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Review

Multichannel assignment protocols in wireless sensor networks: A comprehensive survey

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ABSTRACT

With the spectacular development in radio and MEMS technologies, having sensor nodes capable of efficiently tuning their frequency over different channels is becoming more and more straightforward. For instance, TelosB motes can communicate on multiple frequencies as specified in the 802.15.4 standard. This reality has given birth to the multichannel communication paradigm in Wireless Sensor Networks (WSNs). While, multichannel communication obviously mitigates interferences, jamming and congestion, it also raises a number of challenging issues. In this paper, we set out to present a picture of multichannel assignment protocols in WSNs. After identifying the reasons of resorting to multichannel communication paradigm in WSNs and the specific issues that should be tackled, we propose a classification of multichannel assignment protocols, pointing out different channel selection policies, channel assignment categories and channel assignment methods. We conclude by a recapitulative table presenting many examples of existing multichannel protocols designed for WSNs and highlight promising research directions.

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1. Introduction

Wireless sensor networks (WSNs) consist of a possibly large number of wireless networked sensors which must operate in a potentially hostile environment for a maximum duration without human intervention. Typically, a sensor node is a miniature device that includes four main components: a sensing unit for data acquisition, a microcontroller for local data processing and some memory operations, a communication unit to allow the transmission/reception of data to/from other connected devices and, finally, a power source which is usually a small battery. These sensors transfer collected information to a central entity called the sink, which is generally more powerful than the other nodes, and where this information can be analyzed or transmitted via the Internet.

WSNs support a wide range of applications such as target tracking, environmental monitoring, system control, health monitoring or exploration in hostile environment. Recently, the spectacular success of WSNs has given birth to applications such as the analysis of spectral density, pictorial information that requires parallel transmissions, a higher throughput and a higher data delivery rate. However, application scenarios for WSNs often involve battery powered nodes that should remain operational for a long period, without external human control after their initial deployment. In the absence of energy efficient techniques, a node would drain its battery within a couple of days. Moreover, wireless sensor platforms offer limited bit rates (e.g. 250 kb/s for IEEE 802.15.4). Therefore, achieving emerging applications that need higher data rates with low bandwidth and low power operation of the radios, is a challenging task.

It is worth noting that the problem of reliable and timely communication at high data rates has already been addressed in wireless ad hoc networks. Poor network performances may result if certain factors are not taken into account:

- high contention: a node has to defer its transmission when the medium is busy (when it senses another transmission within its range).
- internal (co-channel) interference: a data packet may be not received because of the interference caused by another transmission.

Briefly, the solutions that researchers have proposed can be classified into three categories:

- Adaptive power control: adjusting the transmission power to a level that is just sufficient to reach the intended neighboring receiving node, resulting in a lower interference.
- Directional antennas: concentrating the transmission power in the direction of the intended receiving node.
- Multiple channels: transmitting on different channels that do not overlap will not interfere with each other, so more transmissions can take place simultaneously without mutual interferences.

In this paper, we focus on the last category dealing with multichannel communications in WSNs. The plethora of multichannel solutions for ad hoc networks [1] are not adequate for WSNs and cannot be directly applied. First, a sensor node is a miniature device equipped with a single radio transceiver such as the CC2420 so it can use only one channel at a time. Second, energy budget constraints and bandwidth limitation constitute a restriction to apply existing multichannel protocols [2]: frequent global information exchanges and a high overhead would shorten the lifetime of the network. Such constraints combined with a typical dense deployment and the requirement for in-network processing (data aggregation, compression) raise challenges to the design of multichannel protocols in WSNs [3]. Typically, multichannel protocols involve two major steps: (1) channel assignment to nodes and (2) multichannel medium access control. Hence the problem of judicious channel assignment arises.

The remainder of this paper is organized as follows. In Section 2, we describe the benefits expected from multichannel communications. Section 3 presents issues related to multichannel communications in WSNs. These issues may be new, such as channel switching, or may already exist in single channel communication but are made more difficult by the presence of multiple channels. In Section 4, we focus on the differences between channel assignment in cellular networks, mesh networks and WSNs. In Section 5 we define and discuss architectures designed to support multichannel communication in WSNs. Section 6 presents the models used by the studied multichannel protocols. In Section 7, we propose our classification of existing multichannel assignment protocols, based on (1) the frequency of the channel assignment, (2) the channel