WIRELESS BODY AREA NETWORKS
Information Dissemination Analysis

Yasir Faheem and Saadi Boudjit
Laboratoire L2TI, Institut Galilée, Université Paris 13, Villetaneuse, France

Keywords: WBANs, Wearable Sensors, Energy Dissipation, Health Care Computing.

Abstract: Telemedicine integrated wearable health monitoring system is a novel technology with aiming to support early detection of abnormal conditions and prevention of its serious consequences. Recent Advances in technology has led to the development of small, intelligent, wearable sensors capable of remotely performing critical health monitoring tasks and then transmitting patient's data back to health care centers over wireless medium. Patients benefit from continuous ambulatory monitoring as a part of a diagnostic procedure, optimal maintenance of a chronic condition or during supervised recovery from an acute event or surgical procedure. This requires continuous functioning of the wearable sensor devices. But to the day, energy remains to be a big constraint in enhancing Wireless Body Area Networks (WBAN) (IEEE 802.15 WPAN Task Group, 2003) lifetime. Some recent literature on WBANs proposes multi-hop sensor-to-gateway data relay as more energy efficient than single hop communication. There are studies which argue contrarily. This study analyzes the single vs multi-hop energy consumption effect for real short range sensor devices.

1 INTRODUCTION

Health cost represents a considerable ratio in the economic budget of developed countries, and certain tendency studies are not optimistic about an improvement in the situation. Average age of the population tends to increase. Number of people requiring more or less care intensive medical monitoring is not small. This increases overall cost of medical care. No doubt, using socio-medical establishments to place people at risk, under surveillance is impractical for cost reasons, but also for reasons of quality of life. Many of these people are fully autonomous, though weakened. Their psychological confinement due to presence nursing staff would be a breach of their freedom. Therefore, partially replacing the assistance of nursing staff by small health surveillance & communication equipments like sensors, networks, monitoring software could be cost effective and would also increase life standard. Focusing on this topic, we are developing a wireless health monitoring platform which aims to continuously monitor mobile patients needing permanent surveillance. The objective of this project is to develop and implement innovative solutions based on information technologies and wireless communication for the benefit of those needing medical permanence. In first step, we propose to study the issues related to the acquisition of medical information concerning a patient via a set of wireless sensors embedded in the patient himself. Secondly, we focus on treatment and use of this information either by a local contractor equipment (central device) with a capacity of calculation or offset after transfer in GPRS and/or WiFi connection to a data server based at the attending physician or hospital.

In this project, we will propose and evaluate solutions to some of related problems that can be encountered in such an environment:

- Information dissemination between wireless sensors and the central device (mobile phone for instance)
- Sensors' auto-configuration
- Authentication and security

The proposed solutions will be evaluated on an experimental platform. This will be achieved by the help of our medical partner LIM&Bio laboratory (LIM&Bio, 2009). Although the platform will not be tested on real patients, but it will be a prototype proof of concept taking into account experimental constraints related to vital parameters of the human body. Thus, the diversity of information that can be collected, their frequency, their importance as, for example, set thresholds for various measurements and above which an alert is sent to the doctor, are fixed by our medical partner.

Faheem Y. and Boudjit S. (2010).
WIRELESS BODY AREA NETWORKS - Information Dissemination Analysis.
In *Proceedings of the Third International Conference on Health Informatics*, pages 489-494
DOI: 10.5220/0002798104890494
Copyright © SciTePress

2 ARCHITECTURE AND POSITIONNING OF THE PROPOSED PLATFORM

A general multi-tier system architecture is shown in Figure 1; the lowest level encompasses a set of intelligent sensors, the second level is the personal server (central device) which could be an Internet enabled PDA, a cell-phone, or a home computer. The third level encompasses a remote health care server with a set of its possible related users (Physician, Clinic, Emergency). Each level represents a fairly complex subsystem with a local hierarchy employed to ensure efficiency, portability, security, and reduced cost. The personal server, running on a PDA or a 3G cell phone, provides the human-computer interface and communicates with the remote server.

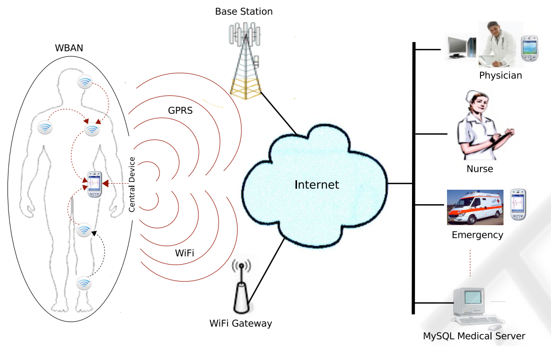

Figure 1: Wireless Health Monitoring Platform.

There are several projects implementing platforms for medical supervision at a distance. BASUMA (BASUMA, 2006) is an example of such a platform of which Philips is the consortium leader. Another similar platform called CodeBlue (CodeBlue, 2008) is being developed at Harvard University. However, these platforms are typically installed in homes of patients, and therefore limit patients' mobility because they must constantly be close to their Internet connection for transmitting real time data. Secondly, security issue has not been addressed in these platforms.

Our purpose in this work is to propose an architecture that combines several wireless technologies (WiFi, ZigBee, GPRS) allowing patients to transmit data in a secure manner to the remote health care server regardless of their location.The proposed platform will address the following issues:

- A Wireless Body Area Network (WBAN) composed of various wireless sensors ultimately connected to a retransmission device and communicating using wireless technologies like Bluetooth (Bluetooth, 2009) and ZigBee (Zigbee Alliance, 2009).
- A retransmitter device (central device), which could be a cell-Phone or a PDA. This component will implement the functions of active patient monitoring, especially in the case of connection loss with the remote server. It will serve as the bridge between the WBAN and the global Internet network and will also ensure the security and confidentiality of that route.
- A remote server that collects all data from various sources and stores it in database. It will generate statistics, information for doctors and alarms, if any, that may be transmitted to a personal care unit.
- The doctor or, generally speaking, the medical staff will be the privileged consumer of platform provided information. Due to this, user can have multiple interactive interfaces:
  - Standard web Interface: interactions with the platform are done using a conventional web browser.
  - Mobile Interface: this interface will be designed for personal digital assistants (PDAs) or smartphones.

However, the establishment of such an architecture requires solving certain scientific problems at all the platform levels. Under this project, we concentrate our analyses on the patient side and we focus on three key issues related to wireless body area networks: routing between sensors and the central device, sensors auto-configuration, and secure transmissions.

3 OUR CONTRIBUTION

Several studies have shown that multi-hop routing in WBAN result in non-negligible lifetime increase of sensors as compared to direct communication between sensors and the central device. In this case, information dissemination between sensors and the central device requires an ad hoc routing protocol.

Some other studies, however, argue contrarily. They show that direct communication between sensors and the central device considerably increase the lifetime of a wireless body area network. They show that executing a multi-hop adhoc routing protocol on embedded sensors consumes more energy.

In this paper we are exploring both information dissemination techniques in a WBAN scenario. Our objectif here is to find a tradeoff between the number of hops in the network and the energy consumption. Energy consumption for various scenarios is evaluated through simulations.

4 PROBLEM ANALYSES

Power consumption for transceivers is different in different communication states i.e. transmission/reception/idle/sleep. Transmission energy depends upon the power with which signal is propagated to attain longer ranges while consumption in other states is less variable. Unlike other technologies, reception/idle state consumption for low power, limited range WSN is not negligible as compared to transmission state power consumption. Thus global energy minimization requires optimum selection of transmission range. Latré et. al. in (Latre et. al., 2004) showed that utilizing multi-hop communication by reducing transmission power in WBAN reduces overall energy consumption. This is true but authors in (Latre et. al., 2004) ignore increased energy consumption due to multiple receptions. Wang et. al. in (Wang et. al., 2006) propose a realistic power consumption model for WSN. (Wang et. al., 2006) shows that multi-hop communication is more energy efficient when destination is out of reach. That is when destination cannot be reached in single hop. They show that multi-hop communication by controlling transmission power does not neccessarily result in energy gain. This is due to non-negligible energy consumptions in reception and Idle modes.

In sensor motes energy consumption in reception and idle mode is relatively high. It can be equal to or greater than transmission energy consumption for low power transmissions. For low transmission ranges as in WBAN, utilizing single hop data delivery to gateway node while other sensors are put in idle/sleep state might be more energy efficient. Real experiments conducted in (Anastasi et. al., 2004) show that reception and idle listening consume a considerable amount of energy. Especially for sensor nodes, very low power transmissions for ranges as short as in WBAN consume lesser power than reception. For micaZ motes (Chipcon AS, 2007), reception energy is higher than transmission energy even with maximum power transmission. Above stated variations in literature, motivated us to better understand this energy consumption scenario and choose a better communication strategy for our future test bed implementation for WBAN.

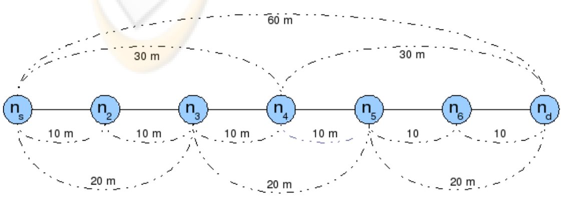

Figure 2: Simulation scenarios.

Table 1: Simulated scenarios.

Scenario	Hops	Distance	Nodes
1	1	60	$n_s \rightarrow d$
2	2	30	$n_s \rightarrow n_4 \rightarrow d$
3	3	20	$n_s \rightarrow n_3 \rightarrow n_5 \rightarrow d$
4	6	10	$n_s \rightarrow n_2 \rightarrow n_3 \rightarrow n_4 \rightarrow n_5 \rightarrow n_6 \rightarrow d$

Table 2: Mica2 Mote Power Consumption and Range Values.

Tx power (dBm)	Power consumed (mW)	Rx power/Idle power (mW)	Tx range (meter)
05	76.2	30	60
-07	32.4	30	30
-14	27.9	30	20
-20	25.8	30	10

4.1 Channel Model and Energy Consumption

Let P_t and P_r be the transmission and reception signal power respectively, where P_r is equal to receive sensitivity of mica2 node (-98 dBm). Let d be the communicating nodes' inter-node distance and, L the system loss, then our WSN model can be represented by the well known *TwoRayGround* radio model (NS2, n.d.):

$$P_r = ReceiveSensitivity = \frac{P_t G_t G_r h_t h_r}{d^4 L} \qquad (1)$$

Where G_t=G_r=1.2 are antenna transmission and reception gains respectively. h_t=h_r=16cm are transmission and receptor's antenna heights. Transmission power P_t is varied according to desired range. Equation (1) can be rearranged to determine d for given values of P_t as follows:

$$d = [\frac{P_t G_t G_r h_t h_r}{P_r L}]^{\frac{1}{4}} \qquad (2)$$

We need minimum P_t that ensures successful reception of packet at destination with P_r>*ReceiveSensitivity*. For given values of P_t, approximate range values are obtained from radio model given in (2). The actual power consumed by mica2 while transmitting with permissible power P_t is obtained from CC1000 data sheet (CC1000, 2007). The range results for given P_t (Table 2) conform to the MICA2 data sheet and experimentally obtained range values.

Energy consumption of sensor nodes in various states can be obtained by the following equations:

$$E_{tx} = P_{tr} \times T_{tx}$$

$$E_{rx} = P_{rec} \times T_{rx}$$

$$E_{idle} = P_{idle} \times T_{idle}$$

where P_{tr}, P_{rec}, P_{idle} are the powers consumed by the Mica2 mote's CC1000 transceiver in transmission, reception and idle mode respectively, and T_{tx}, T_{rx}, T_{idle} are times spent in each mode. Time for transmitting a packet of size b bits is equal to $[\frac{b}{R}]$ where R is the data rate. Total energy consumed by the network is given by;

$$E_{total} = E_{tr} + E_{Rec} + E_{idle}$$

4.2 Simulations

Network Simulator 2 (NS2) is used for performing simulations. We performed simulations utilizing the actual power consumption values of sensor motes in various states. In order to have an insight view of the energy consumption in various working modes, the power consumption values of Mica2 (Crossbow, n.d.) sensor motes have been used. Mica2 has an on-board CC1000 transceiver for communication. Thus power consumption values for communication have been taken from CC1000 data sheet (CC1000, 2007).

Deployed topology consists of a set of seven equidistant nodes $\{n_s, n_2, n_3, n_4, n_5, n_6, n_d\}$ deployed linearly with adjacent inter-node distance of 10 meters. This accounts to maximal source-destination ($n_s \rightarrow n_d$) distance of 60 meters. Source n_s generates packets at regular intervals and transmits them towards sink n_d. Simulations are performed with four different relaying scenarios. Details are given in figure 2 and in table 1. $n_s \rightarrow n_d$ transmission is varied from single hop to a maximum of six hops. In all the scenarios source node n_s sends 50 bytes packets towards desination node n_d. MAC layer issues like collisions, retransmissions and scheduling are not taken into account. This is realistic assumption as the goal here is to analyze only the energy consumption effect with varying hop distances.

Figure 3 shows total network energy consumption when radio is always active i.e. either in Tx/Rx state or in idle state. In this case energy consumption reduces a bit with increasing number of hops. Note that

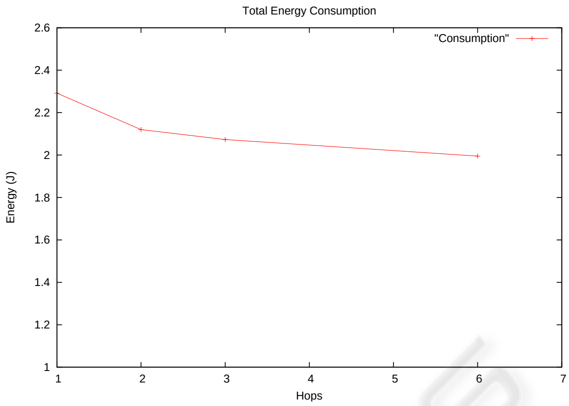

Figure 3: Total Energy Consumption when Radio always ON/IDLE.

for this case P_{rec}=P_{idle}=30mW. This is because current draw through mica2 is same when it is either receiving a packet or performing idle listening. Power transmission values P_{tr} for each case are obtained from table 2. Energy consumption for direct $n_s \rightarrow n_d$ communication is 2.29J. For two hops $n_s \rightarrow n_4 \rightarrow n_d$ and three hops $n_s \rightarrow n_3 \rightarrow n_5 \rightarrow n_d$ scenarios total energy consumption slightly reduces to 2.12J and 2.07J respectively. Results are not very appealing. With least transmission power of -20dBm, that draws 25.8mW from mica2, minimum total consumption of 1.99J is acheived.This accounts to maximum energy saving of 13% as compared to direct $n_s \rightarrow n_d$ communication. At -20dBm, power consumed P_{tr} <P_{rec} (25.8 <30mW). As compared to this, multiple WBAN sensors are very close to each other (tens of centimeters) and to the gateway node e.g. PDA. In such scenario further reduction in transmission power will increase multiple receptions/Listening dominancy over transmission energy. Thus multi-hop option is not practical in small WBAN. Heinzelman et. al. in (Heinzelman et. al., 2000) propose a WSN based energy model. They also conclude that multi-hopping is energy efficient when destination cannot be reached in a single hop. A contrary argument to this point could be that transmission range reduction is neccessary to avoid collisions and large number of overhearings. This is true, but in small scale WBANs, source to sink synchronized single hop communications while keeping other nodes' transceivers off would be more optimal.

Figure 4 shows network energy consumption when nodes switch on their radio only when they need to transmit their information. Energy consumption for direct $n_s \rightarrow n_d$ communication is 0.93J. For two hops $n_s \rightarrow n_4 \rightarrow n_d$ and three hops $n_s \rightarrow n_3 \rightarrow n_5 \rightarrow n_d$ scenarios total energy consumption increases to 0.946J and 1.083J respectively. With least transmission power of -20dBm, that draws 25.8mW from mica2, minimum

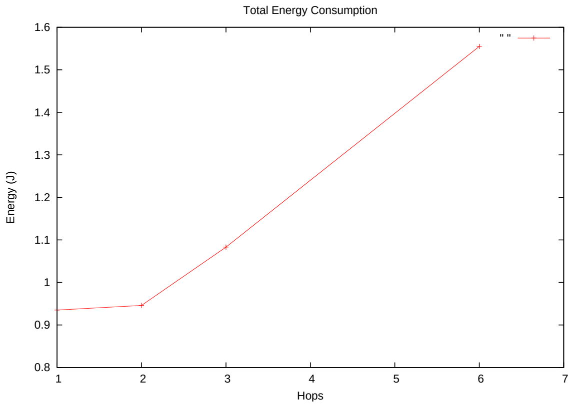

Figure 4: Total Energy Consumption when sensor node Radio "ON" only for transmission.

total consumption of 1.55J is acheived.This accounts to 40% increase in network's total energy consumption as compared to direct $n_s \rightarrow n_d$. Clearly, reducing transmission range to perform data relaying does not seem to be good option in WBAN. Energy efficiency gain in WSN is maximum when sensor nodes periodically go to deep sleep mode. We are not considering this case here as turning off health sensing equipment may prove fatal to patient's life. Patient's health needs to be regularly monitered and transmitted to the concerned data center. Although the periodicity of monitering depends upon the nature of observation and patients condition. It may not be necessary to transfer health update to data center. This could be utilized only under emergency condition to trigger the call for medical assistance. From this discussion, it is concluded that, unless really required, unneccessary relaying should be avoided. Some real experiments show high path atenuation values in WBAN with α as high as 5.8. If such condition arrives the deployed routing mechanism should be able to adapt itself for multi-hop communication. For this reason, we aim to adopt a simple routing protocol that uses a smart neighbour discovery mechanism as in (Jacquet et. al., 2003). This would allow nodes to communicate with sinks over two hops, if required.

5 CONCLUSIONS AND FUTURE WORK

An energy consumption comparison for various communication scenarios has been made. It has been shown that at very low ranges, transceivers consume almost equal or more power on reception than transmission. Thus deliberate reduction of transmission range to induce multi-hop scenario is not efficient. Though this is device dependent but general characteristics of very low power transceivers seem to show the same results.
Our future work is to propose an energy efficient, reliable routing architecture keeping in view the results obtained through this study. Auto-configuration for multi-hop relaying should be added in proposed routing architecture, in case when direct sensor to gateway access is not attainable. Security issues to ensure patient's unique identity will be dealt. At the end, we plan to implement a real working WBAN prototype on specialized wearable *Shimmer* sensors (Shimmer Platform, n.d.).

REFERENCES

IEEE 802.15 WPAN Task Group 6 (TG6) Body Area Networks. (2003). *802.15.4 Standard.* Retrieved Aug. 2009 from www.ieee802.org/15/pub/TG6.html

LIM&Bio: Laboratoire d'Informatique Medicale & Bio-Informatique. Retrieved Jul. 2009 from www.limbio-paris13.org

BASUMA. (2006). *Body Area System for Ubiquitous Multimedia Applications Project.* Retrieved Sept. 2009 from www.basuma.de

CodeBlue: Wireless Sensors for Medical Care. (2008). Retrieved 13, November 2009 from http://fiji.eecs.harvard.edu/CodeBlue

Bluetooth Technology. (2009). Retrieved Oct. 2009 from www.bluetooth.com

ZigBee Alliance. (2009). Retrieved Oct. 2009 from www.zigbee.org

B. Latre, I. Moerman, B. Dhoedt, P. Demeester. (2004). *Networking in Wireless Body Area Networks* 5th FTW PHD Symposium

Q. Wang, M. Hempstead, W. Yang. (2006). *A Realistic Power Consumption Model for Wireless Sensor Network Devices* IEEE Comm. Society Conference on Sensor, Mesh and Ad hoc Communications and Networks

G. Anastasi et. al. (2004). *Performance Measurements of Motes Sensor Networks* International Workshop on Modeling Analysis and Simulation of Wireless and Mobile Systems

Chipcon AS. (2007). *CC2420 2.4 GHz IEEE 802.15.4/ZigBee-ready RF Transceiver* Retrieved Oct. 2009 from http://inst.eecs.berkeley.edu/ cs150/

Chipcon AS. (2007). *CC1000 Single Chip Very Low Power RF Transceiver.* Retrieved from Oct. 2009 from http://focus.ti.com/lit/ds/symlink/cc1000.pdf

Crossbow Technology *MICA2 Motes* Retrieved June, 2009 from www.xbow.com

W. R. Heinzelman, A. Chandrakasan, H. Balakrishnan. (2000). *Energy-efficient communication protocol for wireless microsensor networks* Proceedings of the

33rd Hawaii International Conference on System Sciences

P. Jacquet, P. Muhlethaler, P. Minet, A. Qayyum, A. Laouiti, T. Clausen, L. Viennot, C. Adjih. (2003). *Optimized Link State Routing Protocol* Internet Engineering Task Force Group, RFC 3626

Shimmer Platform. (n.d.) Oct. 2009 Retrieved from http://shimmer-research.com

Network Simulator 2 (n.d.). www.isi.edu/nsnam/ns/