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In traditional RF-based WBANs in the face of body shadowing there is a fundamental tradeoff

Boggarapu Kantha Rao[1]; Pulivarti. Moulavika[2]& Dr. Murali Malijeddi[3]
[1]HOD &Assoc Prof, Medha Institute of Science and Technology for Women
kantharao.b@gmail.com.
2M-Tech ECE Department, Medha Institute of Science and Technology for Women
3Principal and Professor in the Department of ECE in Medha Institute of Science and Technology for Women

Abstract

In this paper we are concerned with the problem of data forwarding from a wireless body area network (WBAN) to a gateway when body shadowing affects the ability of WBAN nodes to communicate with the gateway. To solve this problem we present a new WBAN architecture that uses two communication technologies. One network is formed between on-body nodes, and is realized with capacitive body-coupled communication (BCC), while an IEEE 802.15.4 radio frequency (RF) network is used for forwarding data to the gateway. WBAN nodes that have blocked RF links due to body shadowing forward their data through the BCC link to a node that acts as a relay and has an active RF connection. For this architecture we design a network layer protocol that manages the two communication technologies and is responsible for relay selection and data forwarding. Next, we develop analytical performance models of the medium access control (MAC) protocols of the two independent communication links in order to be used for driving the decisions of the previous algorithms. Finally, the analytical models are used for further optimizing energy and delay efficiency. We test our system under different configurations first by performing simulations and next by using real RF traces.

Keyword: Wireless body area network (WBAN); body sensor network (BSN); IEEE 802.15.4; body shadowing; medium access control (MAC); capacitive body-coupled communication; cooperative communications; relay; performance analysis; delay; energy; optimization.

1. Introduction

IN works (WBAN) are deployed around the human body, several applications where wireless body area netreliable and low delay communication is of paramount importance because of the critical nature of the collected data (e.g., heart rate, blood pressure). Energy consumption is also key for the prolonged operation of the devices attached to the human body. For their communication needs these WBANs usually employ radio frequency (RF) technologies that operate in the industrial, scientific and medical (ISM) radio band. One of the dominant solutions is the IEEE 802.15.4 standard that is engineered specifically for low power devices [1], [2]. However, it is also possible to use the widely popular wireless LAN (WLAN) standard IEEE 802.11 [3], [4] because of the readily available access point (AP) infrastructure. Regardless of the specific wireless communication technology, when multiple sensors are deployed in the human body, a WBAN in a star topology is usually created so that all the on-body nodes communicate with a

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gateway for forwarding the collected data. Fig. 1 (left) depicts the organization of a WBAN in a star topology that is employed by practical systems [2]. Although RF is the only practical mechanism to forward data in this scenario, still several significant problems remain. RF signals suffer considerably from body shadowing in a highly variable way with respect to human body [5], [6], [7]. This makes communication between on-body nodes, and also off-body, very unreliable.

This inherent unreliability of RF communication around the human body is a critical problem for several real-life applications. We discuss two emerging application scenarios here to motivate our system design. One example is vital sign monitoring where multiple nodes need to be deployed in several different places of the human body [8]. Traffic is usually flowing in the uplink direction, i.e., from the BAN nodes to the gateway. Consider for example a human that has a node on the torso and one on the wrist for monitoring the heart rate. If this human is a patient lying in bed, then the RF link of the sensor on the torso might be completely blocked. However, it is possible that the node on the wrist can communicate perfectly with the gateway. Or it can happen the other way around as Fig. 1a indicates. Since humans usually move frequently, any sensor can be potentially blocked and the data may not be communicated on-time to the gateway (or it can be lost completely). Besides health monitoring, the other important application is real-time media entertainment. With the rising popularity of wearable devices,1 it is even possible that high data rate video streams need to be forwarded from the human body (uplink). One specific application example with downlink traffic, is audio streaming from a WiFi access point to onbody earphones without wires [9]. In these two examples RF connectivity between the AP and the earphones/glasses might be unreliable leading to problems in the audio/video transmission. Therefore, the optimal node on the body must be found and act as a relay in order to transmit the data to and from the WiFi AP. This node can be for example a smartphone.

2. Related Work

WORLD population growth is facing three major challenges [1, 2]: demographic peak of baby boomers, increase of life expectancy leading to aging population and rise in health care costs. In Australia, life expectancy has increased significantly from 70.8 years in 1960 to 81.7 years in 2010 and in the United States from 69.8 years in 1960 to 78.2 years in 2010, an average increase of 13.5%1. Given the U.S. age pyramid2 shown in Fig. 1, the number of adults ranging from 60 to 80 years old in 2050 is expected to be double that of the year 2000 (from 33 million to 81 million people) due to retirement of baby boomers3. It is expected that this increase will overload health care systems, significantly affecting the quality of life. Further, current trends in total health care expenditure are expected to reach 20% of the Gross Domestic Product (GDP) in 2022, which is a big threat to the US economy. Moreover, the overall health care expenditures in the U.S. has significantly increased from 250 billion in 1980 to 1.85 trillion in 2004, even though 45 million Americans were uninsured4. These statistics necessitate a dramatic shift in current health care systems towards more affordable and scalable solutions.

On the other hand, millions of people die from cancer, cardiovascular disease, Parkinson’s, asthma, obesity, diabetes and many more chronic or fatal diseases every year. The common problem with all current fatal diseases is that many people experience the symptoms and have disease diagnosed when it is too late. Research has shown that most diseases can be prevented if they are detected in their early stages. Therefore, future health care systems should provide proactive wellness management and concentrate on early detection and prevention of diseases. One key solution to more affordable and proactive health care systems is through wearable monitoring systems capable of early detection of abnormal conditions resulting in major improvements in the quality of life. In this case, even monitoring vital signals such as the heart rate allows patients to engage in their normal activities instead of staying at home or close to a specialized medical service. This can only be achieved through a network consisting of intelligent, low-power, micro and nano-technology sensors and actuators, which can be placed on the body, or implanted in the human body (or even in the blood stream), providing timely data. Such networks are commonly referred to as Wireless Body Area Networks. In addition to saving lives, prevalent use of WBANs will reduce health care costs by removing the need for costly in-hospital monitoring of patients.

2.1 APPLICATIONS OF WBANS:

A. Medical Applications

WBANs have a huge potential to revolutionize the future of health care monitoring by diagnosing many life threatening diseases and providing real time patient monitoring [10]. Demographers have predicted that the worldwide population over 65 will have doubled in 2025 to 761 million from the 1990 population of 357 million. This implies that by 2050 medical aged care will become a major issue. By 2009, the health care expenditure in the United States was about 2.9 trillion and is estimated to reach 4 trillion by 2015, almost 20% of the gross domestic product. Also, one of the leading causes of death is related to cardiovascular disease, which is estimated to be as much as 30 percent of deaths worldwide [11, 12]. Based on advances in technology (in micro-electronic miniaturization and integration, sensors, the Internet and wireless networking) the deployment and servicing of health care services will be fundamentally changed and modernized. The use of WBANs is expected to augment health care systems to enable more effective management and detection of illnesses, and reaction to crisis rather than just wellness [2, 12].

B. Non-Medical Applications:

Non-Medical applications of WBANs can be further classified into five subcategories as follows:

1) Real Time Streaming: This class of applications involve video streaming such as capturing a video clip by the camera in a cellular phone, trading shows for sport goods along with the latest fashion designs and 3D video. Audio streaming is also possible through voice communication for headsets for instance listening to explanation of art at the museum or listening to the bus schedule information on the bus stop, multicasting for conference calls, browsing music samples in a music CD store. This category also includes stream transfer which is used for remote control of entertainment devices, body gesture recognition/motion capture, vital sign and body information-based entertainment service, identification, emotion detection and to monitor forgotten things by sending an alert to the owner.

2) Entertainment Applications: This category consists of gaming applications and social networking. Appliances such as microphones, MP3-players, cameras, head-mounted displays and advanced computer appliances can be used as devices integrated in WBANs. They can be used in virtual reality and gaming purposes (game control with hand gesture, mobile body motion game and virtual world game), personal item tracking, exchanging digital profile/business card and consumer electronics.

3) Emergency (non-medical): Off-body sensors (eg. Built into the house) are capable of detecting a non-medical emergency such as fire in the home or flammable/poisionous gas in the house and must urgently communicate this information to body-worn devices to warn the wearer of the emergency condition [17].

3. Implementation

System Architecture:

We consider a WBAN that consists of N nodes where each node is equipped with an RF transceiver and a BCC transceiver. These two hardware components use different MAC/PHY protocols and are both controlled from a specialized NWK protocol. The nodes are organized into a single-hop BCC network, and a subset Nr of them form a single-hop RF network as shown in Fig. 1. All the nodes that are part of the RF network can connect to a gateway for forwarding the collected data. Each wireless link has different delay/energy characteristics due to channel variations. While only Nr nodes are part of the RF network, all the N nodes participate in the BCC network. Non-relay nodes transmit their packets through the BCC link to one of the relays, while the selected relay transmits wirelessly to the gateway the locally generated and forwarded data packets. Nodes that do not have a relay responsibility are allowed to put into sleep mode the RF transceiver for reducing the energy consumption. However, since it is possible that in the future they assume the role of an RF relay, they wake up periodically, they transmit an RF packet, and after they receive a response they update the received signal strength indication (RSSI) value of their RF link.

3.1 The IEEE 802.15.4 RF Network:

The IEEE 802.15.4 is used for RF communication. A nonbeacon-enabled and un-slotted carrier sense multiple access with collision avoidance (CSMA/CA) algorithm is assumed for channel access. All the nodes sense the channel status during the clear channel assessment (CCA) slots. The basic idea of the un-slotted CSMA/CA algorithm is that backoff and packet transmissions are not aligned to specific slot boundaries. The un-slotted CSMA/CA operates as follows. Each time a device generates a packet for transmission it waits for a random number of slots, called the backoff counter, ranging from 0 to 2BE 1, where BE denotes the backoff exponent. In IEEE 802.15.4, the backoff counter is decremented to zero regardless of the CCA result and by default BE is initialized to 3. When the backoff counter reaches zero, the device performs CCA only once in order to check whether the channel is busy or not. If the channel is idle during the CCA period that has duration Tcca (Fig. 1), the device transmits its data packet. When the channel is busy during the period Tcca, the backoff exponent BE is increased by 1 and the random backoff procedure is repeated. The backslash-shaped blocks in Fig. 1 depict the increase in the backoff time after a failed CCA. More details regarding its operation are provided later while the complete algorithm is available in [1].

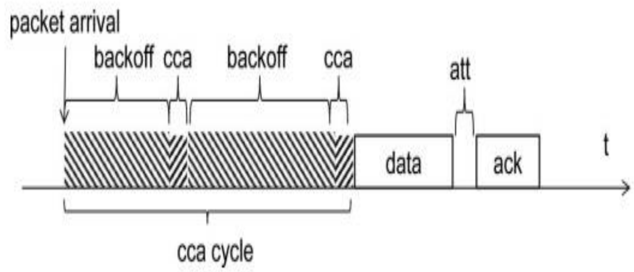


Fig 1: Packet transmission with the IEEE 802.15.4 MAC protocol.

3.2 The BCC PHY and MAC

BCC without requiring skin contact can be realized with two electrode transmitter/receiver devices capacitively coupled to the human body [12]. The transmitter generates a variable electric field while the receiver senses the variable potential of the body with respect to the environment. A signal attenuation of less than 70 dB has been measured between devices placed at various positions of the human body [13]. The human body channel is especially affected by interference below 1 MHz while for higher frequencies the interference level is below 75 dBm. In this paper a BPSK modulation scheme is assumed where the digital pulses are directly transmitted to the human body through the capacitive plates [10]. Digital pulses of 1.2 V for transmission are used, and an receiving band of 1-30 MHz was chosen for improving the BER in the presence of interference. The BER was measured to be lower than 106 for the aforementioned conditions. The energy efficiency of the transceiver was measured at 0.32 nJ/bit. Since the design of the PHY is not the focus of this paper we do not delve into further details. The interested reader can find more details about a typical prototype transceiver in [10].

Regarding the MAC layer it is a protocol that employs the well-known concept of low power listening (LPL) [28]. LPL exploits a specialized wake up receiver hardware that is always in active mode and consumes very little energy while the main receiver is deactivated. Fig. 3 presents the channel access scheme for a single packet. A preamble packet is always transmitted before the transmission of an actual data packet which means that nodes contend with preambles. The contention for the transmission of preambles follows the same backoff procedure with the RF MAC. Nodes that are asleep can wake up with the preamble and prepare for the actual data reception. The preambles contain the destination address so that they wake up the appropriate node.

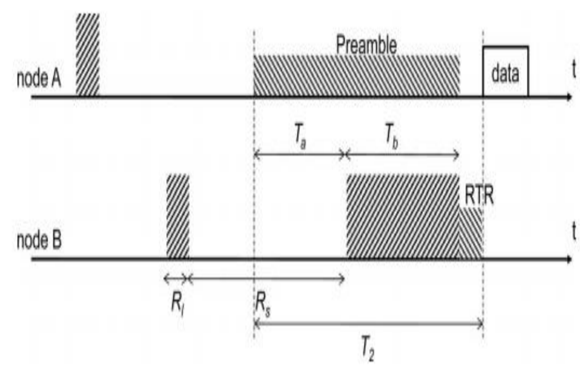
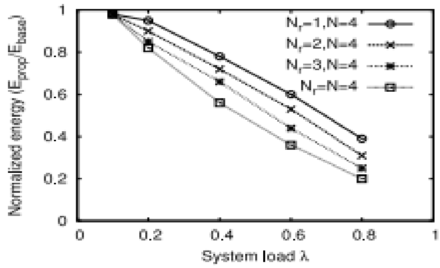
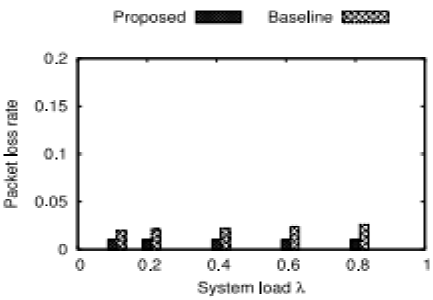


Fig 2: Low power listening and transmission of a preamble when the BCC channel is free. The time period Tb indicates that the BCC node is awake and checks the channel for the presence of preambles.

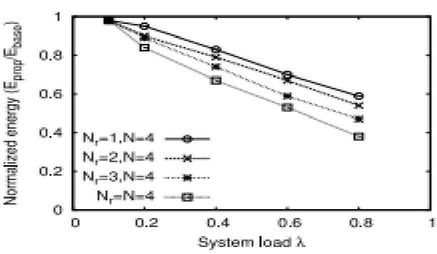
4. Experimental Work



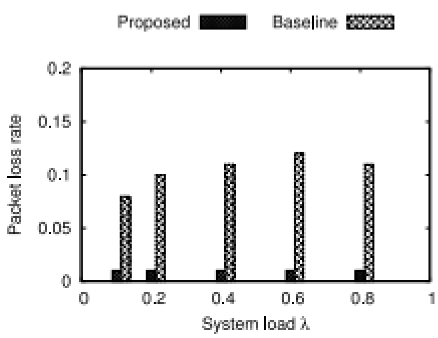
(a) τ=1s



(b) τ=1s, N_r=N=4



(c) τ=50ms



(d) τ=50ms, N_r=N=4

Fig 3: Results for the relative energy consumption and the PLR of the proposed system versus the baseline system for different and Scenario 1.

5. Conclusion

In traditional RF-based WBANs in the face of body shadowing there is a fundamental tradeoff: Either consume more energy for retransmissions or channel coding in order to increase reliability and suffer also higher delay, or reduce delay and energy at the cost of reduced reliability. However, we demonstrated that the above does not have to be the case if nodes cooperate through a delay/energy-efficient secondary link (in this case BCC) in order to select the most efficient RF link for forwarding WBAN data to a gateway. The performance gains are materialized not only with the novel WBAN architecture, but also with a NWK protocol that uses an algorithm for RF relay selection and packet forwarding driven by a performance model. Furthermore, the cross-technology performance models are exploited for local optimization of the MAC parameters of the protocols that operate in the BCC and RF subnetworks. The performance results indicate that the proposed system is more efficient than a state-of-the-art scheme in terms of energy and delay under different realistic channel conditions, application loads, and performance constraints.

6. Reference

[1] Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (WPANs), IEEE std 802.15.4-2996, 2006.

[2] B. Latr e, B. Braem, I. Moerman, C. Blondia, and P. Demeester, “A survey on wireless body area networks,” Wirel. Netw., vol. 17, no. 1, pp. 1–18 Jan. 2011.

[3] Part 11: Wireless LAN Medium Access Control and Physical Layer (PHY)

Specifications, IEEE 802.11-1999 Standard, Aug. 1999.

[4] D. Cavalcanti, R. Schmitt, and A. Soomro, "Performance analysis of 802.15.4 and 802.11e for body sensor network applications," in Proc. 4th Int. Workshop Wearable Implantable Body Sens. Netw., 2007, pp. 9–14.

[5] J. Ryckaert, P. D. Doncker, R. Meys, A. de Le Hoye, and S. Donnay, "Channel model for wireless communication around human body," Electron. Lett., vol. 40, no. 9, pp. 543– 544 Apr. 2004.

[6] E. Reusens, W. Joseph, G. Vermeeren, L. Martens, B. Latre, I. Moerman, B. Braem, and C. Blondia, "Path loss models for wireless communication channel along arm and torso: measurements and simulations," in Proc. IEEE Antennas Propagation Soc. Int. Symp., 2007, pp. 345–348.

[7] Y. I. Nechayev, P. S. Hall, C. C. Constantinou, Y. Hao, A. Alomainy, R. Dubrovka, and C. Parini, "On-body path gain variations with changing body posture and antenna position," in IEEE Antennas Propagation Soc. Int. Symp., 2005, pp. 731–734.

[8] M. R. Yuce, "Implementation of wireless body area networks for healthcare systems," Sens. Actuators A: Phys., vol. 162, no. 1, pp. 116–129, 2010.

[9] H. Baldus, A. Argyriou, K. Klabunde, T. Falck, V. Buil, L. Geurts, T. Schenk, S. Ouzounov, (Nov. 2010) Method for operating an acoustic system and wearable acoustic device, WO Patent App. PCT/IB2010/051,970 [Online]. Available: http://www.google.com/patents/WO2010133991A1?cl=en

[10] A. Fazzi, S. Ouzounov, and J. van den Homberg, "A 2.75mw wideband correlation-based transceiver for body-coupled communication," in Proc. IEEE Int. Solid-State Circuits Conf.-Dig. Tech. Papers, 2009, pp. 204–205.

[11] S. Corroy, A. Argyriou, Z. Wadood, and H. Baldus, "A body-coupled communication and radio frequency dual technology cooperation protocol for body-area networks," in Proc. 2nd Int. Workshop Med. Appl. Netw., Conjunction IEEE Int. Conf. Commun. Workshops, 2010.

[12] H. Baldus, S. Corroy, A. Fazzi, K. Klabunde, and T. Schenk, "Human-centric connectivity enabled by body-coupled communications," IEEE Commun. Mag., vol. 47, no. 6, pp. 172–178 Jun. 2009.

[13] T. C. W. Schenk, N. S. Mazloum, L. Tan, and P. Rutten, "Experimental characterization of the body-coupled communications channel," in Proc. IEEE Int. symp. Wirel. Commun. Syst., Oct. 2008, pp. 234–239.

[14] R. Shah and M. Yarvis, "Characteristics of on-body 802.15.4 networks," in Proc. 2nd IEEE Workshop Wirel. Mesh Netw., 2006, pp.138–139.

[15] A. G. Ruzzelli, R. Jurdak, G. M. O'Hare, and P. Van Der Stok, "Energy-efficient multi-hop medical sensor networking," in Proc. ACM 1st SIGMOBILE Int. Workshop Syst. Netw.

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Support Healthcare Assisted Living Environ., 2007, pp. 37–42.

Authors Profiles

HOD &Assoc Prof, Medha Institute of Scienceand Technology for Women, India,B.KANTHA RAO received the B.Tech. Degree in Electronics and Communication Engineering from Jawaharlal Nehru Technological University, Hyderabad in 2006 and M.Tech in EMBEDDED SYSTEMS from Jawaharlal Nehru Technological University, Hyderabad in 2010, is a faculty member in the department of Electronics and Communication Engineering, Medha Institute of Science and Technology for Women, Khammam and presently working as Associate Professor. His research interests include Embedded systems, VLSI Design. E-mail: kantharao.b@gmail.com.

Pulivarti. Moulavika Department: E.C.E(Embedded &VLSI) Medha Institute of Science & and Technology for Women

Mr.mr.muralimalijeddi has completed his PhD from Andhra University Under Guidance of Prof. Dr. G.S.N Raju, Vice-Chancellor, Andhra University in Antennas and Signal Processing . As a Principal and Professor in the Department of ECE in Medha Institute of Science and Technology for Women KHAMMAM, Telangana State during 2015 December- till date. He published so many international papers and attended confrencesses and guided so many students to do projects and papers in latest technologies..with experience of 20 years…