Survivable and Scalable Wireless Solution for E-health and E-emergency Applications

Abdellah Chehri, Hussein. T. Moutah
School of Information Technology and Engineering,
800 King Edward Avenue Ottawa,
Ontario, Canada, K1N 6N5
achehri,mouftah@uottawa.ca

ABSTRACT
Most conventional medical systems use fixed wired LAN, cable, and other land line systems to transmit medical data or operations. As wireless technology becomes increasingly pervasive, e-health professionals are considering wireless networks for their mobile medicine systems with the advent of e-health care, a wide range of technologies can now be applied to provide medical care products and services. Wireless Sensor Networks (WSNs) are composed by small devices that possess the ability to measure and to exchange a variety of vital data. In this paper we evaluate the performance of wireless sensor network technology for patient's remote monitoring. The system is mainly composed of static biomedical sensor nodes, which are mounted on the patient body in under to collect the main vital data such as temperature, ECG etc. The main characteristic of the networks such as the throughput and ratio delivery packet have been evaluated in this paper.

Keywords
E-health application, wireless body area sensor networks, IEEE 208.15.4

INTRODUCTION

The world is facing problems to provide high quality healthcare services at a reasonable cost to the citizens due to the increasing percentage of graying population.

As the population ages and the risk of chronic disease increases, the cost of healthcare will rise. The solution to decrease both the cost of healthcare services and also the load of medical practitioners requires a dramatic change in the way future healthcare services are provided [1]. The expected necessary changes are: moving from reactive to preventive medicine [2], [3].

By the summer of 2005, the initiative of marrying information technology to medicine seemed clear, and the media was heralding what some called "the e-health" revolution [4].

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The employment of new technologies for medical healthcare could reduce the cost and improve the efficiency of treatment.

Wireless technology capabilities are growing at a fantastic rate. There appears to be no limit to what technology might accomplish, given infinite resources [5].

In this paper, we analyze a survivable and scalable wireless solution for E-health and E-emergency applications. We focus mainly of the performance of wireless body area sensor networks for remote monitoring application.

Using this architecture, patients, doctors, and nurses could be empowered to receive or provide real-time, distant health care services. Both patients and providers would have the freedom to be anywhere in the world while sending, receiving, checking, and examining medical data in a timely fashion.

At the health institutions, patients are monitored during treatment and recovery. This will be the monitoring of vital body functions such as ECG and blood pressure. Compared to wired solutions, the wireless transmission for monitoring provides several advantages [6].

The patient mobility will be improved, and that it will provide the opportunity for monitoring patients outside the health institutions. Patients' well-being and retention of health care has also influenced the recovery time. A transition to wireless systems will therefore help to improve patients' wellbeing and reduce recovery time.

In addition, we describe a global mobile system to provide unconfined e-health services, one that combines WLAN (Wireless Local Area Network) with wireless body sensor networks (WBANs), and the Internet or UMTS (Universal Mobile Telecommunications System, or GSM).

The reminder of the paper is organized as follows: section II gives an overview of a scalable wireless solution for e-health and e-emergency applications. In section III deals with system description. The performance evaluation of the wireless body area sensor networks is given in section IV. Finally, we conclude the paper in section V.

SCALABLE WIRELESS SOLUTION FOR E-HEALTH AND E-EMERGENCY APPLICATIONS

The recent advances in wireless technology have led to the development of wireless body area sensor networks (WBASN), where a set of communicating devices are located around the human body [7].

The application and use of wireless devices and computer-based technologies in health care have undergone an evolutionary process. Advances in information, telecommunication, and network technologies have led to the emergence of a revolutionary new paradigm for health care that some refer to as e-health [8].

These systems use modern wireless communication and information technologies to provide clinical care to remote located individuals. With more research progresses in this field it will be possible to provide a better quality of life to patients while reducing healthcare costs.

Enabling underlying infrastructures such as wireless medical sensor devices, wearable medical systems integrating sensors on body's patient can offers pervasive solutions for continuous health status monitoring through biomedical, biochemical and physical measurements.

Remote monitoring systems typically collect these patient readings and then transmit them to a remote server for storage and later examination by healthcare professionals [2]-[3].

Once available on the server, the readings can be used in numerous ways by home health agencies, by clinicians, by physicians, and by informal care providers. However remote healthcare monitoring systems will be exploited to their full potential when the analysis is also performed automatically through clinical decision support systems fed by expert knowledge.

A clinical practice guide line constitutes the most suitable source of information for building such clinical decision support systems [3].

In this scalable wireless solution for E-health and E-emergency applications, we select several wireless communication standards with publicly available specifications, which are namely Bluetooth (IEEE802.15.1.), Wi-Fi (IEEE 802.11), WPAN (IEEE 802.15.4 / ZigBee) and wireless Mesh networks (IEEE 802.11s).

While comparing all wireless technologies, we had to choose relevant criteria for an evaluation. The main criteria that should be considered in this architecture were robustness, range, energy consumption, availability, usability and security.

This system interfaces to healthcare providers, doctors, care-givers and the medical call centers (see Fig. 1) and also is integrated with a mobile platform for the occupant to remote control his home and another mobile platform for the doctors and nurses to view the state of their patients.

Typically they will receive an alarm in case of a health problem of their patients. This figure shows that the system is integrated with vital sign monitoring devices and sensors.

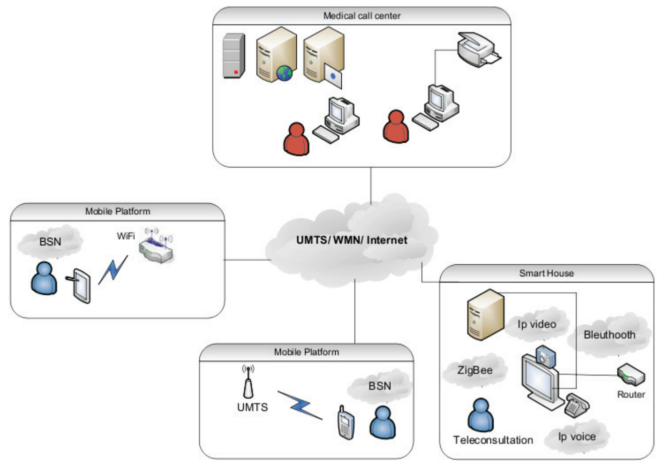

Figure 1: Survivable and scalable wireless solution for E-health and E-emergency applications

WIRELESS BODY AREA SENSOR NETWORKS

In general, wireless body area sensor networks (WBASNs) are wireless networks that support the use of biomedical sensors and are characterized by its (1) very low transmit power to coexist with other medical equipments and provide efficient energy consumption, (2) high data rate to allow applications with high QoS (Quality-of-Service) constraints, (3) low cost, low complexity and miniature size to allow real feasibility [9].

BSN, unlike wired monitoring systems, provide long term and continuous monitoring of patients under their natural physiological states even when they move. The system allows unobtrusive ubiquitous monitoring and can generate early warnings if received signals deviate from predefined personalized ranges.

Figure 2 illustrates the architecture of body sensor network. One patient is equipped with several sensors monitoring different parameters. A WBASN is made up of one or more body area networks and a base station. When the information has been gathered in the sensor network it is forwarded to this base station.

The information is then received at a relay station and passed on through a backbone network. In the end, the information can be viewed at terminals or monitoring stations that are connected to the network. This system has the potential of making remote monitoring and immediate diagnostics a reality [10], [11], [12].

Sensors are heterogeneous, and all integrate into the human body. The number and the type of biosensors vary from one patient to another depending on the state of the patient. The most common types of biosensors are EEG “Electroencephalography” to measure the electrical activity produced by the brain, ECG “Electrocardiogram” to record the electrical activity of the heart over time, EMG “Electromyography” to evaluate physiologic properties of muscles, Blood pressure, heart rate, glucose monitor, SpO2 “Oxymeter” to measure of oxygen saturation in blood, and to measure temperature of the body [13], [14].

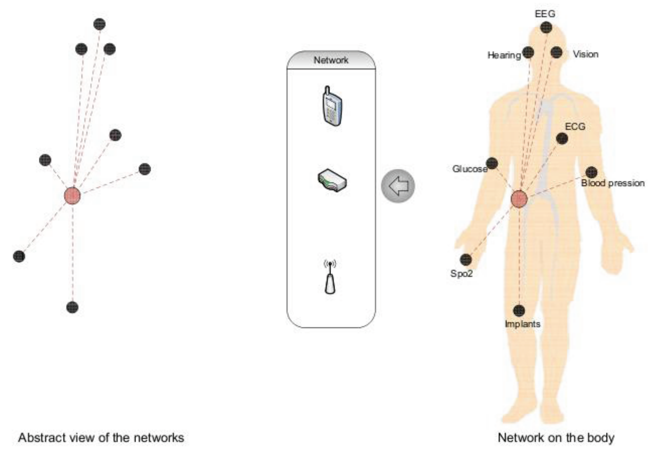

Figure 2: Wireless Body Area Sensor Network organization

As shown in the Table 1, according to the characteristics of physiological measurements or type of application services which can be real-time or non real-time with high or low rate.

Type of Service	Data rate	Latency	Class of Service
ECG	High	Low	Real-time high rate
EEG, EMG	Low	Low	Real-time low rate
Blood pressure, body temperature, heart rate, glucose monitoring	Low	High	Non real-time low rate
Medical image, X-ray, MRI	High	High	Non real-time high rate

Table 1: Service Classification of Physiological Measurements

SIMULATION AND RESULTS

We investigate on wireless body sensor network architecture for smart healthcare that possesses the following proprieties:

- Real-time and long-term remote monitoring;
- Tiny sensor with very low complexity;
- Can be integrated with existing medical practices and technology;

To meet these requirements, we have planned scenario where a patient has been equipped with an important biosensors nodes. Ns2 simulator with WPAN models is used [15].

We have considered a wide range of network topologies and test-validated the performance of WBASN with all considered topologies.

Due to the posed space limitation, we present our results for a static network. We set a 2 m x 2 m area to simulate patient body. We consider a static network configuration with six nodes and a gateway.

These nodes are mounted around his body (Fig. 2). Each node is implemented with one medical biosensor ECG, SpO2, body temperature, glucose monitoring, respiration and blood pressure.

All sensors, including sink node (gateway) are considered static (see fig 2). Transmit power of devices are configured based on the realistic radio map of sensor node around body network. In addition, the propagation model between nodes which are different from general indoor/outdoor models [16].

In the simulations, we evaluate system’s the throughput, and latency of WBASN architecture.

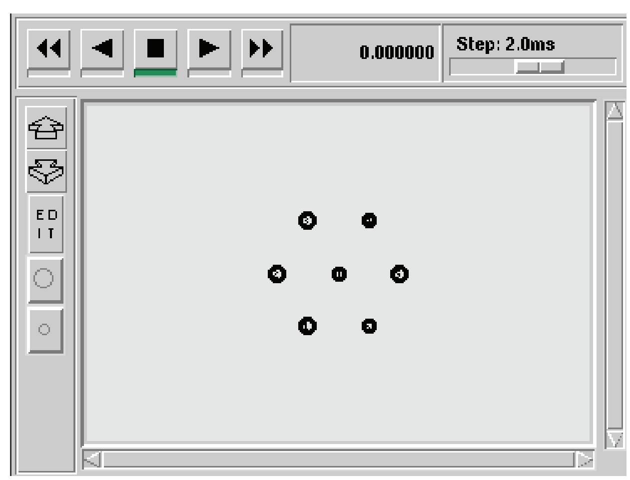

Figure 3: Deployment of WBASN using NS2

Throughput Analysis and packet delivery ratio

In order to analyze the drawbacks of CSMA/CA, we performed simulations of traditional IEEE 802.15.4 network. A beacon-enabled slotted CSMA/CA was chosen where beacons are sent by the PAN Coordinator and all nodes in the network synchronize with the beacon. A single-hop Star topology was considered.

The network performance was analyzed using two transmission scenarios; first where a single node sends data to the cluster head or PAN Coordinator, and, second, where 6 nodes send data to the PAN Coordinator. The traffic load was varied from 10 to 500 kbps. The highest throughput achieved when there is one source is around 160 kbps as shown in Figure 4.

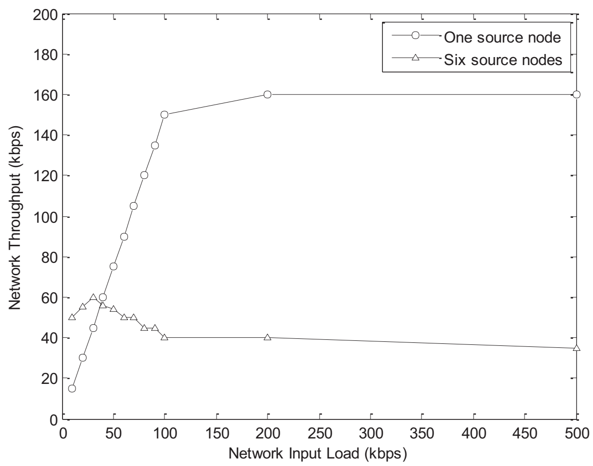

Figure 4: Throughput of the patient monitoring system

The packet delivery ratio also falls drastically with an increase in data rate as shown in Figure 5.

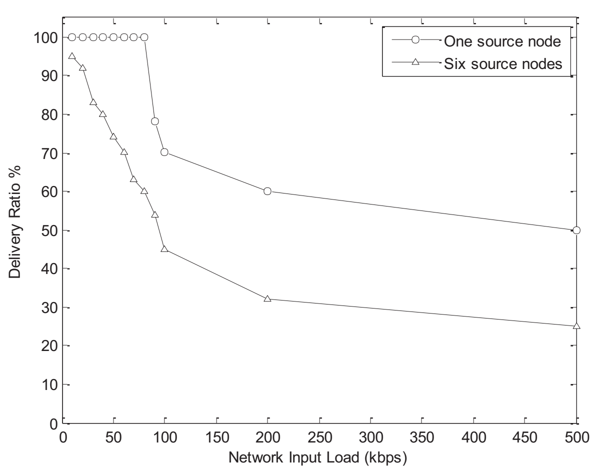

Figure 5: Packet delivery ratio of the patient monitoring system

CONCLUSION

The overall goal of this paper was to contribute and help through simulations towards dimensioning of the sensor networks for patient's remote monitoring. We examined the reliability for both the point-to point communication and multihop communication using IEEE 802.15.4 standard.

These performances are measured in term of throughput and packet error rate. The first results show that it is possible to use wireless body area sensor network to remote the vital data of the patient with reasonable throughput. In the future, more scenarios will be investigated.

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