Towards Power Efficient MAC Protocol for In-Body and On-Body Sensor Networks

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Abstract. This paper presents an empirical discussion on the design and im-
plementation of a power-efficient Medium Access Control (MAC) protocol for
in-body and on-body sensor networks. We analyze the performance of a bea-
con-enabled IEEE 802.15.4, PB-TDMA, and S-MAC protocols for on-body
sensor networks. We further present a Traffic Based Wakeup Mechanism that
utilizes the traffic patterns of the BAN Nodes (BNs) to accommodate the entire
BSN traffic. To enable a logical connection between different BNs working on
different frequency bands, a method called Bridging function is proposed. The
Bridging function integrates all BNs working on different bands into a complete
BSN.

Keywords: BSN, WBAN, MAC, Traffic, Based, Mechanisms, Bridging, In-
body, On-body, Sensor Networks.

1 Introduction

The remote monitoring of body status, and the surrounding environment, are becom-
ing more important for sporting activities, the safety of members of the emergency
services, members of the military and health care. The levels of fitness required for
the very competitive international sporting events require athletes to be at the very
pinnacle of fitness with every muscle used to its utmost. Furthermore, many body
functions are traditionally monitored only rarely and separated by a considerable
period of time. This can give a very incomplete picture of what is really happening.
Consider a patient visiting a doctor for a blood pressure check; he/she may be anxious
and thus have elevated pressure resulting in an inaccurate diagnosis. If, however, the
patient can be fitted with a simple monitoring system that requires no intervention,
then a picture can be built up of how the pressure changes through the day when
he/she goes about their normal business. This will give a better picture of what is
happening and remove inaccurate results caused by going to visit the doctor. To
achieve these requirements, monitoring of movement and body function are essential.
This monitoring requires the sensors and wireless system to be very lightweight and
to be integrated un-obtrusively into the clothing.

A Body Sensor Network (BSN) allows the integration of intelligent, miniaturized,
low power, invasive and non-invasive sensor nodes to monitor body function and the
surrounding environment. Each intelligent node has enough capability to process and forward information to a base station for diagnosis and prescription. A BSN provides long term health monitoring of patients under natural physiological states without constraining their normal activities. It can be used to develop a smart and affordable health care system and can be a part of diagnostic procedure, maintenance of chronic condition, supervised recovery from a surgical procedure and to handle emergency events [1].

A number of ongoing projects such as CodeBlue, MobiHealth, and iSIM have contributed to establish a proactive and unobtrusive BSN system [2]-[4]. A system architecture presented in [5] performs real time analysis of sensor’s data, provides real time feedback to the user, and forwards the user’s information to a telemedicine server. UbiMon aims to develop a smart and an affordable health care system [6]. MIT Media Lab is developing MIThril that gives a complete insight of human-machine interface [7] HIT lab focuses on quality interfaces and innovative wearable computers [8]. IEEE 802.15.6 aims to provide power-efficient in-body and on-body wireless communication standards for medical and non-medical applications [9]. NASA is developing a wearable physiological monitoring system for astronauts called LifeGuard system [10]. ETRI focuses on the development of a low power MAC protocol for a BSN [11].

In this paper, we use the terms BAN Node (BN) and BAN Network Coordinator (BNC) for the sensor node and the network coordinator in a BSN. The rest of the paper is organized into six sections. Section 2 presents discussion on BSN traffic classification. Section 3 and 4 present a brief analysis on in-body and on-body MAC protocols. Section 5 and 6 discuss the Traffic Based Wakeup Mechanism and the Bridging function for a BSN. The final section concludes our work.

2 BSN Traffic Classification

The assorted BSN traffic requires sophisticated and power-efficient techniques to ensure safe and reliable operation. Existing MAC protocols such as SMAC [12], TMAC [13], IEEE 802.15.4 [14], and WiseMAC [15] give limited answers to the heterogeneous traffic. The in-body BNs do not appreciate synchronized wakeup periods because they confine the accommodation of sporadic emergency events. Medical data usually needs high priority and reliability than non-medical data. In case of emergency events, the BNs should be able to access the channel in less than one second [16]. IEEE 802.15.4 Guaranteed Time Slots (GTS) can be utilized to handle time critical events but they expire in case of a low traffic. Furthermore, some in-body BNs have high data transmission frequency than others. We classify the entire BSN traffic into Normal, On-demand, and Emergency traffics as given in Figure 1. The normal traffic is further classified into High, Medium, and Low traffics.

(a)- Normal Traffic: Normal traffic is the data traffic in a normal condition with no time critical and on-demand events. This includes unobtrusive and routine health monitoring of a patient for diagnosis and treatment of many diseases such as gastrointestinal tract, neurological disorders, cancer detection, handicap rehabilitation, and the most threatening heart disease. Some BNs have frequent wakeup periods and thus are designated as high traffic BNs. For example, an ECG node may send data 4 times per