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Review

A meticulous study of various medium access control protocols for wireless sensor networks

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ABSTRACT

During the last decade, Wireless Sensor Networks (WSNs) have evolved as an incredibly useful technology in the area of signal processing and data communication. They have found prolific applications in a wide range of domains which include cell phone monitoring, robotic exploration, disaster management, intrusion detection and medical systems. Medium Access Control (MAC) protocols constitute an important set of regulations which enables the successful and smooth operation of the WSN. A fundamental design goal of all MAC protocols is to prevent energy wastes from various possible sources during data communications. Till now, a wide variety of MAC protocols with different objectives have been accumulated in sensor network literature. A thorough study of these protocols is very important both from the perspectives of understanding the current research trends and determining scopes for further innovative works in this domain. This paper meticulously discusses about the associated issues and difficulties which are faced in designing efficient MAC protocols for WSNs. Several popular MAC protocols are described here with their inherent merits and demerits. In order to provide an up-to-date survey, various MAC protocols which have been developed relatively recently are discussed, together with the traditional benchmark ones. Finally, this paper concludes with outlining a number of innovative ideas and future research directions in this domain.

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1. Introduction

An overwhelming raise in the demand for collecting and utilizing information about the surroundings has been observed throughout the last decade. A breakthrough in this domain is the concept of Wireless Sensor Networks (WSNs) which can process and disseminate knowledge in notably fast speed (Calí et al., 2007). WSNs are beneficial over many other traditional networks in terms of cost, size and efficiency. Over the years, these networks have been used in diversified fields such as cell phone monitoring, robotic exploration, intrusion detection, disaster management, climate control, and temperature pressure monitoring (Yadav et al., 2009; Akyildiz et al., 2002). A typical WSN consists of a large number of sensor nodes which are distributed in the environment to collectively constitute a multi-hop wireless network. Each sensor node is composed of an embedded processor, low power radio and limited memory unit. These nodes are operated through batteries and are organized to perform a common task (Ye et al., 2002). Due to low power capacities of the sensor nodes, a WSN has limited coverage and range for communication as compared to other mobile devices. Thus, such a network must contain large number of interconnecting nodes for successful practical applications.

Sensor networks have different issues and challenges depending on the situations they are applied for. One crucial challenge faced is energy consumption. It is often very difficult to change or replace the exhausted batteries of the constituent nodes in a sensor network which is an obvious obstacle in maximizing the network lifetime. In order to reduce the energy consumption, a major objective of a sensor network is to minimize the associated communication while achieving the desired network operation (Yadav et al., 2009; Demirkol et al., 2006). Extensive research works have been carried out on the design of low power electronic devices to reduce energy consumption in sensor networks. However, due to hardware limitations and manufacturing costs it has been observed that substantial energy consumption can be more economically achieved through designing energy efficient communication protocols.

It is an incredibly challenging task to create a wireless sensor network that implements energy efficient medium access rules among the heavily populated low capacity sensor nodes (Demirkol et al., 2006). Medium Access Control (MAC) is an important technique for the successful and smooth operation of a sensor network. MAC specifies a set of rigorous rules which enables the associated WSN to perform the desired network operations in an energy efficient manner. Designing highly effective power saving MAC protocols is a major way to considerably prolong the sensor network's lifetime. Also, one of the fundamental objectives of a typical MAC protocol is to prevent interfering nodes from colliding while communication (Yadav et al., 2009; Ye et al., 2002). In this regard, a number of attributes must have to be considered while designing a good MAC protocol for a WSN (Ye et al., 2002). The first is the *energy efficiency*. The nodes in a WSN are assumed to be dead when they are out of battery and as such the proposed MAC protocol must be effective enough to reduce the potential energy wastes during data transmissions. Next important attributes are the *scalability* and *adaptability* to changes. The designed MAC protocol should efficiently as well as rapidly handle the changes in network topology, size and node density for a successful adaptation. Another important attribute is the *fairness*. In traditional WSNs, each user desires equal opportunity and time to access the medium and so per-hop MAC level fairness is important. However, in sensor networks, all nodes cooperate for a single common task and normally there is only one application; at a certain time, a node may have considerably more data to send than some other nodes. Thus, fairness is not so important as long as application-level performance is not degraded. Other attributes, e.g. *latency*, *throughput* and *bandwidth utilization* may be useful but are secondary in WSNs.

Designing MAC protocols for WSNs is an active research area having important contributions from numerous researchers. During the last decade, several MAC protocols have been developed for wireless voice and data communication networks which can be broadly classified into two major categories: *contention based* and *schedule based* protocols (Ye et al., 2002). Looking at the increasing number of MAC protocols which have been accumulated in the sensor network literature over the past few years, a thorough and systematic study of them is very important from the perspective of future innovative works in this domain. This paper is destined to meticulously discuss about a wide variety of MAC protocols for