Review of energy management in wireless sensor networks

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Abstract

Wireless sensor networks are a set of connected sensors in which each sensor node is able to collect some information, process, store and, if necessary, communicate with other sensors. One aspect of design in wireless sensor networks is the problem of sensor deployment. The deployment of the sensor represents the cost and capability of detecting a sensor network. The deployment of the sensor network should take into account both the coverage and connection issues. Wireless sensors play an important role in daily life and compose a part of our lives in homes, vehicles, traffic, food production, health care, monitoring and controlling activities. In addition, we can use wireless sensors in order to response to current social issues such as optimizing natural resources, reducing carbon emissions, and even remote monitoring elderly patients. Therefore, according to common using of wireless sensors, in recent years, energy conservation in wireless sensor network is taken into consideration that aims at increase life time of sensors batteries. In this paper, we investigate energy conservation in wireless sensor networks. In the first, existence solutions in energy management of wireless sensor networks are classified. Then, related proposals that increase energy efficiency in wireless sensor networks, are compared and evaluated.

Keywords: Wireless sensor networks, Sensor node, Energy management, Energy conservation.

1.Introduction

Wireless sensor networks consist of a large number of small, cheap and battery-powered sensor nodes whose ability to monitor and process information allows them to retrieve information from their environment. Recent advances in wireless communication and microelectromechanical devices have enabled the development of wireless sensor networks (WSN), which is expected to be one of the most promising technologies in the near future. So, wireless sensors can be deployed in large numbers in order to detect the events of interest or to send periodic reports in the surrounding environment. Wireless sensor networks have various applications. A wireless sensor network is designed to perform high-level information processing tasks such as detection, classification, and tracking. Since, in some environments, access to the target is very dangerous and difficult, sensors are the only solution for monitoring in such harsh environments. Below are some of the fields of application of sensors in the real world:

- ♣ Agriculture
- ♣ Health care supervision
- ♣ Environmental monitoring
- ♣ Fire
- ♣ Military programs
- ♣ Smart buildings
- ♣ Coal mines
- ♣ Air pollution
- ♣ Water quality

One of the basic problems in sensor networks is their lifespan, which is generally short due to the limitation of power supply. In addition, sometimes the special position of a node in the network aggravates the problem. Therefore, energy saving is very important in the design of wireless sensor networks. Energy saving methods usually aim to maximize node and network lifetime. In this regard, energy management mainly focuses on optimizing the energy consumption of nodes. As a result, by providing suitable structural patterns and energy management methods, the lifetime of sensor networks can be increased. In this regard, it is possible to efficiently manage energy in such networks by providing hybrid solutions to provide energy from the environment and optimize the energy consumption of a wireless sensor node.

In the continuation of this article, in the second part, we describe the classification of ways to manage the energy of wireless sensors. In the third part, energy optimization methods in wireless sensor networks are mentioned. In the fourth section, the existing solutions are compared and evaluated. Finally, in the third section, the conclusion of the article is described.

2.Classification of energy management methods in wireless sensor networks

Energy management in wireless sensor networks is defined as a set of rules to manage different mechanisms of energy supply and then energy consumption in a sensor node. The purpose of this section is to inform about various energy management schemes. Since the most common source of energy supply in wireless sensors is the battery, and the limited energy of the battery has led to the development of mechanisms for energy supply using environmental energy. In the following, the classification of energy management methods based on energy supply and energy consumption is presented.

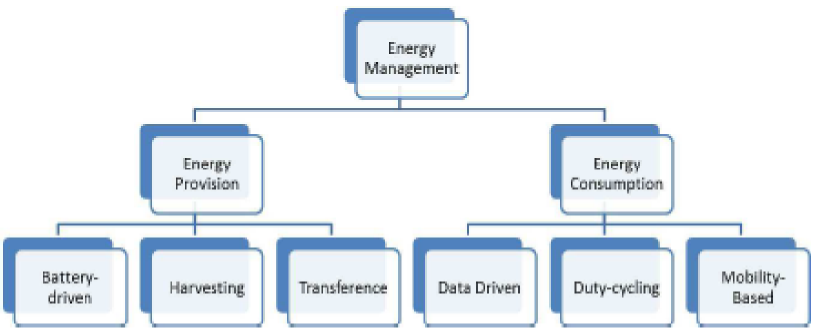

Figure 1: Classification of energy management methods in wireless sensor networks

2.1 Energy management based on energy supply

Energy supply solutions work in the direction of battery production with more energy, battery replacement and battery recharging, the three solutions in Figure 1 are mentioned separately.

2-1-1 Energy supply based on battery supply

Unfortunately, no matter how big the battery capacity is or how efficient the protocols are, eventually the battery will run out of power. It may last a month, a year, or more, but over time and constant use, the battery will drain. Therefore, it is necessary to replace the batteries to avoid communication interruptions or complete network outages. The types of batteries used in sensors are:

•Non-replaceable fixed size battery
• Fixed size replaceable battery

2-1-2 Harvesting energy from the environment

Although it is possible to increase the lifetime of the node by optimal battery consumption, but in case of energy renewal, it is possible to use latent energies in the surrounding environment. Some of the most useful energies are mentioned below:

• Solar Energy
• Wind energy
• Radio signals
• Thermoelectric generators
• Energy based vibration
• Human inputs

Of course, among all environmental energies, solar energy is known as the best and most efficient energy.

2-1-3 Energy transfer

Recent developments have created new dimensions in wireless energy transmission. This method has overcome the limitations related to battery power for sensor nodes, especially in situations where access to deployed nodes is almost impossible, such as military locations. Using a portable host, it wirelessly transmits electrical energy over a 2.4 MHz signal to charge nodes in remote locations. The portable host is also capable of collecting sensed data from deployed nodes. Wireless energy is transmitted through electromagnetic waves to nodes equipped with rechargeable batteries. Some recent advances in wireless energy transfer have increased the network lifetime and optimized the charging process for deployed nodes. Figure 2 presents a wireless charging vehicle (WCV). The mobile wireless charging vehicle visits the nodes regularly and charges the batteries of the nodes deployed at this location. Energy is transferred to the node by a technology based on magnetic resonance called WiTricity.

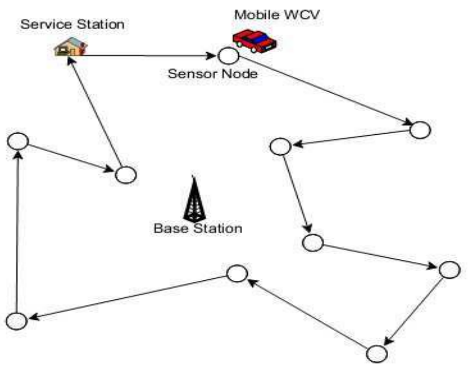

Figure 2: Wireless charging vehicle (WCV) navigates the route to charge sensors deployed in the field

2-2- Energy management based on energy consumption

In recent decades, the discussion of energy consumption optimization in wireless networks has received much attention. In the following, three categories of energy management methods based on energy consumption mentioned in Figure 1 are described:

2-2-1 Data driven approach

Data management generally focuses on data reduction and examines only acceptable data. Such approaches can be categorized as data reduction schemes and optimal data energy acquisition.

Data reduction schemes do not examine unnecessary samples and predict future data. Data routing can be used in situations where the energy sensing nodes in the network are efficient, thus requiring a larger battery size.

2-2-2 duty cycle

In the duty cycle, nodes adjust themselves by alternating sleep and wake states to reduce battery consumption. The idea is to set the node in a low-power state when no data communication is in progress. In this way, energy wastage is avoided because the nodes wake up only when there is a need to send or receive radios.

2-2-3 approach based on mobility

Mobility-based energy saving can be achieved by considering multiple portable nodes in the network. These portable nodes can be of two types based on their behavior, they can be part of the network infrastructure whose mobility is fully controlled or they can be a robot in general. Such nodes may follow a predictable pattern of mobility, on the other hand, they may be part of the environment where the mobility is uncontrollable and unpredictable. However, in some cases, it may follow a movement pattern that is generally not predictable and random. Algorithms based on mobility can be divided into two categories. Mobile sink-based method, where a portable sink is used to collect data from source nodes. Using portable sink nodes can improve the lifetime of networks by 5-10 times compared to using static sink nodes.

3- Energy optimization methods in wireless sensor networks

Channel access methods: Energy efficiency in wireless sensor networks is achieved by channel access methods based on multiple distribution, the purpose of multiplexing is to make more use of a bandwidth resource, where sharing is achieved through the following: space division, division Frequency, time division, orbital angular motion and code division distribution or a combination thereof. In the OSI reference model, these protocols are mainly located in a special layer called the media access layer (MAC) and are called MAC protocols.
A method for categorizing multiple access protocols is presented in Figure 3.

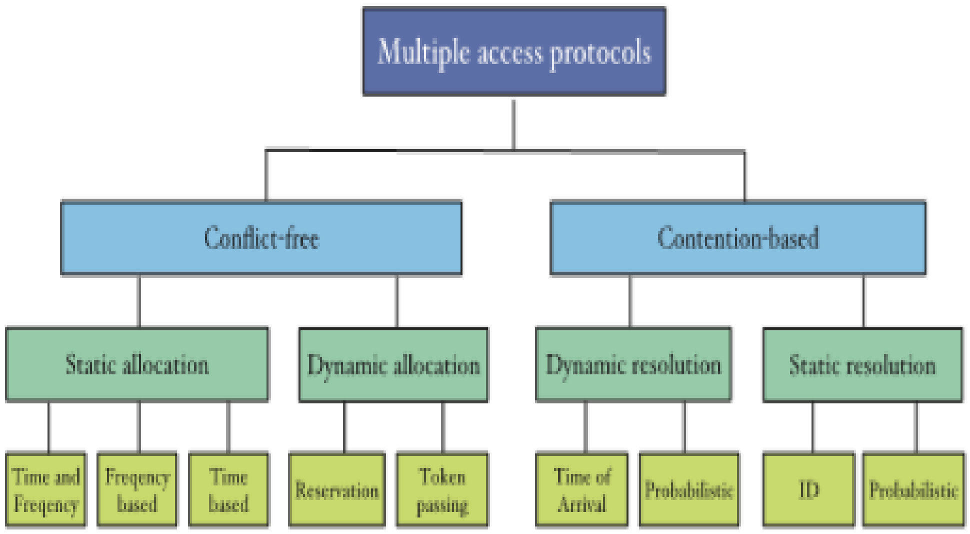

Figure 3: Energy efficiency solutions with MAC

A number of MAC solutions have been proposed with the aim of energy efficiency. An efficient way to reduce energy consumption can be reducing the duty cycle and increasing the sleep time by properly designing the MAC protocol. Therefore, these solutions can be divided based on the nature of the channel access method:
• Conflict-free protocols: In such protocols, transmissions do not interfere with each other. Transmission is done statically or dynamically regardless of channel allocation to users.
• Conflicting protocols: In such protocols, transmissions interfere with each other. In conflict-based methods, the bandwidth or channels are not designated for a specific use in any way, and there is a possibility of collision and interference in the data, and by preventing a series of collisions, interference can be avoided, which include: duty cycle and slots, redundancy, wake-up , groove creation and common divided methods which are discussed in detail in.
• Hybrid protocols: The idea of hybrid methods is to combine the best properties of conflicting and non-conflicting (or simultaneous and asynchronous) transmission methods, the time and memory complexity in this model is high.

3-2- R-MAC

All provided MACs work as a stand-alone solution, while an existing MAC must be used as a solution. Enhanced MAC, or R-MAC, serves as a complementary solution to the existing duty cycle MAC. This type of programmed and developed MAC maintains more accurate sleep/wake timing according to the prevailing application requirements. In the irregular system, a node for transmission sends the data packet with a prefix that is slightly longer than the sleep duration of the receiver. Initially, it consists of short consecutive packets. These consecutive packets take time to power up all surrounding devices at least once. When the receiver receives the packet, it responds with an acknowledgment (ACK) and the transmitter starts transmitting the original data. When the program's sampling rate decreases, the proposed sequence of packets becomes longer and the number of unnecessary sleep/wake cycles increases. The system adjusts the activity periods according to the required sampling rate, which reduces unnecessary sleep/wake cycles, this adjustment can be done in a common step or in a distributed way in the configuration step, all nodes are able to communicate with each other. To improve energy efficiency, the system is proportional to S. To improve energy efficiency, the system is connected closer to the transmitter regulation and to the receiver switch, which shortens the first stage. The sender transmits to the receiver.

3-3- Energy efficiency in routing

In routing, the goal is to choose the best paths from the source node to the destination node. Routing should also be optimized to support some specific needs of applications and networks. The routing requirements shown in Figure 4 are: bandwidth and energy efficiency, quality of service, scalability, redundancy, throughput, mobility, and reliability.

Figure 4: Some requirements of wireless routing protocols

Routing protocols can be classified into several categories: network structure, communication model, data delivery, architecture, and performance requirements.

4- Evaluation and comparison

In this section, according to the classification presented in section 2 and the previous works mentioned in section 3, the works related to energy management in wireless sensor networks are evaluated and compared.

Energy supply solutions based on battery production with more energy try to check energy optimization in terms of hardware and battery-based if there are efficient software methods and routing and MAC protocols to increase battery efficiency. As a result, to create an effective result, it is better to use these two methods together. The method of harvesting energy from the environment and the method of wireless transmission are promising methods. A large number of applications have been developed to develop optimal energy management programs based on energy consumption. In duty cycle-based designs, the goal is to decide the state of nodes between sleep and wake states, in order to achieve optimal energy, nodes are put to sleep in unnecessary situations to consume less energy. So, this method has a lot of room for research because if this sleep and wakefulness is continuous and consecutive and is done hierarchically and repetitively in short times, it will cause more energy consumption.

Duty cycle is introduced in most energy conservation schemes. In addition to duty cycle, topology control schemes that work on the basis of duty cycle are the latest and increase the energy efficiency and longer life of the network. In data-driven approaches, several schemes are adopted to reduce data or predict data, maintaining accuracy at a certain level. In this approach, if certain data are only accepted and the data is selected selectively, they reduce energy consumption, but not all data are accepted. It is a defect and reduces the accuracy of the sensor network.

Motion applications based on the use of a mobile sink or a mobile relay, depending on its behavior, can be used as part of the environment or part of the network, so that several algorithms have been proposed for efficient energy consumption in each case. The model based on energy harvesting is practically demonstrated in a testbed based on robotic mobile nodes, where up to 40% of mobile nodes need to be networked forever. This model is not feasible in real network scenarios because it has additional overhead and by deploying these 40% additional nodes, it reduces the network efficiency.

5. Conclusion

Considering the importance of sensors in everyday life and in society, in this article, solutions to optimize the energy of wireless sensor networks were discussed. Most of the current devices only focus on energy saving based on efficient energy consumption, although the energy efficient design in hardware, software, algorithms and sensor protocols is well done but eventually they give up when the connected batteries are discharged. For example, an energy-saving protocol that relies on efficiency and spatial and temporal scaling can lead to software performance degradation due to long lifetime; Therefore, the analyzes show that it is better to renew the energy rather than relying on the fixed energy that was already associated with the node when the network was deployed. Energy management plans are divided into two categories based on energy supply and energy consumption. Energy supply deals with the characteristics of the energy source and the development of algorithms related to sensor energy. Energy supply methods are classified in the categories of battery supply, energy harvesting from the environment and designs based on energy transfer. On the contrary, methods based on energy consumption refer to algorithms and protocols that do not consider the energy resources of the node and try to reduce the energy consumption by changing the algorithms and protocols of the network. This paper is more focused on identifying different potentials of alternative energy sources and different features in efficient energy production. An energy efficient protocol in a wide network can better manage its work according to the node's energy supply and consumption. Therefore, it is recommended to consider both energy supply and energy consumption in parallel when designing an energy efficient algorithm. A hybrid approach including all three available resources (battery, environment and wireless transmission) can also be considered to increase the lifetime of the network. However, it is still an open research issue and many efforts are needed to implement a permanent wireless sensor network.

References

[1] Cetin, B. K. (2011). ENERGY EFFICIENCY AND ROUTING IN SENSOR NETWORKS. Institut for Elektroniske Systemer, Aalborg Universitet.

[2] Mohamed, R. E. Saleh, A. I. Abdelrazzak, M. & Samra, A. S. (2018). Survey on Wireless Sensor Network Applications and Energy Efficient Routing Protocols. Wireless Personal Communications, 101(2), 1019-1055.

[3] Ramson, S. J., & Moni, D. J. (2017, February). Applications of wireless sensor networks—A survey. In 2017 International Conference on Innovations in Electrical, Electronics, Instrumentation and Media Technology (ICEEIMT) (pp. 325-329). IEEE.

[4] Khan, J. A. Qureshi, H. K. & Iqbal, A. (2015). Energy management in wireless sensor networks: A survey. Computers & Electrical Engineering, 41, 159-176.

[5] Paradiso, J. A., & Starner, T. (2005). Energy scavenging for mobile and wireless electronics. IEEE Pervasive computing, (1), 18-27.

[6] Sudevalayam, S., & Kulkarni, P. (2011). Energy harvesting sensor nodes: Survey and implications. IEEE Communications Surveys & Tutorials, 13(3), 443-461.

[7] King, R. R., Law, D. C., Edmondson, K. M., Fetzer, C. M., Kinsey, G. S., Yoon, H., ... & Karam, N. H. (2007). 40% efficient metamorphic GaInP⁄ GaInAs⁄ Ge multijunction solar cells. Applied physics letters, 90(18), 183516.

[8] Wu, J., Cardei, M., Dai, F., & Yang, S. (2006). Extended dominating set and its applications in ad hoc networks using cooperative communication. IEEE Transactions on Parallel and Distributed Systems, 17(8), 851-864.

[9] Chu, D., Deshpande, A., Hellerstein, J. M., & Hong, W. (2006, April). Approximate data collection in sensor networks using probabilistic models. In 22nd International Conference on Data Engineering (ICDE'06) (pp. 48-48). IEEE.

[10] Mascarenas, D. D. (2008). " Mobile host" wireless sensor networks: a new sensor network paradigm for structural health monitoring applications (Doctoral dissertation, UC San Diego.

[11] Xie, L., Shi, Y., Hou, Y. T., & Sherali, H. D. (2012). Making sensor networks immortal: An energy-renewal approach with wireless power transfer. IEEE/ACM Transactions on networking, 20(6), 1748-1761.

[12] Peng, Y., Li, Z., Zhang, W., & Qiao, D. (2010, November). Prolonging sensor network lifetime through wireless charging. In 2010 31st IEEE Real-Time Systems Symposium (pp. 129-139). IEEE.

[13] Koskela, P. (2018). Energy-efficient solutions for wireless sensor networks.

[14] Al-Karaki, J. N., & Kamal, A. E. (2004). Routing techniques in wireless sensor networks: a survey. IEEE wireless communications, 11(6), 6-28.