Low Power Listening in BAN: Experimental Characterisation

Stefan Mijovic, DEI, University of Bologna, Bologna, Italy
Andrea Stajkic, DEI, University of Bologna, Bologna, Italy
Riccardo Cavallari, DEI, University of Bologna, Bologna, Italy
Chiara Buratti, DEI, University of Bologna, Bologna, Italy

ABSTRACT

This paper presents an implementation of a Low Power Listening-based (LPL) Medium Access Control (MAC) protocol on a platform for Body Area Network (BAN) applications. LPL exploits the transmission of a burst of short packets, called preambles, to synchronize the transmitter and the receiver. In this way, devices are able to spend most of the time in sleeping mode, providing longer lifetime and energy saving. Experiments on the field have been conducted by considering different scenarios and results, in terms of average energy consumed per packet transmitted/received, packet loss rate, average delay and network throughput, have been investigated. Conclusions regarding the proper parameters setting depending on the application requirements were derived. This work has been performed in the framework of the FP7 Integrated Project, WiserBAN.

Keywords: Energy Efficiency, Experimentation, Low Power Listening, Mac Protocol, Wireless Sensor Networks, X-Mac

INTRODUCTION

The increasing use of wireless networks and the constant miniaturisation of electrical devices have empowered the development of Wireless Body Area Networks (WBANs) (Latré, 2011). WBANs are composed of wearable and implantable sensors and/or actuators, capable of communicating among them and with external devices through radio interfaces, to monitor physiological signals collected from a human body. A WBAN can be defined as a collection of low-power, miniaturized, invasive or noninvasive, lightweight devices with wireless communication capabilities that operate in the proximity of a human body (Ullah, 2012).

On one hand, WBANs enable new applications and thus new possible markets with respect to Wireless Personal Area Networks (WPANs) and Wireless Sensor Networks (WSNs); on the other hand, the design is affected by several constraints that call for new paradigms and protocols. With respect to WSNs, the presence of the human body affects the radio wave propagation, leading to a specific and peculiar radio channel, which has

DOI: 10.4018/ijehmc.2014100104
to be properly accounted for in the design of the protocols (Boulis, 2012). The diversity of envisioned applications, which span from the medical field (vital signs monitoring, automatic drug delivery) to the entertainment, gaming and ambient intelligence sectors, creates a set of technical requirements with a wide variation in terms of expected performance metrics (e.g., throughput or delay). Therefore, scalable and flexible architectures and protocols are needed.

This work is dedicated to the design, implementation and verification of a Low Power Listening (LPL) Medium Access Control (MAC) protocol, with the aim of developing an energy-efficient and reliable protocol that will provide the reliable communication while satisfying application constraints. The protocol was designed and then implemented on a platform primarily meant for BANs.

Related Works

The stringent requirements in terms of energy efficiency and reliability, imply the need for designing new protocols, different from those used in WSN, as stressed in (Gopaland, 2010). Standard MAC protocols developed for duty-cycled WSNs can be roughly categorized into synchronized and asynchronous approaches, along with hybrid combinations of them. For comprehensive surveys on this subject the reader should refer to (Carraro, 2013) and (Bachir, 2010), with the former focusing on duty cycling mechanisms for WSN. These approaches are motivated by the desire to reduce idle listening, which is defined as the time the node spends listening to the medium even though no packets are being transmitted to that node (Buettner, 2006), (Bonny, 2004). As a consequence, many approaches for duty-cycling MAC protocols can be found in the literature. A wake-up strategy is introduced in (Omeni, 2008) to deal with failed transmissions and alarms management. (AlAmeen, 2012) focuses on reducing devices duty-cycle, using an out of band centralized and coordinated external wake-up mechanism. In S-MAC (Ye, 2002) nodes periodically wake up, receive and transmit data and then return to sleep. When a node wakes up, it exchanges synchronisation and schedule information with its neighbors and, once devices are synchronized, information is exchanged. T-MAC (van Dam, 2003) improves S-MAC by shortening the active period if the channel is idle. B-MAC (Polastre, 2004) is a Carrier Sense Multiple Access-based (CSMA) protocol, where nodes wishing to transmit data to an intended receiver, first transmit a preamble that is slightly longer than the sleeping period of the receiver, to wake up the target node. WiseMAC (El-Hoiydi, 2005) is ALOHA-based protocol, which uses a similar technique as B-MAC, but it reduces the length of the preamble. Another low power MAC protocol which is the most similar to the one proposed in this paper is X-MAC (Buettner, 2006). The protocol works as follows: nodes in the networks exchange sleeping and awake phases. Transmitter wishing to send a packet starts transmitting a burst of short preambles until the receiver detects one of them. Once the receiver becomes aware that it is the destination of the data packet, it responds with an acknowledgement frame and then the data is exchanged. Whenever any non-target receiver detects a preamble it goes back to sleep. Once the data is exchanged, the receiver stays awake for a given interval of time, until the awake period expires and then goes back to sleep. The authors of (Beaudaux, 2014) analyze the original X-MAC description, expose the black spots in the design and propose possible solutions. They went on to implement X-MAC on a very large scale test bed, intended for Internet of Things applications, investigate some of the claims of the original paper and prove them to be right or wrong. The paper gives a very good insight about the scalability of the protocol. In (Ullah, 2013) the authors introduce a collision avoidance mechanism to the original X-MAC protocol with the aim to maximally randomize transmissions in overcrowded networks. Their results show that the throughput of the X-MAC protocol can be increased by 30% for a 40-nodes network. Preamble sampling protocols as the ones described in this section, may suffer from the collisions of preambles sent by
The Introduction of an Electronic Patient Care Information System and Health Care Providers’ Job Stress: A Mixed-Methods Case Study
Jean E. Wallace, Steven P. Friesen, Deborah E. White, Janet G. Gilmour and Jane B. Lemaire (2012). Advancing Technologies and Intelligence in Healthcare and Clinical Environments Breakthroughs (pp. 33-46).
www.igi-global.com/chapter/introduction-electronic-patient-care-information/67853?camid=4v1a