Editorial

ICSES Transactions on Computer Networks and Communications (ITCNC)

Journal Homepage: www.i-cses.com/itcnc

Compressed Sensing based Data Collection Algorithms in Wireless Adhoc/Mobile Sensor Networks

Minh T. Nguyen [1,*]

[1] Thai Nguyen University of Technology, Thai Nguyen City, Viet Nam

* Corresponding Author: nguyentuanminh@tnut.edu.vn tuanminh.nguyen@okstate.edu

I. INTRODUCTION

WIRELESS sensor networks (WSNs) have found numerous uses in both military and civilian applications [1]. Sensors in WSNs are usually randomly dropped/deployed in a sensing area that needs to be monitored. They are often deployed in harsh conditions without maintenance or renewable power supply. Therefore, the connections and operation of these networks rely on these small and inexpensive devices under a severe energy constraint. Saving energy in data collection in such networks is always a critical problem that directly impacts the network lifetime. Mobile sensor networks (MSNs) facilitate many existing application areas such as monitoring (temperature, humidity, acoustic, vibration) or detecting targets or special events (intruders, chemical leak, vehicle passing) in which mobility plays a key role in the execution of the applications [2]. The networks are combined from sensors, vehicles or robots, control algorithms and other dynamic factors which depend on specific purposes or application scenarios [3, 4].

Energy efficiency is the most important issue for either WSNs or MSNs [5, 6, 7]. There are many existing data collection algorithms that have been exploited in order to reduce the total power consumption for such networks [8, 9, 10]. The proposed methods are different due to different network structures, different functions or status of sensors in the networks.

In traditional WSNs, all static sensors could use different routing methods such as random walk, cluster-based, tree-based, multi-hop routing, etc. to forward their sensing data to the base-station (BS). Each method has different point of advantages since there is a trade-off between some characteristics, sensing range, transmission distance, budget, latency, data processing time [11, 12, 13, 14].

Mobile base-stations have been used to collect data from static sensor nodes [15, 16, 17, 18]. The networks could use one mobile sensor as a mobile BS to be able to collect all data and finally transmit directly the collected data from the network to a data processing center [15]. The mobile sensor can follow random routes or predefined routes to collect data [16]. In order to reduce the burden falling on the only one mobile sensor, multiple-agents are deployed to collect data from static sensors [17, 18]. The mobile ones can share the sensing field to be observed.

Using all mobile sensors which are attached into vehicles or mobile robots could be more active since the mobile ones can reach all the points of interest in the sensing field that static ones cannot cover [19, 20]. The sensors collect data from the areas they can cover and finally send their own data to the BS or data processing center. In order to avoid missing data, distributed agents are deployed. Each mobile sensor is capable as a BS to be able to collect all data itself. In this case, if the others could be destroyed by enemies or some technical problems, a distributed mobile sensor (robot) can still build a full scalar map [21, 22].

Emerging techniques have been utilized to improve data collection problems in such networks. Compressive sensing (CS) [23, 24] provides a data processing tool that can measure a small number of measurements to be able to recover a huge amount of data. The number of CS measurements is much smaller than the number of sample that Nyquist/Shannon would allow. This significantly reduces the total power consumption for communication in the networks. There exist some data collection methods utilizing CS for collecting data in the networks mentioned above [25, 26, 27, 28, 29].

Some control algorithms have been deployed to lead mobile sensors or robots to observe the sensing fields.

 — ISSN: 2588-5847
Website: www.i-cses.com — E-mail: info@i-cses.com

Flocking control algorithms [30] could lead the robots to avoid obstacles [31]. Sensors can exploit the random mobility to sample data with random direction, random velocities [32, 33].

This article reviews data collection methods following energy-efficient approach and points out emerging topics to be exploited for research work in either WSN or MSNs utilizing CS.

II. Energy Efficient Approach

Saving energy in WSNs is always a critical issue. Sensor nodes are extremely resource constrained such as short communication and sensing ranges, the limited amount of memory, and limited computational capacity. The less the total power consumption the longer the service they can contribute. There are some problems that need to be solved in our project as follows.

A. Data Collection Methods Utilizing CS in General

CS techniques work well with sensing data to be able to reduce data transmitting among the networks. The requisite conditions to be able to apply CS are that the data should be correlated or compressible. The networks deploying CS can reduce a significant amount of data to be sent to the BS. Each CS measurement is a linear combination of sensor readings. Depending on a chosen measurement matrix, all sensors or just a certain number of random sensors contribute to create a CS measurement. And, only certain number of CS measurements need to be sent to the BS to be able to reconstruct all sensing data from the networks.

B. Balance Power Consumption Among Sensors with Data Gathering Methods

There are some ways for sensors to transmit sensor readings to the base-station (BS). Sensors can transmit directly their own data to the BS, but they have to deal with the huge power consumption for the long distances. Muti-hop routing could be used to solve the energy burden but it can initiate other problems relating to latency, computation capacity, node failure tolerant, and especially unbalanced power consumption among sensors. Some common routing techniques have not completely solved the problems, such as tree-based, cluster-based, gossip-based, random walk routing, etc. New methods are expected to shorten data transmitting distances from sensors to the BS and to balance power consumption in the networks. In addition, some optimal points should be suggested in order to minimize the total power consumption.

C. Exploit Sensor Mapping or Indexing in WSNs

As mentioned, the sensing data is often highly correlated. All sensor readings that correspond to sensors in such networks need to be indexed and arranged to be able to apply CS. Based on this point, CS techniques perform with higher quality to recover data. Indexing sensors or points of interest (POI) in sensing areas is very important while collecting sensor readings. This point could be used to evaluate the received data at the BS. In addition, mapping POIs combines routing methods could increase the network performance.

D. Use Sleeping Schedules for Sensors

In order to reduce power consumption for the networks and to balance power consumption among sensors, sleeping schedules can be exploited. CS sampling allows to collect data from a few random sensors each time to create one CS measurement. Based on this point, these methods should both guarantee the information that needs to be collected in the networks and leave a certain number of sensors in inactive status for saving energy.

E. Exploit Control Algorithms for Mobile Sensors

The most advantage of mobile sensor networks (MSNs) is that mobile sensors can visit all most POIs that static sensors cannot reach. So, control algorithms to lead the sensors in the sensing field to be observed in order to reduce not only sensor motion but also power consumption for communicating between sensors. Some existing algorithms, such as flocking control algorithms or random mobility algorithms with random directions and random velocities could be upgraded to be suitable with service requirements in MSNs. In addition, the mobility of sensors can be exploited for the CS sampling to create CS measurements at each mobile sensor or mobile robots. Note that the greater the number of CS measurements, the higher the quality of data reconstruction at a BS.

F. Collaborate Between Mobile Sensors

Depending on specific observation purposes, mobile sensors collaborate to each other to exchange or to relay sensing data, and finally forward all data to a data processing center. Distributed sensors can communicate to their own neighbors to pass their information to the others. They have capacity of computation and power to be able to work independently as a base-station (BS) or a data processing center. This can support to keep all received information from the sensing areas safely if the mobile robots work in battle fields. When these mobile sensors collaborate, they can share CS measurements to each other. And each distributed one can reconstruct data to build a full map itself.

G. Other Topics

Propagation models for mobile sensor/robots should be considered while applying CS. Since the mobile sensors move around in sensing areas, the propagation models for them is much more complicated compared to the propagation ones in static sensor networks. Fading models should be considered to guarantee data communication problems in such networks. The sensing data could be lost due to refraction, reflection, scattering and other problems. The communication budget should be analyzed in different cases of propagations in order keep the quality of received data as acceptable.

In order to save wireless frequency bands which is a very limited resource. Cognitive radio (CR) could be applied for sensors in such networks. CR can support primary and secondary sensor nodes opportunities to share communication channels to increase the network capacity or to use the channels effectively.

Capacity in either WSNs or MSNs is a very important point to satisfy the increasing demand of services. Since sensors could measure different kinds of data, temperature, humidity or image, they need more capacity for storage, processing, and communicating. In order to upgrade the networks, not only device problems but also embedded technologies and communication methods should be considered.

Security in WSNs is considered seriously since many applications are integrated and connected to the internet. The goal of security services in WSNs is to protect the information and resources from attacks and misbehavior. Some problems, such as public key and private key operations, cryptography algorithms, management protocols, secure routing protocols, etc. should be considered in order to protect either the networks or the sensing data.

Coding and programming individual sensor nodes in WSNs are extremely challenging since the nodes are small, inexpensive with low computational capacity. There are many challenges in designing efficient wireless sensor networks. Performance of wireless communication systems is severely affected by high path loss, fading, and interference. Furthermore, change in network topology due to mobility complicates neighbor discovery, routing, and scheduling. A coding strategy over networks is necessary to provide both reliability and efficiency when applied to WSNs in the presence of such obstacles.

Reducing the complexity for both WSNs and MSNs should be considered. This problem includes the complexity of coding/decoding, signal processing, data gathering, information detecting, etc. The problems relate to almost the aspects presenting in both networks. The problems need to be solved to improve the networks' performance in general.

III. Conclusion

This paper review the necessity of saving energy in both WSNs and MSNs for many applications different fields. Data collection methods utilizing CS are focused for reducing power consumption in such networks. The paper also points out some emerging to topics to be exploited to improve the network performance. The future work would be addressed with real systems and more trends for upgrading the networks.

With Regards
Minh T. Nguyen, PhD
May 23, 2018

Minh T. Nguyen received his B.S., M.S. and PhD degrees in Electrical Engineering from Hanoi University of Communication and Transport, Hanoi, Vietnam in 2001, Military Technical Academy, Hanoi, Vietnam in 2007, Oklahoma State University, Stillwater, OK, USA, in 2015, respectively. Dr. Minh Nguyen is currently the director of International training and Cooperation center at Thai Nguyen University of Technology, Vietnam, and also the director of Advanced Wireless Communication Networks (AWCN) Lab. He has interest and expertise in a variety of research topics in the communications, networking, and signal processing areas, especially compressive sensing, and wireless/mobile sensor networks. He serves as technical reviewers for several prestigious journals and international conferences. He also serves as Editors for Wireless Communication and Mobile Computing journal and ICSES Transactions on Computer Networks and Communications.

References

[1] J. Yick, B. Mukherjee, and D. Ghosal, "Wireless sensor network survey," Computer Networks, vol. 52, no. 12, pp. 2292–2330, Aug. 2008.

[2] B. Liu, O. Dousse, P. Nain, and D. Towsley, "Dynamic Coverage of Mobile Sensor Networks," IEEE Transactions on Parallel and Distributed Systems, vol. 24, no. 2, pp. 301–311, Feb. 2013.

[3] I. I. Hussein and D. M. Stipanovic, "Effective Coverage Control for Mobile Sensor Networks with Guaranteed Collision Avoidance," IEEE Transactions on Control Systems Technology, vol. 15, no. 4, pp. 642–657, Jul. 2007.

[4] M. T. Nguyen, H. M. La, and K. A. Teague, "Compressive and collaborative mobile sensing for scalar field mapping in robotic networks," 2015 53rd Annual Allerton Conference on Communication, Control, and Computing (Allerton), Sep. 2015.

[5] T. Rault, A. Bouabdallah, and Y. Challal, “Energy efficiency in wireless sensor networks: A top-down survey,” Computer Networks, vol. 67, pp. 104–122, Jul. 2014.

[6] S. R. Gandham, M. Dawande, R. Prakash, and S. Venkatesan, “Energy efficient schemes for wireless sensor networks with multiple mobile base stations,” GLOBECOM ’03. IEEE Global Telecommunications Conference (IEEE Cat. No.03CH37489).

[7] N. Heo and P. K. Varshney, “Energy-Efficient Deployment of Intelligent Mobile Sensor Networks,” IEEE Transactions on Systems, Man, and Cybernetics - Part A: Systems and Humans, vol. 35, no. 1, pp. 78–92, Jan. 2005.

[8] A. Mainwaring, D. Culler, J. Polastre, R. Szewczyk, and J. Anderson, “Wireless sensor networks for habitat monitoring,” Proceedings of the 1st ACM international workshop on Wireless sensor networks and applications - WSNA ’02, 2002.

[9] E. J. Duarte-Melo and M. Liu, “Data-gathering wireless sensor networks: organization and capacity,” Computer Networks, vol. 43, no. 4, pp. 519–537, Nov. 2003.

[10] M. Zhong and C. G. Cassandras, “Distributed Coverage Control and Data Collection with Mobile Sensor Networks,” IEEE Transactions on Automatic Control, vol. 56, no. 10, pp. 2445–2455, Oct. 2011.

[11] A. A. Abbasi and M. Younis, “A survey on clustering algorithms for wireless sensor networks,” Computer Communications, vol. 30, no. 14–15, pp. 2826–2841, Oct. 2007.

[12] N. Al-Karaki and A. E. Kamal, “Routing techniques in wireless sensor networks: a survey,” IEEE Wireless Communications, vol. 11, no. 6, pp. 6–28, Dec. 2004.

[13] M. T. Nguyen, K. A. Teague, and N. Rahnavard, “CCS: Energy-efficient data collection in clustered wireless sensor networks utilizing block-wise compressive sensing,” Computer Networks, vol. 106, pp. 171–185, Sep. 2016.

[14] M. T. Nguyen and K. A. Teague, “Compressive sensing based random walk routing in wireless sensor networks,” Ad Hoc Networks, vol. 54, pp. 99–110, Jan. 2017.

[15] M. Di Francesco, S. K. Das, and G. Anastasi, “Data Collection in Wireless Sensor Networks with Mobile Elements,” ACM Transactions on Sensor Networks, vol. 8, no. 1, pp. 1–31, Aug. 2011.

[16] C. Tunca, S. Isik, M. Y. Donmez, and C. Ersoy, “Distributed Mobile Sink Routing for Wireless Sensor Networks: A Survey,” IEEE Communications Surveys & Tutorials, vol. 16, no. 2, pp. 877–897, 2014.

[17] M. T. Nguyen and K. A. Teague, “Compressive and cooperative sensing in distributed mobile sensor networks,” MILCOM 2015 - 2015 IEEE Military Communications Conference, Oct. 2015.

[18] M. T. Nguyen and K. A. Teague, “Random sampling in collaborative and distributed mobile sensor networks utilizing compressive sensing for scalar field mapping,” 2015 10th System of Systems Engineering Conference (SoSE), May 2015.

[19] J. Choi, S. Oh, and R. Horowitz, “Distributed learning and cooperative control for multi-agent systems,” Automatica, vol. 45, no. 12, pp. 2802–2814, Dec. 2009.

[20] F. Bullo, J. Cortés, and S. Martínez, “Distributed control of robotic networks: a mathematical approach to motion coordination algorithms” Princeton University Press, Jan. 2009.

[21] H. M. La, Weihua Sheng, and Jiming Chen, “Cooperative and Active Sensing in Mobile Sensor Networks for Scalar Field Mapping,” IEEE Transactions on Systems, Man, and Cybernetics: Systems, vol. 45, no. 1, pp. 1–12, Jan. 2015.

[22] M. T. Nguyen, H. M. La, and K. A. Teague, “Collaborative and Compressed Mobile Sensing for Data Collection in Distributed Robotic Networks,” IEEE Transactions on Control of Network Systems, pp. 1–1, 2017.

[23] D. L. Donoho, “Compressed sensing,” IEEE Transactions on Information Theory, vol. 52, no. 4, pp. 1289–1306, Apr. 2006.

[24] E. J. Candes, J. Romberg, and T. Tao, “Robust uncertainty principles: exact signal reconstruction from highly incomplete frequency information,” IEEE Transactions on Information Theory, vol. 52, no. 2, pp. 489–509, Feb. 2006.

[25] C. Luo, F. Wu, J. Sun, and C. W. Chen, “Compressive data gathering for large-scale wireless sensor networks,” Proceedings of the 15th annual international conference on Mobile computing and networking - MobiCom ’09, 2009.

[26] L. Xiang, J. Luo, and A. Vasilakos, “Compressed data aggregation for energy efficient wireless sensor networks,” 2011 8th Annual IEEE Communications Society Conference on Sensor, Mesh and Ad Hoc Communications and Networks, Jun. 2011.

[27] M. T. Nguyen and K. A. Teague, “Tree-based energy-efficient data gathering in wireless sensor networks deploying compressive sensing,” 2014 23rd Wireless and Optical Communication Conference (WOCC), May 2014.

[28] M. T. Nguyen, “Minimizing energy consumption in random walk routing for Wireless Sensor Networks utilizing Compressed Sensing,” 2013 8th International Conference on System of Systems Engineering, Jun. 2013.

[29] Y. Mostofi, “Cooperative Wireless-Based Obstacle/Object Mapping and See-Through Capabilities in Robotic Networks,” IEEE Transactions on Mobile Computing, vol. 12, no. 5, pp. 817–829, May 2013.

[30] R. Olfati-Saber, “Flocking for Multi-Agent Dynamic Systems: Algorithms and Theory,” IEEE Transactions on Automatic Control, vol. 51, no. 3, pp. 401–420, Mar. 2006.

[31] H. M. La and Weihua Sheng, “Flocking control of a mobile sensor network to track and observe a moving target,” 2009 IEEE International Conference on Robotics and Automation, May 2009.

[32] D. Jea, A. Somasundara, and M. Srivastava, “Multiple Controlled Mobile Elements (Data Mules) for Data Collection in Sensor Networks,” Lecture Notes in Computer Science, pp. 244–257, 2005.

[33] M. T. Nguyen, K. A. Teague, and S. Bui, “Compressive wireless mobile sensing for data collection in sensor networks,” 2016 International Conference on Advanced Technologies for Communications (ATC), Oct. 2016.