, we assume a much weaker population of distributed devices which are exchanging energy in a "peer to peer" manner with each other, without any special charger nodes. It addressed a quite general case of diverse energy levels and priorities in the network and study the problem of how the system can efficiently reach a weighted energy balance state distributive, under both loss-less and lossy power transfer assumptions. Three protocols are designed, analyzed and evaluated, achieving different performance trade-offs between energy balance quality, convergence time and energy efficiency.

Joselin et.al [17] proposed a novel Energy Efficient Connected Coverage (EECC) scheduling to maximize the lifetime of the WSN. The EECC adheres to Quality of Service (QoS) metrics such as remaining energy, coverage and connectivity. In EECC the sensor which doesn't contribute to coverage will act as a relay node to reduce the burden of the sensing node. The sensing node senses the target whereas the relaying node communicates the sensory information to the sink. The EECC forms non-disjoint cover sets using remaining energy, coverage and connectivity of every sensor. The proposed EECC outperforms similar scheduling algorithms found in the literature in an energy efficient way with the short execution time. Through simulations the constancy of EECC in extending the lifetime of WSN is confirmed.

G. Hang et.al [18] proposed a Location Aided Controlled Spraying (LACS) routing algorithm to deal with the challenging issues in DTN routing. Only the routing information carried by the contacted nodes is needed in this algorithm, and there is no need for global networks knowledge and hardware support. The routing process is divided into two stages, i.e., controlled spraying routing stage and single-copy routing stage. The maximum transfer throughput of the contact is checked before each message is forwarded. During the controlled spraying stage, the current node adjusts spraying strategy according to the encounter angle of the contact nodes. During the single-copy stage, a location prediction model based on the semi-Markov process (SMP) is introduced, and the node's behaviors can be captured both in the temporal and spatial domains with this model. The current node predicts the destination node's location, and then decides whether to forward the message to target node based on the time used for meeting the destination node. Simulation results show that the proposed algorithm can achieve better performance than the traditional routing schemes of DTNs in terms of delivery ratio, network overhead and transmission delay under both random node movement model and realistic trace scenario.

P.J.Shete et.al [19] addressed the goal of achieving higher throughput capacity in multi-hop wireless ad hoc networks than estimated by capacity scaling laws of Gupta and Kumar (2000) [1]. By exploiting the implications pointed in earlier research, a cross-layer design based channel quality aware rate adaptive MAC algorithm CQRA-MAC is proposed to achieve this goal. CQRA-MAC dynamically switches the MAC transmission rate on the basis of channel quality experienced at the physical layer. The proposed algorithm is implemented by modifying the IEEE 802.11 model of Qualnet 4.5 simulator and its performance is evaluated in static and mobile network scenarios following the random access transport capacity approach. Experimental results show that CQRA-MAC achieves higher throughput than DCF and ARF.

J. Li et.al [20] presented a data gathering scheme, called mobility assisted data gathering with solar irradiance awareness (MADG-SIA), where sensor nodes are clustered around cluster heads that adaptively change their positions according to solar irradiance, and the sensing data are forwarded to the data sink by these cluster heads working as data aggregation points. We evaluate the performance of the proposed scheme by extensive simulations and the results show that MADG-SIA provides significant improvement in terms of balancing energy consumption and the amount data gathered compared to previous work.

TABLE I
REVIEW

Techniques	Author & Reference	Year	Advantages	Limitations
Heuristic algorithm to move the single vehicle in the wsn field	Tao Zou, Wenzheng Xu, Weifa Liang, Jian Peng, Yiqiao Cai, Tian Wang [1]	2017	Longest and average sensor dead durations are less than other existing algorithms	Heuristic algorithm is designed without any prior base description
Hybrid of k means clustering and tabu search	Chi Lin, Guowei Wu, Mohammad S. Obaidat, Chang Wu Yu [2]	2016	Reduce charging time, shorten travelling time	Charging scheduling scheme for large number of nodes is a challenge
Groups incoming charging request and plan tour using heuristic optimisation	Lyes Khelladi, Djamel Djenouri, Michele Rossi, Nadjib Badache [3]	2017	Less complex and minimum number of stopping stops of charging vehicle	Waiting time is introduced after charging
Survey of bio inspired optimisation algorithms	Pazhaniraja, N., P. Victer Paul, G P Roja, K. Shanmugapriya and Banwait Sonali [4]	2017	Optimization based on intelligent animals like human, dolphin etc. are good than others	Very few papers are considered for survey
Porcellio scaber algorithm	Yinyan Zhang, Shuai Li, Hongliang Guo [5]	2017	Latest best optimisation algorithm	Not tested for multi objective problems
Porcellio scaber algorithm	Zhang, Yinyan and Shuai Li [6]	2017	Latest best optimisation algorithm	Tested only on benchmark functions
Grid based routing and charging algoritm	Guangjie Han, Aihua Qian, Jinfang Jiang, Ning Sun, Li Liu [7]	2016	The routing protocol is designed based on charging characteristics within the charging grids, which brings energy balance in local grid area	Less energy efficient
Coordinated multiple chargers are used	Adelina Madhja, Sotiris Nikoletseas, Theofanis P. Raptis [8]	2016	Easily handles communication overhead	Uniform network is considered
Clustering and TS optimisation	Chi Lin, Guowei Wu, Mohammad S. Obaidat, Chang Wu Yu [9]	2016	Reduce charging time, shorten travelling time	Charging scheduling scheme for large number of nodes is a challenge
temporal and distantial priority scheduling for charging	Chi Lin, Zhiyuan Wang, Ding Han, Youkun Wu, Chang Wu Yu, Guowei Wu [10]	2016	Higher throughput and shorter response time	Fails in collaborative charging model
Mathematical formulation is developed	L. Xie [11]	2015	Near optimal solution is developed	Very computational complex and preplanned path is considered. If optimization of path is to be considered, problem space will increase
Based on travelling salesman problem	Weijian Tu , Xianghua Xu, Tingcong Ye and Zongmao Cheng [12]	2017	Considered nodes residual energy and travelling time	NA
Hop based mobile charging policy	Zhigang Chen, Xuehan Chen, Deyu Zhang, Feng Zeng [13]	2017	Reduces the required mobile chargers and also their travelling time	Same data gathering rate and uniform network is considered
Formulated TSP based on speed variations	Feiyu Chen, Zhiwei Zhao, Geyong Min, Weifeng Gao, Jinjun Chen, Hancong Duan, Po Yang [14]	2018	Reduces the delay in charging	Multiple chargers and charging deadline are not considered
Approximation algorithm for this problem	Aipeng Dai, Xiaobing Wu, Guihai Chen, Lijie Xu, Shan Lin [15]	2014	Performance improvement	Bounds are not considered
Mathematical formulation for weighted energy balance state of mobile charger	Sotiris Nikoletseas, Theofanis P. Raptis, Christoforos Raptopoulos [16]	2017	Diverse energy levels of nodes are considered	NA
Energy efficient connected coverage (EECC)	J. Roselin, P. Latha, S. Benitta [17]	2017	Improves remaining energy and coverage and connectivity	Same kind of sensors are considered
Semi-Markov Process	Hang Guo, Xingwei Wang, Hui Cheng, Min Huang [18]	2017	Performed well in random movement model and realistic trace	NA

III. Conclusion

Limited battery in WSN nodes is solved by a moving charging vehicle in the field. Multiple charging vehicles can't be moved due to budget constraint. Several researchers worked on the problem of minimizing the travelling time and waiting time considering the maximum number of alive nodes in the network. The base of almost all methods is that problem is NP hard problem and iterative method with constraints is the only way to solve this. Travelling salesman problem is the first method which could solve it but due to real time reach and charging at rapid rate is also added as constraint in it.

References

[1] Tao Zou, Wenzheng Xu, Weifa Liang, Jian Peng, Yiqiao Cai, Tian Wang, "Improving charging capacity for wireless sensor networks by deploying one mobile vehicle with multiple removable chargers", Ad Hoc Networks, Volume 63, 2017.

[2] Chi Lin, Guowei Wu, Mohammad S. Obaidat, Chang Wu Yu," Clustering and splitting charging algorithms for large scaled wireless rechargeable sensor networks", Journal of Systems and Software, Volume 113, 2016.

[3] Lyes Khelladi, Djamel Djenouri, Michele Rossi, Nadjib Badache, "Efficient on-demand multi-node charging techniques for wireless sensor networks", Computer Communications, Volume 101, 2017.

[4] Pazhaniraja, N., P. Victer Paul, G P Roja, K. Shanmugapriya and Banwait Sonali. "A study on recent bio-inspired optimization algorithms." *2017 Fourth International Conference on Signal Processing, Communication and Networking (ICSCN)* (2017).

[5] Yinyan Zhang, Shuai Li, Hongliang Guo, "Porcellio scaber algorithm (PSA) for solving constrained optimization problems:, MATEC Web Conf. 139 00033 (2017).

[6] Zhang, Yinyan and Shuai Li. "PSA: A novel optimization algorithm based on survival rules of porcellio scaber." *CoRR* abs/1709.09840 (2017).

[7] Guangjie Han, Aihua Qian, Jinfang Jiang, Ning Sun, Li Liu, "A grid-based joint routing and charging algorithm for industrial wireless rechargeable sensor networks", Computer Networks, Volume 101, 2016.

[8] Adelina Madhja, Sotiris Nikoletseas, Theofanis P. Raptis, "Hierarchical, collaborative wireless energy transfer in sensor networks with multiple Mobile Chargers", Computer Networks, Volume 97, 2016.

[9] Chi Lin, Guowei Wu, Mohammad S. Obaidat, Chang Wu Yu, "Clustering and splitting charging algorithms for large scaled wireless rechargeable sensor networks", Journal of Systems and Software, Volume 113, 2016

[10] Chi Lin, Zhiyuan Wang, Ding Han, Youkun Wu, Chang Wu Yu, Guowei Wu, "TADP: Enabling temporal and distantial priority scheduling for on-demand charging architecture in wireless rechargeable sensor Networks", Journal of Systems Architecture, Volume 70, 2016

[11] L. Xie *et al*., "A Mobile Platform for Wireless Charging and Data Collection in Sensor Networks," in *IEEE Journal on Selected Areas in Communications*, vol. 33, no. 8, pp. 1521-1533, Aug. 2015.

[12] Weijian Tu , Xianghua Xu, Tingcong Ye and Zongmao Cheng," A Study on Wireless Charging for Prolonging the Lifetime of Wireless Sensor Networks", Sensors 2017.

[13] Zhigang Chen, Xuehan Chen, Deyu Zhang, Feng Zeng, Collaborative mobile charging policy for perpetual operation in large-scale wireless rechargeable sensor networks, Neurocomputing, Volume 270, 2017.

[14] Feiyu Chen, Zhiwei Zhao, Geyong Min, Weifeng Gao, Jinjun Chen, Hancong Duan, Po Yang, Speed control of mobile chargers serving wireless rechargeable networks, Future Generation Computer Systems, Volume 80, 2018.

[15] Haipeng Dai, Xiaobing Wu, Guihai Chen, Lijie Xu, Shan Lin, Minimizing the number of mobile chargers for large-scale wireless rechargeable sensor networks, Computer Communications, Volume 46, 2014.

[16] Sotiris Nikoletseas, Theofanis P. Raptis, Christoforos Raptopoulos, Wireless charging for weighted energy balance in populations of mobile peers, Ad Hoc Networks, Volume 60, 2017.

[17] J. Roselin, P. Latha, S. Benitta, Maximizing the wireless sensor networks lifetime through energy efficient connected coverage, Ad Hoc Networks, Volume 62, 2017.

[18] Hang Guo, Xingwei Wang, Hui Cheng, Min Huang, A location aided controlled spraying routing algorithm for Delay Tolerant Networks, Ad Hoc Networks, Volume 66, 2017.

[19] Prasanna J. Shete, R.N. Awale, Satish Y. Ket, Channel quality aware cross-layer design based rate adaptive MAC for improving the throughput capacity of multi-hop ad hoc networks, Ad Hoc Networks, Volume 63, 2017.

[20] Ji Li, Yuanyuan Yang, Cong Wang, Mobility assisted data gathering with solar irradiance awareness in heterogeneous energy replenishable wireless sensor networks, Computer Communications, Volume 69, 2015.