ISSN 2320-9984

Volume 2 Issue 1 | March 2014

ISSN: 2320-9984 (Online)

International Journal of Modern Engineering & Management Research

Website: www.ijmemr.org

A Review Study of Wireless Sensor Network and Lifetime of Sensor Network

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Abstract—*Wireless sensor networks basically consist of low cost sensor nodes which collect data from environment and relay them to a sink, where they will be subsequently processed. Since wireless nodes are severely power-constrained, the major concern is how to conserve the nodes' energy so that network lifetime can be extended significantly. Employing one static sink can rapidly exhaust the energy of sink neighbors. Furthermore, using a non-optimal single path together with a maximum transmission power level may quickly deplete the energy of individual nodes on the route. This all results in unbalanced energy consumption through the sensor field, and hence a negative effect on the network lifetime. In this paper, we present a comprehensive taxonomy of the various mechanisms applied for increasing the network lifetime. These techniques, whether in the routing or cross-layer area, fall within the following types: multi-sink, mobile sink, multi -path, power control and bio-inspired algorithms, depending on the protocol operation. In this taxonomy, special attention has been devoted to the multi-sink, power control and bio-inspired algorithms, which have not yet received much consideration in the literature. Moreover, each class covers a variety of the state-of-the-art protocols, which should provide ideas for potential future works. Finally, we compare these mechanisms and discuss open research issues.*

Keywords: *wireless sensor networks (WSNs), network lifetime, energy-efficiency, multi-path, multi-sink, mobile sink, power control, bio-inspired protocols Wireless sensor networks (WSNs) are composed of a lot of small, low cost sensor nodes that work together to measure various parameters of the environment and send the data to a unique or several sinks where.*

1. INTRODUCTION

Wireless sensor networks (WSNs) are composed of a lot of small, low cost sensor nodes that work together to measure various parameters of the environment and send the data to a unique or several sinks where they will be processed [1]. WSNs have a wide range of uses in military, medical, metropolitan and industrial venues. They are employed in many applications such as security surveillance, battlefield and habitat monitoring, intrusion detection, and target tracking purposes. Although reducing the size of sensors could make them cheaper, this also requires that all hardware equipment, specially the batteries, be extremely small. Since the sensor nodes should be functional for a long period of time and battery replacement in harsh environments like battlefields is usually impossible, nodes may lose their energy very fast, thus becoming nonfunctional in a short time. This situation can negatively affect the whole network connectivity, fault tolerance and lifetime.

Therefore, optimization for energy consumption is an important issue, especially to prolong network lifetime in WSNs [2]. To address this problem, a variety of approaches are implemented in the area of routing strategies, which play a key role in network functionality and performance [3].

Routing in wireless sensor networks is very challenging. One of the problems that affect the network lifetime refers to nodes in the vicinity of the sink, whose activity imposes a high traffic on this series of sensor nodes. In this state, the nodes that are closer to the sink lose their energy very fast. These nodes are the neighbors located at one hop away from a single static sink. Not only do they utilize energy to relay the data from any other nodes through the network to the sink, but also for sending their own data. This problem is known as the "sink neighborhood problem" [4], which can lead to premature network disconnection. When most of the sink's neighbors' energy is fully depleted, this isolates the sink from the rest of the network, while there is still a huge potential for most of the sensor nodes to continue to perform their tasks and functionalities normally.

2. RELETED WORK

The growing interest in wireless sensor networks on the one hand, and the continual emergence of new architectural techniques in the other hand have inspired some previous efforts for surveying the characteristics, applications and communication protocols for such a technical area [16, 17]. In this subsection we point out the features that distinguish our paper and highlight the differences in scope.

The authors in presented full categories of routing protocols for WSNs, as did the authors in [16]. However, none of them include the recent energy-efficient mechanisms (such as mobile sink, multi-sink, *etc.*) which could be combined with routing algorithms to increase the network lifetime. Moreover, all of the mentioned approaches only consider the routing algorithms in WSNs from the network structure and the protocol operation point of view. In our paper, we classify not only the routing schemes based on protocol operation, but also from the viewpoint of energy-efficiency.

A taxonomy of different energy-saving strategies applicable in wireless sensor networks is developed in [1]. According to these surveys, the energy-aware routing protocols in sensor networks are classified by considering several factors such as data cycling, mobility, topology control and data-driven techniques. However, the authors do not focus sufficiently on the network layer and these papers do not include bio-inspired and multi-sink mechanisms for routing protocols. Our survey can serve those who seek deeper insight into energy-efficient routing issues and schemes in wireless sensor networks.

A comprehensive study of mobile techniques for increasing network lifetime is presented in [2]. The authors explained the protocols proposed in all aspects of mobility such as mobile sinks, mobile sensors redeployment, and mobile relays. Although the paper covers a number of routing protocols that support mobility, it does not provide a classification for other energy-efficient techniques applied in routing algorithms. As the best of our knowledge, our paper is the first one that presents a taxonomy of energy-efficient mechanisms, including mobile sink, multi-sink, multi-path, power control and specially bio-inspired schemes, in order to prolong the WSNs' lifetime.

3. BACKGROUND AND PRELIMINARIES

3.1. Wireless Sensor Network Architecture

Before describing the high-level taxonomy of energy saving protocols, it is better to have an understanding of the node-level and network architecture for future reference.

The structure of a typical wireless sensor node [1].

- A node consists of four main elements with two optional subsystems as follows:
- A sensing unit, including one or several sensors equipped with analog -to-digital converters for data collection.
- A processing unit, including a microprocessor and memory which cooperate to process the sensed data locally.
- A radio unit used as a transmitter/ receiver.
- A power supply unit, including one or more batteries.
- A global positioning system to find the sensors' locations (*optional*).
- A mobilizer unit to change their position (*optional*).

It is worth mentioning that as indicated, the last two components are optional and may be used based on application requirements [1].

3.2. General Classification of Routing Protocols in WSNs

Is mentioned, according to the network structure, routing protocols in WSNs can be divided into three categories data-centric (flat), hierarchical, and geographic (location-based). They are described as follows:

Data-Centric Protocols: Multi-hop data-centric routing protocols are basically the first class to be introduced in WSNs. Considering a large number of nodes in sensor networks, flat algorithms employ *query-based* mechanisms in which the sink node only requests the desired data in order to prevent continuous data transmissions and thus save power. In this group, Sensor Protocols for Information via Negotiation (*SPIN*) [28], Directed Diffusion [29], Energy-Aware Routing (*EAR*), Rumor Routing and Minimum Cost Forwarding Algorithm (*MCFA*) are some of the most famous flat algorithm paradigms.

Hierarchical Protocols: Different from the flat category, in hierarchical protocols that utilize a clustering scheme, nodes are assigned different roles or functionality. In fact, energy conservation can be achieved in these protocols by some aggregation and reduction of data in so-called cluster heads (CHs). In this class, Two Tier Data Dissemination (*TTDD*), Low-Energy Adaptive Clustering Hierarchy (*LEACH*), Threshold-Sensitive Energy-Efficient Sensor Network Protocol (*TEEN*), Adaptive Periodic Threshold-Sensitive Energy -Efficient Sensor Network Protocol (*APTEEN*) and Power-Efficient Gathering in Sensor Information Systems (*PEGASIS*) are some inspiring protocols.

Location-Based Protocols: The possibility to apply position information in routing schemes will be used in location-based algorithms to route data towards the desired regions in the sensor field. This can save energy by limiting the flooding through the network [17]. *GPSR*, *GAF* [12], and *GEAR* [13] fall in this class.

4. LIFETIME IMPROVEMENT MECHANISMS IN ROUTING

In the next subsections, the main categories of energy-aware mechanisms applied to routing protocols in WSNs will be discussed in detail. Figure 1 shows the taxonomy of the methods covered in this paper.

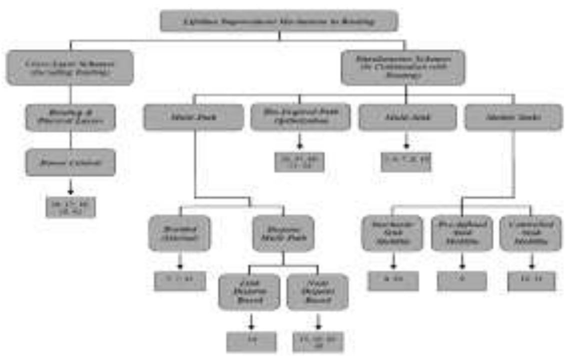

Figure 1. Classification of fundamental lifetime improvement mechanisms in routing protocols for WSNs.

In this figure, the numbers represent the corresponding references. However, some protocols [5, 7, 8, 10,] fall in more than one category. Lifetime improvement mechanisms in routing protocols for WSNs are basically divided into two main categories: simultaneous schemes and cross-layer schemes.

Simultaneous schemes [16] usually refer to the mechanisms which could be combined with routing algorithms in order to achieve a specific goal like energy-efficiency. In WSNs, these mechanisms are classified based on the protocol operation. However, cross-layer schemes [1] investigate different layers simultaneously to make the protocol more energy-efficient. In the following, we discuss the various classes under these two categories.

5. CONCLUSIONS

In wireless sensor networks, the nodes which are located on a non-optimal single path and forward data packets with maximum transmission power level may run out of energy quickly. This causes network partitioning along the paths through the sensor field. Furthermore, the sink neighbors tend to lose their energy much faster than the nodes which are far away from the sink due to the fact they are carrying heavier traffic loads. This also results in network partitioning around the sink and consequently causes sink isolation phenomena. All these problems can decrease the network lifetime significantly. In recent years, many approaches were proposed to address these problems. Nevertheless, there is a need to discuss and classify these methods as well as investigate their advantages and weakness points. In this paper, we present a new classification of the fundamental mechanisms that are applied in routing protocols to prolong the network lifetime. Figure 1 showed this taxonomy in detail. These mechanisms are categorized into five groups: multi-sink, mobile sink, multi-path, power control and bio-inspired schemes. Among them, power control is definitely a cross-layer technique including routing and physical features while the rest are simultaneous schemes which are applied in routing protocols. We discuss all mechanisms in detail, with an emphasis on their advantages and disadvantages as well as their significance. Comprehensive comparisons of these methodologies are based on their inherent characteristics. Although these energy-efficient mechanisms look promising, there are still many challenges that need to be resolved in order to improve sensor network lifetime. We note those challenges and have highlighted future research trends in this regard.

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