Editorial

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Sleeping Schedules for Energy-Efficiency Purpose in Wireless Sensor Network: Benefits and Challenges

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Abstract—Sleeping schedules have been considered as one of the energy-efficient methods to reduce energy consumption in wireless sensor networks (WSNs). In such networks, a certain number of sensors are awake to monitor or to observe sensing data while the rest can fall into idle status to save battery energy. The sensors take turns to be awake or idle as scheduled. This benefits the networks at some points but also have some challenges that need to be improved. This article analyzes those points and also suggests a combination between the schedules and a data processing technique, called compressed sensing, that could improve the networks for more energy saving. This also provides promising research points for further explorations in the fields.

Keywords—Wireless sensor network; energy efficiency; sleeping schedule; data transmission; compressed sensing.

I. Introduction

WIRELESS sensor networks (WSNs) have been well exploited in many different fields, either supporting in civil applications or in military applications [1]. Sensors are used to detect events or to collect sensing data from an area to be sent to a data processing center, usually called base-station (BS). With detection function, sensors have some capacity to analyze data and to decide the event to be able to send some warnings to the BS. They can cooperate with some others around the event and decide together before sending in the monitoring results. For example, sensors used for detecting fire in a forest need to cooperate to others around a phenomenon to be able to decide more exactly if the phenomenon is a fire based on smoke, heat, light detecting sensors. In other kinds of application, sensors need to collect raw sensing data to be sent to the BS. The sensing data could be used for building scalar maps for observation purposes. In this case, WSNs usually send whole sending data from the networks to the BS that consume a lot of energy from all sensors, especially from the relaying ones.

Saving energy consumption for WSNs is always a critical problem. Since sensors are dropped from airplanes without any power supplies to recharge, they only keep working until all the batteries deplete. The networks is also disconnected if some relaying sensors out of battery. There are many energy-efficient methods employed to reduce energy consumption for either the networks or each sensor to prolong the network lifetime.

Sleeping schedules for WSNs have been employed to be able to save energy [2, 3]. In general, some sensors are chosen to be awake while the others can fall asleep for energy saving purposes. In that case, the sensor networks are deployed in an ad hoc fashion, with individual nodes remaining largely inactive for long periods of time, but then becoming suddenly active when something is detected. Different kinds of sleeping schedules support different networks with the same purpose. For example, some support a data forwarding interruption problem in tree based routing protocol [4], while the others support cluster based network [5] or many different topologies. The schedules are chosen to reduce the energy consumption of sensor nodes thus increasing significantly the network lifetime.

II. Analysis of Benefits and Challenges

Sleeping schedules provide significant energy saving for WSNs. It depends on the rate of active sensors out of all sensors deploying in the sensing field. It is obvious that the number of sleeping sensors is almost linearly proportional to the amount of energy saving. Based on some different wake-up schedules, sleeping sensors can wake up as programmed or they can wake up when some event phenomenons come up. In the real world, reducing the number of active sensors initiates some problems. First, when the active sensors far away from each other, they need longer communication range to get connected as a network. This requires more energy consumption since the transmitting distances among sensors increase. Second, a small number of sensor may not provide enough the quality of service. A few sensors may not provide enough trustable information in detecting purposes.

There would be a trade-off between the sensor communication range (R_c) and the number of active sensors. If this number is small, it means that we need to increase the communication range to maintain the network connected. So, if we consider the rate of the number of active sensors out of the whole sensors and the range, we can optimize the total energy consumption in WSNs. In addition, active sensors are often chosen randomly among the whole sensors. This could combine with some techniques to improve the network lifetime that is mention in the next section.

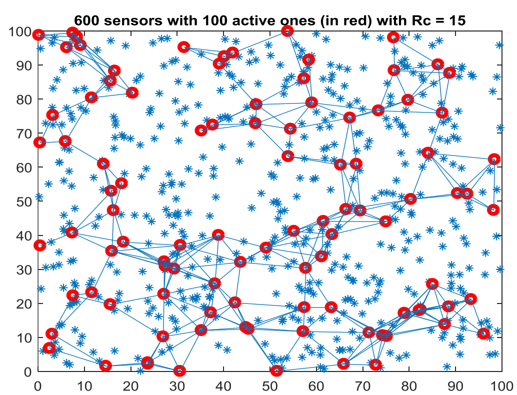

Figure 1. 600 sensors randomly deployed in a square sensing area 100*100 unit square; 100 sensors are active and the communication range should be R_c = 15 unit to be able to connect all active sensors.

In Fig. 1, 100 active sensors need to maintain at least R_c=15 to connect to each other. If we set up only 50 active sensors at a time, the range should be at least R_c=25 to maintain the connection. If we choose 150 active sensors at a time, the average R_c=12 unit. So, reducing the number of active sensors to save energy for sleeping sensors may cause more energy consumption for data transmission in WSNs. This sleeping schedule should be combined with another appropriate technique for further improvement.

III. Compressed sensing based Energy-Efficient Approach

Compressed sensing (CS) techniques [6] support many novel ideas to improve data processing in not only WSNs but also in many different fields. CS exploits the data correlation of sensing data, then allows to collect a small number of CS measurements to be able to reconstruct the whole data from a WSNs. Different data collection methods have been exploited with CS. Tree based [7], cluster based [8] and random walk routing [9] have shown the benefits to reduce energy consumption significantly.

In CS, all sensing points that needs to be observed are considered as a data vector as $\underline{X} = [x_1, x_2, \ldots x_N]$. This vector is sampled as $\underline{Y} = \Phi\underline{X}$, where $\underline{Y} \in R^M$ includes M measurements as linear combinations of $\underline{X}$. The most important point is that CS allows $M \ll N$.

The measurement matrix Φ, also called projection matrix or sensing matrix, in this case, can be random binary matrix.

$$\Phi = \begin{bmatrix} 1\,0 & 1\cdots & 0 \\ \vdots & \ddots & \vdots \\ 0\,1 & 0\cdots & 1 \end{bmatrix}_{M\times N} \quad (1)$$

In each row, all the entries of "1" represent all active sensors contributing their data to one CS measurement and all the entries "0" show the number of sleeping sensors at the sampling time. It is obvious that, we can exploit the measurement matrices [10] as changing the number of active sensors for energy saving purpose. While changing the number of active sensors, we need to consider if the matrix satisfies the restricted isometry properties (RIP) of order k if there exists a $\delta_k \in (0, 1)$ that affects the CS performance, as shown in Equation 2.

$$(1 - \boldsymbol{\delta}k)||X||_2^2 \leq ||\Phi X||_2^2 \leq (1 + \boldsymbol{\delta}k)||X||_2^2 \,. \quad (2)$$

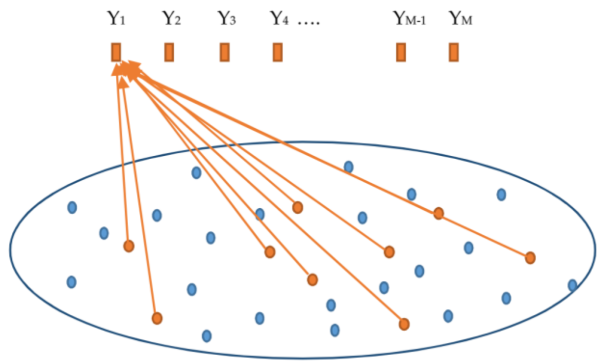

Figure 2. N sensors are deployed in a sensing area; only active sensors contribute to one CS measurement at a sampling time.

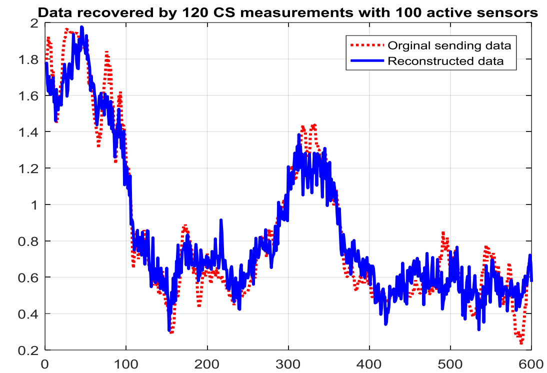

Figure 3. 100 active sensors create one CS measurements and whole reconstructed data recovered from 120 CS measurements

Fig. 2 illustrates a WSN with N sensors randomly deployed in a circular sensing area. Only a certain number of sensors being active while the others being on a sleep schedule for saving energy. These active sensors collect data from their positions and send to a base-station (BS), directly or relaying through intermediate nodes, to create one CS measurements. Another group of active sensors will create another CS measurement to be sent to the BS. After the BS receive M CS measurements, it will recover the whole sensing data from N sensors deploying in the sensing area. As shown in Fig. 3, reconstructed data from 600 sensors are recovered from 120 measurements with 100 active sensors. It also means that, each row weight of the measurement matrix equals to 100.

IV. Conclusions and Future Work

This article analyzes the benefits and challenges while WSNs utilizing sleeping schedules for energy saving purposes. Some main points have been mentioned and analyzed that can lead to optimal points for the network to consume the least energy. In addition, the paper also provide a recommendation to combine CS and sleeping schedules for further saving, not only to reduce energy consumption but also reduce data transmission in such networks. The simulation results show promising points and also open new research approaches for WSNs.

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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 Associated Editor for ICSES Transactions on Computer Networks and Communications.