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A Survey on Different Approaches for Energy Conservation in Wireless Sensor Networks

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Abstract

In the recent years the applications of wireless sensor networks in the fields such as scientific, military and healthcare have developed. So it has gained more attention in research area. A sensor node is basically a battery powered device and the use of battery has become a constraints. The main motive is to reduce the energy consumption of sensor node to increase the network lifetime. In this paper, we have discussed about the energy consumption of a particular sensor node of WSNs. Then we have represented various systematic and comprehensive schemes of energy conservation, which are subsequently discussed in depth. Special attention has been given to the literature survey and devotion of promising solutions faced in each technique. We have provided some solutions that are being faced in each technique. In the final part we will look into the different directions for research about energy conservation of wireless sensor networks.

Keywords

Sensor, Wireless Sensor Networks, Energy Efficiency, Energy Conservation.

1. Introduction

A sensor is a small device that responds to physical phenomenon like temperature, humidity, vibrations or pressure and then generates a signal that can be monitored, measured or converted to another form of signal [1]. A wireless sensor network consists of some sensor nodes deployed over a large geographical area, called Sensor Field.

Basically, a sensor node consists of three components, namely; a sensing subsystem, a processing subsystem and a communication subsystem [2]. The sensing subsystem is generally used for physical data acquisition from the surrounding environment. To process the local data and to store them we use the processing unit. Data transmission is done by wireless communication subsystem. In addition to this, a power supply is required for providing energy to perform all the tasks. In WSNs we use battery to drive the systems but it has energy limitation [3]. It is not possible to recharge the battery if the nodes are deployed in hostile area. Again in some cases, the sensor network should need long lifetime to fulfil the required application. So we need to extend the network lifetime. So the energy conservation is a vital issue in the design of wireless sensor networks. Experiments show us that the required energy of transmitting a single bit of information is approximately same as that needed for processing thousands of operations in a sensor node [4]. The energy consumption of the sensing subsystem mainly depends on the type of sensor. In most of the cases the energy consumption of sensing subsystem is negligible with respect to that of processing system. It mainly depends upon the communication subsystems. On the other hand, the energy required for data sensing is greater than that needed for data transmission. So the energy-saving techniques mainly focus on the sensing subsystem and the communication subsystem.

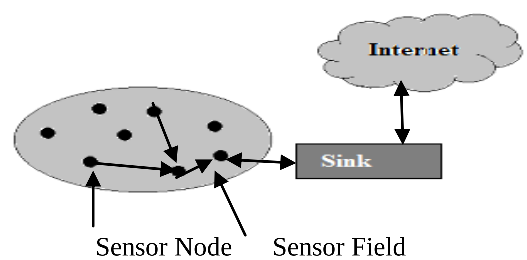

Fig.1: Architecture of Sensor Network.

A typical sensor network model is shown in Fig.1 which consists of one sink node, also termed as base station and a large number of sensor nodes placed over a large geographic area called sensing field. Through Multi-hop communication scheme data is transferred from sensor nodes to sink node [5][6].

Fig. 2 represents a typically adopted model of wireless sensor nodes which consists of four main components: (i) a sensing subsystem which includes sensors and analog-to-digital converters for data acquisition. (ii) a processing unit including a micro-controller and memory for data processing; (iii) a radio subsystem for wireless data communication; and (iv) a power supply unit. The sensor nodes also contain a location searching system, a mobilizer for relocation and reconfiguration [1][6][7].

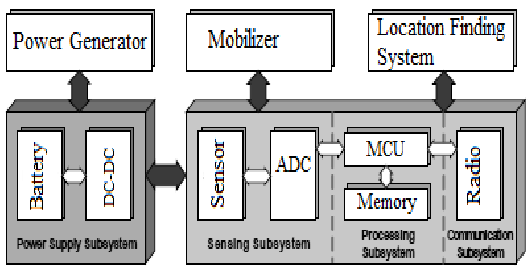

Fig.2: Wireless Sensor Network Architecture.

In this paper, at first we consider the case in which both the sink and the sensor nodes are static. Here we survey the commonly used techniques for energy conservation in sensor networks. Specially, we focus on the networking subsystem by considering mainly three parameters, i.e., Duty Cycling, Data Reduction and Mobility [8]. We also survey the main techniques suitable for reduction in energy consumption of sensors as the energy cost for data acquisition cannot be neglected. In the last part, we have introduced mobility as a new energy conservation scheme to extend the network lifetime. These techniques are fundamental for all networking protocol and solution for optimizing energy [9].

2. General Approaches of Energy Conservation

Based on the architecture shown in Fig. 2 and power breakdown, several approaches are identified to reduce the power consumption level in wireless sensor networks.

At first, we identify three main enabling techniques: Duty Cycling, Data-Driven Approaches, and Mobility as shown in Fig.3.

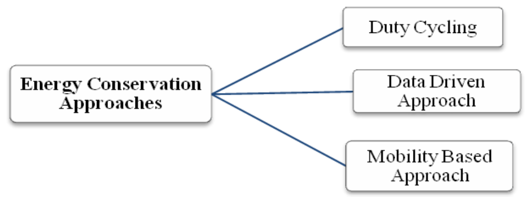

Fig.3: Basic Approaches to Energy Conservation in WSNs.

A. Duty Cycling Approach

In most of the cases whenever data exchange is not required we put the low power radio transceiver in Sleep Mode, which is an effective energy-conserving operation. But in ideal case the system should be switched off as soon as there is no communication (data transfer) and should be resumed as soon as a new data packet becomes ready to transmit or receive [10]. In this way nodes fluctuate between active and sleep mode depending upon the network activity. This behaviour is termed as Duty Cycling. However this technique is unconscious of the data that are sampled by the sensor nodes [1].

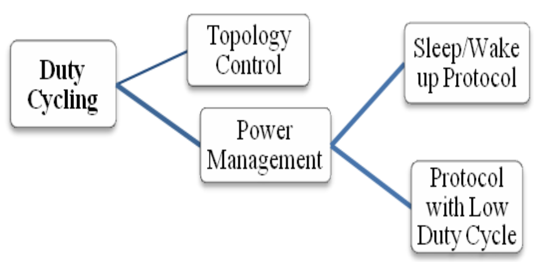

Fig.4: Duty Cycling Approaches.

As shown in Fig.4, duty cycling can be achieved by two different and complementary schemes. It is possible to spread the node redundancy in sensor networks, and select only a minimum subset of nodes to remain active (also called Active Node) for ensuring the connectivity. Nodes that are not currently in use for maintaining connectivity can go to Sleep Mode and thereby save energy. This method of finding the optimal subset of nodes that gives guarantee for connectivity is termed as topology control. Therefore, the basic idea of topology control is spreading the network redundancy to extend the network longevity. As a result, we can improve the network lifetime with respect to a network that has all nodes in the ON state always [10][11]. On the other hand, Active Nodes are not required to be ON continuously. Therefore they can be switched OFF and may be sent to the Sleep Mode when there is no network activity, hence alternating between Sleep and Wakeup Modes.

Again we consider Duty Cycling operated on active nodes as power management in WSNs. Hence we can say that the topology control and the power management that implement Duty Cycling are complementary to each other.

Depending on the network architecture Power management techniques can be further subdivided into two categories as shown in Fig.4. The first approach is Sleep/Wakeup Protocols which runs on top of a MAC Protocol, especially at the network or application layer. Another approach is Protocol with Low Duty Cycle which is integrated with the MAC Protocol itself [12][13]. This approach permits optimization of the medium access functions based on specific Sleep/Wakeup mode, used for power management. On the other hand, independent Sleep/Wakeup Protocols permits a greater flexibility and can be used with any MAC Protocol [14][15][16].

B. Data-Driven Approach

To improve energy efficiency further, compared to Duty Cycling, we have implemented Data-Driven Approaches [9]. This approach is designed to reduce the number of sampled data by keeping the sensing accuracy within an acceptable range. Generally, data sensing focus on the energy consumption of sensor nodes in two ways:

(i) Excess samples: They result in useless energy consumption, even if the cost of sampling is negligible, because they result in unwanted communication [17].
(ii) Power consumption of the sensing subsystem: This subsystem requires some energy for its operation. Data driven approach looks into this issue whenever the power consumption of this part is high [1].

Data-Driven approaches can be implemented by two schemes as shown in Fig. 5. Specifically, Data-Reduction consider the case of unwanted samples, while Energy-Efficient Data Acquisition schemes mainly focus on reducing the energy spent by the sensing subsystem. Even, some of them can reduce the energy spent for communication as well. The three classifications of data reduction aims at reducing the amount of data to be delivered to the sink node though the principles behind them are different.

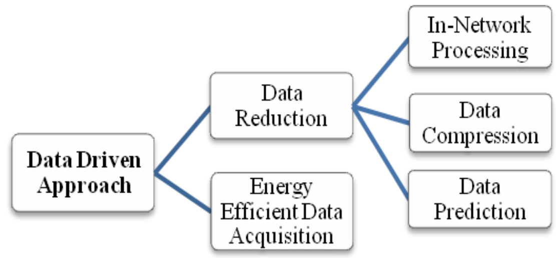

Fig.5: Data-Driven Schemes.

- In-Network processing performs the function of data aggregation at intermediate nodes between the source and the sink [18]. As a result, the amount of data is reduced while traversing the network towards the sink node. The appropriate In-Network processing technique depends on the specific application [19].

- Data Compression scheme can be applied to reduce the amount of information sent by source nodes. In general compression techniques are not suitable for WSNs [5][17].

- As the name suggests the Data Prediction refers to describe an abstraction of a sensed data, i.e. a model building data evolution. This model can predict the value sensed by sensor nodes within certain error bounds, and resides both at the sensor and the sink [1][8]. If the values are within needed accuracy range, requests issued by users can be evaluated at the sink node without getting the exact data from nodes.

- We have to keep in mind that when the model is not accurate enough, explicit communication between sensor nodes and the sink is required. Hence in this case the model has to be updated and /or the actual sample has to be retrieved. So it is clear that data prediction reduces the number of packets of information sent by source nodes and also minimizes the energy needed for communication.

C. Mobility-Based Scheme

In a static sensor network, packets transmitted from sensor nodes follow a multi-hop communication path to the sink node. So some paths can get more loaded than others. Hence the nodes closer to the sink have to relay more packets so that they are more subject to premature energy depletion [7].

Now we consider the case when some of the sensor nodes are mobile. Here mobility can be used as a tool to reduce the energy consumption (apart from Duty Cycling and Data-Driven Approaches). For mobile nodes, the traffic flow can be altered if mobile devices are responsible for data collection directly from static nodes. Ordinary nodes wait for the passage of the mobile device, and send messages towards it so that the communications take place directly or with a minimum Multi-hop traversal [8]. As a result, the ordinary nodes can save energy because of reduced path length and forwarding overheads. In addition to this, the mobile nodes can relocate the network to ensure more energy consumption due to communications.

When we consider mobile schemes, an important issue is the type of control the sensor-network designer has on the mobility of nodes. Mobile nodes can be of two types: they can be significantly designed as part of the network infrastructure, or as a part of the environment. When they are part of the infrastructure, their mobility can be fully controlled by the controller but when they are a part of the environment they may be not always controllable. If they follow a proper guideline, they have a completely predictable mobility. Otherwise they may have a random nature; as a result no reliable assumption can be made on their mobility [9]. So we can say, they may follow a mobility pattern which is neither predictable nor completely random. In such cases, mobility patterns can be determined based on successive observations and estimated with some accuracy.

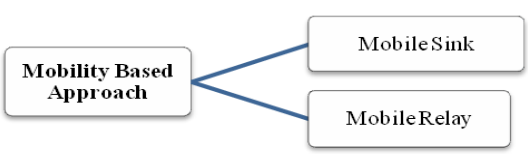

Fig. 6: Mobile Based Approaches.

Mobility-based Approaches can be done by two schemes, termed as Mobile-Sink and Mobile-Relay schemes as shown in Fig.6.

- Sensor networks with Mobile Sinks (MSs) mainly rely on a Linear Programming methodology which is used to optimize the parameters such as network lifetime, energy consumption, etc [7][20].

- The Mobile Relay (MR) approaches for data collection have already been implemented in Multi-hop Ad-Hoc Networks or Wireless Sensor Networks [21]. One of the well-known approaches is known as message ferrying scheme. In this scheme some special mobile nodes are introduced in the network to provide message relaying [22][23]. They roam around in the network area and collect data from the source nodes and send them towards the destination. This scheme gives a high success rate. In this scheme, to save energy, a new protocol named as history-based data collection and dissemination protocol is proposed. Here each node is assigned to a hierarchy level, where the level expresses the closest path to the access point. The level of a particular node depends on its ability to have successfully transmitted data to the access point in the past. In fact, nodes which have recently been in the range of the access point are preferred to relay messages directly, though a number of other nodes are there. The hierarchy level of a node is increased when it is near to the access point and it is decreased when they are far from the access point. The history-based data dissemination protocol has proved that it reduces the energy consumption compared to other approaches [7][24][25].

3. Conclusion and Future Work

In this paper we have surveyed the main approaches of energy conservation in Wireless Sensor Networks. Special attention has been given to all the solution schemes along with their importance, provided by the researchers. Now we can be able to draw our conclusions in the different approaches to energy management. Energy-efficient discovery schemes are thus required to minimize the energy consumption by keeping the probability of information loss as low as possible. An interesting point that can be noticed here, is, that most of the solutions are proposed assuming the energy consumption of the radio (used in communication subsystem) to be much higher than that due to data processing or sampling. Many real applications have shown that the power consumption of the sensor is same or even greater than the power needed by the radio. From the past literature study we see that the field of energy conservation by Data Acquisition has not yet been explored in detail. So we can emphasize on developing convenient techniques to reduce the energy consumption of the sensors by this approach. Again as Mobile Based Approaches are new in the research field, the research community for energy conservation is mainly focused on Mobile Based approaches, especially on the Mobile Relay Approach.

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