Demo Abstract: Spectrum Agile Medium Access Control Protocol for Wireless Sensor Networks

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ABSTRACT

In this demonstration paper we describe a low-power spectrum agile medium access control protocol for wireless sensor networks. Our protocol allows sensor nodes to dynamically select an interference minimal channel for data communication. It does not pose any synchronization restrictions on the nodes and effectively handles the dynamics of the network such as new nodes joining and old nodes leaving the network. During the "table-top" demonstration, we show the various energy efficient spectral sensing features of the protocol on which the dynamic channel selection is based. As part of the demo we describe the protocol details and show that even in highly crowded spectrum and environments with random interference, sensor nodes are able to communicate in a reliable and energy efficient manner.

Categories and Subject Descriptors: C.2.1 Computer-Communication Networks – *Wireless communication*
General terms: Algorithms, Design, Performance, Experimentation
Keywords: Spectrum Agility, Medium Access Control, Low-power, Wireless Sensor Networks

1. INTRODUCTION

With the ever growing popularity of wireless devices and networks, wireless spectrum is getting crowded. Congestion of the spectrum leads to mutual interference among devices which share the same medium. In many networks, especially in the case of sensor networks, traffic load is generally low and wireless channels usually remain under-utilized. Dedicating an interference minimal wireless channel for each network is not only a waste of resources but is also less practical due to the increasing scarcity of the spectrum. Therefore, an efficient use of the spectral resources and the need for symbiotic coexistence features in the medium access procedures becomes necessary. Since sensor nodes are energy constrained and use low transmit power, they always remain handicapped when competing for the same wireless channel against other less power constrained devices. It has been shown by empirical studies that under moderate and high traffic conditions low power sensor node radios suffer huge packet losses due to interference from different WLAN standards [1]. Therefore, in order to avoid collisions and unnecessary retransmissions, spectrum agility becomes an important feature for MAC protocols that are designed for future Wireless Sensor Networks (WSNs). Wireless nodes are required to sense the spectrum and to agree on using a particular interference free channel. This agreement can either be achieved through a dedicated common control channel [2] or in a distributed way through a decentralized channel selection algorithm [3]. The latter approach is more desirable since it does not require devoting a common channel especially in the case when the volume of data traffic is typically very small in sensor networks. Furthermore dedicating a control channel in the crowded spectrum is becoming less practical with the increasing scarcity of the spectrum. In this work, we demonstrate a MAC protocol carrying out channel assignment distributively. It is designed for a single radio sensor node platform having the ability of switching radio channels on-the-fly.

2. PROTOCOL OVERVIEW

WSNs have stringent power budget limitations and have typically rare, irregular and short-timed communication requirements. Owing to different nature of WSNs, spectrum agile MAC protocols for sensor networks can only rely partly to the work done towards classical spectrum agile cognitive MAC protocols. Our spectrum agile MAC protocol is based on the preamble sampling technique. A transmitter sends a long preamble followed by the data in one of the available free channels. Unlike single channel MACs, a receiving node sequentially scans all the frequency channels in the available pool and is able to detect activity in the channel being used by the transmitter. At the same time, the receiving node is also able to ascertain the presence of external interferers and their strengths. We optimize the length of the preamble sequence in order to achieve energy conservation. We combine together the various preamble length optimization techniques from single channel protocols such as MFP-MAC [4], WiseMAC [5] and X-MAC [6]. The monolithic preamble is divided into micro-frames (MFP), each containing the information of the destination node, the time of the data transmission and the sleep schedule of the node. Upon receiving a micro-frame, a non-addressed node is able to immediately switch back to the sleep state and avoid receiving undesired preamble sequence and the data packet following it. Figure 1 shows a simplified operational cycle of the nodes. Node A performs low-power listening (LPL) operation by scanning the available channels and then switching to the sleep state. Node B transmits a data packet after scanning the different channels and making sure that the medium is free and no packet is destined to itself. Node C receives the data packet. Note that when Node C switches to the channel being used for data communication, it extends the channel listening interval until it is able to receive a complete micro-frame. The MAC protocol also maintains a sleep schedule table of the

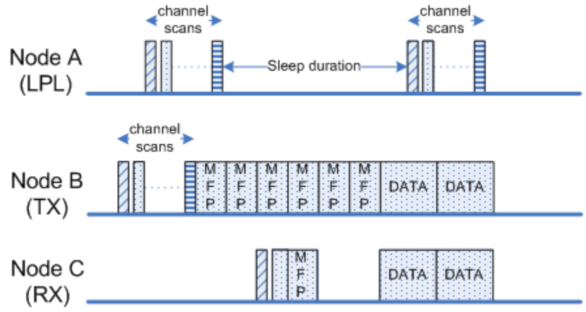

Figure 1: Operational cycle of the MAC protocol for broadcast data transmission.

neighbouring nodes announced inside the preamble frames. After exchanging a few packets, all the nodes come to know the sleep schedule of all of their neighbours. Shortening of the preamble length based on the gathered sleep schedule information of the neighbouring nodes is applied in the case of unicast, i.e. a transmitting node delays a unicast transmission until the time when the potential receiver is scheduled to wakeup, thereby saving energy expended in undue preamble transmission. The MAC protocol uses strobed preamble technique for unicast transmission, where after transmitting a micro-frame preamble the transmitter waits for an acknowledgement of the micro-frame from the potential receiver. Subsequent preamble frames are transmitted after timing out for the acknowledgement of the previously transmitted preamble frame. After receiving an acknowledgment, the transmitter immediately sends the data. This way a transmitter only needs to send a reduced preamble sequence. Since clock drifts are established over time and the sleep schedule information of the neighbours becomes imperfect, preamble strobing also allows compensation of such inaccuracies.

Efficient spectrum sensing is an important aspect of the protocol. More realistic and practical metric obtained from sensor network radios is the spectral energy detection. It may be noted that scanning all the channels is quite exhaustive for the nodes and leads to high energy consumption in idle listening. Weights are associated with each channel depending upon the occupancy level. When a channel is found free and data communication is established, both the receiver(s) and the transmitter increase the weight associated with the channel. On the contrary, if a particular channel is found to be occupied by an external interferer, its weight is decreased. If a certain channel is found to be frequently occupied by an external interferer, over the time, its weight is reduced so much that it is dropped from the pool of the available channels. Also if the channel pool becomes small and the quality is observed to be deteriorated, the nodes expand the channel set. The channel selection and weight assignment is govern through a light-weight algorithm. We have implemented our protocol in TinyOS 2.x on the TelosB nodes with Texas Instruments' IEEE 802.15.4 compliant CC2420 radio transceiver.

3. DEMONSTRATION DESCRIPTION

A GUI based tool will be used during the demonstration to interactively generate different types and levels of random interferences in the channels used by the sensor nodes.Varying degree of traffic loads and hence fluctuating levels of interferences will be generated through WLAN access points. The sensor nodes running the spectrum agile MAC protocol will be shown to dynamically abstain from using interference-prone channels and establish a reliable data communication. We will also visually show on-the-fly channel profiling and channel weighting algorithm running on the sensor nodes and how the nodes adapt the weights based on the subjected interference. Correspondingly, the dynamic expansion and contraction of the channel poll will also be presented. Furthermore, we will demonstrate that nodes joining and/or leaving the network asynchronously can be efficiently handled by our protocol and it poses no restriction on the synchronization of the nodes performing duty cycle operation. We will show that distributed channel selection algorithm is realizable in an energy efficient manner. The demonstration will be enhanced by a poster describing the protocol details.

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